CHEMISTRY

FOR TTCs

TUTOR'S GUIDE

YEAR

2

OPTION: SME

FOREWORD

Dear tutors,

Rwanda Basic Education Board is honoured to present Year 2 Chemistry tutor's guide which serves as a guide to competence-based teaching and learning to ensure consistency and coherence in the learning of chemistry subject. The Rwandan educational philosophy is to ensure that learners achieve full potential at every level of education which will prepare them to be well integrated in society and exploit employment opportunities.

In line with efforts to improve the quality of education, the government of Rwanda emphasizes the importance of aligning teaching and learning materials with the syllabus to facilitate their learning process. Many factors influence what they learn, how well they learn and the competences they acquire. Those factors include the relevance of the specific content, the quality of tutors' pedagogical approaches, the assessment strategies and the instructional materials available. We paid special attention to the activities that facilitate the learning process in which learners can develop ideas and make new discoveries during concrete activities carried out individually or with peers. With the help of the teachers, learners will gain appropriate skills and be able to apply what they have learnt in real life situations. Hence, they will be able to develop certain values and attitudes allowing them to make a difference not only to their own life but also to the nation.

This is in contrast to traditional learning theories which view learning mainly as a process of acquiring knowledge from the more knowledgeable who is mostly the teacher. In competence-based curriculum, learning is considered as a process of active building and developing of knowledge and understanding, skills and values and attitude by the learner where concepts are mainly introduced by an activity, situation or scenario that helps the learner to construct knowledge, develop skills and acquire positive attitudes and values.

In addition, such active learning engages learners in doing things and thinking about the things they are doing and they are encouraged to bring their own real experiences and knowledge into the learning processes. In view of this, your role is to:

- Plan your lessons and prepare appropriate teaching materials.
- Organize group discussions for learners considering the importance of social constructivism suggesting that learning occurs more effectively when the learner works collaboratively with more knowledgeable and experienced people.

- Engage learners through active learning methods such as inquiry methods, group discussions, research, investigative activities and group and individual work activities.
- Provide supervised opportunities for learners to develop different competences by giving tasks which enhance critical thinking, problem solving, research, creativity and innovation, communication and cooperation.
- Support and facilitate the learning process by valuing learners' contributions in the class activities.
- Guide learners towards the harmonization of their findings.
- Encourage individual, peer and group evaluation of the work done in the classroom and use appropriate competence-based assessment approaches and methods. To facilitate you, in your teaching activities, the content of this teacher`s guide is self-explanatory so that you can easily use it. It is divided in 3 parts:

The part 1: Explains the structure of this book and gives you the methodological guidance;

The part 2: Gives the sample lesson plans as reference for your lesson planning process;

The part 3: Provides details about the teaching guidance for each concept given in the student book.

Even though this tutor`s guide contains the answers for all activities given in the learner's book, you are requested to work through each question and activity before judging learner's findings.

I wish to sincerely appreciate all people who contributed towards the development of this tutor`s guide, particularly REB staff who organized the whole process since its inception. Special gratitude goes to the University of Rwanda which provided experts in design and layout services, illustrations and image anti-plagiarism, lecturers and tutors who diligently worked to successful completion of this book. Any comment or contribution would be welcome for the improvement of this textbook for the next edition.

Dr. MBARUSHIMANA Nelson

Director General, REB

ACKNOWLEDGEMENT

I wish to express my appreciation to all the people who played a major role in development of this Chemistry textbook for year 2. It would not have been successful without active participation of different education stakeholders.

I owe gratitude to different Universities and schools in Rwanda that allowed their staff to work with REB in the in-house textbooks production project. I wish to extend my sincere gratitude to lecturers, tutors and all other individuals whose efforts in one way or the other contributed to the success of writing of this textbook.

Special acknowledgement goes to the University of Rwanda which provided experts in design and layout services, illustrations and image anti-plagiarism.

Finally, my word of gratitude goes to the Rwanda Basic Education Board staff particularly those from the Curriculum, Teaching and Learning Resources Department (CTLRD) who were involved in the whole process of in-house textbook writing.

Joan MURUNGI,

Head of Curriculum, Teaching and Learning Resources Department

TABLE OF CONTENT

FOREWORD iii

ACKNOWLEDGEMENT v

PART I. GENERAL INTRODUCTION 1

1.0. About the tutor's guide 1
1.1 Methodological guidance 3

PART II: SAMPLE LESSON PLANS 16

PART III: UNIT DEVELOPMENT 23

UNIT 1: TRENDS OF CHEMICAL PROPERTIES OF GROUP 13 ELEMENTS AND THEIR COMPOUNDS 23

1.1. Key unit competence 23
1.2. Prerequisite (knowledge, skills, attitudes and values) 23
1.3. Cross-cutting issues to be addressed 2 3
1.4. Guidance on introductory activity 24
1.5. List of lessons/sub-heading 25
1.6. Summary of the Unit 35
1.7. Additional information for teachers 35
1.8. Additional activities 37
1.9. Extended activities 40

UNIT 2: CHEMICAL PROPERTIES OF S- BLOCK ELEMENTS 42

2.1. Key unit competence 42
2.2. Prerequisite (knowledge, skills, attitudes and values) 42
2.3. Cross-cutting issues to be addressed 42
2.4. Guidance on introductory activity 42
2.5. List of lessons/sub-heading 43
2.6. Summary of the Unit 51
2.7. Additional information for teachers 52
2.8. Additional activities 53
2.9. Extended activities 56

UNIT 3: TRENDS IN CHEMICAL PROPERTIES OF GROUP 14 ELEMENTS AND THEIR COMPOUNDS 58

3.1. Key unit competence 58

3.2. Prerequisite (knowledge, skills, attitudes and values) 58

3.3. Cross-cutting issues to be addressed 58

3.4. Guidance on introductory activity 59

3.5. List of lessons/sub-heading 59

3.6 Summary of the Unit 70

3.7 Additional information for teachers 71

3.8. Additional activities 74

3.9. Extended activities 75

UNIT 4: TRENDS IN CHEMICAL PROPERTIES OF GROUP 17 ELEMENTS AND THEIR COMPOUNDS 76

4.1. Key unit competence 76

4.2. Prerequisite (knowledge, skills, attitudes and values): 76

4.3. Cross-cutting issues to be addressed: 76

4.4. Guidance on introductory activity 77

4.5. List of lessons/sub-heading 78

4.6. Summary of the Unit 89

4.7. Additional information for teachers 89

4.8. Additional activities 91

4.9. Extended activities 92

UNIT 5: TRENDS IN CHEMICAL PROPERTIES OF PERIOD 3 ELEMENTS AND THEIR COMPOUNDS. 94

5.1 Key unit competence 94

5.2. Prerequisite (knowledge, skills, attitudes and values) 94

5.3. Cross-cutting issues to be addressed: 94

5.4. Guidance on introductory activity 95

5.5. List of lessons/sub-heading 95

5.6. Summary of the Unit 106

5.7. End unit assessment 107

5.8. Additional activities 108
5.9. Extended activities 112

UNIT 6: PROPERTIES AND USES OF TRANSITION METALS 116
6.1. Key unit competence 116
6.2. Prerequisite (knowledge, skills, attitudes and values) 116
6.3 Cross-cutting issues to be addressed: 116
6.4. Guidance on introductory activity 117
6.5. List of lessons/sub-heading 117
6.6. Summary of the Unit 124
6.7. Additional information for teachers 124
6.8. Additional activities 130
6.9. Extended activities. 136

UNIT 7: INTRODUCTION TO ORGANIC COMPOUNDS 138
7.1. Key Unit competence 138
7.2. Prerequisite (knowledge, skills, attitudes and values) 138
7.3. Cross cutting issues to be addressed 138
7.4. Guidance on introductory activity 139
7.5. List of lessons 139
7.6. Summary of the unit 149
7.7. Additional Information for teachers 150
7.8. Additional activities (Questions and answers) 155
7.9. Extended activities 157

UNIT 8: ALKANES 158
8.1. Key unit competence 158
8.2. Prerequisite 158
8.3. Cross-cutting issues to be addressed: 158
8.4. Guidance on introductory activity 159
8.5. List of lessons/sub-heading 160
8.6. Summary of the Unit 167
8.7. Additional information for tutors 168

8.8. Additional activities 170
8.9. Extended activities 171

UNIT 9: ALKENES AND ALKYNES 172
9.1. Key unit competence 172
9.2. Prerequisite 172
9.3. Cross-cutting issues to be addressed: 172
9.4. Guidance on introductory activity 174
9.5. List of lessons/sub-heading 174
9.6. Summary of the Unit 187
9.7. Additional information for teachers 188
9.8. Additional activities 191
9.9. Extended activities 193

UNIT 10: HALOGENOALKANES (ALKYL HALIDES) 194
10.1. Key unit competence 194
10.2. Prerequisite 194
10.3. Cross-cutting issues to be addressed: 194
10.4. Guidance on introductory activity 195
10.5. List of lessons/sub-heading 196
10.6. Summary of the Unit 203
10.7. Additional information for teachers 204
10.8. Additional activities 205
10.9. Extended activity 206

UNIT 11: ALCOHOLS AND ETHERS 207
11.1. Key unit competence 207
11.2. Prerequisite 207
11.3. Cross-cutting issues to be addressed: 207
11.4. Guidance on introductory activity 208
11.5. List of lessons/sub-heading 208
11.6 Summary of the Unit 219
11.7. Additional information for teachers 220

11.8. Additional activities 223
11.9. Extended activities 223

UNIT 12: CARBONYL COMPOUNDS 225
12.1. Key unit competence 225
12.2. Prerequisite 225
12.3. Cross-cutting issues to be addressed: 225
12.4. Guidance on introductory activity 226
12.5. List of lessons/sub-heading 226
12.6. Summary of the Unit 233
12.7. Additional information for teachers 234
12.8. Additional activities 236
12.9. Extended activities 238

UNIT 13: CARBOXYLIC ACIDS AND ACYL CHLORIDES 241
13.1. Key unit competence 241
13.2. Prerequisite 241
13.3. Cross-cutting issues to be addressed 241
13.4. Guidance on introductory activity 241
13.5. List of lessons 242
13.6. Summary of the unit 258
13.7 Additional information for the teacher 260
13.8 Additional activities 264
13.9. Extended activities 267

UNIT 14: ESTERS, ACID ANHYDRIDES, AMIDES AND NITRILES 269
14.1. Key unit competence 269
14.2. Introduction 269
14.3. Cross-cutting issues to be addressed 269
14.4. Guidance on the introductory activity 270
14.5. List of lessons 271
14.6. Summary of the unit 291
14.7. Additional information for the teacher 292

14.8. Additional activities 296
14.9. Extended activities 301

UNIT 15: AMINES AND AMINO ACIDS 305
15.1 Key unit competence 305
15.2 Prerequisites 305
15.3 Cross-cutting issues to be addressed 305
15.4 Guidance on introductory activity 306
15.5 List of lessons 307
15.6 Summary of the unit 328
15.7 Additional Information for teachers 330
15.8 Additional activities 340
15.9. Extended activities 346

UNIT 16: FACTORS THAT AFFECT CHEMICAL EQUILIBRIUM 347
16.1. Key unit competence 347
16.2. Prerequisite knowledge and skills 347
16.3. Cross-cutting issues to be addressed 347
16.4. Guidance on introductory activity 348
16.5. List of lessons: 348
16.6. Summary of the Unit 358
16.7. Additional information 360
16.8. Additional activities 365
16.9. Extended activities 373

UNIT 17: QUANTITATIVE CHEMICAL EQUILIBRIUM 377
17.1. Key unit competence 377
17.2. Prerequisite knowledge and skills 377
17.3. Cross-cutting issues to be addressed 377
17.4. Guidance on the introductory activity: 378
17.5. List of lessons 379
17.6. Summary of the unit 389
17.7. Additional information 389

17.8 Additional activities 395
17.9. Extended activities... 400

UNIT 18: ACIDS AND BASES 402
18.1. Key unit competence.. 402
18.2. Prerequisite knowledge and skills 402
18.3. Cross-cutting issues to be addressed... 402
18.4. Guidance on Introductory activity 402
18.5. List of lessons 403
18.6 Summary of the unit 408
18.7 Additional information for tutors 410
18.8. Additional Activities... 412
18.9 Extended activity.. 415

UNIT 19: ENERGY CHANGES AND ENERGY PROFILE DIAGRAMS 418
19.1. Key unit competence.. 418
19.2. Prerequisite knowledge and skills 418
19.3. Cross-cutting issues to be addressed... 418
19.4. Guidance on Introductory activity 418
19.5. List of lessons 420
19.6. Summary of the unit... 425
19.7. Additional activities 427

REFERENCES...432

PART I. GENERAL INTRODUCTION

1.0. About the tutor's guide

This book is a tutor's guide for Chemistry Year two in TTC. It is designed to accompany Year two student teacher's book and intends to help tutors in the implementation of competence based curriculum specifically Chemistry syllabus.

As the name says, it is a guide that tutors can refer to when preparing their lessons. Tutors may prefer to adopt the guidance provided but they are also expected to be more creative and consider their specific classes' contexts and prepare accordingly.

The structure of the guide

This section presents the overall structure, the unit and sub-heading structure to help teachers to understand the different sections of this guide and what they will find in each section.

Overall structure

The whole guide has three main parts as follows:

- **Part I: General Introduction.**

This part provides general guidance on how to develop the generic competences, how to integrate cross cutting issues, how to cater for learners with special educational needs, active methods and techniques of teaching chemistry and guidance on assessment.

- **Part II: Sample lesson plan**

This part provides a sample lesson plan, developed and designed to help the tutor develop their own lesson plans.

- **Part III: Unit development**

This is the core part of the guide. Each unit is developed following the structure below. The guide ends with references.

Each unit is made of the following sections:

- **Unit title:** from the syllabus
- **Key unit competence**: from the syllabus
- **Prerequisites (knowledge, skills, attitudes and values)**

This section indicates knowledge, skills and attitudes required for the success of the unit. The competence-based approach calls for connections between units/topics within a subject and interconnections between different subjects.

The tutor will find an indication of those prerequisites and guidance on how to establish connections.

- **Cross-cutting issues to be addressed**

  This section suggests cross-cutting issues that can be integrated depending on the unit content. It provides guidance on how to come up with the integration of the issue. Note that the issue indicated is a suggestion; teachers are free to take another cross-cutting issue taking into consideration the learning environment.

- **Guidance on the introductory activity**

  Each unit starts with an introductory activity in the learner's book. This section of the teacher's guide provides guidance on how to conduct this activity and related answers. Note that learners may not be able to find the right solution but they are invited to predict possible solutions or answers. Solutions are provided by learners gradually through discovery activities organized at the beginning of lessons or during the lesson.

- **List of lessons/sub-heading**

  This section presents in a table suggestion on the list of lessons, lesson objectives copied or adapted from the syllabus and duration for each lesson. Each lesson /subheading is then developed.

- **End of each unit**

  At the end of each unit the teacher's guide provides the following sections:

  - Summary of the unit which provides the key points of content developed in the student's book.
  - Additional information which provides additional content compared to the student's book for the teacher to have a deeper understanding of the topic.
  - End unit assessment which provides the answers to questions of end unit assessment in the textbook and suggests additional questions and related answers to assess the key unit competence.
  - Additional activities: (remedial, consolidation and extended activities). The purpose of these activities is to accommodate each learner (slow, average and gifted) based on end unit assessment results.

Structure of each sub heading

Each lesson/sub-heading is made of the following sections:

Lesson /Sub heading title 1: ……………………………..

- **Prerequisites/Revision/Introduction:**

  This section gives a clear instruction to tutor on how to start the lesson

- **Teaching resources**

  This section suggests the teaching aids or other resources needed in line with the activities to achieve the learning objectives. Tutors are encouraged to replace the suggested teaching aids by the available ones in their respective schools and based on learning environment.

- **Learning activities**

  This section provides a short description of the methodology and any important aspect to consider. It provides also answers to learning activities with cross reference to text book:

- **Exercises/application activities**

  This provides questions and answers for exercises/ application activities.

1.1 Methodological guidance

1.1.1 Developing competences

Since 2015 Rwanda shifted from a knowledge based to a competence based curriculum for pre-primary, primary and general secondary education and since 2018 for Teacher Training Colleges (TTCs). This called for changing the way of learning by shifting from teacher centered to a learner centered approach. Tutors are not only responsible for knowledge transfer but also for fostering student teachers learning achievement, and creating safe and supportive learning environment. It implies also that a learner has to demonstrate what he/she is able to do using the knowledge, skills, values and attitude acquired in a new or different or given situation.

The competence-based curriculum employs an approach of teaching and learning based on discrete skills rather than dwelling on only knowledge or the cognitive domain of learning. It focuses on what learner can do rather than what learners know. Learners develop basic competences through specific subject unit competences with specific learning objectives broken down into knowledge, skills and attitudes. These competences are developed through learning activities disseminated in learner-centred rather than the traditional didactic approach. The student teacher is evaluated against set standards to achieve before moving on.

In addition to specific subject competences, learners also develop generic competences which are transferable throughout a range of learning areas and situations in life. Below are examples of how generic competences can be developed in Chemistry:

Generic competence	**Examples of activities that develop generic competences**
Critical thinking	- Classifying organic compounds - Observe, record, interpret data recorded during experiments - Choose the best reagent to test for a substance or to distinguish substances
Research and Problem solving	- Research using internet or books from the library - Design a project for making bioplastics - Design a questionnaire for data collection during field visit
Innovation and creativity	- Create an experiment procedure to prove a point - Develop a graph to illustrate information - Design a data collection survey/ questionnaire - Conduct experiments with objectives, methodology, observations, results, conclusions - Identify local problems and ways to resolve them
Cooperation, Personal and Interpersonal management and life skills	- Work in Pairs - Small group work - Large group work

Communication	- Organise and present in writing and verbally a complete and clear report of an experiment - Observe, record, interpret the results of a measurement accurately. - Select and use appropriate formats and presentations, such as tables, graphs and diagrams.
Lifelong learning	- Exploit all opportunities available to improve on knowledge and skills. Reading scientific journals to keep updated.

1.1.2 Addressing cross-cutting issues

Among the changes in the competence based curriculum is the integration of cross cutting issues as an integral part of the teaching learning process-as they relate to and must be considered within all subjects to be appropriately addressed. The eight cross cutting issues identified in the national curriculum framework are: genocide studies, environment and sustainability, gender, Comprehensive Sexuality Education (CSE), Peace and Values Education, Financial Education, standardization Culture and Inclusive Education.

Some cross-cutting issues may seem specific to particular learning areas or subjects but the teacher need to address all of them whenever an opportunity arises. In addition, learners should always be given an opportunity during the learning process to address these cross-cutting issues both within and out of the classroom so as to progressively develop related attitudes and values.

Below are examples on how crosscutting issues can be addressed in Chemistry:

Cross-cutting issue	Examples on how to integrate the cross-cutting issue
Inclusive education	Involve all learners in all activities without any bias. Eg: allow a learner with physical disability (using wheelchair) to take notes or lead the team during an experiment.
Gender	Involve both girls and boys in all activities: No activity is reserved only to girls or boys. Teachers should ensure equal participation of both girls and boys during experiments as well as during cleaning and tidying up related activities after experiments.
Peace and Values Education	During group activities, debates and presentations, the teacher will encourage learners to help each other and to respect opinions of colleagues.
Standardization culture	- Some lessons involve carrying out experiments. Instructions should be clear for learners to **always** check if they are not using expired chemicals or defective apparatus. - In addition, when performing experiments learners have to record data accurately. - For tasks involving calculations, they have to always present accurate results.
Environment and sustainability	- In order to avoid the environment pollution, before, during or after experiments learners avoid throwing away chemicals anywhere; special places or appropriate containers should be used. - Learners also have to be aware of the impacts of the use of hydrocarbons as fuels, halogenoalkanes, plastics,... on the environment.
Financial Education	When performing experiments, learners avoid waste of chemicals: they have to use the amounts that are just required.

1.1.3 Attention to special educational needs specific to each subject

In the classroom, students learn in different way depending to their learning pace, needs or any other special problem they might have. However, the teacher has the responsibility to know how to adopt his/her methodologies and approaches in order to meet the learning need of each student in the classroom.

Also teachers need to understand that student with special needs, need to be taught differently or need some accommodations to enhance the learning environment. This will be done depending to the subject and the nature of the lesson.

In order to create a well-rounded learning atmosphere, teachers need to:

- Remember that children learn in different ways so they have to offer a variety of activities (e.g. role-play, music and singing, word games and quizzes, and outdoor activities)
- Maintain an organized classroom and limits distraction. This will help students with special needs to stay on track during lesson and follow instruction easily.
- Vary the pace of teaching to meet the needs of each child. Some children process information and learn more slowly than others.
- Break down instructions into smaller, manageable tasks. Students with special needs often have difficulty understanding long-winded or several instructions at once. It is better to use simple, concrete sentences in order to facilitate them understand what you are asking.
- Use clear consistent language to explain the meaning (and demonstrate or show pictures) if you introduce new words or concepts.
- Make full use of facial expressions, gestures and body language.
- Pair a child who has a disability with a friend. Let them do things together and learn from each other. Make sure the friend is not over protective and does not do everything for the child. Both children will benefit from this strategy
- Use multi-sensory strategies. As all children learn in different ways, it is important to make every lesson as multi-sensory as possible. Students with learning disabilities might have difficulty in one area, while they might excel in another. For example, use both visual and auditory cues.

Below are general strategies related to each main category of disabilities and how to deal with every situation that may arise in the classroom. However, the list is not exhaustive because each child is unique with different needs and that should be handled differently.

Strategy to help student with developmental impairment:

- Use simple words and sentences when giving instructions.
- Use real objects that the student can feel and handle. Rather than just working abstractly with pen and paper.

- Break a task down into small steps or learning objectives. The student should start with an activity that s/he can do already before moving on to something that is more difficult.
- Gradually give the student less help.
- Let the student work in the same group with those without disability.

Strategy to help student with visual impairment:

- Help children to use their other senses (hearing, touch, smell and taste) to play and carry out activities that will promote their learning and development.
- Use simple, clear and consistent language.
- Use tactile objects to help explain a concept.
- If the child has some sight, ask them what they can see. Get information from parents/caregivers on how the child manages their remaining sight at home.
- Make sure the child has a group of friends who are helpful and who allow the child to be as independent as possible.
- Plan activities so that children work in pairs or groups whenever possible

Strategy to help student with hearing impairment:

- Strategies to help children with hearing disabilities or communication difficulties
- Always get the child's attention before you begin to speak.
- Encourage the child to look at your face.
- Use gestures, body language and facial expressions.
- Use pictures and objects as much as possible.
- Ask the parents/caregivers to show you the signs they use at home for communication use the same signs yourself and encourage other children to also use them.
- Keep background noise to a minimum.

Strategies to help children with physical disabilities or mobility difficulties:

- Adapt activities so that children who use wheelchairs or other mobility aids, or other children who have difficulty moving, can participate.
- Ask parents/caregivers to assist with adapting furniture e.g. The height of a table may need to be changed to make it easier for a child to reach it or fit their legs or wheelchair under.

- Encourage peer support friends can help friends.
- Get advice from parents or a health professional about assistive devices.

1.1.4 Guidance on assessment

Each unit in the tutor's guide provides additional activities to help learners achieve the key unit competence. Results from assessment inform the tutor which learner needs remedial, consolidation or extension activities. These activities are designed to cater for the needs of all categories of learners; slow, average and gifted learners respectively.

Assessment is an integral part of teaching and learning process. The main purpose of assessment is for improvement. Assessment for learning/ **Continuous/ formative assessment** intends to improve learners' learning and teacher's teaching whereas assessment of learning/summative assessment intends to improve the entire school's performance and education system in general.

Continuous/ formative assessment

It is an ongoing process that arises out of interaction during teaching and learning process. It includes lesson evaluation and end of sub unit assessment. This formative assessment should play a big role in teaching and learning process. The teacher should encourage individual, peer and group evaluation of the work done in the classroom and uses appropriate competence-based assessment approaches and methods.

In Year one textbook, formative assessment principle is applied through application activities that are planned in each lesson to ensure that lesson objectives are achieved before moving on. At the end of each unit, the end unit assessment is formative when it is done to give information on the progress of students and from there decide what adjustments need to be done. Assessment standards are taken into consideration when setting tasks.

Summative assessment

The assessment done at the end of the term, end of year, is considered as summative. The tutor, school and parents are informed on the achievement of educational objectives and think of improvement strategies. There is also end of level/ cycle assessment in form of national examinations.

1.1.5. Student teachers' learning styles and strategies to conduct teaching and learning process

There are different teaching styles and techniques that should be catered for. The selection of teaching method should be done with the greatest care and some of the factors to be considered are: the uniqueness of subjects; the type of lessons; the particular learning objectives to be achieved; the allocated time to achieve the objective; instructional available materials; the physical/sitting arrangement of the classroom, individual student teachers' needs, abilities and learning styles.

There are mainly four different learning styles as explained below:

a) Active and reflective learners

Active learners tend to retain and understand information best by doing something active with it, discussing or applying it or explaining it to others. Reflective learners prefer to think about it quietly first.

b) Sensing and intuitive learners

Sensing learners tend to like learning facts; intuitive learners often prefer discovering possibilities and relationships. Sensors often like solving problems by well-established methods and dislike complications and surprises; intuitive learners like innovation and dislike repetition.

c) Visual and verbal learners

Visual learners remember best what they see-pictures, diagrams, flow charts, time lines, films, demonstrations, etc.; verbal learners get more out of words-written and spoken explanations.

d) Sequential and global learners

Sequential learners tend to gain understanding in linear steps, with each step following logically from the previous one. Global learners tend to learn in large jumps, absorbing material almost randomly without seeing connections, and then suddenly "getting it."

1.1.6. Teaching methods and techniques that promote the active learning

The different student learning styles mentioned above can be catered for, if the teacher uses active learning whereby learners are really engaged in the learning process.

What is Active learning?

Active learning is a pedagogical approach that engages students in doing things and thinking about the things they are doing. In active learning, learners are encouraged to bring their own experience and knowledge into the learning process.

The role of the teacher in active learning

- The teacher engages learners through active learning methods such as inquiry methods, group discussions, research, investigative activities and group and individual work activities.
- He/she encourages individual, peer and group evaluation of the work done in the classroom and uses appropriate competence-based assessment approaches and methods.
- He provides supervised opportunities for learners to develop different competences by giving tasks which enhance critical thinking, problem solving, research, creativity and innovation, communication and cooperation.
- Teacher supports and facilitates the learning process by valuing learners' contributions in the class activities.

The role of learners in active learning

Learners are key in the active learning process. They are not empty vessels to fill but people with ideas, capacity and skills to build on for effective learning. A learner engaged in active learning:

- Communicates and shares relevant information with other learners through presentations, discussions, group work and other learner-centred activities (role play, case studies, project work, research and investigation)
- Actively participates and takes responsibility for their own learning
- Develops knowledge and skills in active ways
- Carries out research/investigation by consulting print/online documents and resourceful people, and presents their findings
- Ensures the effective contribution of each group member in assigned tasks through clear explanation and arguments, critical thinking, responsibility and confidence in public speaking
- Draws conclusions based on the findings from the learning activities.

Some active techniques that can be used in chemistry

The teaching methods strongly emphasised in the competence Based Curriculum (CBC) are active methods. Below are some active techniques that apply in sciences:

A. Practical work/ experiments

Many of the activities suggested in the chemistry curriculum as well as in the student's book are practical work or experiments.

Practical work is vital in learning chemistry; this method gives the learner the opportunity to implement a series of activities and leads to the development of both cognitive and hands-on skills. The experiments and questions given should target the development of the following skills in students: observation; recording and report writing; manipulation; measuring; planning & designing.

A practical lesson/Experiment is done in three main stages:

- **Preparation:** Checking materials to ensure they are available and at good state; try the experiment before the lesson; think of safety rules and give instructions to lab technician if you have any.
- **Performance:** sitting or standing arrangement of students; introduction of the experiment: aims and objectives; setting up the apparatus; performing the experiment; write and record the data.
- **Discussion:** observations and interpreting data; make generalisations and assignment: writing out the experiment report and further practice and research.

In some cases, demonstration by the teacher is recommended when for example the experiment requires the use of sophisticated materials or very expensive materials or when safety is a major factor like dangerous experiments and it needs specific skills to be learnt first.

In case your school does not have enough laboratory materials and chemicals, experiments can be done in groups but make sure every student participates. In case your school does not have materials make arrangements with the neighbouring science school of excellence and take your students there for a number of experiments.

B. Research work

Each learner or group of learners is given a research topic. They have to gather information from internet, available books in the library or ask experienced people and then the results are presented in verbal or written form and discussed in class.

C. Project work

Chemistry teachers are encouraged to sample and prepare project works and engage their students in, as many as possible. Learners in groups or individually, are engaged in a self-directed work for an extended period of time to investigate and respond to a complex question, problem, or challenge. The work can be presented to classmates or other people beyond the school. Projects are based on real-world problems that capture learners' interest. This technique develops higher order thinking as the learners acquire and apply new knowledge in a problem-solving context.

D. Field trip

One of the main aims of teaching chemistry in Rwanda is to apply its knowledge for development. To achieve this aim we need to show to students the relationship between classroom science lessons and applied sciences. This helps them see the link between science principles and technological applications.

To be successful, the field visit should be well prepared and well exploited after the visit:

Before the visit the teacher and learners:

- agree on aims and objectives
- gather relevant information prior to visit
- brainstorm on key questions and share responsibilities
- discuss materials needed and other logistical and administrative issues
- discuss and agree on accepted behaviours during the visit
- Visit the area before the trip if possible to familiarise yourself with the place

After the visit

When students come back from trip, the teacher should plan for follow-up. The follow-up should allow students to share experiences and relate them to the prior science knowledge. This can be done in several ways; either: Students write a report individually or in groups and give to the teacher for marking. The teacher then arranges for discussion to explain possible misconceptions and fill gaps. *Or:* Students write reports in groups and display them on the class notice board for everyone to read.

Main steps for a lesson in active learning approach

All the principles and characteristics of the active learning process highlighted above are reflected in steps of a lesson as displayed below. Generally the lesson is divided into three main parts whereby each one is divided into smaller steps to make sure that learners are involved in the learning process. Below are those main parts and their small steps:

1) Introduction

Introduction is a part where the teacher makes connection between the current and previous lesson through appropriate technique. The teacher opens short discussions to encourage learners to think about the previous learning experience and connect it with the current instructional objective. The teacher reviews the prior knowledge, skills and attitudes which have a link with the new concepts to create good foundation and logical sequencings.

2) Development of the new lesson

The development of a lesson that introduces a new concept will go through the following small steps: discovery activities, presentation of learners' findings, exploitation, synthesis/summary and exercises/application activities, explained below:

- **Discovery activity**

  Step 1

  - The teacher discusses convincingly with students to take responsibility of their learning
  - He/she distributes the task/activity and gives instructions related to the tasks (working in groups, pairs, or individual to instigate collaborative learning, to discover knowledge to be learned)

  Step 2

  - The teacher let the students work collaboratively on the task.
  - During this period the teacher refrains to intervene directly on the knowledge
  - He/she then monitors how the students are progressing towards the knowledge to be learned and boost those who are still behind (but without communicating to them the knowledge).
- **Presentation of learners' productions**
  - In this episode, the teacher invites representatives of groups to present the students' productions/findings.

  - After three/four or an acceptable number of presentations, the teacher decides to engage the class into exploitation of the students' productions.

- **Exploitation of learner's productions**
  - The teacher asks the students to evaluate the productions: which ones are correct, incomplete or false
  - Then the teacher judges the logic of the students' products, corrects those which are false, completes those which are incomplete, and confirms those which correct.
- **Institutionalization (summary/conclusion/ and examples)**
  - The teacher summarises the learned knowledge and gives examples which illustrate the learned content.
- **Exercises/Application activities**
  - Exercises of applying processes and products/objects related to learned unit/sub-unit
  - Exercises in real life contexts
  - Teacher guides learners to make the connection of what they learnt to real life situations. At this level, the role of teacher is to monitor the fixation of process and product/object being learned.

3) Assessment

In this step the teacher asks some questions to assess achievement of instructional objective. During assessment activity, learners work individually on the task/activity. The teacher avoids intervening directly. In fact, results from this assessment inform the teacher on next steps for the whole class and individuals. In some cases the teacher can end with a homework assignment

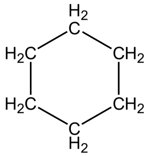
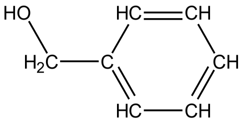
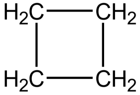
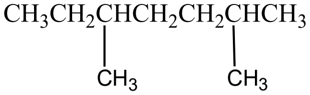
PART II: SAMPLE LESSON PLANS

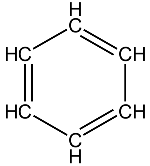
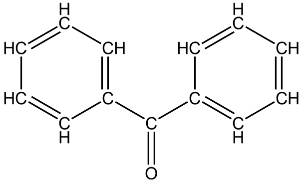
School Name: ....**Teacher's name**: ……………………….

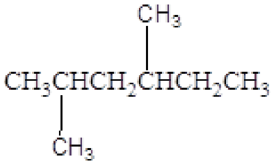
Term	Date	Subject	Class	Unit Nº	Lesson Nº	Duration	Class size
II	... /..../2019	Chemistry	Year 2	7	1 of 5	80	45

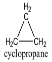
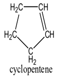
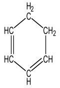
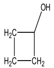
Type of Special Educational Needs to be catered for in this lesson and number of learners in each category	Use of braille in cases of visual impairment
Unit title	Introduction to organic chemistry
Key unit competency:	To apply IUPAC rules to name organic compounds and explain the types of isomers for organic compounds
Title of the lesson	Classification of organic compounds as aliphatic, aromatic and alicyclic
Instructional Objective	By the end of this lesson leaners should be able to properly classify organic as aliphatic organic, aromatic and alicyclic compounds
Plan for this Class (location: in / outside)	Inside the class
Learning Materials (for ALL learners)	Textbooks, blackboard, chalks and internet if available.
References	E.N.Ramsden (2000), A_level CHEMISRTY, FOURTH EDITION, Nelson Thornes

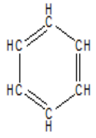
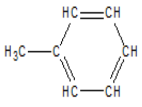
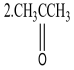
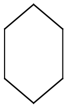
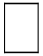
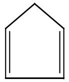
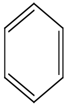
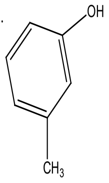
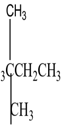
Timing for each step	Description of teaching and learning activity		Generic competences and cross cutting issues to be addressed + a short explanation
	Through group discussions, and presentations student teachers classify organic compounds as aliphatic, aromatic and alicyclic		
	Teacher activities	**Learner activities**	
Introduction 15 min	The tutor asks student teachers to form groups , ask the student teachers to look at the introductory activity in student book and answer the questions Provide the materials for student teachers to use for answering question 2	- Form groups and discuss question one in the introductory activity - Carry out the practical to determine the behaviour of vinegar and petroleum	**Cooperation** and **communication skills developed** through group discussions. Practical skills of observing and handling of materials
Development of the lesson			
2.1 **25 min**	- The tutor provides activity 7.1 in the student teacher book - Asks student teachers to remain in their groups and answer the questions.	- Student teachers remain in their previous groups and to discuss and answer the questions	**Generic competences** - Cooperation and communication skills through discussions - Lifelong learning by developing research culture **Cross-cutting issues** - Financial education through using limited amounts of petroleum and vinegar . - Environment and sustainability through cleaning working places/ laboratory - **Peace and values education; Cooperation, mutual respect, tolerance** through discussions with people with different views

2.2 Presentation of learner's productions 10 min	• Tutor chooses one student teacher to present their answers (allow a minimum group to spare sometime) • Tutor moves around in the different groups guiding them and answering any question that may arise with in the groups. • Tutor corrects some misconceptions during the presentations • Tutor asks student teachers to take notes during the presentation	• Student teachers make presentation of their findings from the discussed activity. **Expected answers:** 1. CH_3-CH_2-CH_2-CH_2-CH_2-CH_3 2. CH_3-CH_2-$C\equiv CCH_2CH_3$ 3. $CH_3CH_2CH_2OH$ 4.  5.  6. CH_3-CH_2-$CH=CH_2$ 7.  8.  $CH_3CH_2\underset{CH_3}{\underset{\vert}{CH}}CH_2CH_2\underset{CH_3}{\underset{\vert}{CH}}CH_3$	**Generic competences** • Cooperation and communication/ attentive listening during presentations and group discussions

		9.  10  • 1, 2, 3, 6, 8 : aliphatic compunds • 4, 7, : alicyclic compounds • 5, 9, 10 : aromatic compounds	
2.3 **Exploitation** **5**	The tutor asks the student teachers to make evaluation of them by comparing their answers with the correct presented answers.	Each group evaluates the findings of other groups.	**Generic competences** • Cooperation and communication skills through discussions • Critical thinking through evaluating other's ideas/ findings.

2.4.Conclusion/ **Summary** **15**		Student teachers write the summary on their notes books: Aliphatic Compounds are the large class of organic molecules consisting essentially of straight or branched chains of carbon atoms. Aliphatic compounds include the alkanes, alkenes, and alkynes and their derivatives.	Cross-cutting issues Environment and sustainability through using alcohols as fuels.
		Examples of aliphatic compounds $CH_3CH_2CH_2CH_2CH_2CH_3$ Hexane  $CH_3CH(CH_3)CH_2CH(CH_3)CH_2CH_3$ 2,4-dimethylhexane $HC\equiv CH$ Acethylene	

		$H_2C{=}CHCH_2CH_3$ But-1-ene Alicyclic or cyclic compounds are organic compounds that contain one or more carbon rings that may be saturated (joined by single bonds) or unsaturated (joined with double or triple bond).Examples of alicyclic compounds  cyclopropane  cyclopentene  cyclohexadiene  cyclobutane **Aromatic compounds** are large class of unsaturated chemical compounds characterized by one or more planar rings of atoms joined by covalent bonds of two different kinds. Benzene (C_6H_6) is the best-known aromatic compound and the parent to which numerous other aromatic compounds is related.	

		Examples of aromatic compounds  benzene  toluene	
1. **Assessment** **10 minutes**	Teacher assesses the learned content by providing some few questions	Student teachers do the exercises individually 1. $CH_3CH_2CH_2CH_2OH$ 2. $\underset{\displaystyle O}{\overset{}{CH_3\overset{}{\underset{\Vert}{C}}CH_3}}$ 3. 4. 5. 6. 7. 8. 9. $CH_3\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{C}}CH_2CH_3$	Critical thinking and problem solving
Observation on lesson delivery	The lesson is well delivered.		
Case study/scenario:			

PART III: UNIT DEVELOPMENT

UNIT 1

TRENDS OF CHEMICAL PROPERTIES OF GROUP 13 ELEMENTS AND THEIR COMPOUNDS

1.1. Key unit competence

Compare and contrast the chemical properties of the Group 13 elements and their compounds in relation to their position in the Periodic Table.

1.2. Prerequisite (knowledge, skills, attitudes and values)

Components of an atom and their properties, definition of an atomic number, mass number and electronic structure, chemical reactions ,trend in physical properties of elements in periodic table, handling laboratory equipment, safety rules and regulations in laboratory.

1.3. Cross-cutting issues to be addressed

(a)Environment and sustainability

We live in environment where human beings have a significant impact, both positive and negative. The demand for survival requires hard working without thinking on direct impact of our action. Handling chemical requires taking into consideration their different effect on the environment .This unit is an opportunity to guide learners on understanding the impact of air, water and soil pollution. This issue should be addressed especially considering the different uses of chemicals and different ways of waste management mainly chemical wastes.

- Help learner to work in healthy environment
- Learners perform experiment by keeping the classroom environment clean before and after the experiment.
- Learners are skilled on the ways of waste management
- Learners are also skilled on the rational use of chemical by avoiding or reducing all means of pollution.

(b)Inclusive education

This unit involves a number of activities that involve practical work; observation, use of sense organ, reading and writing. This may be challenging to students with special educational needs especially children with physical impairment, hearing impairment, visual impairment. However, the teacher can make some arrangements like:

- Classroom should be accessible to all learners
- Grouping students. Students with special educational needs are grouped with others and assigned roles basing on individual student‘s abilities.
- Providing procedure earlier before the activity so that students get familiar with them. They can be written on the chalkboard or printed depending on available resources. If you have children with low vision remember to print in appropriate fonts or in Braille.
- Every important point is written and spoken. The written points help students with hearing impairment and speaking aloud helps students with visual impairment
- Remember to repeat the main points of the lessons
- Remember to allow learners with disabilities to get helped with their colleagues without disabilities

c) financial education

As any field that involves some kind of expenses, the teacher should focus on the rational use of chemical while performing experiment, strategies that should put into action to minimize the cost of manufactured products, so as to enhance the competition with products from various factories

1.4. Guidance on introductory activity

The tutor may ask student teacher to look at the introductory activity and briefly discuss and answer the questions where possible.

Note: this introductory activity should not take a lot of time since it’s not a lesson on itself. It’s just introduction of the unit. Remember student teachers may or may not have the answers for this activity.

Answers to the introductory activity questions.

(1) aluminium sheets produced in the factory B:Electric poles with wires C:Airplane /Air craft D: Test tubes

(ii) A: aluminium metal, B: aluminium pole with aluminium wires, C: Aluminium metal for Air craft boards, D: boron

(iii) For instance aluminium is used to manufacture aircrafts boards because aluminium is light(has low density),

- aluminium is used to make for electric transmission wires because it is a good conductor of electricity.
- Boron is used to make boiling test tubes because it has high melting point to withstand high temperatures.

1.5. List of lessons/sub-heading

#	Lesson title	Learning objectives	Periods
1	Physical properties of Group 13 elements (physical state, metallic character, physical appearance).	State the physical properties of Group13 elements.	1
2	Reactions of group 13 elements with oxygen, water, halogens, dilute acids and sodium hydroxide.	Explain the reactivity of Group 13 elements with oxygen, water, halogens, dilute acids and sodium hydroxide.	2
3	Amphoteric character of aluminium and gallium oxides and hydroxides.	Describe the properties of oxides, hydroxides and chlorides of Group 13 elements.	1
4	-Anomalous properties of boron and its compounds	Identify the anomalous properties of boron and its compounds	1
5	Identification of Al^{3+} ion in aqueous solution. Uses of Group 13 elements and their compounds: Boron: making electronic devices.	Perform chemical tests for the presence of aluminium ion in the solution. State the uses of Group 13 elements and their compounds.	2
End unit assessment			1

Lesson 1: Physical properties of Group 13 elements

(a)Prerequisites

This lesson is related to the periodicity and student teachers should recall some of the physical properties of elements on the periodic table about the variation of metallic character, physical state, ionization energy electronegativity across the period and down the group.

(b)Teaching resources:

- SME Student book for year 2 and SME student book for year 1
- Internet if available
- And any other necessary material such as aluminium sheet
- Periodic table of elements

(c)Learning activities

Guidance

The tutor may bring a piece of aluminium sheet in class to observe its appearance and if the electric poles are nearby available in school, the tutor can move outside with students to see the electric pole and observe the wires. Immediately the tutor may ask student teachers either to form groups or individually attempt activity 1.1

Answers to activity 1.1

(i) A: Aluminium sheet for roofing and B is aluminium sheet for packaging

(ii) They look shiny

(iii) Belongs to group 13

(iv) Iron is much heavier than aluminium.

(v) Roofing because it resistant to corrosion and packaging because it cannot react with moisture

d)Application activities

Answers to application activity 1.1

1. Down group 13, electrical conductivity increases due to increase in metallic character of the elements.

2.Refer to the notes (table 1.1 showing the physical properties of group 13) for group 2 elements the melting points decrease because the nuclear attraction reduces which reduces the metallic bond strength hence reduction in melting points.

The atomic radius in both groups 13 and 2 increases due to increase in shielding/screening effect down the group.

Lesson 2: Reactions of group 13 elements with oxygen, water, halogens, dilute acids and sodium hydroxide.

(a)Prerequisites/ Revision/ Introduction

The student teachers should have knowledge of how some elements react with water, dilute acids oxygen and halogens from ordinary level classes.

(b)Teaching resources

- Apparatus: Deflagrating spoon, Bunsen burner, glass beaker.
- Chemicals: aluminium sheet, hydrochloric acid, sodium hydroxide
- Other requirements: match box and petroleum gas/any other source of heat

(c)Learning activities

Guidance

The tutor may right way ask the student teachers to do activity 1.2 in their groups or individually and then share I to the whole class. This must take a very short time so that you can have ample time to do experiment 1.2 (a) and 1.2(b) in student book.

Answers to activity 1.2

1. (a) Al: $1s^2 2s^2 2p^6 3s^2 3p^1$

   (b) Aluminium possess 3 electrons in the outer shell (valence electrons) as seen from electronic configuration which contains ……$3s^2 3p^1$

   (c) $AlCl_3$

   (d) AlCl is not formed because it will be unstable since all the 3valence electrons have to be used for bonding for aluminium to become stable.

2. s-block elements form corresponding oxides of their metals when they react with oxygen, for instance

   (i) $4Na(s) + O_2(g) \longrightarrow 2Na_2O(s)$

   (ii) $Mg(s) + HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$

   (iii) $Na(s) + H_2O(l) \longrightarrow NaOH(aq) + H_2(g)$

   (iv) $Mg(s) + Cl_2(s) \longrightarrow MgCl_2(s)$

3. Basic oxides

4. Refer to notes about reactions of group13 elements to compare the reactivity with group 2 elements.

d) Application activity

Answers to application activity 1.2

1. When it reacts with water it forms aluminium oxide which is formed as layer on the surface of aluminium sheets that prevents further reaction and prevents the metal from further corrosion.

2.

$$2Al(s) + 6HCl(aq) \longrightarrow 2AlCl_3(aq) + 3H_2(g)$$

$$2Al(s) + 6H_2SO_4(aq) \longrightarrow Al_2(SO_4)_3(aq) + 3SO_2(g) + 6H_2O(g)$$

$$2Al(s) + 2NaOH(aq) + 6H_2O(l) \longrightarrow 2NaAl(OH)_4(aq) + 3H_2(g)$$

$$Al(s) + HNO_3(l) \longrightarrow Al(NO_3)_3(aq) + NO_2(g) + H_2O(l)$$

Lesson 3: Amphoteric character of aluminium, gallium oxides and hydroxides.

(a)Prerequisites/ Revision/ Introduction

The tutor can ask questions such as,

(1) To identify the type of oxide formed when calcium reacts with water.

(2) Write equation for the reaction that occurs when the oxide suggested reacts with water.

(b)Teaching resources

Aluminium oxide, test tubes, distilled water, 1M hydrochloric acid, universal indicator, 1M sodium hydroxide, Magnesium oxide, 1M nitric acid.

(c)Learning activities

Guidance

The tutor can provide the materials/ apparatus to be used in the activity 1.3 experiments and asks them to do the study questions after experiment as you guide them to write the equations that take place in the experiment.

Answers to activity 1.3

(a)No observable change, this indicates that aluminium oxide does not react with water.

(b) The change on the universal indicates shows the basic character of the aluminium oxide.

(c) The change on the universal indicate shows the acidic character of the aluminium oxide.

For (d) and (e) in procedure in 1. Refer to notes under activity 1.3

(d) Application activity

Answers to Application activity 1.3

1(a)This is due to fact that these elements being in the middle of the periodic table their characteristics are shared between those of metals and non-metals that's why group 13 oxides react with bases and acids.

(b)Refer to notes in the student book about amphoteric character of aluminium hydroxide

$$3HCl(aq) + Al(OH)_3(s) \longrightarrow AlCl_3(aq) + 3H_2O(l)$$

$$Al(OH)_3(s) + NaOH\ (aq) \longrightarrow Na[Al(OH)_4]$$

(c) S- block elements form basic oxides because they react with water to form basic solutions and reacts with acids to form salt and water.

(d)Refer to the note about reactions of oxides of aluminium oxide and other oxides in the same group(13)

2. $BeO + 2HCl \longrightarrow BeCl_2 + H_2O$ (dissolves in acid)

$BeO + 2NaOH \longrightarrow Na_2BeO_2 + H_2O$ (dissolves in base) and silicon dioxide also behaves in a similar way.

Lesson 4: Anomalous properties of boron and its compounds

(a)Prerequisites/ Revision/ Introduction

The tutor can make introduction about the causes of the anomalous behaviour in the first members of the groups on the periodic giving examples such as lithium, beryllium, boron, and fluorine in group 17. The anomalous behaviour of first element of s and p block elements of each group as compared to other group members is due to following reasons: Small size of atom, large charge/ radius ratio, high electronegativity and non- availability of d-orbitals in their valence shell.

(b)Teaching resources

- SME Student book for year 2 and SME student book for year 1
- Internet if available
- And any other necessary material such as aluminium sheet
- Periodic table of elements

(c)Learning activities

Guidance

Provide this activity to student teachers in advance such as may be two days before the lesson to allow them make a research and discussions to answer effectively activity 1.4

Answers to activity 1.4

- Beryllium has a high charge density due to the small atomic size. It shows a great tendency to form covalent compounds. Aluminium also has a tendency to form covalent compounds.
- Beryllium and aluminium show nearly the same value of electronegativity.
- Both beryllium and aluminium do not decompose water even on boiling. This is because of their weak electropositive character.
- Beryllium reacts very slowly with dilute mineral acids and liberates hydrogen similar to aluminium.

$$Be + 2HCl \longrightarrow BeCl_2 + H_2$$

$$2Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2$$

- Beryllium becomes passive (resistant to the attack of Conc. HNO_3). This is due to the formation of an inert oxide film on its surface. Also, aluminium shows similar behaviour. It forms an oxide layer when treated with Conc. HNO_3.
- Both elements, Be and Al reacts with caustic alkalis to form berylate and aluminate respectively.

$$Be + NaOH \longrightarrow Na_2BeO_2 + H_2$$

$$2Al + 2NaOH + 2H_2O \longrightarrow 2NaAlO_2 + 3H_2$$

- Beryllium oxide is extremely hard, non-volatile, and is amphoteric (dissolves in acids as well as in alkalis). It has a high melting point. Aluminium oxide also follows the same properties
- Beryllium oxide or hydroxide and aluminium oxide or hydroxide both is amphoteric in nature.

$BeO + 2HCl \longrightarrow BeCl_2 + H_2O$ (dissolves in acid)

$BeO + 2NaOH \longrightarrow Na_2BeO_2 + H_2O$ (dissolves in base)

$Al_2O_3 + 6HCl \longrightarrow 2AlCl_3 + 3H_2O$ (dissolves in acid)

$Al_2O_3 + 2NaOH \longrightarrow 2NaAlO_2 + H_2O$ (dissolves in base)

- Beryllium carbide gives methane on hydrolysis. Similarly, aluminium carbide gives methane on hydrolysis.
- Beryllium and aluminium form polymeric covalent hydrides in the vapour phase.

(d) Application activity

Answers to application activity 1.4

(a)Due to very small size, high electronegativity, high ionization enthalpy, absence of vacant d-orbital, Boron shows some anomalous properties

- Boron is a non-metal others are metals.
- Boron is extremely hard with high melting point. But, other elements are soft metals with low melting point.
- Boron forms only covalent compounds. But the other elements can form covalent as well as ionic compounds.
- The oxide of Boron is acidic. but the oxides of other elements are amphoteric or basic.
- Hydrides of Boron are stable.
- The trihalides of Boron cannot form dimer.

(b) The most basic anomaly that we notice in these elements is that Boron is a non-metal. In contrast to this, aluminium is a metal.

- While boron is a non-conductor of electricity, aluminium is a very good conductor of electricity.
- We can find Boron in two structures. These are the amorphous and crystalline structures. It does not exist in various structures.

- The boiling point and melting point of boron are much greater as compared to those of aluminium.
- Boron forms just covalent compounds while aluminium forms even some ionic compounds.
- The oxides and hydroxides of boron are acidic in nature. As compared to this, the oxides and hydroxides of aluminium are amphoteric in nature.
- The trihalides of boron (BX_3) are monomers. On the other hand, aluminium halides exist as dimers (Al_2X_6).

Lesson 5: Identification of Al3+ ion in aqueous solution and Uses of Group 13 elements and their compounds:

(a)Prerequisites/ Revision/ Introduction

Students should be reminded of how copper (ii) iron (ii), iron (iii) and other cations are tested and confirmed in the laboratory from ordinary level classes.

(b)Teaching resources

- **Apparatuses:** beaker, test tubes, droppers, test tube rack
- **Chemicals:** aluminium salt solution, sodium hydroxide, ammonia solution
- SME Student book for year 2 and SME student book for year 1
- Internet if available
- And any other necessary material such as aluminium sheet
- Periodic table of elements

Caution: Sodium hydroxide is corrosive and should be handled with care. Ammonia solution produces fumes which may cause suffocation if inhaled for long time.

(c)Learning activities

Guidance

- Prepare the procedure sheet and arrange the equipment and other chemicals need in time
- Make appropriate groups depending on your class size and materials available

- You can read the procedure together before you allow the student teachers to work on their own, so that some clarification is made in the procedure if needed.

Answers to activity 1.5

After performing the experiment, proper observations and report provided confirms the understanding and the skills you need to develop.

Find equations in student's book.

(d)Application activity

Answers to Application activity 1.5

1. $Al^{3+}(aq) + 3NaOH(aq) \longrightarrow Al(OH)_3(S) + 3Na^+(aq)$

White precipitate

$Al(OH)_3(s) + OH^-(aq) + \text{Water} \longrightarrow Al(OH)_4^-(aq)$

Colourless solution

$Al^{3+}(aq) + 3NH_4OH(aq) \longrightarrow Al(OH)_3(s) + 3NH_4^+(aq)$

$Al(OH)_3(s) + \text{excess ammonia} \longrightarrow \text{no observable change}$

(ammonia is a weak base and does not provide enough hydroxide ions to precipitate aluminium hydroxide where as a solution of sodium hydroxide precipitate aluminium hydroxide since it is a strong base

2. Materials/equipment : aluminium oxide, a 1M hydrochloric acid, droppers, test tube rack and test tube holder, boiling test tube, spatula. 1M sodium hydroxide, 1M ammonia solution

Procedure:

(i) Add one spatula full of aluminium oxide into a boiling test tube

(ii) Add enough hydrochloric acid solution into a test tube containing aluminium oxide.

(iii) Leave the experiment to stand for some time until all the oxide has dissolved.

(iv) Put about 1cm^3 of the solution obtained in (iii) into another boiling test tube followed by a few drops of ammonia solution drop -wise until in excess.

Expected observation: white precipitate insoluble is formed

(v) Repeat procedure (iv) using sodium hydroxide solution

Expected observation: **a white precipitate is formed in excess**

Conclusion: aluminium ions confirmed in procedure (v) present.

Skills lab 1

Provide the guidance on how they can carry out the skills lab by providing the internet link to the student teachers to carry out their research with ease.

https://www.scribd.com/document/46305653/Preparation-of-Aluminium-Oxide

1.6. Summary of the Unit

- Most of the elements of group 13 are metals showing non metallic character(amphoteric)
- Aluminium is a reactive metal but its reactivity is suppressed by a thin coating of inert unreactive oxide
- The high charge density is responsible for :
- The intermediate ionic/covalent bonding of aluminium oxide and its amphoteric character.
- The polarisation of anions with which it is associate resulting in partially covalent nature of aluminium chloride and other aluminium salts;
- The hydration of Al^{3+} ions in aqueous aluminium salts
- Aluminium hydrides hydrolyse easily in aqueous medium
- Aluminium oxide and aluminium hydroxide are amphoteric,dissolving in acids to form aluminium salts and in alkalis to form aluminates
- Boron is a non metal with a very small size and form covalent compounds
- Boron foms polymers (boranes)in which several molecules are held together and stabilised by hydrogen bridge.

1.7. Additional information for teachers

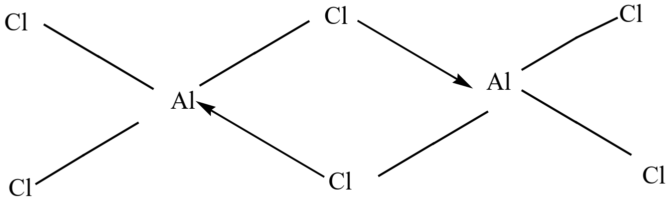
Bonding in Halides (AlF_3, $AlCl_3$, $AlBr_3$, AlI_3)

Aluminium shows an oxidation state of +3 in all of its compounds.

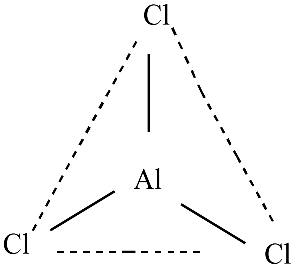
Because of high charge (large positive) and small ionic radius, Al^{3+} exerts polarizing effect on the halide ion in contact with it. This polarization is greatest as the size of the halide ion increases. Therefore the iodide (I^-) ion with greatest size is most polarized while the fluorine (F^-) ion experiences negligible polarization. Therefore AlF_3 is ionic while $AlCl_3$ is intermediate between ionic and covalent. Aluminium chloride exists as dimmer, Al_2Cl_6 in vapour phase and on heating sublimes at 180°C.

In the dimeric structure each aluminium atom accepts a lone pair of electrons from the chlorine atom bonded to the other aluminium atom. In doing so each aluminium atom completes its octet.

The structure of aluminium chloride in vapour phase



At ordinary conditions, $AlCl_3$ adopts trigonal planar structures



Aluminium bromide is typically covalent because of the large Br- size. Like aluminium chloride, it also exists as dimmer. Al_2I_6 is covalent and has also similar properties as Al_2Br_6.

Answers to end unit assessment.

1.(a)(i)Aluminium metal has low density

$$2Al(s) + 2NaOH(aq) + 6H_2O(l) \longrightarrow 2NaAl(OH)_4(aq) + 3H_2(g)$$

(ii)Sodium hydroxide reacts with Aluminium to evolve hydrogen gas. Thus the pressure of the gas produced can be used for clogged drains.

(iii)Aluminium does not react with nitric acid because it renders the acid inactive by a layer of aluminium oxide which prevents further reaction.

(iv)Aluminium is a good conductor of electricity

3.**Reagent**: sodium hydroxide

Observations: calcium ions form a white precipitate insoluble in excess aluminium ions from a white precipitate which dissolves in excess to form a colourless solution.

$$Ca^{2+}(aq) + 2OH^{-}(aq) \longrightarrow Ca(OH)_2(s)$$

$$Al^{3+}(aq) + 3OH^{-}(aq) \longrightarrow Al(OH)_3(s)$$

$$Al(OH)_3(s) + OH^{-}(aq) \longrightarrow Al(OH)_4^{-}(aq)$$

4.(i)Gallium reacts slowly with hydrochloric and other mineral acids to give the gallium ion, Ga^{3+}

$$2Ga(s)+6H_2O(l)+2OH^{-}(aq) \longrightarrow 3H_2(g)+2Ga(OH)_4^{-}(aq)$$

(ii)Refer to notes for this question for amphoteric character of aluminium oxide.

5. (a) Manufacture of window frames : light and resistant to corrosion

(b)Electrical wiring : good conductor of electricity

(c) Packaging food: prevents moisture since it reacts to form a layer of oxide that prevents further reaction.

(d) Suits for fire fighters: fire-fighter helmet with its non-flammable aluminium shell naturally withstands the enormous radiation heat with flame impact of a flash-over in extreme cases.

1.8. Additional activities

1.8.1. Remedial activities (Questions and answers)

1. Given the element Al (Z=13) and O (Z=8).

(i)Write their respective electronic structure in term of s, p, d, f orbitals.

(ii)Write the equation of reaction between Al and oxygen gas

(iii) The product formed in (ii) is amphoteric. What does it mean? Explain your answer using chemical reactions.

2. Explain why aluminium: a) conducts electric current.

b) has high melting point

3. What do you observe when to aluminium chloride salt is:

a) Added sodium hydroxide solution until excess

b) Added ammonia solution until excess.

In each case give the formula of the final aluminium containing species

4. Explain why it is better to use cooking utensils made up of aluminium.

5. Boron exhibits an exceptional boiling point compared to other element of the same group. Explain why.

Answers to remedial activities

1. (i)Al (Z=13):$1s^2\ 2s^2\ 2p^6\ 3s^2 3p^1$

O (Z=8): $1s^2\ 2s^2\ 2p^4$

(ii) $2Al(s) + 3O_2(g) \longrightarrow 2Al_2O_3(s)$

(iii) Amphoteric means compounds that react with both acids and bases

Example: Aluminium oxide is amphoteric:

-it dissolves in mineral acids to form aluminium salts: in this case it acts as a base.

$$Al_2O_3(s) + 6H^+(aq) \longrightarrow 2Al^{3+}(aq) + 3H_2O(l)$$

- it dissolves in caustic alkali to form aluminate: in this case it acts as an acid.

1. $Al_2O_3(aq) + 2OH^-(aq) + 3H_2O(l) \longrightarrow 2[Al(OH)_4]^-(aq)$

(a) (i) Al conducts electricity due to free electrons

(ii) The higher melting point originates from strong metallic bond caused by 3 electrons lost by each atom involved

3. By adding sodium hydroxide to an aluminium salt solution until excess a white precipitate of aluminium hydroxide is formed .this one dissolves in excess sodium hydroxide forming tetrahydroxoaluminate $Al(OH)^-_4$

By adding to ammonia solution to aluminium salt solution until excess a white precipitate of $Al(OH)_3$ insoluble in excess is formed

4. It is better to use cooking utensils made up of aluminium because of its bright appearance and lightness, resistance to corrosion, and its thermal conductivity

5. Boron exhibits an exceptional boiling point compared to other element of the same group because of its small size and high charge which results in strong

attraction between the nucleus and electrons hence strong bond.

1.8.2. Consolidation activities

1. The list below is about the chloride of group 13 elements: $GaCl_3$, BCl_3, $InCl_3$, $AlCl_3$, $TlCl_3$. Arrange them according to their decreasing order of ionic character and explain the general trend in the character.
2. Arrange the following compounds in increasing order of the covalent character and justify.

GaI_3, $GaCl_3$, $GaBr_3$

3. The following table shows 3 unknown group 13 elements halides A, B, C and some of their melting points. Predict among the group 13 elements halides (AlF_3, $AlBr_3$, $AlCl_3$), which one should correspond to A,B,C. Justify your answer

Element	Melting points (^oC)
A	180
B	1265
C	97

Answers to consolidation activities

1. The decreasing order of ionic character is as follows: $TlCl_3$, $InCl_3$, $GaCl_3$, $AlCl_3$, BCl_3, Bigger cations give ionic compounds, smaller cations give covalent compounds. The ionic character increases down the group as the atomic radius increases
2. The increasing order of the covalent character means from the more ionic to the less ionic or from the less covalent to the more covalent. We have therefore, $GaCl_3$, $GaBr_3$,GaI_3

   For a same cation the ionic character increases as the radius of the anion decreases
3. A: has an intermediate value of melting point. It is probably $AlCl_3$

   B: has a higher melting point .It has an ionic character therefore it is AlF_3. Where Al is bonded to small anion fluoride

   C: with lower melting point, the property for covalent compounds. It is $AlBr_3$where Al is bonded to bigger anion bromide

1.9. Extended activities

1. An element A reacts with another element B to form a AB_3compound of formula .The element B exists as diatomic B_2. Some properties of A, B_2, and AB_3 are tabulated below:

	A	**B_2**	**AB_3**
Melting point	High(in the range of 700^0C-1200^0C)	Very low(less than -100^0C)	High(in the range of 1000^0C-1270^0C)
Electrical conductivity of the solid	High	Very low	Very low
Electrical conductivity of molten material	High	Very low	High
Electrical conductivity of aqueous solution of the material			High

(a) Which particles will move when a potential difference is applied across on

(i) Solid A (ii) Molten AB_3

(b) Explain why the electrical conductivity of molten AB_3 is high whereas that of the solid is very low.

(c) Suggest the type of bond present in each material and justify.

2. An element E of group 13 forms compound F when it is reacted with chlorine. The same element cannot react with oxygen to produce an oxide. However its oxide G is produced by heating its corresponding acid H. The study of the compound of this element E shows the following results:

F has low melting point and does not conduct electric current in molten and aqueous solution.

G is acidic and can react with a solution of sodium hydroxide

a) Identify the element E.

b) Write the equation of reaction between E and chlorine to form the compound F

c) Give the formula of the oxide G

d) Write the equation of reaction between the oxide G and sodium hydroxide.

e) (i) Give the formula of the acid H from which the oxide G is obtained.

(ii) Write the equation of thermal decomposition of the acid H to produce the oxide G.

Answers to extended activities

1. (a) particles that will move when a potential difference is applied across on

(i) Solid A: Electrons

(ii) Molten AB_3: Free ions

b) In the molten state the ions are free to move in AB_3

c) A: has metallic bond due to high melting point and electrical conductivity in solid state

B_2: has covalent bond due to lower melting point and very low electrical conductivity in molten state

AB_3: ionic bond due to electrical conductivity in molten state, higher melting point and high electrical conductivity in aqueous solution.

2. (a) E is boron

b) $2B(s) + 3Cl_2(g) \longrightarrow 2BCl_3(g)$ (F)

(c) Formula of G: B_2O_3

d) $B_2O_3(s) + 2NaOH(aq) \longrightarrow 2NaBO_2(aq) + H_2O(l)$

(e) H_3BO_3 (i) Give the formula of the acid H from which the oxide G is obtained.

$2\ H_3BO_3(s) \longrightarrow B_2O_3(s) + 3H_2O(l)$

UNIT
2

CHEMICAL PROPERTIES OF S- BLOCK ELEMENTS

2.1. Key unit competence

Describe the trends in chemical properties of s -bloc elements and their compounds.

2.2. Prerequisite (knowledge, skills, attitudes and values)

Components of an atom and their properties, definition of an atomic number, mass number and electronic structure, chemical reactions ,trend in physical properties of elements in periodic table ,handling laboratory equipment, safety rules , regulations in laboratory and Periodicity of elements.

2.3. Cross-cutting issues to be addressed

a) Financial education

As any field that involves some kind of expenses, the teacher should focus on the rational use of chemical while performing experiment, strategies that should put into action to minimize the cost of manufactured products, so as to enhance the competition with products from various factories

b) Standardisation culture

Chemistry is an area of study where standards must be remembered. This concerns equipment handling, writing chemical formulae of different substances and laboratory rules in general.

2.4. Guidance on introductory activity

The tutor can provide a sketch of the periodic table or ask the student teachers to look into their student books about the introductory activity to answer the questions below the picture.

2.5. List of lessons/sub-heading

Lesson tittles	Learning Objectives	No of periods
Reactivity of Group 1 and 2 elements with: oxygen, water and the halogens.	Describe and explain the reactivity of the Group 1 and 2elements with oxygen, water and the halogens Compare the reactivity of Group 1 and 2 elements.	1
Properties of Group 1 and 2 oxides and hydroxides.	State and explain the properties of Group 1 and 2 oxides and hydroxides. Perform experiments to test the alkalinity of Group 1 and2 hydroxides	1
Effect of heat on Group 1 and 2 carbonates and nitrates.	Interpret the trends in the thermal decomposition of Group 1 and 2carbonates and nitrates	1
Solubility of Group 1 and 2 compounds and uses elements and their compounds.	Explain the trends in the solubility of Group 1 and 2 compounds.	1
End unit assessment		1

Lesson 1: Reactivity of Group 1 and 2 elements with: oxygen, water and the halogens.

a) Prerequisites/ Revision/ Introduction

Periodicity of elements, chemical bonding, electronic configuration of elements and ions

b) Teaching resources

- SME Student book for year 2 and SME student book for year 1
- Internet if available
- And any other necessary material such as aluminium sheet
- Periodic table of elements

c) Learning activities

Guidance

The tutor may form groups and provides the activity 2.1. The tutor should provide written questions to groups to minimise time wastage during writing on the blackboard or provides a student book and write the page on the black board.

Answers to activity 2.1

1. Very reactive elements therefore oil/paraffin prevents them from exposure to oxygen or moisture.
2. Calcium reacts vigorously with concentrated hydrochloric acid with great effervescence which splashes the solution out of the reaction container.
3. When exposed to air, it tarnishes due to the reaction with air/oxygen to form sodium oxide.
4. The reaction is highly exothermic and produces hydrogen gas which catches fire due to the oxygen in the air.
5. Solid Sodium chloride.
6. Study questions for experiment in application activity 2.1
   a) Refer to notes for group 1 and 2 elements
   b) Refer to notes for the products formed in each case.
   c) When they are tested with water their aqueous solutions turn a red litmus paper blue since they are alkaline in nature.
   d) Refer to notes about reactions of oxides of group1 and 2 with water.

d) Application activity

Answers to application activity 2.1

1. (a)(i)Calcium reacts with cold water vigorously forming a milky solution of calcium hydroxide

(ii) Magnesium reacts slowly with cold water forming magnesium hydroxide but reacts with hot water (steam) vigorously to form magnesium oxide and hydrogen gas.

(iii)Barium reacts much faster that calcium forming Barium hydroxide

(b)Reactivity of group 1 and 2 increases downs the groups therefore, barium reacts faster with water than calcium likewise, and rubidium reacts faster with water than sodium.

Similarly, calcium reacts to form corresponding salts and hydrogen gas.

$$Na(s) + 2HCl(aq) \longrightarrow NaCl(aq) + H_2(g)$$

$$2\ Na(s) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + H_2(g)$$

$$2Na(s) + H(NO_3)_2(aq) \longrightarrow NaNO_3(aq) + H_2(g)$$

Lesson 2: Properties of Group 1 and 2 oxides and hydroxides.

a) Prerequisites/ Revision/ Introduction

Ionic and covalent bonding, types of oxides

b) Teaching resources

- SME Student book for year 2 and SME student book for year 1
- Internet if available
- And any other necessary material such as aluminium sheet
- Periodic table of elements.

c) Learning activities

Guidance:

The tutor provides the activity 2.2 to student teachers in their groups and asks them to discuss and provide answers. Student teachers share the the answers to different groups.

Answers to activity 2.2

1. Calcium oxide.

$$CaO(s) + H_2O\ (l) \longrightarrow Ca(OH)_2(s)$$

(Milky solution) it turned litmus paper blue because it is alkaline solution

It neutralizes acidic soils

(a) $4Na(s) + O_2(g) \longrightarrow 2Na_2O(s)$ sodium oxide

$2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$ magnesium oxide

$2Ca(s) + O_2(g) \longrightarrow 2CaO(s)$ calcium oxide

$2Ba(s) + O_2(s) \longrightarrow 2\ BaO(s)$ Barium oxide

(c)The solutions of the products when dropped in water and tested with red litmus paper, it turned blue because they are alkaline solutions.

d) Application activity

Answers to application activity 2.2

Refer to student book notes for answers

Lesson 3: Effect of heat on Group 1 and 2 carbonates and nitrates.

a) Prerequisites/ Revision/ Introduction

Students will learn better the effect of heat on carbonates and nitrates if they have understanding on: the variation in trends of physical properties of elements in periodic table, the arrangement of elements in the periodic table and writing the electronic configuration of elements, (refer to unit 5), the chemical reactions as they have learnt it in senior 2 &3 O' level, the safety rules and regulations learnt in senior 1&3 O' level.

b) Teaching resources

- **Apparatus:** glass test tubes, pair of tongs, wooden splint/match stick, Bunsen burner/heat source and spatula.
- **Chemicals:** Lithium nitrate, potassium nitrate
- Other requirements: match box

c) Learning activities

Guidance

Form groups and provide practical activity (experiment) with procedure but if the student book are available they can use student book and refer to activity 2.3

Answers to activity 2.3

Refer to the notes about the decomposition of nitrates

Nitrates of group 1, decompose to form their corresponding nitrites and whereas nitrates of group 2 decompose to form their corresponding nitrates , nitrogen dioxide and oxygen gas

Refer to the decomposition of carbonates

Carbonates of group 1 do not have effect on heating. However, carbonates of group 2 decompose to form their corresponding oxides and carbon dioxide.

d) Application activities

Answers to application activity 2.3

1. a) The thermal stability of magnesium carbonate is less stable compared to calcium carbonate

$$MgCO_3 (s) \longrightarrow MgO(s) + CO_2(s)$$

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$$

b) The thermal stability increases down the group due increase in size of cations that reduces polarization of cations and increases ionic character.

c) sodium carbonate decomposes at very high temperatures compared to magnesium since magnesium cation is smaller than sodium ion which polarizes more the carbonate and distort the electron distribution hence covalence in magnesium carbonate.

2) (i)Magnesium oxide

$MgCO_3(s) \longrightarrow MgO(s) + CO_2(s)$

3) (i) Magnesium oxide

(ii) $Mg(NO_3)_2(s) \longrightarrow MgO(s) + 4NO_2(g) + O_2(s)$

(iii)Nitrogen dioxide gas

4) $NaNO_3(s) \longrightarrow NaNO_2(aq) + O_2(g)$

Colourless gas is oxygen and colourless solution is sodium nitrate.

Lesson 4: Solubility of Group 1 and 2 compounds and uses of elements and their compounds.

a) Prerequisites/ Revision/ Introduction

The ionic and covalent bonding. The ionic compounds are soluble in water while covalent compounds do not dissolve in water. However, some covalent compounds with polar bonds dissolve in water.

b) Teaching resources

Magnesium carbonate, sodium carbonate, Calcium hydroxide, sodium hydroxide, barium hydroxide, magnesium hydroxide, Barium carbonate, potassium carbonate, calcium nitrate, sodium nitrate, test tubes, paraffin, beakers, spatula, sodium oxide and calcium oxide.

c) Learning activities

Guidance

Form groups and provide the experimental activity 2.4 in their groups. First allow them to go through the procedure before starting. Ask student teachers if there is something not clear and need clarification.

Answers to activity 2.4

Carbonates of group2 are slightly soluble in water while the carbonates of group 1 dissolve readily in water.

Hydroxides of group 2 behave similarly like their corresponding carbonates and group 1 hydroxides are very soluble in water forming strong alkaline solutions

All nitrates are soluble in water irrespective of the group element they are derived from.

d) Application activities

Answers to application activity 2.4

1(a) Due to large size of the cations their tendency to transfer electrons from their outer shell is high

(ii) They are soluble in polar solvents such as water but insoluble in non-polar solvents such organic solvents(e.g. ethanol, acetone, dichloromethane, etc…)

(b) Anomalous behaviour of an element refers to the deviation of the properties and behaviour of an element from its usual or normal behaviour.

It is due to the following reasons:

(i) Exceptionally small size of its atom and ion

(ii) High polarizing power

The anomalous behaviour of lithium is as follows:

- Lithium is harder than other metals of the respective group.
- It has higher Melting and boiling point than other metals
- It is least reactive.
- It is strongest reducing agent.
- Unlike other metals LiCl is deliquescent and exist as $LiCl.2H_2O$
- Li^+ ion polarizes water molecules readily than other alkali metals of the respective group and hence the lithium salts attracts the water molecules and it exists as water of crystallization ($2H_2O$). As the polarizing power decreases with the increasing size of the ions the other alkali metal ions usually form anhydrous salts.
- Heating lithium nitrate results in the production of lithium oxide, Li_2

$$4LiNO_3 \longrightarrow 2Li_2O + 4NO_2 + O_2$$

Lithium nitrate Lithium oxide

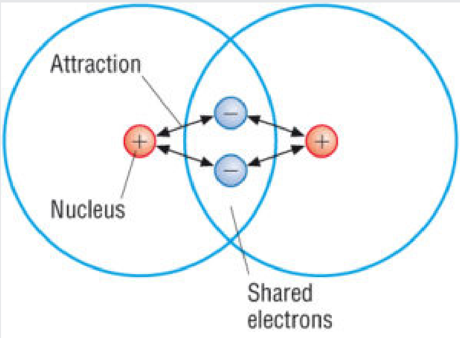
- Heating nitrates of other alkali metal results in the decomposition of the nitrate leading to the production of their corresponding nitrite.

$$2NaNO_3 \longrightarrow 2NaNO_2 + O_2$$

Sodium nitrate Sodium nitrite

Properties of covalent compounds

- Covalent compounds usually have low melting points. An exception to this includes molecules of silica and diamonds that have a high melting point.
- These compounds have low boiling points. This can be attributed to their weak force of attraction between the various bonded atoms. Van Der Waals forces bind these atoms.
- These compounds are usually gases and liquids with low boiling and melting points.
- The solid covalent compounds have soft structures like graphite. This is because of the presence of a cloud of electrons in between each layer of carbons atoms.
- These compounds are non-conductors of electrical charge. The absence of charged ions is the main reason behind this. An exception to this is graphite, where we see a cloud of electrons. These make graphite a good conductor.
- They are bad conductors of heat also. Their molecules lack free electrons and that obstructs the flow of heat energy.
- Covalent compounds do not possess polar characteristics as a general property. Therefore, these compounds are insoluble in water. Water molecules are not absolutely neutral and have a slight negative charge on the oxygen atom and slight positive charges on the hydrogen atoms and since covalent compounds are made up of neutral molecules or molecules with slight charges and hence are not attracted to water molecules strongly.



2 and 3 refer to the notes for answers on decomposition of carbonates and nitrates of group 1and 2.

3carbonates decompose to corresponding oxides and carbon dioxide gas whereas the nitrates decompose to oxides, nitrogen dioxide and oxygen except group 1 nitrates which decompose to nitrites and oxygen gas

Carbon dioxide gas: turns lime water milky and the colourless in excess carbon dioxide

Oxygen: Relights a glowing splint

Nitrogen gas: a brown gas turns litmus red.

Skills lab 2

Divide the students into two groups and give one group

(i) solubility of carbonates of group2

(ii) Thermal stability of carbonates.

Ask the student teachers to present their findings and share the information with clearly written report.

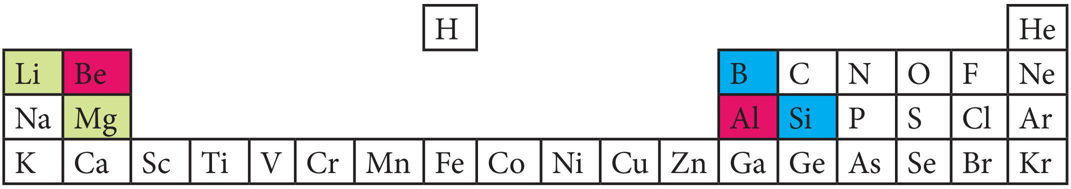
2.6. Summary of the Unit

- They are comprised of group 1 & 2 elements
- Are good reducing agents. Their reducing power increases the top to the bottom down the group.
- Lithium behaves differently from other element in this group because of its small size which results in its polarizing power
- Group1 form strong ionic compounds with non-metals than group 2
- React with water to produce hydrogen gas and an alkaline solution
- Group 1 elements react with oxygen to form monoxides, peroxides and superoxide. Lithium forms only monoxide whereas group 2 elements react with oxygen to form corresponding oxides which are alkaline.
- Form various compounds such as: oxides, hydroxides, carbonates, nitrates,
- Thermal decomposition of Lithium carbonate and lithium nitrate differs from that of the rest of the group due to small size of lithium.
- Group 2 elements contain soft, silvery metals that are less metallic in character than group 1 elements. Although many characteristics are common across the group, the heavier metals such as Ca, Sr, Ba and Ra are almost as reactive as the group 1 metals.
- Solubility of their hydroxides increases as you go up in the group, while that of Sulphates decreases as you go down the group.

2.7. Additional information for teachers

Diagonal relationship

Three examples are shown in the diagram below. Notice that the similarities occur in elements which are diagonal to each other - not side-by-side.



							H										He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr

At the beginning of periods 2 and 3 of the Periodic Table, there are several cases where an element at the top of one group has some similarities with an element in the next group.

For example, boron is a non-metal with some properties rather like silicon. Unlike the rest of Group 2, beryllium has some properties resembling aluminium. And lithium has some properties which differ from the other elements in Group 1, and in some ways resembles magnesium.

There is said to be a diagonal relationship between these elements.

There are several reasons for this, but each depends on the way atomic properties like electronegativity vary around the Periodic Table.

So we will have a quick look at this with regard to electronegativity - which is probably the simplest to explain.

End unit assessment

Answers to end unit assessment 2

1. A:Calcium oxide B: calcium hydroxide C: calcium carbonate D: calcium hydrogen carbonate
2. A: Calcium metal

$$Ca(s) + O_2(g) \longrightarrow CaO(s)$$

$$Ca(s) + H_2O(l) \longrightarrow Ca(OH)_2(s)$$

$$Ca(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2(g)$$

3(a)The reaction very vigorous and splashes out of the container because it produces a lot of effervescence.

(b) (i)hydrogen gas, solid calcium hydroxide

$$Ca(s) + H_2O(l) \longrightarrow Ca(OH)_2(s) + H_2(g)$$

ii) $Ca(OH)_2(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l)$

The solution formed is heated to dryness until crystals start to form and cool the solution.

4. A: Strontium hydroxide B: Hydrogen gas C: Strontium oxide D carbon dioxide gas

2.8. Additional activities

2.8.1. Remedial activities (Questions and answers)

1. Explain the origin of the name alkali metal for group 1 element .Illustrate your answer using reaction of sodium with water.
2. Why does group 1 element form ionic compounds?
3. Potassium oxide is an basic oxide. What does it mean?
4. Write the equation of reaction between potassium with:
   a) Oxygen
   b) Chlorine
   c) Water
5. Write the electronic structure of (Z=19) that of the ion K^+
6. Show how the following substances can be obtained.
   a)CaO from Ca
   b)$BaCl_2$ from Ba
   c)$Mg(OH)_2$ from $MgCl_2$
   d)$Ca(OH)_2$ from $CaCO_3$

Answers to remedial activities

1. The name alkali comes from the ability of group 1 element to form strong alkaline solution when they react with water.

   $2Na(s) + 2H_2O\ (l) \longrightarrow 2NaOH(aq) + H_2(g)$

2. Group 1 element form ionic compounds because they lose easily their single outermost electrons.
3. Potassium is a basic oxide because it reacts with water to form a basic solution.

4.a) $K(s) + O_2(g) \longrightarrow KO_2(s)$

b) $2K(s) + Cl_2(g) \longrightarrow 2KCl(s)$

c) $2K(s) + 2H_2O(l) \longrightarrow 2KOH\ (aq) + H_2(g)$

5. K (Z=19) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$ that of the ion K^+: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

6.

a) $Ca(s) + O_2(g) \longrightarrow CaO(s)$

b) $Ba(s) + 2HCl(aq) \longrightarrow BaCl_2(aq)$

c) $MgCl_2\ (aq) + 2NaOH(aq) \longrightarrow Mg(OH)_2(s) + 2NaCl(aq)$

d) Heating the salt:
$CaCO_3(s) \longrightarrow CaO(s) + CO_2(aq)$

$CaO + H_2O \longrightarrow Ca(OH)_2$

2.8.2. Consolidation activities

1. (a) The statements below are about white solid compound containing an s-block element. For each statement say what conclusions can be drawn at that stage:

   i) The compound reacted with water to give a colourless gas and an alkaline solution

   ii) The gas gives pop sound when tested with a small lighted wax candle

   iii) A flame test on the solution gives a lilac flame

b) Write the equation for the reaction.

2. (a) This question concerns a white solid compound of an s-block metal. For each statement say what conclusions you can draw at that stage

i) On heating it produced a brown gas and a white powder

ii) The resulting white solid was soluble to give an alkaline solution

iii) A flame test on the original solid gave a deep red colour

b) Write the equation for the reactions in (i) and in (ii)

3. Magnesium and strontium are typical group 2 metals.

a) Complete the electron configuration of magnesium atom.

b) The second ionization energy of magnesium is 1064kJ.mol^{-1}.

i)Write an equation to represent the second ionization energy of magnesium. Include states and symbols.

ii)Magnesium has a greater, second ionization energy than strontium. Explain why?

c) A student watches a demonstration in which strontium is added to water.

The equation for the reaction is shown below.

$$Sr(s) + 2H_2O(l) \longrightarrow Sr(OH)_2(aq) + H_2(aq)$$

Answers:

1. (a) i. Alkali metal is suspected

ii) Hydrogen gas confirmed by pop sound with burning candle

iii) K is confirmed by the lilac flame colour

b)$2\ K(s) + 2H_2O(l) \longrightarrow 2KOH(aq) + H_2(g)$

2. (a) i)Brown NO_2 gas is suspected resulting from decomposition of a nitrate

ii) An alkali oxide that dissolves in water is suspected

iii) Lithium ion are confirmed by the deep red flame test colour

b i) $2LiNO_3(s) \longrightarrow Li_2O(s) + 2NO_2(g) + 1/2\ O_2(g)$

ii) $Li_2O(s) + H_2O(l) \longrightarrow 2LiOH(aq$

3. (a) Mg (z = 12):$1s^2 2s^2 2p^6 3s^2$

b) i) $Mg \rightarrow Mg^+ + e^-$ First ionization

$Mg^+ \rightarrow Mg^{2+} + e^-$ Second ionization

ii) Magnesium is above strontium in the periodic table. The second ionization energy decreases as you go down the group, because the second electrons will be more distant from the nucleus when number of shells increases. The nuclear attraction decreases and the electron is removed easily.

c) i) The aqueous ions are: Sr^{2+} (aq) and $2OH^-_{(aq)}$

ii) Strontium has the ability of losing the electrons (electropositivity), while oxygen has the ability of gaining them. Strontium is oxidized by oxygen of water.

iii) Example: $SrCl_2$ and NaOH

(d)H_2SO_3 reacts, with $Sr(OH)_2$

2.9. Extended activities

1. An s-block element A is a starting point of a series of reaction that are described in the following lines.

The element A reacts with water to produce a solution of substance B and a colourless gas C. When A is burnt in chlorine gas, the substance D is obtained.

The aqueous solution of the substance D conducts electricity and gives a yellow colour on a Bunsen flame.

On the other side A burns in oxygen gas giving 2 types of oxides E and F.

The oxide E gives a solution of substance B, while the oxide F reacts with water producing a solution of substance B and the release of a gas a colourless gas G.

The substance B reacts with an acidic solution of nitric acid to give a salt solution H of nitrate of A which decomposes on heat to produce a salt I and the colourless gas G.

a) Identify substance A to I
b) Write the equations of reactions that lead to substance B in the description above.
c) Explain what happens when A is burnt in oxygen to form E and F
d) Write the equation of reaction between F and water.
e) Describe the chemical tests to differentiate the gases C and G
f) Write the equation of thermal decomposition of substance H

2. A chemist carries out reactions of barium nitride, Ba_3N_2.

Reaction 1: Barium is reacted with water

Reaction 2: Barium nitride is reacted with water, forming an alkaline solution and an alkaline gas.

Reaction 3: Barium is reacted with an excess of oxygen at 500°C, forming barium peroxide, BaO_2

a) Write equations for reaction 1 and reaction2 (Ignore state and symbols)

b) Determine the oxidation states of barium and nitrogen in Ba_3N_2.

c) BaO_2 formed in reaction 3 contains barium and peroxide ions. The peroxide ion has the structure $[O\text{-}O]^{2-}$.

Determine the oxidation states of barium and oxygen.

Answers:

1. a) The key of the statement is located on the confirmatory yellow flame test which indicates the presence of Na^+

So D is a salt that contains sodium ions. The beginning point A is Na .So the series of reactions contain sodium in the following stages

Stage 1: A: Na, B: NaOH, C:H_2, D:NaCl,

Stage 2: E: Na_2O, F: Na_2O_2, substance B: NaOH, Colourless gas G is O_2

Stage 3: H: $NaNO_3$ I: $NaNO_2$ G: O_2

b) $Na(s)+H_2O(l) \longrightarrow NaOH(aq) +H_2(g)$

c) Normal oxide of sodium and sodium peroxide are formed because of the vigorous reactivity of Na

d) $Na_2O_2\ (s)+H_2O\ (l) \longrightarrow 2NaOH(aq)+O_2(g)$

e) C: is hydrogen and tested by a burning splint. The pop sound is heard

G: is oxygen and tested using a glowing splint that is relighted.

f) $2NaNO_3(s) \longrightarrow 2\ NaNO_2(s) +O_2(g)$

2. a) Reaction1: $Ba + 2H_2O \longrightarrow Ba(OH)_2 + H_2$

Reaction 2: $Ba_3N_2 + 3H_2O \longrightarrow 3Ba(OH)_2(aq) + N_2(g)$

b)Barium: Oxidation state = $^+2$

Nitrogen: Oxidation state = $^-3$

c) Ba: Oxidation state = $^+2$

O: Oxidation state = $_-1$

UNIT
3

TRENDS IN CHEMICAL PROPERTIES OF GROUP 14 ELEMENTS AND THEIR COMPOUNDS

3.1. Key unit competence

Compare the chemical properties of the Group 14 elements and their compounds in relation to their position in the periodic table

3.2. Prerequisite (knowledge, skills, attitudes and values)

The physical properties of metals and of non-metals, electronegativity, atomic radius, metallic character and ionization energy of elements

3.3. Cross-cutting issues to be addressed

a) Gender

- General needs of people to complement each other without conflict in order to be peaceful.

The nature of atoms can be related to relationship in human beings. There is a serious issue of misunderstanding of gender equality in our society.

- When introducing this unit, it would be an opportunity to guide learners on understanding the importance of gender equality and how the issues related to gender inequality may be addressed.
- Help learners to:

i) Understand that complementarities are very important. Atoms constituents such as protons and neutrons coexist in the atomic nuclei for playing the specific role. Students should know that females and males are both human beings and no one should assume to be more important than another.

ii) Understand that gender equality plays a big role in the development of the country.

iii) Understand that females need males and vice-versa in different ways for their future achievement.

iv) Underlining the necessity of cooperation and working in mixed groups rather than working in single groups)

This can be done in a short whole class discussion. This may be an opportunity for you as chemistry teacher to confront the individual students who need advice on relationship matters.

b) Inclusive education

This unit involves a number of activities on the properties and means of extraction; the activities require reading and writing. This may be challenging to students with special educational needs especially children with visual impairment. However, the teacher can make some arrangements like:

- Grouping students. Students with special educational needs are grouped with others and assigned roles basing on individual student's disabilities.
- Providing the procedure early enough before the activity so that students get familiar with them. They can be written on the chalkboard or marker board or printed depending on available resources. If you have children with low vision, remember to print in appropriate fonts or in Braille.
- Every important point is written and spoken. The written points help students with hearing impairment and speaking aloud helps students with visual impairment
- Remember to repeat the main points of the lessons.

3.4. Guidance on introductory activity

Ask the student teachers to analyse the picture carefully and ask them to answer the questions below it.

Note: this activity should not take long since it's not a learning activity.

i) Mining (machines used for mining and showing underground soil)

ii) Any mentioned and any suggested problems such as soil erosion, or land degradation, displacement of people, etc.

iii) Tin since Z are tin containers

3.5. List of lessons/sub-heading

#	Lesson title	Learning objectives	Periods
1	Comparative study of physical properties of the Group 14 elements: physical state, metallic character, electrical conductivity.	- State physical properties of Group 14 elements. - State the chemical properties of Group 14 elements.	1

2	Reactions of C, Sn, Pb, Si with oxygen, hydrogen, chlorine, dilute acids/ concentrated acids and hydroxides.	Distinguish between the chemical reactions of the oxides and chlorides of Group 14 elements	2
3	Reaction of oxides, chlorides of group 14 with water, acids and strong alkaline solutions.	Distinguish between the chemical reactions of the oxides and chlorides of Group 14 elements	. 2
4	Thermal stability of oxides, halides and hydroxides.	Explain the trends in thermal stability of the oxide, halides and hydrides of Group 14 elements.	1
5	Trends in stability of oxidation states: +2 and +4 as a result of inert pair effect. - Uses of Group 14 elements.	Explain the variation in stability of oxidation state of +2 and +4 down the Group 14 elements. Mention the uses of Group 14 elements.	2
	End unit assessment		1

Lesson 1: Comparative study of physical properties of the Group 14 elements: physical state, metallic character, electrical conductivity.

a) Prerequisites/ Revision/ Introduction

The chemical properties of group13 elements, chemical bonding, physical and chemical properties of s- block elements. Writing electronic configuration according s,p, d and f notations.

b) Teaching resources

- Periodic table of elements
- SME student book
- Internet can be used if available

c) Learning activities

Guidance

Form groups or pairs and provide the activity 3.1

Answers to learning activity 3.1

i) Metallic character increases down the group from boron to thallium

ii) they all exist solids at room temperature

iii) They all conduct electric current except Boron which is a non-metal.

2. Carbon graphite has delocalized electrons between the hexagonal layers which are used to conduct electricity current whereas carbon diamond all electrons are used in bonding and luck delocalized electrons.

d) Application activities

Answers to application activity 3.1

Refer to S-block, group 13 and group 14.

Lesson 2: Reactions of C, Sn, Pb, Si with oxygen, hydrogen, chlorine, dilute acids/concentrated acids and hydroxides.

a) Prerequisites

Chemical reactions of S- block elements, group 13 elements with hydrogen, dilute and concentrated acids

b) Teaching resources

- Periodic table of elements
- SME student book
- Internet can be used if available

c) Learning activities

Guidance

Form groups or pairs and provide the activity 3.2. After discussions in the groups allow some groups to share their findings

Answers to learning activity 3.2

1. Refer to students book unit 1

2. (i) Refer to notes about reactions of group 13 elements under 1.2

   (ii) It dissolves in mineral acids to form aluminium salts: in this case it acts as a base.

   (iii) $Al_2O_3(aq) + 6\,HCl(aq) \longrightarrow 2AlCl_3(aq) + 3H_2O(l)$ **(Basic nature)**

Or $Al_2O_3(s) + 6H^+(aq) \longrightarrow 2Al^{3+}(aq) + 3H_2O(l)$

It dissolves in caustic alkali to form aluminate: in this case it acts as an acid.

$Al_2O_3(s) + 2NaOH(aq) \longrightarrow Na_2Al_2O_3 + H_2O$ **(Acidic nature)**

Or $Al_2O_3(aq) + 2OH^-(aq) + 3H_2O(l) \longrightarrow 2[Al(OH)_4]^-(aq)$

Similarly, Aluminium hydroxide also shows amphoteric properties.

$3HCl(aq) + Al(OH)_3(s) \longrightarrow AlCl_3(aq) + 3H_2O(l)$

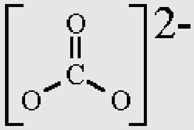
$Al(OH)_3(s) + NaOH\,(aq) \longrightarrow Na[Al(OH)_4]$

   (iv) Aluminium reacts with sodium hydroxide, so it cannot be used to carry sodium hydroxide.

d) Application activities

Answers to application activity 3.2

1. CO_2 : $O{=}C{=}O$ CO_3^{2-} :



   Carbon monoxide CO: $O\overset{\rightarrow}{\equiv}C$ or $O\equiv C$

2. Carbon dioxide reacts with water to form a weak carbonic acid which turns blue litmus paper pink.

3. React with bases and acid as follows:

   (i) $Al_2O_3(s) + 6HCl(aq) \longrightarrow 2ACl_3(aq) + 3H_2O(l)$

   Aluminium oxide hydrochloric acid Aluminium chloride

(ii) $$Al_2O_3(s) + 2NaOH(aq) \longrightarrow 2NaAlO_2(aq) + H_2O(l)$$

Aluminium Oxide

Sodium hydroxide

Sodium aluminate

4. Refer to notes about the reactions of elements of group 14 in student book

Lesson 3: Reaction of oxides, chlorides of group 14 with water, acids and strong alkaline solutions.

a) Prerequisites/ Revision/ Introduction

Chemical bonding, reactions of S-block elements, reactions of group13 elements

b) Teaching resources

- Periodic table of elements
- SME student book
- Internet can be used if available

c) Learning activities

Guidance

For student teachers to recall some the reactions in group 13 and S-block elements, you can form the groups and provide activity 3.3. Allow the learners to discuss in their groups and share their findings to the whole class.

Answers to activity 3.3

. (i) Aluminium oxide is insoluble in water and does not react like sodium oxide and magnesium oxide. The oxide ions are held too strongly in the solid lattice to react with the water.

$$4Al + 3O_2 \longrightarrow 2Al_2O_3(s)$$

(i) $$Al_2O_3(s) + 6HCl(aq) \longrightarrow 2ACl_3(aq) + 3H_2O(l)$$

Aluminium oxide

hydrochloric acid

Aluminium chloride

(ii) $$\underset{\text{Aluminium Oxide}}{A_2O_3\,(s)} + \underset{\text{Sodium hydroxide}}{2NaOH(aq)} \longrightarrow \underset{\text{Sodium aluminate}}{2NaAlO_2(aq)} + H_2O(l)$$

2. The aluminium chloride reacts with the water rather than simply dissolving in it. In the first instance, hexaaquaaluminum complex ions and chloride ions are formed:

$$AlCl_3(s)+6H_2O(l) \longrightarrow [Al(H_2O)_6]^{3+}(aq)+3Cl^-(aq)$$

The acid-base equilibrium for this reaction lie further to the right than those for magnesium, and so the solution formed is more acidic—more hydronium ions are formed, as shown:

$$[Al(H_2O)_6]^{3+}+H_2O \longrightarrow [Al(H_2O)_5(OH)]^{2+}+H_3O^+$$

$$[Al(H_2O)_6]^{3+}+H_2O \longrightarrow [Al(H_2O)_5(OH)]^{2+}+H_3O^+$$

or, more simply:

$$[Al(H_2O)_6]^{3+}(aq) \longrightarrow [Al(H_2O)_5(OH)]^{2+}(aq) +H^+$$

d) Application activities

Answers to application activity 3.3

1. Reaction with water (hydrolysis)

Silicon tetrachloride

Silicon has an additional advantage: there are empty 3d orbitals available to accept a lone pair from the water molecule. Carbon lacks this advantage because there are no empty 2-level orbitals available.

The oxygen atom can therefore bond to silicon before a silicon-chlorine bond breaks, makes the whole process easier energetically. In practice, silicon tetrachloride therefore reacts violently with water, forming white solid silicon dioxide and HCl gas.

$$SiCl_4+2H_2O \longrightarrow SiO_2+4HCl$$

Liquid $SiCl_4$ fumes in moist air for this reason—it reacts with water vapour in the air.

Lead tetrachloride (lead(IV) chloride)

The reaction of lead(IV) chloride with water is just like that of silicon tetrachloride. Lead(IV) oxide is produced as a brown solid, and fumes of hydrogen chloride given off (this can be confused with the decomposition of the lead(IV) chloride, which gives lead(II) chloride and chlorine gas as mentioned above).

$$PbCl_4 + 2H_2O \longrightarrow PbO_2 + 4HCl$$

Lead(II) chloride

Unlike the tetrachlorides, lead (II) chloride can be considered ionic in nature. It is slightly soluble in cold water, but more soluble in hot water. Water solubility involves disruption of the ionic lattice and hydration of the lead(II) and chloride ions to give $Pb^{2+}_{(aq)}$ and $Cl^{-}_{(aq}$

2. Carbon tetrachloride has no reaction with water. When added to water, it forms a separate layer underneath the layer of water. Chlorine atoms are so bulky and the carbon atom so small that the oxygen atom is sterically hindered from attacking the carbon atom.

The other problem is that there is no appropriate empty carbon orbital the oxygen lone pair can occupy.

3. (i)to the changes occurring during the reaction

   (ii) there was formation of an acid

   (iii) $CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$

4. (i)Refer to question 3 above

   (ii)the acidic carbon dioxide neutralizes the sodium hydroxide solution in the neutralization reaction

   (iii) $CO_2(g) + NaOH(aq) \longrightarrow Na_2CO_3(aq) + H_2O(l)$

Lesson 4: Thermal stability of oxides, halides and hydroxides.

a) Prerequisites/ Revision/ Introduction

Thermal stability of nitrates carbonates of S-block elements.

b) Teaching resources

- Periodic table of elements
- SME student book
- Internet can be used if available.

c) Learning activities

Guidance

Form the groups and provide activity 3.4. Allow the learners to discuss in their groups and share their findings to the whole class.

Answers to activity 3.4

1. The thermal stability of group 2 carbonates increases down the group due increase in ionic character which makes the bond between the metal and the carbonate stronger and requires more energy to break.
2. It is very difficult to predict the thermal stability but I suppose it increases down the group for the oxide for the same reason as above in carbonates.

   The chlorides change from covalent to ionic down the group; due to increase in this character we expect the thermal stability to increase. This applies to hydroxides as well.

d) Application activities

Answers to application activity 3.4

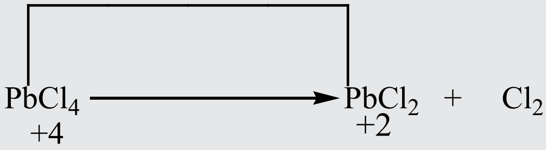
1.(i)Carbon dioxide consists of individual molecules with one central carbon atom double bonded to two oxygen atoms. Silicon does not form double bonds with oxygen. Carbon dioxide is gas but $SO_2$is solid because the silicon dioxide is in giant molecular structure but the carbon dioxide is simple molecular structure. Because of this reason carbon dioxide is gas but silicon dioxide is solid

(ii) Down the group the relative stability of +4 oxidation state decreases whereas the relative stability +2 oxidation increases. This causes the compounds in +4 oxidation state(covalent) to decompose to +2 oxidation state(ionic) which are more stable

$$PbCl_4 \longrightarrow PbCl_2 + Cl_2$$

(iii) At the top of Group 4, the most stable oxidation state is +4. This is the oxidation state of carbon and silicon in CCl_4 and $SiCl_4$. These compounds have no tendency to break down into dichloride's. However, the relative stability of the +4 oxidation state decreases down the group, and the +2 oxidation state becomes the most stable for lead and below. Lead (IV) chloride decomposes at room temperature to form the more stable lead(II) chloride and chlorine gas.

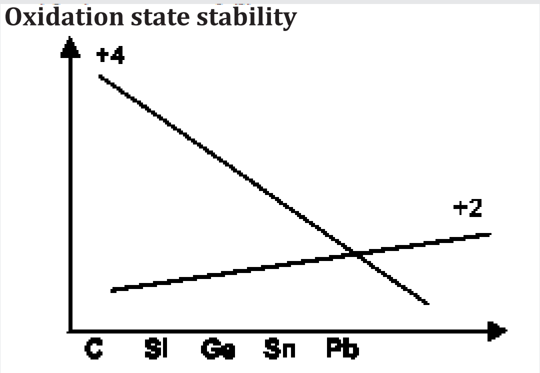
Easy reduction of lead from+4 to +2



$$\underset{+4}{PbCl_4} \longrightarrow \underset{+2}{PbCl_2} + Cl_2$$

(iv)Refer to notes in student book

2. The oxides in +4 oxidation state are easily reduced to +2 oxidation which are more stable and the same applies to the chlorides.



Lesson 5: Trends in stability of oxidation states: +2 and +4 as a result of inert pair effect and Uses of Group 14 elements.

a) Prerequisites/ Revision/ Introduction

Thermal stability of carbonates and nitrates of group1&2 elements

b) Teaching resources

- Periodic table of elements
- SME student book
- Internet can be used if available

c) Learning activities

Guidance

Form groups and provide activity 3.5 to student teachers. Student teachers should discuss and share their findings to the whole class.

Answers to activity 3.5

(i) C: $2s^22p^2$ Si: $3s^23p^2$ Ge: $4s^24p^2$ Sn: $5s^25p^2$ Pb: $6s^26p^2$

(ii) nS^2np^2, these elements contain 4 electrons in valence shell.

(iv)Carbon graphite is a simple common example which is used as electrodes because it's a good conductor of electricity. Carbon diamond is used to make jewellery because of its shininess.

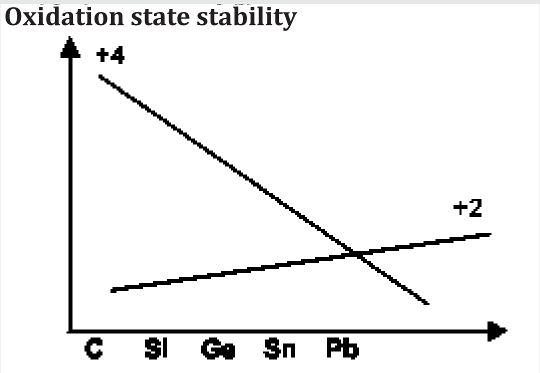
Lead is used to make car batteries(lead acid accumulators)

d) Application activities

Answers to application activity 3.5

1. Each element has four outer electrons ns^2 np^2. The shielding of the outer shell for C and Si is quite efficient. However, as we descend the group due to the presence of d and f electrons, which offer poor shielding, the outer s electrons are withdrawn into the atomic core and begin to behave as inner electrons. Hence, Pb and Sn often behave as if they only have two outer electrons and show valences of +2 and +4.

2. The relative stabilities of the oxidation states vary within the group as shown in the following graph.



+4 Oxidation State

a) All elements have four outer electrons and so the main oxidation state for most elements is +4. The bonding in most compounds is covalent as too much energy would be needed to form M^{4+} ion.

Only PbF_4 and SnF_4 are truly ionic. Most compounds have a tetrahedral arrangement around the metal.

b) +4 is the most stable state for C, Si, Ge and Sn but is the least stable for Pb. Compounds of Pb(IV) are easily reduced to Pb(II) and are strong oxidising agents.

For example: $PbO_{2(s)} + 4HCl_{(aq)} \rightarrow PbCl_{2(s)} + 2H_20_{(l)} + Cl_{2(g)}$

+2 Oxidation State

In this oxidation state only the p electrons are used in bonding and the s electrons exhibit the inert-pair effect. It is most unstable for C and Si but is most stable for Pb.

Compounds of both Pb(II) and Sn(II) are common and the bonding in them ionic. Compounds of C(II), Si(II), Ge(II) and Sn(II) are easily oxidised and are therefore strong reducing agents.

For example: $2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$

3. Carbon graphite has delocalized electrons and therefore used to as electrodes in dry cells

Diamond is hardest substance and used to make drilling tips and tools to cut glasses.

Skills lab 3

Materials needed: books, pens and probably a camera or smart phone to take some pictures

During the visit student teachers will take notes to make a report

After visit: student teachers will individually make a present their reports

Questionnaire

(i)Name of place from which mining is occurring?

(ii)Educational careers for mining personnel

(iii) Explained process of mining

(iv) Economic importance of the mining to the society.

(v) Dangers associated with mining process to the community and environment

(vi) Where do the mineral sold and what do they do with the mineral?

3.6 Summary of the Unit

- Of the **Group 14 elements**, only carbon and silicon form bonds as non-metals (sharing electrons covalently). Silicon and germanium are semimetals (metalloids), existing in **compounds** with either +4 or -4 charges. Tin and lead are definitely metals
- Silicon and germanium also usually form four simple covalent bonds with a tetrahedral arrangement.
- Tin and lead, which are larger in volume, have smaller ionization energies than carbon and silicon, and they often lose just two of their valence electrons to form the Sn^{2+} and Pb^{2+} ions.
- Dioxides of the group 14 elements become increasingly basic down the group and their metallic character increases
- The hydrides become thermodynamically less stable down the group
- The stability of the carbon tetrahalides decreases as the halogen increases in size because of poor orbital overlap and steric crowding
- Because the covalent bond strength decreases with increasing atomic size and greater-than-expected ionization energies due to an increase in Z_{eff}, the stability of the +2 oxidation state increases from carbon to lead.

3.7 Additional information for teachers

A **diagonal relationship** exists between certain pairs of diagonally adjacent elements in the second and third periods of the periodic table. These pairs (Lithium (Li) and Mg, Be and Al, boron (B) and silicon (Si)) exhibit similar properties; for example, boron and silicon are both semiconductors, they form halides that are hydrolysed in water and have acidic oxides.

- Both B and Si exist in amorphous and crystalline state and exhibit allotropy.
- Both B and Si possess close electronegativity values (B=2.0; Si=1.8).
- The chlorides of B and Si are liquid, fume in most air and readily hydrolyse in water:

$$BCl_3 + 3H_2O \longrightarrow B(OH)_3 + 3HCl$$

$$SiCl_4 + H_2O \longrightarrow Si(OH)_4 + 4HCl$$

- Both B and Si form binary compounds with several metals to give borides and silicide. These borides and silicides react with H_3PO_4 to give mixtures of boranes and silanes.

$$3Mg+2B \longrightarrow Mg_3B_2 \text{ (Magnesium boride);}$$

$$Mg_3B_2 + H_3PO_4 \longrightarrow \text{Mixture of boranes}$$

$$2Mg + Si \longrightarrow Mg_2Si \text{ (magnesium silicide);}$$

$$Mg_2Si + H_3PO_4 \longrightarrow \text{Mixture of silanes}$$

- The carbides of Boron and silicon (B_4C and SiC) are very hard and used as abrasive.
- Oxides of B and Si are acidic and can be reduced by limited amount of Mg. In excess of Mg, boride and silicide are formed.

$$B_2O_3 + 3Mg \longrightarrow 3MgO + 2B$$

$$SiO_2 + 2Mg \longrightarrow 2MgO + Si$$

- Borates and silicates of B and Si have tetrahedral structural units. Their borosilicate are known in which boron replaces silicon in the three dimensional lattice. Boron can however form planar BO_3 units.

End unit assessment

Answers to end unit assessment 3

1. Refer to uses of carbon in the notes under uses of group14 elements.
2. Refer to question 6 below.
3. Lake Kivu and it used as source of power/energy
4. Insulation
5. Packing of food and other materials that can be destroyed by moisture.
6. **Diamond** has the highest hardness and thermal conductivity of any natural material, properties that are utilized in major industrial applications such as cutting and polishing tools. They are also the reason that **diamond** anvil cells can subject materials to pressures found deep in the Earth.
7. Lead: lead acid accumulator

Tin: tin cans for packing food

Silicon: Silicon dioxide main component of glass.

8. (i)silicon dioxide, silicon(iv)chloride and sodium silicate

   (ii)lead nitrate, lead sulphate and lead (ii) chloride
9. Reagent: sodium hydroxide:

Lead (ii) ions react with sodium hydroxide to form lead(II) hydroxide, which dissolves in excess sodium hydroxide (amphoteric) to give a clear colourless solution but does not dissolve in excess ammonia solution. (amphoteric behaviour with NaOH as with zinc hydroxide which also dissolves in acids too.

lead(II) ion: $Pb^{2+}(aq) + 2OH^-(aq) \longrightarrow Pb(OH)_2(s)$

a white precipitate forms

$$Pb(OH)_2(s) + 2OH^-(aq) \longrightarrow [Pb(OH)_4]^{2-}(aq)$$

colourless solution

10. Refer to application activity 3.4 number 1

11.

Period	*Element*	*Symbol*	*Atomic Number*	*Electronic Configuration*
2	Carbon	C	6	$[He]2s^2 2p^2$
3	Silicon	Si	14	$[Ne]3s^2 3p^2$
4	Germanium	Ge	32	$[Ar]3d^{10} 4s^2 4p^2$
5	Tin	Sn	50	$[Kr]4d^{10} 5s^2 5p^2$
6	Lead	Pb	82	$[Xe]4f^{14} 5d^{10} 5s^2 5p^2$

12. (a)Lead is a metal, and chlorine is a non-metal that is a strong oxidant. Thus we can expect a redox reaction to occur in which the metal acts as a reductant. Although lead can form compounds in the +2 and +4 oxidation states, Pb^{4+} is a potent oxidant (the inert-pair effect). Because lead prefers the +2 oxidation state and chlorine is a weaker oxidant than fluorine, we expect $PbCl_2$ to be the product.

(b)This is the reaction of water with a metal silicide, which formally contains the Si^{4-} ion. Water can act as either an acid or a base. Because the other compound is a base, we expect an acid–base reaction to occur in which water acts as an acid. Because Mg_2Si contains Si in its lowest possible oxidation state, however, an oxidation–reduction reaction is also a possibility. But water is a relatively weak oxidant, so an acid–base reaction is more likely. The acid (H_2O) transfers a proton to the base (Si^{4-}), which can accept four protons to form SiH_4. Proton transfer from water produces the OH^- ion, which will combine with Mg^{2+} to give magnesium hydroxide.

(c)We expect germanium dioxide (GeO_2) to be amphoteric because of the position of germanium in the periodic table. It should dissolve in strong aqueous base to give an anionic species analogous to silicate.

3.8. Additional activities

3.8.1. Remedial activities (Questions and answers)

1. Explain the term” catenation” of carbon and write the chemical formula of 2 compounds formed as a result of catenation.
2. Which of the following bond energy ordering is correct?

a) Sn-Sn>Si-Si>C-C

b) C-Br>C-Cl

c) C-Cl>Si-Cl>Pb-Cl

d) Si-O>C-O>Sn-O

3. Which of the following statements is false?

a) $Pb(NO_3)_2$ and PbO_2 are soluble in water.

b) $SnCl_2$ dissolves in water

c) PbO reacts with NaOH solution.

d) $SnCl_2$ is ionic

Answers to remedial activity

1. Catenation is the formation of many bonds between carbon atoms to form chains such as in alkanes. Examples: C_4H_{10}, C_6H_{14}
2. Answer is c)
3. Answer is a)

3.8.2. Consolidation activities

1. Explain why $SiCl_4$ hydrolyses in water.
2. Give 1 test reagent for Pb^{2+} ions in solution and indicate the observable changes as well as the equation of reaction.
3. Explain why silicon is a semi-metal.
4. Explain why graphite conducts electricity but diamond does not.

Answers to consolidated activity

1. $SiCl_4$ hydrolyses in water because silicon atom possesses vacant d-orbitals available for bonding with H_2O while the reaction is taking place.
2. Reagent test: KI solution. There is a deep yellow precipitate.

Equation: $Pb^{2+}(aq) + 2I^-(aq) \longrightarrow PbI_2(s)$

3. Silicon is a semi-metal because the electrons in the atoms are loosely held and they can easily be lost when they are in contact with more reducing agents.
4. - Graphite conducts electricity because each carbon forms 3 bonds with other carbons in the structure and the four electrons is free such that it can be delocalised to move and conduct electricity.

   - Diamond forms four bonds such that all the four electrons are used in bond formation. So diamond cannot conduct electricity.

3.9. Extended activities

1. Explain why SiO_2 has a higher melting point than $SiCl_4$.
2. Carry out a brief research and write the chemical formula of 2 compounds of silicon in cement.
3. Describe 2 hazards caused by compounds of group 14 elements.

Answers to Extended activities

1. SiO_2 has a higher melting point than $SiCl_4$ because:
   - SiO_2 has covalent bonds linked to others in a giant structure whereas $SiCl_4$ forms covalent bonds with individual molecules attracted to other by van der Waal's forces.
2. Compounds of silicon (formula in cement):

i) Ca_2SiO_5 ii) $BeSiO_4$ iii) $FeSiO_4$

3. Hazards of compounds of carbon:

i) Fluorochlorocarbons cause air pollution because it destroys the ozone layer in the atmosphere.

ii) Leaded petrol can emit lead toxic element in the atmosphere to cause pollution during the combustion of petrol in car engines.

The lead causes illnesses in humans if it has been inhaled in big quantities.

UNIT 4

TRENDS IN CHEMICAL PROPERTIES OF GROUP 17 ELEMENTS AND THEIR COMPOUNDS

4.1. Key unit competence

Explain the chemical properties of group 17 and their compounds.

4.2. Prerequisite (knowledge, skills, attitudes and values):

Students will learn better the **trends in chemical properties of Group 15 elements and their compounds** if they have understood on: Chemical bonding, the arrangement of elements in the periodic table, Variation in trends of the physical properties of elements, the symbols of elements and compounds, concept of chemical reactions, and electronic configuration of elements.

4.3. Cross-cutting issues to be addressed:

a) Gender inequality

General need of people to complement one each over without conflict in order to be peaceful.

The nature of atoms can be related to relationship in human beings. There is a serious issue of misunderstanding of gender equality in our society. When introducing this unit, it would be an opportunity to guide learners on understanding the importance of gender equality, equity and how the issues related to gender inequality and inequity may be addressed.

Help learners to:

i) Understand that complementarities are very important. *These elements in group 17 do not exist in isolation, but they are in combination with substances. These elements also exist as diatomic molecules because they are unstable in monoatomic form.* Students should know that female and male are both human beings and no one should say that he/she is more indispensable than another.

ii) Understand that gender equality plays a big role in the development of the country.

iii) Understand that female needs male and vice-versa in different ways for their future achievement.

iv) Underlining the necessity of cooperation and working in mixed group rather than working in single group)

You can do this in a short whole class discussion. This may be an opportunity for you as chemistry teacher to confront the individual students who need advice on relationship matter.

b) Inclusive education

This unit involves a number of activities on the activities require reading and writing. This may be challenging to students with special educational needs especially children with visual impairment. However, the teacher can make some arrangements like:

- Grouping students. Students with special educational needs are grouped with others and assigned roles basing on individual student's abilities.
- Providing procedure earlier before the activity so that students get familiar with them. They can be written on the chalkboard or printed depending on available resources. If you have children with low vision remember to print in appropriate fonts or in Braille.
- Every important point is written and spoken. The written points helps students with hearing impairment and speaking aloud helps students with visual impairment
- Remember to repeat the main points of the lessons.

c) Environment and sustainability

This unit involves identifying the dangers associated with the use halogen compounds such as chlorofluorocarbons with low boiling points and used in refrigeration, aerosols and propellants. These can escape into the atmosphere and destroy the ozone layer. These substances should be used with care or avoided where necessary.

4.4. Guidance on introductory activity

Before introducing the unit, allow student teachers to look at the picture in student book carefully at the beginning of this unit. And answers the questions that follow.

Expected answers for the introductory activity

(i)A: Swimming pool B: Surgeons in surgery room D: Cell phone jacket E: Plastic pipes

(ii) Chlorine (iii) anaesthetics (iv) halogens mainly.

4.5. List of lessons/sub-heading

#	Lesson title	Learning objectives	Periods
1	Comparative study of chemical properties of halogens		2
2	Trends in oxidizing power down the group (displacement reactions).	.	1
3	Reaction with metals and non-metals.		1
4	Preparation and behaviour of hydrides of halogens.		2
5	Uses and hazards of halogens and their compounds.		1
	End unit assessment		1

Lesson 1: Comparative study of chemical properties of halogens

a) Introduction

All halogens occur in sea water as halide ions. Halogens also occur in minerals such as, NaCl (rock salt), CaF_2, $Ca(PO_4)_3F$ and $NaAlF_6$. Chlorides also occur in the Great Salt Lake and the Dead Sea, and in extensive salt beds that contain NaCl, KCl or $MgCl_2$. Hydrochloric acid is present in the human stomach to help in the digestion process of food.

Bromine compounds occur in the Dead Sea and underground brines. Iodine compounds are found in small quantities in chile saltpeter, underground brines.

The best sources of halogens (with the exception of iodine) are halide salts. It is possible to oxidize the halide ions to produce the diatomic molecules by various methods, depending on the ease of oxidation of the halide ion. Fluoride is the most difficult to oxidize, whereas iodide is the easiest.

b) Teaching resources

- Periodic table of elements
- SME student book
- Internet can be used if available

c) Learning activities

Guidance: The tutor provides the activity 4.1 to student teachers in in their groups and ask them to discuss and answers the questions and make presentation to share their answers.

Answers to activity 4.1

(i)$Cl_2(g) + H_2O(l) \longrightarrow HCl(aq) + HClO(aq)$

(ii)Chlorine and Oxygen

(iii)Halogen become more covalent in character as they are not metals and change from gases through liquid to solid whereas group 1and 2 metallic character increases down and ability lose electrons increases.

(iv)Refer to reactions of group 1 and 2 in unit 2.

(d)Application activities

Answers to Application activity 4.1

1. $2Na(s) + 2\,H_2O(l) \longrightarrow 2NaOH(aq) + H_2(g)$

$NaOH(aq) + Cl_2(g) \longrightarrow NaCl(aq) + NaClO(aq) + H_2O(l)$

$\downarrow$ Cold dilute sodium hydroxide

$\downarrow$ sodium hypochlorite which is the main component of bleaching chemicals

2.(i) $6NaOH(aq) + 3Cl_2(g) \longrightarrow 5NaCl(aq) + NaClO_3(aq) + 3\,H_2O(l)$

$\downarrow$ Hot concentrated sodium hydroxide

(ii) $NaClO_3(s) \longrightarrow 2NaCl(s) + 3\,O_2(g)$

(iii)Alkalis react with halogens under two conditions:

- cold dilute sodium hydroxide solution
- Hot concentrated sodium hydroxide solution forming products as indicated in 1 and 2(i) above but chlorine is replaced by bromine.

(iv)Fluorine reacts with cold dilute sodium or potassium hydroxide form oxygen fluoride while hot and concentrated solution evolves oxygen gas as follows

Hot and concentrated

$$F_2 + NaOH \longrightarrow O_2 + NaF + H_2O$$

Cold and dilute alkali

$$F_2 + NaOH \longrightarrow OF_2 + NaF + H_2O$$

Lesson 2: Trends in oxidizing power down the group 17 elements

a) Prerequisites/ Revision/ Introduction

- Variation of atomic size down the group and factors that determine the variation of atomic size.
- Variation of electronegativity down the group 17 elements.

b) Teaching resources

- Periodic table of elements
- SME student book
- Internet can be used if available

c) Learning activities

Guidance: the tutor provides the activity 4.2 and can ask student teachers to pair think and share. Allow some student teachers to share with the whole class.

Answers to activity 4.2

(i) $CuSO_4(aq) + Zn(s) \longrightarrow ZnSO_4(aq) + Cu(s)$

$ZnSO_4(aq) + Cu(s) \longrightarrow \times$

Copper is less reactive therefore, it cannot displace Zinc from its solution but zinc displaces copper because it is more reactive than copper.

In the reaction above , copper (ii) is reduced to copper while zinc is oxidised to zinc(ii) ions. Copper (ii) is an oxidizing agent while zinc is a reducing agent.

(ii) $KCl(aq) + Br_2(l) \longrightarrow \times$

$2KI(aq) + Br_2(l) \longrightarrow 2KBr(aq + I_2(g)$

(d)Application activities

Answers to application activity 4.2

i) $KCl(aq) + Br_2(l) \longrightarrow$ No reaction occurs

ii) $NaBr(aq) + I_2(s) \longrightarrow$ No reaction occurs

iii) $KBr(aq) + I_2(s) \longrightarrow$ No reaction

iv) $KI(aq) + Br_2(l) \longrightarrow KBr(aq) + I_2(s)$

v) $KI(aq) + I_2(aq) \longrightarrow$ No reaction

f) (b)The reaction of halogen decreases downs the group from fluorine to iodine thus, fluorine can displace chlorine from its solution and chlorine displaces bromine and bromine displaces iodine respectively. However, bromine cannot displace chlorine from its solution.

Lesson 3: Reaction of halogens with metals and non-metals.

a) Prerequisites

Chemical reactions of S- block metals with halogens, chemical reactions of group13 elements with halogens.

b) Teaching resources

- Periodic table of elements
- SME student book
- Internet can be used if available

c) Learning activities

Guidance: provide the activity to student teachers as a research before the lesson and ask them to attempt individually and thereafter ask them to exchange their worksheets or exercise books mark themselves. Ask one of them to lead the whole class in providing answers.

Answers to Activity 4.3

1. Solid Sodium chloride

2. Phosphorous reacts to form phosphorous(iii) and (v) chlorides depending on the amount of chlorine

Metals for corresponding chlorides of their metals.

$$Mg(s) + Cl_2(g) \longrightarrow MgCl_2(s)$$

$$Ca(s) + Cl_2(g) \longrightarrow CaCl_2(s)$$

$$P + Cl_2 \longrightarrow PCl_3 \quad \text{or} \quad P + Cl_2 \longrightarrow PCl_5$$

3.chlorine is strong oxidizing agent , it oxidises iron to iron (iii) chloride

$$2Fe(s) + 3Cl_2 \longrightarrow 2FeCl_3(s)$$

(d)Application activities

Answers to application activity 4.3

(i) and (ii) refer to activity 4.3 unit 4

(iii) Note: Hydrochloric acid is always produced after an article has been bleached with chlorine. Therefore, the article must be washed thoroughly to remove the HCl, or else it will be attacked by the acid.

The bleached material does not change back to its original when exposed to air.

On cold dilute aqueous solution of alkalis (e.g., NaOH and KOH). The products are Oxo chlorate (I) and chloride of the metal.

. $CI_2(g) + 2NaOH(aq) \longrightarrow NaOCl(aq) + NaCl(aq) + H_2O(l)$

- On hot concentrated aqueous solution of alkalis - a mixture of trioxochlorate (V) and the chloride of the metal are produced.

$$6NaOH(aq) + 3Cl_2(g) \longrightarrow NaClO_3(aq) + 5NaCl(aq) + 3H_2O(l)$$

Bleaching by chlorine is an oxidation process. Chlorine bleaches damp dye by the following procedure:

2. Chlorine reacts with the water in the dye to form oxochlorate(l), also called hypochlorous acid.

$$Cl_2(g) + H_2O(l) \longrightarrow \underset{\text{oxochlorate(l)}}{HOCl(aq)} + HCl(aq)$$

2. The oxochlorate (I) acid is a very reactive compound and readily gives up its oxygen to the dye, resulting in the dye being colourless.

$$dye + HOCl \longrightarrow \underset{\text{Acid}}{HCl} + \underset{\text{Colourless}}{(dye + O)}$$

Lesson 4: Preparation and behaviour of hydrides of halogens

(a) Prerequisites/ Revision/ Introduction

- Variation of boiling and melting points down the S-block elements,
- Variation of boiling and melting points down group 13 elements and halogens

(b)Teaching resources

- Periodic table of elements
- SME student book
- Internet can be used if available.

(c)Learning activities

Guidance: Form groups and provide activity 4.4. Allow the groups to discuss and share in their groups and thereafter share their findings to the whole class.

Answers to activity 4.4

1.(a) An acid is a proton donor according to Arrhenius theory of acids and bases.

(b)a strong acid is one which dissociates completely in water. While a weak acid is one which partially dissociates in water

(c)Bond length and Bond strength: the stronger the bond the weaker is the acid because the hydrogen ions will not be easily released into solution. If the bond is longer then, the stronger the acid.

The size of the atoms: the smaller the atoms joined to hydrogen the more the attraction and hence the weaker is the acid and vice-versa.

(d)water forms stronger hydrogen bonding a that requires more energy to break thus, increasing the boiling point

(e) Electronegativity and size of the atoms.

d) Application activities

Answers to application activity 4.4

1. a) $NaCl(s) + conc.\ H_2SO_4 \longrightarrow NaHSO_4 + HCl$

   b) When a concentrated solution of sulphuric acid is added to solid halides the first product is the hydrogen halide. Being relatively volatile , these hydrogen halides are evolved as gases

halide (s) + sulphuric acid ⟶ hydrogen halide + hydrogen sulphate of metal halide

However, concentrated sulphuric acid is also an oxidizing agent. It is powerful enough to oxidize Hydrogen to Bromine and hydrogen to iodine, but it cannot oxidize Hydrogen fluoride and hydrogen chloride.

$$2HBr(g) + H_2SO_4(l) \longrightarrow Br_2(g) + 2H_2O(l) + SO_2(g)$$

$$2HI(g) + H_2SO_4(l) \longrightarrow I_2(g) + 2H_2O(l) + SO_2(g)$$

When concentrated sulphuric acid is used in presence of even strong oxidizing agent such as manganese (iv)oxide, the oxidizing conditions are sufficient to oxidize Hydrogen chloride to chlorine but hydrogen fluoride is still not oxidized.

$$4HCl(l) + MnO_2(s) \longrightarrow Cl_2(g) + MnCl_2(aq) + 2H_2O(l)$$

   c) $H_3PO_4\ (l) + NaBr(aq) \longrightarrow HBr(g) + NaH_2PO_4(aq)$

Phosphoric acid is a weaker oxidizing agent and does not oxidize hydrogen bromide to bromine

2. NaCl: addition of iron (iii) ions, there was no colour since chloride ions are also a strong oxidizing agent. A

   NaI : addition of iron(iii) ions oxidizes iodide ions to iodine(violent) and is itself reduced to iron(ii) because iodide ions are strong reducing agent B

Lesson 5: Uses and hazards of halogens and their compounds.

a) Prerequisites/ Revision/ Introduction

Students have already learnt the different types of halogens, their compounds as well as the chemical and physical properties of their compounds. So it will be easy to lead them into the content of uses. Halogens were also encountered in ordinary level, therefore the knowledge they acquired at that level can be of significant use to understand better this lesson content.

b) Teaching resources

- Periodic table of elements
- SME student book
- Internet can be used if available

(c)Learning activities

Guidance: the tutor asks the student teacher to look at the picture in the student book carefully and answer the questions for the activity 4.5 in the groups. Allow them to discuss and present their answers.

Answers to activity 4.5

Expected answers

(a)A: man suffering from Goitre B:Tooth C:cell tape /adhesive tape D: plastic tubes E:Flying pan

(b)(i)Goitre caused by luck of iodine and can be prevented by taking iodized salt.

(ii)It is recommended to brush at least three times a day

Fluoride ions in form of sodium fluoride. Most toothpastes share common ingredients, both active and inactive. Active ingredients are what help fight cavities and reduce your risk of gum disease.

(iii)C and D are plastic while for E it handle is also plastic

(c)Plastic are difficult to recycle since most of them are non-biodegradable and may pollute the environment by destroying ozone layer when join the atmosphere.

(d) Application activities

Answers to application activity 4.5

1. Chlorofluorocarbons (CFC) molecules are made up of chlorine, fluorine and carbon atoms and are extremely stable. This extreme stability allows CFC's to slowly make their way into the stratosphere (most molecules decompose before they can cross into the stratosphere from the troposphere). This prolonged life in the atmosphere allows them to reach great altitudes where photons are more energetic. When the CFC's come into contact with these high energy photons, their individual components are freed from the whole. The following reaction displays how Cl atoms have an ozone destroying cycle:

(step 1) $Cl+O_3 \rightarrow ClO+O_2$

(step 2) $ClO+O. \rightarrow Cl+O_2$

(Overall reaction) $O_3+O. \rightarrow 2O_2$

Chlorine is able to destroy so much of the ozone because it acts as a catalyst. Chlorine initiates the breakdown of ozone and combines with freed oxygen to create two oxygen molecules. After each reaction, chlorine begins the destructive cycle again with another ozone molecule. One chlorine atom can thereby destroy thousands of ozone molecules. Because ozone molecules are being broken down they are unable to absorb any ultraviolet light so we experience more intense UV radiation at the earth's surface

Alternatively, the Chapman Cycle

The stratosphere is in a constant cycle with oxygen molecules and their interaction with ultraviolet rays. This process is considered a cycle because of its constant conversion between different molecules of oxygen. The ozone layer is created when ultraviolet rays react with oxygen molecules (O_2) to create ozone (O_3) and atomic oxygen (O). This process is called the *Chapman cycle*.

Step 1: An oxygen molecule is photolyzed by solar radiation, creating two oxygen radicals:

(1)$h\nu+O_2 \rightarrow 2O$

Step 2: Oxygen radicals then react with molecular oxygen to produce ozone:

(2)$O_2+O. \rightarrow O_3$

Step 3: Ozone then reacts with an additional oxygen radical to form molecular oxygen:

(3)$O_3+O. \rightarrow 2O_2$

Step 4: Ozone can also be recycled into molecular oxygen by reacting with a photon:

(4)$O_3+h\nu \rightarrow O_2+O$

It is important to keep in mind that ozone is constantly being created and destroyed by the Chapman cycle and that these reactions are natural processes, which have been taking place for millions of years. Because of this, the thickness the ozone layer at any particular time can vary greatly. It is also important to know that O_2 is constantly being introduced into the atmosphere through photosynthesis, so the ozone layer has the capability of regenerating itself.

2. (a) Effects of uv rays on animals:

(i) Skin cancer due to excessive burns

(ii) Cataract

(iii) Ageing

(iv) Tanning

(v) Wrinkling of skin

(b) Effects of u.v rays on plants:

(i) Decrease the crop yield

(ii) Impairs growth (plants minimize their exposure to U.V by limiting the surface area of foliage.)

(iii) Decreases the rate of photosynthesis.

(iv) May inhibit flowering.

(v) Increases the rate of water loss (transpiration)

Skills lab 4

Provide the links to the student teachers. After the research allow them to share their findings through presentation.

https://sci-toys.com/ingredients/bleach.html

https://en.wikipedia.org/wiki/Bleach

4.6. Summary of the Unit

The melting and boiling points of halogens increases down the group

Solubility of halogens in water decreases down the group.

Reactivity of halogens decreases down the group.

Acidity of aqueous solutions of hydrogen halides increases down the group.

Halogens react to combine with metals and non-metals.

Halogens are useful in some cases but they may cause hazards in other cases, for example chlorofluorocarbons that cause the hazard of depleting the ozone layer in the atmosphere.

4.7. Additional information for teachers

- Chlorine oxides, $\mathbf{Cl_2O}$, $\mathbf{ClO_2}$, $\mathbf{Cl_2O_6}$ and $\mathbf{Cl_2O_7}$ are highly reactive oxidising agents and tend to explode.

  The bromine oxides, $\mathbf{Br_2O}$, $\mathbf{BrO_2}$, $\mathbf{BrO_3}$are unstable halogen oxides and exist only at low temperatures. They are very powerful oxidising agents.

- Iodine oxides, $\mathbf{I_2O_4}$, $\mathbf{I_2O_5}$, and $\mathbf{I_2O_7}$ are insoluble solids and decompose on heating.
- Iodine is the only halogen that forms an $\mathbf{XY_7}$ interhalogen compound, and it does so only with fluorine.
- In oxoacids:

Amongst halic acids, chloric acid has the highest acidity.

$HClO_3$	>	$HBrO_3$	>	HIO_3
chloric acid		bromic acid		iodic acid

- Since chlorine is more electronegative than bromine and iodine, the shared electron pair lies moderately closer to chlorine in a Cl-O bond than bromine in Br-O bond or iodine in an I-O bond.

- As a result, the O-H bond turns out to be much weaker if there should arise an occurrence of chloric acid, along these lines encouraging the release of a proton well.

End unit assessment

Answers to end unit assessment 4

1.Hydrogen fluoride, hydrogen chloride, hydrogen bromide and hydrogen iodide

2.hydrohalic acids contain oxygen atoms such as HOCl/HClO, $HClO_2$, $HClO_3$ and $HClO_4$

3. Fluorine is anomalous in many properties like, ionization enthalpy, electronegativity, enthalpy of bond dissociation that are higher than expected from the regular trends among the halogens. Its ionic and covalent radii, melting and boiling points, and electron gain enthalpy is quite lower than expected. All these is caused by Small size and highest electronegativity, Low F-F bond dissociation enthalpy and Absence of d-orbitals

4.

(a) $NaCl(s) + H_2SO_4(l) \longrightarrow NaHSO_4(aq) + HCl(g)$

(b) $3Br_2(l) + 6NaOH(aq) \longrightarrow 5\,NaCl(aq) + NaClO_3(aq) + 3H_2O(l)$

5. The order is HCl<HBr<HI<HF

HF due to hydrogen bonding is least volatile. As the molecular weight increases the intermolecular force increases due to van-der waal's force of attraction. Thus HI is liquid and HCl is a gas. But due to hydrogen bonding in HF it is least volatile.

6. **Halides are all gases with the following properties:**

HF is a colourless fuming gas - b.pt = 20°C

HCl is a colourless gas - b.pt = -85°C

HBr is a colourless gas - b.pt = -69°C

HI is a colourless gas - b.pt = -35°C

The abnormality of HF is due to the presence of **hydrogen bonding.**

They are covalent substances soluble in polar solvents.

The bond strength of HX decreases down the group as the bonds become less polar. This property governs the reactivity of the halides.

7. Hydrogen halides are covalent in nature. However, hydrogen fluoride dissolves in water and exist as as a liquid at room temperature. Hydrogen chloride dissolves less readily. The solubility decreases down the group due to inability to form hydrogen hydrogen bonds decrease as electronegativity decreases.

8. observations: water is colourless whereas chlorine water is yellow-green liquid.

9. (i) $Br_2(l) + H_2O(l) \longrightarrow HBr(aq) + HBrO(aq)$

(ii) $Br_2(l) + \underset{\text{cold dilute}}{NaOH(aq)} \longrightarrow NaCl(aq) + NaOCl(aq) + H_2O(l)$

$Br_2(l) + \underset{\text{Hot concentrated}}{6NaOH(aq)} \longrightarrow 5NaCl(aq) + NaClO_3(aq) + 3H_2O(l)$

(iii) $Br_2(aq) + Fe(s) \longrightarrow FeBr_3(s)$

(iv) $KI(aq) + Br_2(aq) \longrightarrow 2\,KBr(aq) + I_2(aq)$

4.8. Additional activities

4.8.1. Remedial activities (Questions and answers)

1. Write the chemical formula of a halogen ion that is displaced by bromine in solution.

2. Write the electronic configuration of bromine (atomic number of Br =35).

3. Explain the change that takes place when chlorine comes in contact with :

   a) Blue litmus paper

   b) Is bubbled in cold dilute NaOH solution.

4. a) State the reaction that takes place when chlorine comes in contact with sodium.

   b) Write the equation of reaction between Cl_2 and Na.

Answers to remedial activity

1. I^- ions

2. Configuration: $1S^2\ 2S^2\ 2P^6\ 3S^2\ 3P^6\ 4S^2\ 3d^{10}\ 4P^5$

3. a) Blue litmus paper turns red and the red colour disappears in excess of Cl_2 gas to give a white colour.

b)Sodium hydroxide reacts to give sodium hypochlorite, ClO^- .

4. a) Chlorine burns to produce NaCl, so there is a reaction of combination.

   b) $2Na(s) + Cl_2(g) \longrightarrow 2NaCl(s)$

4.8.2. Consolidation activities

1. Describe how you can distinguish between Br^- ions and Cl^- ions.
2. Explain why HF is a weaker acid than HCl.
3. a) Describe the observation seen when HCl gas is made to be in contact with NH_3 gas.

   b) Write the equation of reaction between HCl and NH_3.

Answers to consolidated activity

1. Heat a solution of Br^- in a 2 mol/litre $H_2SO_{4(aq)}$, there is a red liquid formed which give out red vapours gas.

   When Cl^- ions are heated with the 2 mol/litre $H_2SO_{4(aq)}$,there is no colour change.

2. HF is a weaker acid than HCl because of 2 reasons:

   (i) The H-F bond is stronger than H-Cl. So less H^+ ions are obtained in HF acid.

   (ii) The Cl^- ion is larger than F^- , so the electron on the Cl^- is more stable than on the F^- The electron on $Cl^-$is less available to pick a H^+ ion from the solution. Therefore, more H^+ ions in HCl acid are expected.

3. a) There is formation of white fumes when HCl gets in contact with NH_3 .

   b) $HCl(g) + NH_3(g) \longrightarrow NH_4Cl(S)$

4.9. Extended activities

1. Explain why chlorine can form compounds in oxidation state of -1, +1, +3 and +5 but fluorine cannot form such compounds.
2. Explain why the bond energy of F-F is weaker than Cl-Cl.
3. Find 3 cases where chlorine is changed to another useful compound.
4. Describe the change in pH of water when chlorine gas is dissolved in it.
5. Describe the type of bonds formed between chlorine and:

   a) Phosphorous

   b) Sodium.

Answers to extended activity

1. It is because fluorine does not have vacant orbitals to be occupied by other molecules.
2. The bond F-F is weaker than Cl-Cl because the lone pairs in the F atoms repel each other and the bond weakens.
3. NaCl, KCl, $CaCl_2$
4. The pH turns acidic because the pH will read less than 7.
5. The bonds formed between chlorine and:
    (i) Phosphorous are covalent bonds.
    (ii) Sodium is ionic.

UNIT
5

TRENDS IN CHEMICAL PROPERTIES OF PERIOD 3 ELEMENTS AND THEIR COMPOUNDS.

5.1 Key unit competence

Explain the variation of Period 3 elements and their compounds in relation to their positions in the Periodic Table

5.2. Prerequisite (knowledge, skills, attitudes and values)

Chemical bonding, periodicity of elements in the periodic table and electronic configuration of elements.

5.3. Cross-cutting issues to be addressed:

a) Gender inequality and inequity

General need of people to complement one each over without conflict in order to be peaceful.

- Understand that complementarities are very important. Students should know that female and male are both human beings and no one should say that he/she is more indispensable than another.
- Understand that gender equality plays a big role in the development of the country.
- Understand that female needs male and vice-versa in different ways for their future achievement.
- Underlining the necessity of cooperation and working in mixed group rather than working in single group).

b) Inclusive education

This unit involves a number of activities on the activities require reading and writing. This may be challenging to students with special educational needs especially children with visual impairment. However, the teacher can make some arrangements like:

- Grouping students. Students with special educational needs are grouped with others and assigned roles basing on individual student’s abilities.

- Providing procedure earlier before the activity so that students get familiar with them. They can be written on the chalkboard or markerboard or printed depending on available resources. If you have children with low vision remember to print in appropriate fonts or in Braille.
- Every important point is written and spoken. The written points helps students with hearing impairment and speaking aloud helps students with visual impairment
- Remember to repeat the main points of the lessons.

5.4. Guidance on introductory activity

Before you introduce the lesson, ask student teachers to look at the picture carefully of the introductory activity and answer the questions that follow below the picture

Suggested answers to introductory activity.

(i)They are in the same period 3

(ii) Their electronic configuration has three shells/energy levels

(iii) Na: $1s^2 2s^2 2s^6 3s^1$ Mg: $1s^2 2s^2 2p^6 3s^2$ Al: $1s^2 2s^2 2s^6 3s^2 3p^1$

Si: $1s^2 2s^2 2s^6 3s^2 3p^2$

P: $1s^2 2s^2 2s^6 3s^2 3p^3$ S: $1s^2 2s^2 2p^6 3s^2 3p^4$ Cl: $1s^2 2s^2 2s^6 3s^2 3p^5$

Ar: $1s^2 2s^2 2p^6 3s^2 3p^6$

5.5. List of lessons/sub-heading

#	Lesson title	Learning objectives	Period
1	Properties of period III elements: Physical properties e.g. melting and boiling points, atomic radius, physical state, polarisability, ionization energy, conductivity, electronegativity and metallic character.	Relate the physical properties of compounds of the Period 3 elements to their nature of bonds across the period.	3
2	Chemical properties: reaction with hydrogen, trends in oxidizing/reducing power across the period III	Describe the trends in oxidizing and reducing properties of period 3 elements	2

3	Properties of Period 3 compounds: alkalinity and acidity of oxides.	Explain the trends in alkalinity and acidity of periods elements	2
4	Ionic and covalent character of compounds (chlorides, hydrides and oxides.	Describe the nature of the oxides of Period 3 elements and the type of bonding in their chlorides, oxides and hydrides	2.
	End unit assessment		1

Lesson 1: Physical properties of period 3 elements

a) Prerequisites

Variation of physical properties of elements in their groups. such as ionisation energy, electronegativity, electron affinity, melting and boiling points, electrical conductivity, physical state e.tc.

b) Teaching resources

- Periodic table of elements
- SME student book
- Internet can be used if available.

c) Learning activities

Guidance: provide the activity 5.1pair, think and share and brainstorm in general to provide answers suggested here under.

Answers to the activity 5.1

1 (a)Nitrogen and Fluorine

(b) Boron (B) forms giant atomic structure

(c)Boron (BCl_3)

(d) Neon

(e)Beryllium(Be)

2. (a)Fluorine (F)

(b)From Lithium (Li) to Beryllium(Be) they are metals whereas the rest are Non metals

(c) Metals may conduct electricity but non -metals do not since they luck delocalized electrons

d) Application activities

Answers to application activity 5.1

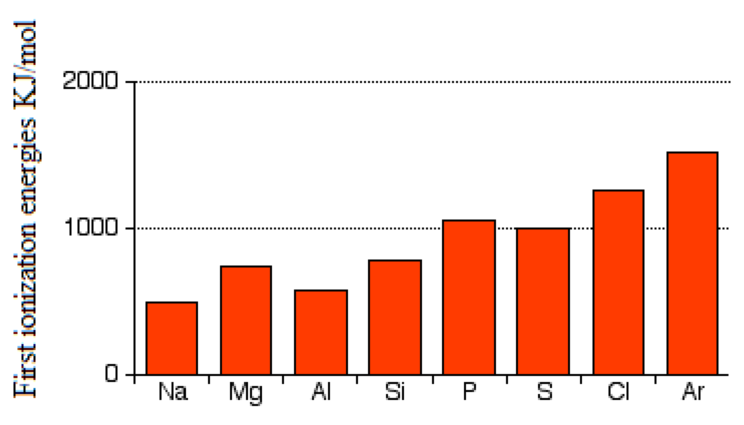
1(i) First Ionization Energy

The first ionization energy is the energy required to remove the most loosely held electron from one mole of gaseous atoms to produce 1 mole of gaseous ions each with a charge of +1.

(1)$X(g) \rightarrow X+(g)+e^-$

The molar first ionization energy is the energy required to carry out this change per mole of X.

The pattern of first ionization energies across Period 3



There is a general upward trend across the period, but this trend is broken by decreases between magnesium and aluminium, and between phosphorus and sulphur.

Explaining the pattern

First ionization energy is dependent on four factors:

the charge on the nucleus;

the distance of the outer electron from the nucleus;

the amount of screening by inner electrons;

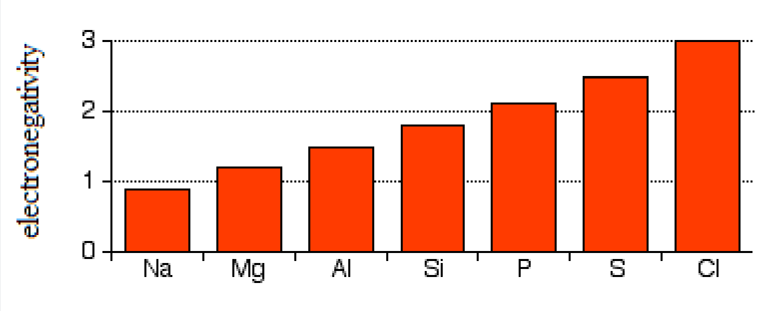
whether the electron is alone in an orbital or one of a pair.

Electronegativity

This is a measure of the tendency of an atom to attract a bonding pair of electrons. The Pauling scale is most commonly used. Fluorine (the most electronegative element) is assigned a value of 4.0, and values decrease toward caesium and francium which are the least electronegative at 0.7.

The trend

The trend across Period 3 looks like this:



Argon is not included; because it does not form covalent bonds, its electronegativity cannot be assigned.

Explaining the Trend

The explanation is the same as that for the trend in atomic radii. Across the period, the valence electrons for each atom are in the 3-level. They are screened by the same inner electrons. The only difference is the number of protons in the nucleus. From sodium to chlorine, the number of protons steadily increases and so attracts the bonding pair more closely.

(iii)The upward trend: In the whole of period 3, the outer electrons are in 3-level orbitals. These electrons are at approximately the same distance from the nucleus, and are screened by corresponding electrons in orbitals with principal atomic numbers n =1 and n =2. The determining factor in the increase in energy is the increasing number of protons in the nucleus from sodium across to argon. This creates greater attraction between the nucleus and the electrons and thus increases the ionization energies. The increasing nuclear charge also pulls the outer electrons toward the nucleus, further increasing ionization energies across the period.

The decrease at aluminium: The value for aluminium might be expected to be greater than that of magnesium due to the extra proton. However, this effect is offset by the fact that the outer electron of aluminium occupies a 3p orbital rather than a 3s orbital. The 3p electron is slightly farther from the nucleus than the 3s electron, and partially screened by the 3s electrons as well as the inner electrons. Both of these factors offset the effect of the extra proton.

The decrease at sulphur: In this case something other than the transition from a 3s orbital to a 3p orbital must offset the effect of an extra proton. The screening (from the inner electrons and, to some extent, from the 3s electrons) is identical in phosphorus and sulphur, and the electron is removed from an identical orbital. The difference is that in the case of sulphur, the electron being removed is one of the $3p_x^2$ pair. The repulsion between the two electrons in the same orbital creates a higher-energy environment, making the electron easier to remove than predicted.

2 and 3 refer to notes under period 3 physical properties of elements

Lesson 2: Chemical properties of period III

a) Prerequisites

Chemical properties of S-block elements, chemical properties of group 14, chemical properties of group 17 elements.

b) Teaching resources

- Periodic table of elements
- SME student book
- Internet can be used if available.

c) Learning activities

Guidance:

Form the groups and provide activity 5.2 Allow the learners to discuss in their groups and share their findings to the whole class.

Answers to activity 5.2

1. SiH_4 GeH_4 SnH_4 PbH_4
2. The first hydrides of in their groups do not react/ hydrolyse in water because they luck d-empty orbitals to accommodate water molecules. However, the rest of the hydrides hydrolyse in water to liberate white fumes of hydrogen chloride.
3. All hydrides contain covalent bonds but molecules are held together by weak intermolecular forces / Van der Waals forces.

4. The oxidizing power of halogens decrease down the group because of decrease in electronegativity which reduces the ability to attract electrons. The reducing power is the opposite of oxidizing ability which increases down. Iodine is a strongest reducing agent while fluorine is the strongest oxidizing agent.

5. Metals are reducing agents while non-metals are oxidizing agents. Reducing power of metals decrease as you move from left to right. While oxidizing power increases across the period. Argon is either reducing or oxidizing agent.

d) Application activities

Answers to application activity 5.2

1.Refer to the notes in student book

2.

NaH	MgH_2	AlH_3	SiH_4	PH_3	H_2S	HCl
Ionic	Ionic	intermediate	covalent	covalent	Covalent	covalent
Giant ionic High melting point	Giant ionic High melting point	Intermediate Sublimes	Simple molecular Low melting point	Simple molecular Low melting point	Simple molecular Low melting point	Simple molecular Low melting point
Dissolves readily to evolve hydrogen gas forming alkaline solutions		Hydrolyses	No reaction	Forms slightly alkaline solution	Dissolves to form slightly acidic a solution	Dissolves to forms acidic solution

Lesson 3: Properties of Period 3 compounds: alkalinity and acidity of oxides.

a) Prerequisites

Alkalinity and acidity of oxides of S-block elements, group 13 elements and group14 elements

(b)Teaching resources

- Periodic table of elements
- SME student book
- Internet can be used if available.

b) Learning activities

Guidance: provide the activity 5.3 to student teachers and ask them to discuss and share answers to each other in the group and then each group make a presentation if possible.

Answers to activity 5.3

1(a) the litmus turned blue because the solution is basic due to the formation of sodium hydroxide solution.

(b) $Na_2O(s) + H_2O(l) \longrightarrow 2NaOH(aq)$

2. Calcium reacts with water vigorously forming a milky solution of calcium hydroxide with evolution of hydrogen gas

$Ca(s) + H_2O(l) \longrightarrow Ca(OH)_2(aq) + H_2(g)$

3. If aluminium chloride is dissolved in a large amount of water the solution is acidic, but this has nothing to do with formation of hydrochloric acid. The solution contains hydrated aluminium ions and chloride ions:

$AlCl_3(s) + (aq) \longrightarrow [Al(H_2O)_6]^{3+}(aq) + 3Cl^-(aq)$

The hexaqua complex ion behaves exactly like ions of similar type formed from transition metals; the small, highly charged metal ion polarises (withdraws electron density from) the water molecules that are attached to the aluminium ion through dative covalent bonds. This makes the hydrogen atoms d^+ and susceptible to attack from solvent water, which is acting as a base. The complex ion is deprotonated, causing the solution to be acidic from the formation of hydroxonium ions H_3O^+:

$[Al(H_2O)_6]^{3+}(aq) + H_2O(l) \longrightarrow [Al(H_2O)_5OH]^{2+}(aq) + H_3O^+(aq)$

Sodium chloride does not hydrolyse therefore, the solution is neutral

c) Application activities

Answers to application activity 5.3

1.(a)

Oxide	CaO	Al_2O_3	Na_2O	MgO	P_2O_5	SO_2	SiO_2
Nature of oxide	Basic	Amphoteric	Basic	Basic	Acidic	Acidic	Weakly acidic

(b) A given oxide is dissolved in water and a litmus paper is inserted into the solution

Conclusion. If the solution turns a blue litmus to red, it is acidic

If a red litmus turns blue it is a basic oxide

Note: amphoteric oxides dissolve in both acids and bases; they do not dissolve in water.

2. (a) Sodium oxide: giant ionic

Aluminium oxide: amphoteric (intermediate between ionic and covalent)

(b)(i)This information tells us that it could be giant covalent molecular.

(ii)Dissolve it organic solvent to check its solubility, if it dissolves , it is covalent

3(a) $NaH + H_2O \longrightarrow NaOH + H_2$

$MgH_2 + 2H_2O \longrightarrow Mg(OH)_2 + H_2$.

(b) SiH_4 is a simple molecular substance which is non- polar with little attraction to water molecules.

(c) $PH_3 + H_2O \rightleftharpoons PH_4^+ + OH^-$

(d) $HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$

(e) Metal hydrides contain H- ions which react with water to form hydrogen gas and OH- ions. The OH^- ions make the final solution alkaline

SiH4 is non-polar molecule which has no reaction with water

PH_3 is simple molecule in which the P atom has a lone pair of electrons to attract H^+ ions from water molecules. This leaves OH^- ions to make the solution alkaline

H_2S and HCl contain electronegative S and Cl atoms which form negative ions S^{2-} and Cl^- and releases H^+ ions .The H^+ ions make the solution acidic.

Lesson 4: Ionic and covalent character of compounds

a) Prerequisites

Ionic and chemical bonding, electronic structure of elements and ions.

b) Teaching resources

- Periodic table of elements
- SME student book
- Internet can be used if available.

c) Learning activities

Guidance: student teachers form groups and discuss the activity provided by the tutor and make presentation.

Answers to activity 5.4

1. According to Fajan's rule ionic character should increase down the group as the size of cation increase.
   So it must be

   Explanation: As the size of the metal cation increases down the group, the lattice energy of the hydrides decreases down the group. Consequently, the reactivity of the alkali towards hydrogen decreases down the group.

   iii. The ionic character of the alkali metal hydrides increases from Li to Cs.

   Explanation: Since ionizations enthalpy of alkali metals decreases down the group, tendency to form cations as well as the ionic character of the hydrides increases.

2. The greater the electronegativity **between two bonded atoms, the greater the likelihood of an ionic bond being formed.**

   However, the electronegativity of an element itself is not the only factor in deciding bond character.

   The different results of the 'tug of war' between two positive nuclei acting on the intermediate bonding electrons produces a range of bond character from complete electron transfer in ionic bond formation (e.g. M^+ and X^-), to a highly polar covalent bond ($M^{\delta+}–X^{\delta-}$) of partially charged atoms and at the other extreme a virtually non–polar bond (X–Y) of two atoms, neither of which carries a significant partial charge.

   Electronegativity, the power of an element to attract bonding electrons towards itself in a bonding situation, is just one, though important factor in deciding the outcome of the character of an individual bond.

   The stronger the polarizing power of the cation and the higher the polarizability of the anion the more covalent character is expected in a bond.

   If a cation has appreciable polarizing power to draw bonding electron clouds towards it OR the bonding electron clouds of an anion are attracted towards the cation, then covalent bonding character is more likely.

   Polarizing power for cations is very much a case of increasing with increased ion charge/ionic radius. So, the smaller the ionic radius or the bigger the positive charge, the greater the polarizing power of the cation. e.g. in terms of polarizing power $Al^{3+} > Mg^{2+} > Na^+$ for the series of Period 3 positive ions where you have both coincident decreasing radii and increasing charge.

   For Group ions, polarizing power will decrease down the group with increasing ionic radius and constant charge; therefore in polarizing power $Li^+ > Na^+ > K^+$ for Group 1 Alkali Metals.

d) Application activities

Answers to application activity 5.4

Oxide	Cao	Al_2O_3	Na_2O	MgO	P_2O_5	SO_2	SiO_2
Nature of bond	Basic	Amphoteric	Basic	Basic	Acidic	Acidic	Weakly acidic

(b) The oxide is dissolved in water and the solution obtained tested with a blue and red litmus paper,

Observations: acidic oxides turn blue litmus paper red while basic oxides turn red litmus paper blue.

Note: amphoteric oxides have both basic and acidic properties.

2 (a)sodium oxide is ionic since it an oxide of a metal and dissolves in water.

Aluminium oxide is amphoteric because it is found in the middle of the periodic table and is intermediate between ionic and covalent.

(b) High melting point and does not dissolve in water means it's a giant molecular oxide of non- metal.

3. (a)

$$2NaH(s) \ + H_2O(l) \longrightarrow 2NaOH(aq) \ + H_2(g)$$

$$MgH_2(s) \ + H_2O(l) \longrightarrow Mg(OH)_2(aq) \ + H_2(g)$$

(b) Silicon hydride (SiH_4) is a simple molecular substance which is non-polar with little attraction to water molecules.

(c) $PH_3 + H_2O \rightleftharpoons PH_4^+ + OH^-$

(d) $HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$

(e) Metal hydrides contain H^- ions which react with water to form hydrogen gas and OH^- ions The OH^- ions make the final solution alkaline.

SiH_4 is non- polar molecule and has no reaction with water.

PH_3 is a simple molecule in which the P atom has a lone pair of electrons to attract H+ ions from water molecules. this leaves OH^- ions to make the solution alkaline/basic

H_2S and HCl contain electronegative S and Cl atoms which form negative S^{2-} and Cl^- and release H^+ ions make the solution acidic.

Skills lab 5

Provide the activity for skills lab to student teachers and them to follow the instructions of the activity in the student book.

Note: activity may take a week or more since the banana leaves have to dry first normally and drying must be done under no direct sunlight.

Student's teachers should be provided with sodium hydroxide solution and litmus papers to test the product.

After testing student teachers should make presentations in the class .

5.6. Summary of the Unit

Property	NaCl	$MgCl_2$	Al_2Cl_6	$SiCl_4$	PCl_3	PCl_5	Cl_2
With water	Dissociates	Dissociates	Hydrolyses	Reacts	Reacts	Reacts	Disproportionate
Products	free ions	free ions	$[Al(H_2O)_6]^{3+}$ + Cl^- ions	HCl + $Si(OH)_4$	H_3PO_3 + HCl	H_3PO_4 + HCl	HOCl + HCl
Structure	ionic	ionic	covalent	covalent	Covalent	covalent	covalent
Conductivity	Good	Good	None	None	None	None	None
m.p./ºC	801	714	178	-70	-112		-101

- Summary: Bonding in the oxides and chlorides of the third period

element	**sodium**	**magnesium**	**aluminium**	**silicon**	**phosphorus**	**sulfur**	**chlorine**
formula	Na_2O	**MgO**	Al_2O_3	SiO_2	P_4O_{10}	SO_2 **and** SO_3	Cl_2O and Cl_2O_7
oxide	*(Giant) ionic*		*(Giant) ionic with covalent character*	*(Giant) covalent macro-molecular*	*(Simple) covalent molecular*		
chloride	ionic	ionic	covalent	covalent	covalent	covalent	covalent

- Reaction summary of the period 3 oxides

	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10} (or P_4O_6)	SO_3 (or SO_2)	Cl_2O_7
Adding H_2O	$Na_2O + H_2O \rightarrow 2NaOH$	$MgO + H_2O \rightarrow Mg(OH)_2$	Insoluble	Insoluble	$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$	$SO_3 + H_2O \rightarrow H_2SO_4$	$Cl_2O_7 + H_2O \rightarrow HClO_4$
Adding HCl	$Na_2O + H^+ \rightarrow 2Na^+ + H_2O$	$MgO + 2H^+ \rightarrow Mg^{2+} + H_2O$	$Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$	No reaction	No reaction	No reaction	No reaction
Add NaOH	No reaction	No reaction	$Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2Al(OH)_4$	$SiO_2 + 2OH^- \rightarrow SiO_3^{2-} + H_2O$	$P_4O_{10} + 12OH^- \rightarrow 4PO_4^{3-} + 6H_2O$	$SO_3 + OH^- \rightarrow SO_4^{2-} + H_2O$	$Cl_2O_7 + OH^- \rightarrow 2ClO_4^- + H_2O$
Nature	Basic Oxide	Basic Oxide	Amphoteric Oxide	Acidic Oxide	Acidic Oxide	Acidic Oxide	Acidic Oxide
Conductivity	Good	Good	Good	None	None	None	None
mp / °C	1275	2852	2027	1610	24	17	-92

5.7. End unit assessment

Answers to end unit assessment 5

1(a) sodium chloride forms a giant ionic structure with strong electrostatic forces of attraction. The boiling point reduces in $MgCl_2$ due to a small size of magnesium ion that polarizes the big chloride ion and distorts the arrangement of electrons and increase covalence character.

(b)The PH is Acidic in Aluminium Chloride due to hydrolysis of Al^{3+} ions that produces hydrogen ions in solution hence acidic whereas sodium chloride is neutral.

2. Hydrolysis is the reaction with water(chemical process) whereas dissolving in separation of ions in water(physical process)

(b)Sodium chloride or all chlorides of metals and aluminium chloride/silicon chloride or other chlorides of group14 except CCl_4.

(c)

Formula	NaCl	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_3	S_2Cl_2	Cl_2
Nature of bonding	Giant ionic	Giant ionic	Intermediate	Covalent	Covalent	covalent	covalent

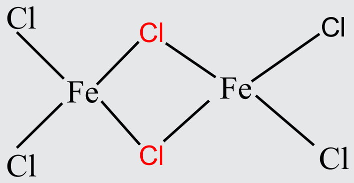
3. (a) $BeCl_2 + 4\ H_2O \longrightarrow (Be(H_2O)4]^{+2}\ Cl^-$

Beryllium chloride is *covalent* and *hydrolyses* to form $Be(OH)_2(s)$ and HCl(aq):

$BeCl_2(s) + 2H_2O(l) \rightarrow Be(OH)_2(s) + 2HCl(aq)$

(b)Refer to the notes on bonding yr1

(c)



4. (a)hydrogen chloride gas

(b) $SiCl_4 + 2H_2O(l) \longrightarrow SiO_2 + 4HCl$

(c)Refer note on chlorides of group 14 elements

5.8. Additional activities

5.8.1. Remedial activities (Questions and answers)

1. The elements of period 3 are as follows: Sodium, magnesium aluminium, silicon, phosphorous, chorine and argon.

All your answers below should relate to those elements.

(a) Which elements can exist as: diatomic and giant atomic?

(c) Which pairs of elements combine to produce compounds with formulae of type XY?

(d)Two elements form chlorides with formulae of the type XCl_3. Draw displayed formulae for these two chlorides, and suggest values for the bond angles.

(e)(i) One element combines with oxygen to form an oxide which reacts with water to give a strongly alkaline solution. Name the element and write a balanced equation for the oxide reacting with water.

(ii) One element combines with oxygen to form an oxide of the type XO_2, which reacts with water to give an acidic solution. Name the element and write a balanced equation for the oxide reacting with water.

2. This question is about some Period 3 elements and their oxides.

(a) Describe what you would observe when, in the absence of air, magnesium is heated strongly with water vapor at temperatures above 373 K. Write an equation for the reaction that occurs.

(a)Explain why magnesium has a higher melting point than sodium.

(b)State the structure of, and bonding in, silicon dioxide. Other than a high melting point, give **two** physical properties of silicon dioxide that are characteristic of its structure and bonding.

(c)Give the formula of the species in a sample of solid phosphorus (V) oxide. State the structure of, and describe fully the bonding in, this oxide.

(d)Sulfur (IV) oxide reacts with water to form a solution containing ions. Write an equation for this reaction.

(e)Write an equation for the reaction between the acidic oxide, phosphorus (V) oxide, and the basic oxide, magnesium oxide.

3. (a) Describe in detail the bonding which occurs in the compounds formed between hydrogen and

(i) Sodium (in sodium hydride),

(ii) Carbon (in methane),

(iii) Nitrogen (in ammonia).

(b) Describe the reactions, if any, which take place between water and the hydrides of the elements in (a).

(c) Comment upon the significance of the relative values of the following boiling points of the halogen hydrides:

Hydride	**HF**	**HCl**	**HBr**	**HI**
Temperature/ ^{0}C	19.5	-85	-67	-36 (°C)

Answers to remedial activity

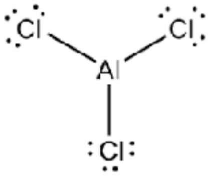
1. (a)

(i) Chlorine

(ii) Silicon

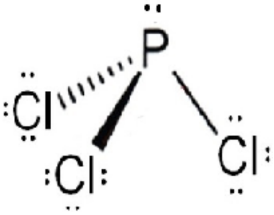
c)Sodium and chlorine

d)Aluminium and chlorine



Displayed formula:

Phosphorous (iii) chloride



Displayed formula:

(e)(i)Sodium

$Na(s) + H_2O(l) \longrightarrow NaOH(aq)$

(ii)Sulphur

$SO_2(g) + H_2O(l) \longrightarrow H_2SO_3(aq)$

2. (a)Bubbles of a colorless gas is evolved that produces a pop sound when lit.

$Mg(s) + H_2O(g) \longrightarrow MgO(s) + H_2(g)$

(b)Magnesium has more delocalized electrons than sodium hence more attraction forces that require more energy to break.

(c)Tetrahedral Giant covalent structure with a net work of covalent bonds where silicon atoms are surrounded by four atom of oxygen.

(d)Formula: P_4O_{10}

Structure: simple molecular

Bonding: covalent

(e)$SO_2(g) + H_2O(l) \longrightarrow H_2SO_3(aq)$

(e)$P_4O_{10} + H_2O \longrightarrow H_3PO_4$

3. (a) (i)Giant ionic structure with strong electrostatic forces of attraction.

(ii)Simple molecular structure with only Van der Waals forces existing between molecules.

(iii)Simple molecular structure with only Van der Waals forces existing between molecules.

(b)Refer to student book page…… for reaction of hydrides with water.

(c) Boiling temperatures increase as the size of the molecule increase due to increase in van der-Waals forces. However, hydrogen fluoride has extra hydrogen bonding that require more energy to separate the molecules.

5.8.2. Consolidation activities

1) By reference to the structure of, and the bonding in, silicon dioxide, suggest why it is insoluble in water.

2) State how the melting point of phosphorus (V) oxide compares with that of silicon dioxide. Explain your answer in terms of the structure of, and the bonding in, phosphorus (V) oxide.

3) Magnesium oxide is classified as a basic oxide.

   Write an equation for a reaction that shows magnesium oxide acting as a base with another reagent.

4) Phosphorus (V) oxide is classified as an acidic oxide.

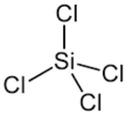
   Write an equation for its reaction with sodium hydroxide.

5) 5. Sodium chloride is a high melting point solid which dissolves in water to make a colorless solution. Silicon (IV) chloride is a liquid at room temperature which fumes in moist air, and reacts violently with water.

   (a) Explain why the arrangement of particles in solid sodium chloride leads to a high melting point.

6) Draw a simple diagram to show the structure of silicon (IV) chloride, and explain why silicon (IV) chloride is a liquid at room temperature.

Silicon (IV) chloride structure:



7) Why is there such a big difference between the chlorides of sodium and silicon?

8) Briefly describe and explain the difference in electrical conductivity between sodium chloride and silicon (IV) chloride.

Answers to consolidated activity

1) By reference to the structure of, and the bonding in, silicon dioxide, suggest why it is insoluble in water.

(1)Covalent bonds with almost the same electronegativity difference and tends to be non- polar.

2) Silicon exists as a giant covalent molecule and phosphorus (V) oxide as simple molecule only with weak van der Waals that need less energy to break.

3) $MgO(s) + HCl(aq) \longrightarrow MgCl_2(aq) + H_2O(l)$

4) $12NaOH(aq)+P_4O_{10}(s) \longrightarrow 4Na_3PO_4(aq)_{+}6H_2O(l)$

5) Sodium chloride has a high melting and boiling point. There are strong electrostatic attractions between the positive and negative ions, and it takes a lot of heat energy to overcome them.

6) Silicon tetrachloride is a colourless liquid at room temperature which fumes in moist air. The only attractions between the molecules are van der Waals dispersion forces.

7) Sodium chloride: giant ionic structure and exists a solid at room temperature

Silicon chloride: simple molecular structure and exists as a liquid at room temperature.

8) Both in solid state they do not conduct electric current. However, in molten state sodium chloride conducts since it forms whereas silicon (IV) does not in molten state since it does not form ions.

5.9. Extended activities

1. Aluminium chloride changes its structure on heating. At room temperature the aluminium is 6-coordinated – each aluminium is surrounded by 6 chlorines. The structure is essentially ionic although with a high degree of covalent character. At about 180°C, its structure changes and the aluminium become 4-coordinated.

a) Write the structure of in vapor phase at 180^0C

If you only add a small amount of formula, and draw the electronic structure of the form of aluminium chloride at 180°C.

b) What effect does this change have on the physical properties of the aluminium chloride? Explain your answer.

c) The structure changes again at higher temperatures. Write an equation to show that change.

d) The reaction of aluminium chloride with an excess of water could be written as

$$AlCl_3(s)+6H_2O(l) \longrightarrow [Al(H_2O)_6]^{3+}(aq)+3Cl^-(aq)$$

e) The solution formed is acidic. Explain why that is? When Water added to some solid aluminium chloride, you get a vigorous reaction with some steamy fumes given off. Explain what is happening.

2. Answer the following questions by considering only the highest oxides of the Period 3 elements:

Na_2O MgO Al_2O_3 SiO_2 P_4O_{10} SO_3 Cl_2O_7

(a)(i) Which is the most basic oxide?

(ii) What is it about this oxide which makes it basic?

(iii) Write an equation to show its reaction with dilute hydrochloric acid.

(iv)Write an equation to show its reaction with water.

(b)(i) Which is the next most basic oxide?

(ii) Why is it less basic than the one you have described in part (a)?

c) (i) Name an Amphoteric oxide.

(ii) Explain what the term Amphoteric means. Your answer should include one or more equations as necessary, relating to the reactions of the oxide you have named.

d) The acidic oxides are often thought of in terms of in terms of the strengths of the acids formed when they react with water.

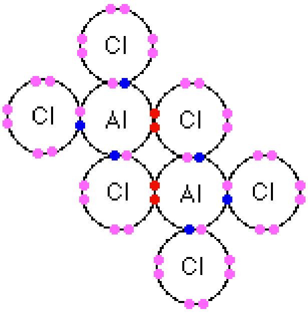
(i) Write the equations for the reactions of SO_3 and P_4O_{10} with water.

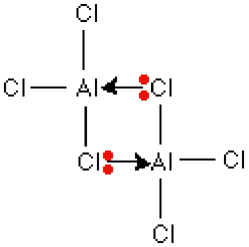
(ii) Which of the two acids that you have produced in part (i) is the stronger? Draw the structures for the two acids, and use these to help to explain why that acid is stronger.

(iii) SO_3 can also act as an acid in its own right by reacting with a base. Write an equation to show it reacting with a base.

Answers to extended activity.

1. a) Al_2Cl_6





b) Because this is a covalent molecule, it only has relatively weak van der Waals forces to hold it to its neighbours instead of ionic bonds. This causes it to sublime once it has taken up this structure.

c) $Al_2Cl_6 \rightleftharpoons 2AlCl_3$

d) The highly positive aluminium ion at the centre of the complex with the water molecules pulls electrons from the water strongly towards the aluminium. The net effect is to make the hydrogens in the water molecules fairly positive. These can react with water molecules in the solution to give hydroxonium ions, and therefore an acidic solution.

$$[Al(H_2O)_6]^{3+}(aq) + H_2O(l) \rightleftharpoons [Al(H_2O)_5(OH)]^{2+} + H_3O^+(aq)$$

or, more simply:

$$\mathbf{[Al(H_2O)_6]^{3+}(aq) \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}(aq) + H^+ (aq)}$$

e) The reaction is strongly exothermic. The hydrogen ions (hydroxonium ions) produced as above and the chloride ions already present (from the reaction of the aluminium chloride with the water) will form a solution containing hydrochloric acid. If there is only a small amount of water present, the heat released will boil off steamy fumes of hydrogen chloride.

2. (a) (i) Na_2O

(ii) The presence of the very basic oxide ions, O^{2-}

(iii) $Na_2O + HCl \longrightarrow NaCl + H_2O(l)$

(iv) $Na_2O + H_2O \longrightarrow NaOH(aq)$

b)

(i) MgO

(ii) There are much stronger attractions between 2+ and 2- ions than between 1+ and 2- ions.

The oxide ions aren't so free to react with acids as they are in sodium oxide.

c) (i) Aluminium oxide

(ii) Amphoteric means that it reacts as both a base and an acid. That means that it will react with an acid or with a base.

Reacting as a base (reacting with an acid)

$$Al_2O_3(s) + 6HCl(aq) \longrightarrow 2AlCl_3(aq) + 3H_2O(l)$$

Reacting as an acid (reacting with a base):

$Al_2O_3(s)+2NaOH(aq)+3H_2O(l) \xrightarrow{\qquad\qquad} 2NaAl(OH)_4(aq)$

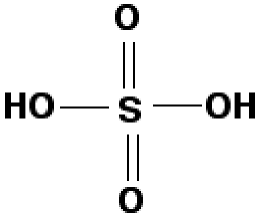
(If you have been taught a different version of this equation producing either $NaAlO_2$ or

$Na_3Al(OH)_6$, then use that one instead, but make sure that it balances properly.)

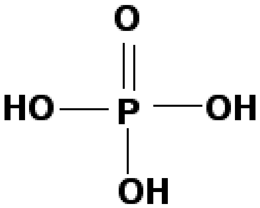
d) (i) $SO_3(g)+H_2O(l) \xrightarrow{\qquad\qquad} H_2SO_4(aq)$

$P_4O_{10}(s)+6H_2O(l) \xrightarrow{\qquad\qquad} 4H_3PO_{4(aq)}$

(ii) Sulphuric acid. The structures are:



and



When either acid loses a hydrogen ion from one of the OH groups, it leaves a negative charge on the oxygen. This can be delocalized over the rest of the structure by interaction with the electrons in the C=O double bond(s). There are two such bonds in the ion from the sulphuric acid, but only one with the phosphoric (V) acid. The more the delocalization, the more stable the ion, and the more likely it is to form, and remain as an ion rather than reacting with a hydrogen ion again.

(iii) $CaO + SO_3 \xrightarrow{\qquad\qquad} CaSO_4$ but you could equally well give an equation with MgO (just like the one above) or with Na_2O to produce Na_2SO_4 - or something similar.

UNIT
6

PROPERTIES AND USES OF TRANSITION METALS

6.1. Key unit competence

Explain the properties and uses of transition metals

6.2. Prerequisite (knowledge, skills, attitudes and values)

Students will learn better the properties and uses of transition metals if they have understanding on: electronic configuration, atomic spectra, chemical bonding, chemistry of the elements in the periodic table (main group elements), redox reactions, Lewis acids and bases(all these covered in senior four); nomenclature of inorganic and organic compounds (covered from senior one to senior five)

6.3 Cross-cutting issues to be addressed:

Environment and sustainability

Transition metals are among the heavy metals (metals with density greater than $5g/cm^3$). Heavy metals consist of both biological essential and non-essential metals. Biological essential heavy metals include copper, nickel, iron and zinc. Although they are necessary, they become toxic at high concentrations.

Heavy metals are a natural part of the earth's crust. They enter the sea usually through riverine influx (after weathering and erosion of rocks), atmospheric deposition (dust particles from volcanoes for instance). Humans add both the reverine deposition (waste water of factories) and atmospheric deposition (cars, factories ...). Heavy metals are stable and cannot be broken down, which makes them to accumulate in the environment.

Transition metals form complexes which are soluble in water. Though they are really important in the human body; their excessiveness causes dangers to the body. And yet most common metallic materials used in daily life are made of transition metals. How are the old ones disposed off? When metals are spread on the ground (this is land pollution in itself), they run into water bodies carried by rain water from mountains through erosion. In water bodies, they dissolve by forming complexes causing its contamination, hence causing water pollution.

Young people should be addressed about this issue so that they can avoid to the dispose waste materials everywhere. Waste materials should be collected together in areas reserved for them according to their categories. The majority of old materials made of metals can be recycled to form new ones without polluting environment.

This will help them to understand the importance of sustainability as they grow up and become responsible for the world around them.

Inclusive education

This unit requires learners to carry out a lot of researches to be able to understand first, then share and discuss on things like structure of benzene, its stability, and so on. This may be challenging to students with special educational needs especially slow learners. However, as teacher you can organise your class and use different strategies to help all learners understand well.

6.4. Guidance on introductory activity

The tutor may ask the student teachers to observe the picture carefully and answer the questions below.

6.5. List of lessons/sub-heading

#	Lesson title	Learning objectives	Periods
1	-Definition and Electronic configuration of transition metals (1st series)	Relate the electronic configuration to the definition of a transition metal/element as d-block elements.	1
2	Physical and special Properties of the transition metals The anomalous properties of Zn and Sc.	Discuss qualitatively the properties of transition elements when compared to those of calcium as a typical s-block metal Explain the principle of ligand exchange. Explain why scandium and zinc are not considered as true transition metals	3.
End unit assessment			1

Lesson 1: Definition and Electronic configuration of transition metals (1st series)

a) Prerequisites/ Revision/ Introduction

Students will learn better this lesson if they have knowledge about the electronic configuration of atoms and ions using s, p, d... notation and classification of elements into blocks from the electronic configuration (covered in senior four)

b) Teaching resources

- Use periodic table of elements.
- projectors and internet if available
- SME student book year 2

c) Learning activities

Guidance

- Tutor provides the activity 6.1 to student teachers in their groups.
- Student teachers discuss and make presentation.

Answers to activity 6.1

1(a)$1s^22s^22p^63s^23p^64s^2$ (b) $1s^22s^22p^63s^23p^6$ (c) $1s^22s^22s^63s^1$ (d) $1s^22s^22p^6$

2(a)Refer to the notes

(b)-These elements contained electrons in the d-orbital

-Some elements such as Chromium and copper adopt a unique electronic configuration to attain stability.

Scandium and zinc ions have none and filled d-orbital hence unique characteristics different from those of other transition elements.

(c)Transition element is one with partially filled d-orbital

3. Conduct electric current, low first ionization energies some are soft with low melting and boiling points.

(d) Application activities

Answers to application activity 6.1

1. They contain d-orbital partially or filled with electrons
2. Refer to notes in the student book about electronic configuration
3. Refer to notes in the student book about electronic configuration of transition elements

Lesson 2: Physical and Special Properties of the transition metals.

a) Prerequisites/Revision/Introduction:

Students will learn better all the properties of transition elements if they have knowledge on electronic configuration ; calculation of oxidation states (from redox reaction), atomic spectra and general physical properties of metals.

b) Teaching resources

Use worksheets or books; projectors and/or chalkboard

Materials such as various metals; beakers, test tubes, test tube holders, spatula, bunsen burners, pair of tongs, match box,...

Chemicals such as various compounds including those of transition metals and their solutions

c) Learning activities

Guidance

You can start by asking your students questions about the physical properties of metals in general as revision. Some of the materials to be used can be brought by students by themselves to increase their participation.

Answers to activity 6.2(a)

The melting and boiling points increase as the number of delocalized electrons increase in metallic lattice from sodium through magnesium to aluminium.

Answers to activity 6.2(b) research before the lesson.

The metallic character decreases from sodium to aluminium and therefore the density decrease across the period 3 elements.

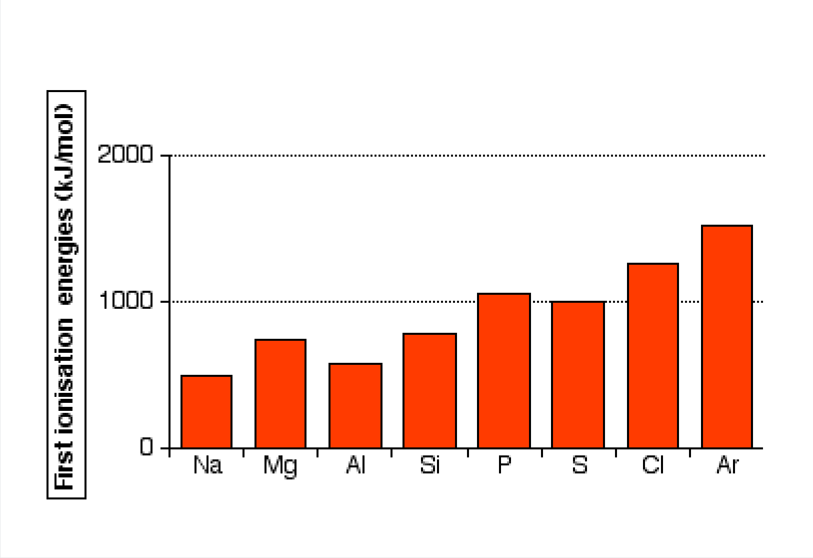
Refer to the transition metal notes in student book

Answers to activity 6.2(c)

(i) The first ionization energy is the energy required to remove the most loosely held electron from one mole of gaseous atoms to produce 1 mole of gaseous ions each with a charge of 1^+.

$X(g) \longrightarrow X^+(g) + e^-$

It is the energy needed to carry out this change per mole of



.

Notice that the general trend is upwards, but this is broken by falls between magnesium and aluminium, and between phosphorus and sulphur.

Explaining the pattern

First ionization energy is governed by:

- the charge on the nucleus;
- the distance of the outer electron from the nucleus;
- the amount of screening by inner electrons;
- whether the electron is alone in an orbital or one of a pair

(2) $Mg(g) \longrightarrow Mg^+(g) + e^-$

$Mg^+(g) \longrightarrow Mg^{2+}(g) + e^-$

$Al(g) \longrightarrow Al^+(g) + e^-$

$Al^+(g) \longrightarrow Al^{2+}(g) + e^-$

$Al^{2+}(g) \longrightarrow Al^{3+}(g) + e^-$

The fall at aluminium

You might expect the aluminium value to be more than the magnesium value because of the extra proton. Offsetting that is the fact that aluminium's outer electron is in a 3p orbital rather than a 3s.

The 3p electron is slightly more distant from the nucleus than the 3s, and partially screened by the 3s electrons as well as the inner electrons. Both of thesefactors offset the effect of the extra proton

Answers to activity 6.2(d)

(i)Sodium ion (Na^+) : has only one outer shell electron/valence electron

Magnesium(Mg^{2+}): has two outer shell electrons/valence electrons

Aluminium(Al^{3+}): has three outer shell electrons/valence electrons

(iii)The charges here correspond to group number

Answers to activity 6.2(e)

(i) A catalyst is a substance which speeds up the chemical reaction but is not consumed during the reaction and remain unchanged at the end of the reaction.

(ii)Finely divide iron metal

3. Digestion (amylase catalyses the digestion of starch in the mouth, pepsin catalyses digestion of proteins in stomach e.tc.)

Answers to activity 6.2(f)

1.

Objects attracted by a magnet	Objects not attracted by a magnet
A.nails C. falk, spoon and nife D.coins	B. piece of chalk E. iron sheet

2. Those attracted by magnet are made from element having unpaired electrons in their 3d sub-shells and therefore have the property of paramagnetism.

Answers to activity 6.2(g)

(i) stainless steel (iron mixed with carbon)

(ii) resist corrosion since they are kitchen utensils commonly exposed to water that may bring rusting

Answers to activity 6.2(h)

(a)Hexa aqua aluminium (iii) ions

(b) Aluminium chloride contain 3d-empty orbitals to accommodate water mole cules and form dative coordinate bonds

(d)Application activities

Answers to application activity 6.2

1 (a) This is due to the build-up of electrons in the immediately underlying d-sub-shells that efficiently shields the 4s electrons from the nucleus and minimizing the increase in **effective nuclear charge** from element to element

(b)Removing an electron Iron (ii) to form Iron (iii) is much easier than removing an electron from stable manganese (ii) to form manganese (iii) which is less stable.

2. Manganese (ii) is much more stable with a half filled d-orbital compared with Mn^{3+}

3. You are provided with substance D which contains one cation and one anion. You are required to identify the cation and anion in D. Carry out the following tests and record your observations and deductions in the table below. Identify any gas evolves. Copy and complete the table.

Tests	**Observations**	**Deductions**
1) Note appearance of **D**	Green solid	Fe^{2+}, Cr^{3+}, Cu^{2+} or Ni^{2+} ions are suspected
2) Put one spatula end-full of **D** in a test tube and heat it strongly until there is no further change	- Colourless vapour which condenses on the cooler part of the test tube. - A colourless pungent gas which turns potassium dichromate green is formed. - The residue is a dark green solid.	- hydrated salt present. - Gas is SO_2 probably SO_3^{2-} or SO_4^{2-} salt present. - **D** is a transition compound probably containing Cr^{3+} or Ni^{2+}

3) Dissolve one spatula of D in about 10cm^{3}of water and divide the resultant solution into five parts.	D dissolves to give green solution.	Probably D contains Cr^{3+}, Ni^{2+}, Fe^{2+} or Cu^{2+}.
a) To the 1st part is added sodium hydroxide solution drop wise until in excess	A green precipitate which slightly dissolves to give a violet solution.	Probably Cr^{3+} present
b) To the second part is added dilute sodium hydroxide solution dropwise until in excess followed by 1cm^3 of 10% hydrogen peroxide solution and the resultant mixture boiled and later cooled. the resultant solution is then divided into three portions	A green precipitate soluble in excess NaOH to form a green solution. On boiling with H_2O_2 a yellow solution is formed with evolution of a colourless gas which relights a glowing splint.	Cr^{3+} presence confirmed. H_2O_2 oxidises Cr^{3+} in an alkaline medium to yellow chromate. The gas is oxygen.
i) To the 1st portion is added silver nitrate solution dropwise until no further change takes place.	A brick red precipitate.	Silver chromate is formed. Hence CrO_4^{2-} compound formed.
ii) To the second portion is added a drop of barium chloride solution	A pale yellow precipitate.	Barium chromate formed. Hence CrO_4^{2-} compound formed
iii) To the 3rd portion is added a few drops of hydrochloric acid.	The yellow solution turns orange	A dichromate has been formed from a chromate
c) To the third part of the solution is added a few drops of butanol followed by 3 drops of dilute H_2SO_4	A deep blue lake is formed	Presence of Cr^{3+}
d) To the fourth part was added a few drops of lead nitrate solution.	A white precipitate is formed	Probably Cl^-, CO_3^{2-} or SO_4^{2-} present
e) To the last part was carried a test of one's own choice. <u>Test</u>: To the last portion is added a few drops of barium nitrate followed by 1 cm^3 of dilute nitric acid.	A white precipitate insoluble in nitric acid is formed	Presence of SO_4^{2-} confirmed.

- The cation in D is **Cr^{3+}**
- The anion in D is **SO_4^{2-}**

6.6. Summary of the Unit

Transition metals elements are the elements that form ions with partially filled *d*-orbitals .They are also called d-block elements because their electrons end in d-orbitals.

The properties of transition elements are between the highly reactive metallic elements of the s-block elements which generally form ionic compounds and the less reactive elements of the p-block which form covalent compounds. Transition elements form ionic compounds as well as covalent compounds.

These metals are all hard and dense, good conductors of heat and electricity. One exception, Mercury, is liquid at room temperature. They do not show added gradation in physical properties across the period as it is in s block metals. They are remarkably similar to one another in their properties in general. The reason for the similarity of the first transition series from left to right, while each additional electron is entering the 3d shell, the chemistry of the elements continues to be determined largely by the 4s electrons.

However, they have their characteristics that differentiate them from main group elements such as the following:

- They have variable oxidation states
- They have high ability of being catalysts
- Many of their compounds are paramagnetic
- They from alloys
- They form complex ions
- Many of their ions and compounds are coloured

All these characteristics are due to their electronic configuration which has a partially filled 3d-orbital.

Zinc and Scandium show abnormal properties compared to the other members of the series because the 3d-orbitals of their ions/compounds are completely filled or empty respectively.

6.7. Additional information for teachers

Types of ligands and naming complex transition compounds.

(a) Monodentate ligands

The ligands which have only one donor atom or are coordinated through one electron pair are called *monodentate ligands because they have only one tooth with which to attach themselves to the central cation or atom*. Such ligands are coordinated to the central metal at one site or by one metal-ligand bond only.

These ligands may be neutral molecules or in anionic form.

Examples: table below provides examples of some monodentate ligands.

Table 6.7: some monodentate ligands

Ligand symbol	Ligand name
$H_2\ddot{O}$:	Aqua/aquo
$:NH_3$	Ammine
CO	Carbonyl
F^-	Fluoro
Cl^-	Chloro
CN^-	Cyano (coordination through C-atom)
NC^-	Isocyano (coordination through N-atom)
NO_2^-	Nitro (coordination through n-atom)
NH_2^-	Amido

Ligands that can use different sites to coordinate to the central metal are called "**ambidentate**": e.g. CN^- and NC^-(see table above).

Notice that a ligand with a donor atom that possesses 2 lone pairs of electrons, such as $H_2\ddot{O}$:, is not bidentate, since it cannot use both lone pairs simultaneously to bind to the metal because of the steric effect.

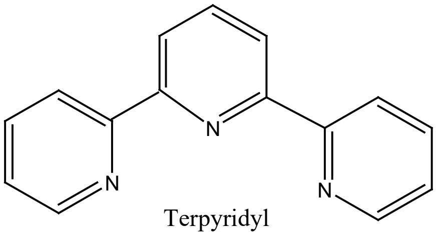
(b) *Polydentate ligands*

These may be bidentate, tridentate, tetradentate, pentadentate, and hexadentate ligands if the number of donor atoms present in one molecule of the ligand attached with the central metallic atom is 2, 3, 4, 5, and 6 respectively. Thus one molecule of these ligands is coordinated to the central metallic atom at 2, 3, 4, 5, and 6 sites respectively. In other words, we can say that one molecule of these ligands makes 2, 3, 4, 5, and 6 *metal-ligand coordinate bonds* respectively.

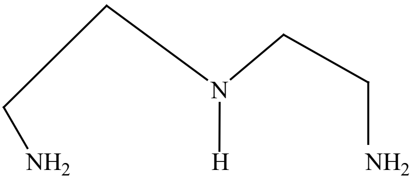
- **Bidentate:**

Ethylenediammine

- **Tridentate**



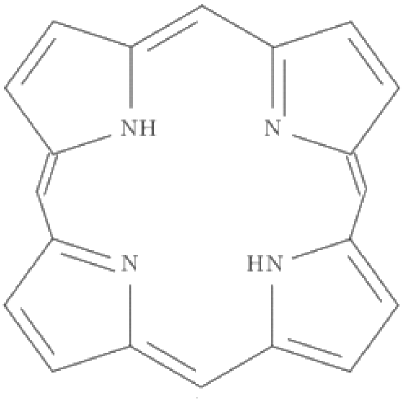
Terpyridyl
(terpy)



Bisethylenediammine

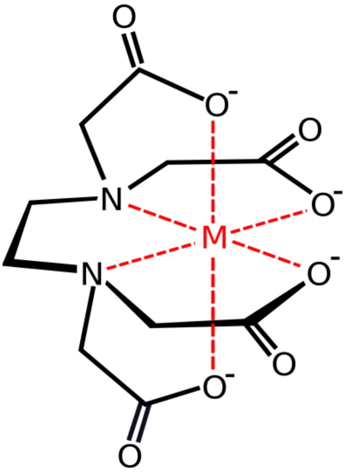
(tris)

- **Tetradentate**



- **Hexadentate**

The structure shows that it has *two neutral N- atoms* and *four negatively charged O-atoms* as its donor atoms which can form coordinate bonds with a transition metal ion.



The complex ions which form between polydentate ligands and cations are known as ***chelates*** or ***chelated complexes***.

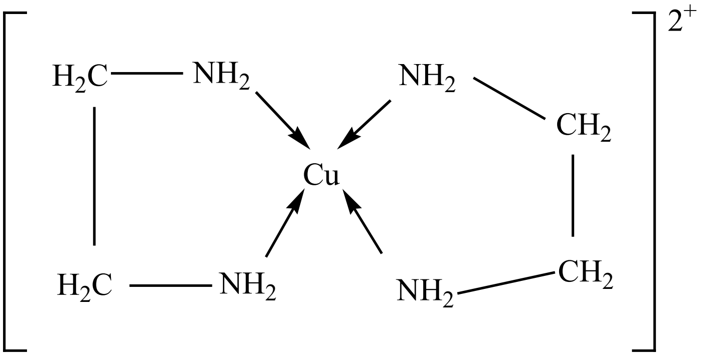
In general, polydentate ligands form more stable complexes than monodentate ligands. The stability of complex is much enhanced by **chelation.** A polydentate ligand can hold the central cation more strongly.

Examples of complexes:

- Copper (II) ions have a ***coordination number of four*** in most of its complexes:

  $[Cu(H_2O)_4]^{2+}$, $[Cu(NH_3)_4]^{2+}$, $[CuCl_4]^{2-}$, $[Cu(NH_2\text{-}(CH_2)_2\text{-}NH_2)_2]^{2+}$, ...

  $2NH_2CH_2CH_2NH_2 + Cu^{2+} \longrightarrow$



- Most ions have *coordination number of 6*.

  $[Cr(H_2O)_6]^{3+}$, $[Cr(NH_3)_6]^{3+}$, $[Cr(H_2O)_4Cl_2]^-$, ...

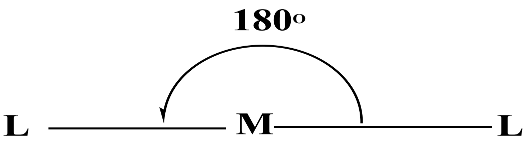
- Very few ions have a *coordination number of 2*: $[Ag(NH_3)_2]^+$, $[Ag(CN)_2]^-$, $[CuCl_2]^-$, ...

Geometry of complexes

Complexes have a variety of geometries or shapes, but the most common geometries are the following:

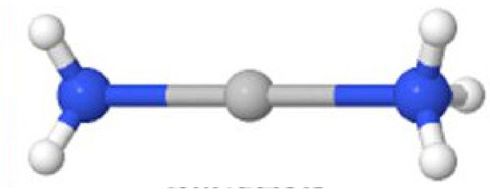
Complexes with **coordination number 2** adopt a ***linear shape***. Example: $[Ag(NH_3]_2^+$: $[H_3N\text{-}Ag\text{-}NH_3]^+$

The complexes having coordination number of 2 are **linear** since this geometry provides minimum ligand repulsion.

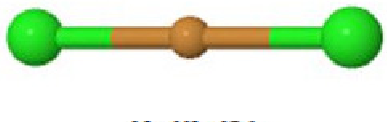


Cu^+, Ag^+ and Au^+ form such complexes

Examples: $[Cu(CN)]_2^-$, $[Cu(NH_3)]_2^+$, $[Hg(CN)]_2^-$, $[CuCl_2]_2^-$



$[Ag(NH_3)]_2^+$

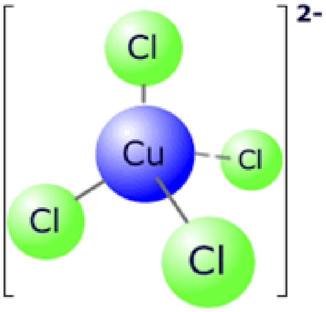


$[CuCl_2]^-$

Complexes with **coordination number 4** adopt a ***tetrahedral shape*.**

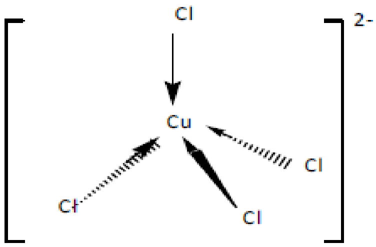
Examples: $[Zn(NH_3)_4]^{2+}$, $[NiCl_4]^{2-}$, $[CuCl_4]^{2-}$ and some few others adopt a *square planar shapes*, examples: $[Cu(NH_3)_4]^{2+}$, $[Ni(CN)_4]^{2-}$,$[CuCl_4]^{2-}$,$[CoCl_4]^{2-}$,...

The square plannar geometry is characteristic of transition metal ions with eight d electrons in the valence shell, such as platinum(II)and gold(III)

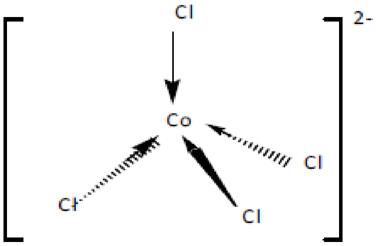


tetrachlorocuprate (II) ion

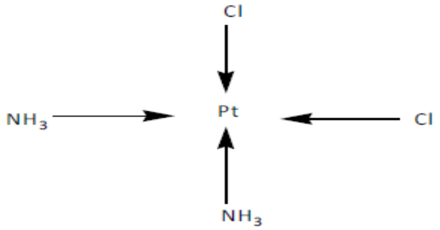
Copper (II) and cobalt (II) ions have four chloride ions bonded to them rather than six, because the chloride ions are too big to fit any more around the central metal ion.



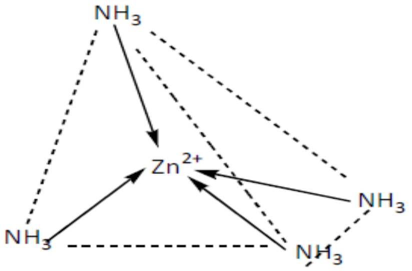
$[CuCl_4]^{2-}$



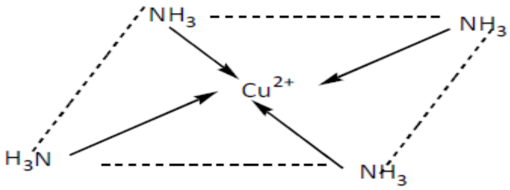
$[CoCl_4]^{2-}$



$Pt(NH_3)_2Cl_2$



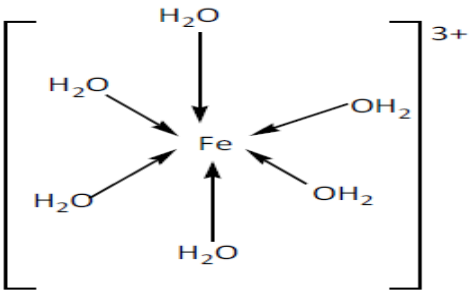
Tetrahedral structure



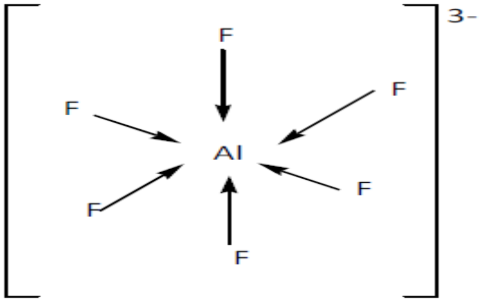
Square planar structure

Complexes with **coordination number 6** adopt an ***octahedral shape*.** Example: $[Cr(NH_3)_6]^{3+}$.

These ions have four of the ligands in one plane, with the fifth one above the plane, and the sixth one below the plane.



$[Fe(H_2O)_6]^{3+}$



$[AlF_6]^{3-}$

End unit assessment (answers)

1. Transition metals have high melting points compared to s-block elements; this is due to many delocalized electrons that increase the metallic bond strength in transition metals.

2. Cu: [Ar]4S13d10 Co2+: [Ar]3d7 Ti3+: [Ar]3d2

3. (a) the second electron in copper is removed from 3d- orbital which is full filled and stable.

(b) Refer to notes in student book under unit 6(physical properties of transition elements)

(c) Second electron is removed from inner 3d-sub shell and more difficult to remove an electron.

4. (a)Iron has many delocalized electrons

(b) Sodium has only one electron in the outer shell whereas iron has 2 electrons in 4S-orbita and other electrons in 3d which are all delocalized.

(c) Fe^{3+} is more paramagnetic than Fe^{2+} because Fe^{3+} has five unpaired electrons while Fe^{2+} has four unpaired.

5. A:Zinc (ii) ions B:Copper(ii) ions C:Nickel (ii) ions

6.8. Additional activities

6.8.1. Remedial activities

1. Explain why solutions of copper (ii) ions are coloured whereas solutions of copper(i) ions are colourless .
2. Suggest the difference between the properties of **Sc, Zn** and **other transition metals**
3. Predict whether the following substances are paramagnetic or not. Explain

   (a)$CuSO_4$ (b) Co (c) Ca (d) Cr

4. Sketch the arrangement of bonds in the complexes

   (a)Hexaaquacobalt(iii)ion

   (b)Hexacyanoiron(iii) ion

   ©Diamminesilver(i)ion

   (d)Tetracarbonyl nickel

5. Name the following complex ions

   a $[Cr(OH)_6]^{3+}$ b $[Al(OH)_4]^-$

   c $[Cu(NH_3)_4]^{2+}$ d. $[CuCl_4]^{2-}$

6. State the oxidation and coordination number of the metal in each of the complexes

(a)$Ag(NH_3)_2NO_3$

(b)$Ni(CO)_4$

(c)$K_3Fe(CN)_6$

(d)$K_4Fe(CN)_6$

(e)$[CuCl_4]^{2-}$

(f)$[CuCl_4]^{3-}$

(g)$Zn(NH_3)_4SO_4$

7. The addition of aqueous ammonia to copper (ii) sulphate resulted in the formation of a pale blue precipitate . This dissolved on addition of more aqueous ammonia to give a deep blue precipitate solution. The precipitate also dissolved in dilute hydrochloric acid to give a pale blue solution and concentrated hydrochloric acid to give a green solution. Explain these colour changes, giving the name of each coloured species.

Answers to remedial activities

It is basically because of empty d- orbitals that compounds of transition metals show colours. When an electron jumps from lower energy level to higher energy level some amount of energy is absorbed. This energy corresponds to the frequency of light observed, which mostly lies in visible region. Colour of compound observed is complementary of the colour absorbed. This is the reason why ions of metals having configuration d^1 or d^{10} does not have coloured compound.

2. Refer to notes in student book

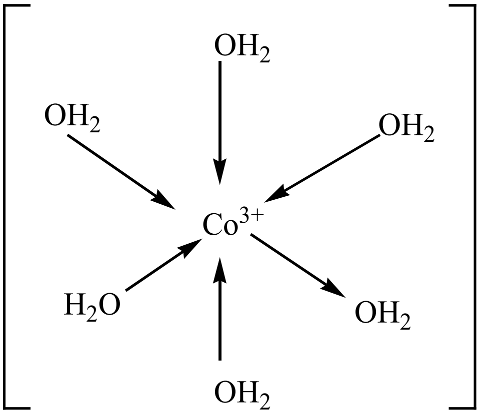
$CuSO_4$ - paramagnetic

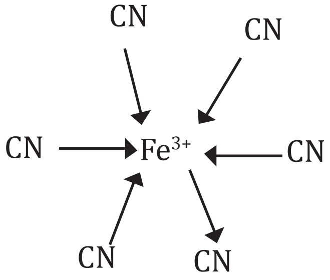
Co $[Ar]4s^1 3d^9$ paramagnetic

Ca $[Ar]4s^2$ Non paramagnetic

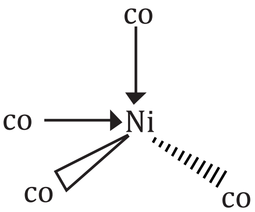
Cr $[Ar]4s^1 3d^5$ paramagnetic

4.





$[H_3N \longrightarrow Ag^{+} \longrightarrow H_3N]$



5.(a)hexaaquahydroxochromium(iii) ion

(b)Tetrahydroxoaluminate (iii) ion

(c)Tetraammine copper(ii) ion

(d)Tetra chlorocuprate (ii) ion

(a)Oxidation number (+1), coordination number (2)

(b) Oxidation number (0), coordination number (4)

(c) Oxidation number (+3) , coordination number (6)

(d)Oxidation number (+2), coordination number (6)

(e) Oxidation number (+2), coordination number (4)

(f) Oxidation number (+1), coordination number(4)

(g) Oxidation number (+2) , coordination number(4)

$$Cu^{2+}(aq) + 2OH^{-}(aq) \longrightarrow Cu(OH)_2(s)$$ white precipitate

8. $$Cu(OH)_2(s) + 4NH_3(aq) \longrightarrow [Cu(NH_3)_4]^{2+}(aq) + 2OH^{-}(aq)$$

deep blue solution

$$Cu(OH)_2(s) + 2HCl(aq) \longrightarrow CuCl_2(aq) + H_2O(l)$$

pale blue solution

$$CuCl_2(aq) + 2Cl^{-}(aq) \longrightarrow [CuCl_4]^{2-}(aq)$$

Green solution

6.8.2. Consolidation activities

1. Discuss on the following questions:

a) What do you understand by the term “isomerism”?

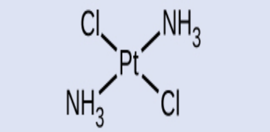
b) Is there any relationship between isomers and isomerism?

c) Give examples of molecules that can exist as isomers and explain their isomerism

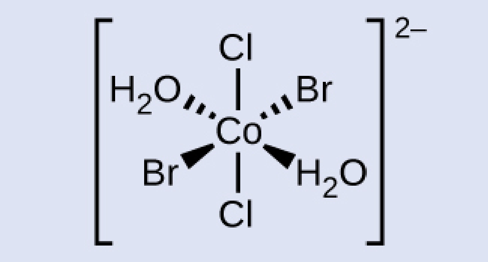
2. Read and discuss the summary below to understand how complex ions/ compounds exhibit isomers

Present your findings to your colleagues and teacher to share your understanding.

1) Answers

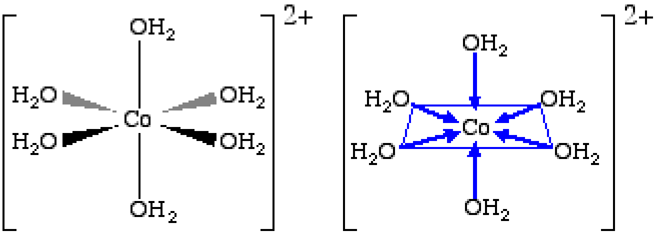


Name: Trans-diamminedichloroplatinum (II)

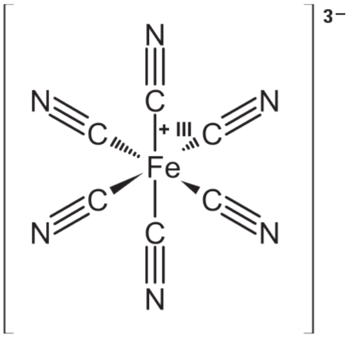


2)

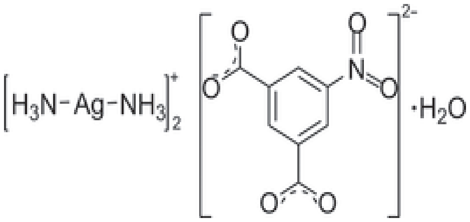
a) Hexaaquacobalt(III) ion



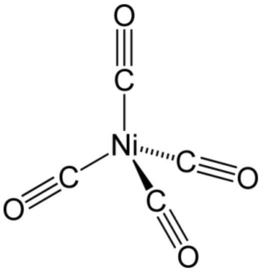
b) Hexacyanoiron (III) ion



c) Diamminesilver (I) ion



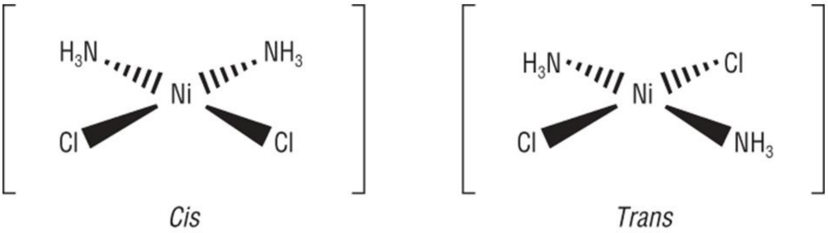
d) The complex compound tetracarbonylnickel



4)

i. Tetrahedral structure. This structure can have cis-trans isomers, while tetrahedral structure could not.

ii. Cis-trans isomerism $[NiCl_2(NH_3)_2]$



5)

a) +4

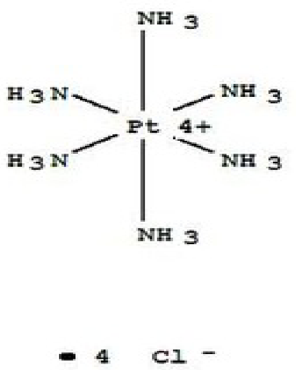
b) **A** is $[Pt(NH_3)_6]^{4+}(Cl^-)_4$; **B** is $[Pt(NH_3)_5Cl]^{3+}(Cl^-)_3$; **C** is $[Pt(NH_3)_4Cl_2]^{2+}(Cl^-)_2$; **D** is [Pt]

$(NH_3)_3Cl_3]^+Cl$;

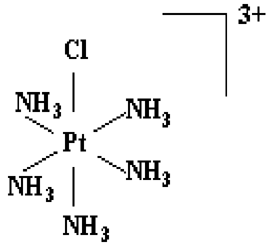
E is $[Pt(NH_3)_2Cl_4]$

c.

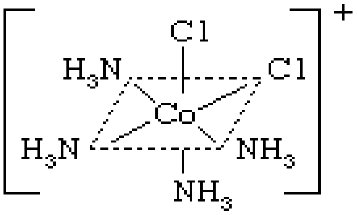
A



B

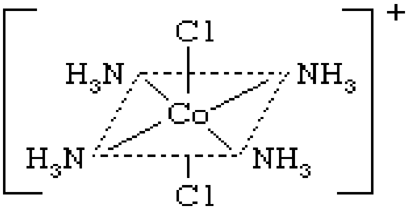


C

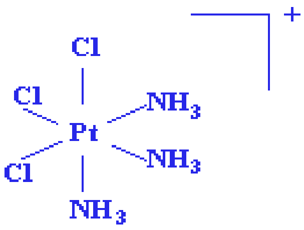


cis

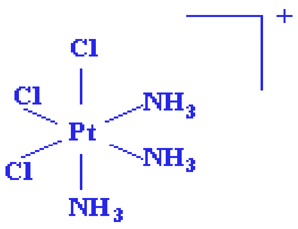
D



trans



fac



fac

d) C and D

6.9. Extended activities.

Complete the table below using the names of the given metals when they are in anionic complexes

Element	Name in an anionic complex
Ti	
V	
Cr	
Mn	
Co	
Zn	
Hg	
B	
Al	
Ge	

2. Give the systematic names for the following complex ions/compounds:

(a) $[Cr(NH_3)_3(H_2O)_3]^{3+}$

(b) $[Co(H_2NCH_2CH_2NH_2)_3]_2(SO_4)_3$

(c) $K_4[Fe(CN)_6]$

Fe(CO)5

Answer to extended activities

1.

Element	Name in an anionic complex
Ti	Titanate
V	Vanadate
Cr	Chromate
Mn	Manganate
Co	Cobaltate
Zn	Zincate
Hg	Mercurate
B	Borate
Al	Aluminate
Ge	Germanate

2. Give the systematic names for the following complex ions/compounds:

(a) $[Cr(NH_3)_3(H_2O)_3]^{3+}$: Triamminetriaquachromium (III) ion

(b) $[Co(H_2NCH_2CH_2NH_2)_3]_2(SO_4)_3$: Tris-ethylenediamminecobalt (III) sulphate

(c) $K_4[Fe(CN)_6]$: Potassium hexacyanoferrate (II) or potassium ferrocyanide

Fe(CO)5: Pentacarbonyliron (0)

UNIT 7

INTRODUCTION TO ORGANIC COMPOUNDS

7.1. Key Unit competence

Apply IUPAC rules to name organic compounds and explain the types of isomers for organic compounds

7.2. Prerequisite (knowledge, skills, attitudes and values)

Students will learn better the introduction to organic chemistry if they have understanding on: The symbols of elements and their valences, Concepts of mole, chemical bonding and particularly molecular structures. The teacher will help learners to recap the concepts above.

7.3. Cross cutting issues to be addressed

This unit involves a number of activities on the organic compounds. The activities require reading and writing. This may be challenging to students with special educational needs especially children with visual impairment. However, the teacher can make some arrangements like:

- Grouping students. Students with special educational needs are grouped with others and assigned roles basing on individual student's abilities.
- Providing procedure earlier before the activity so that students get familiar with them. They can be written on the chalkboard or markerboard or printed depending on available resources. If you have children with low vision remember to print in appropriate fonts or in Braille.
- Every important point is written and spoken. The written points help students with visual impairment and speaking aloud helps students with hearing impairment
- Remember to repeat the main points of the lessons.

a) Gender

During group activities try to form heterogeneous groups (with boys and girls) or when students start to present their findings encourage both (boys and girls) to present.

b) Peace and values education

During group activities, the teacher will encourage learners to help one each other and to respect opinions of colleagues.

7.4. Guidance on introductory activity

- For this activity, the teacher forms groups of five students (depending to the class size) that are as heterogeneous as possible. Then he/she avails all necessary materials(alcohol, vinegar, petroleum, beakers, and water)
- He/she lets them to answer questions described in the introductory activity 7 in the student book.
- The Tutor makes sure that each student from each group participates in answering different questions.
- The teacher provides a clear sheet for reporting
- The teacher asks randomly representative of two or three groups to present their answers.
- After presentation, the teacher decides to engage the class into exploitation of the students' findings.
- After presentation the teacher asks the students to judge findings from different groups and harmonize their work.
- The teacher summarizes their findings and introduces the new unit

Expected answers for the introductory activity

1. Carbon (coal, charcoal,) and its compounds such as alcohol, propane, methane, etc.
2. They have different functional groups and hence behave differently in water (vinegar: less soluble, alcohol: soluble, petroleum: insoluble)

7.5. List of lessons

#	Lesson title	Learning objectives	Number of Periods
1	Classification of organic compounds as aliphatic	Classify organic compounds as aliphatic	2
2	Types of formulae for organic compounds	Determine different formulae for given organic compounds.	3
3	Functional group and homologous series.	Name different organic functional group and homologous series.	2

4	Isomerism in organic compounds	Describe the structural isomers of organic compounds.	2
5	General rules of nomenclature of organic compounds according to IUPAC.	- Use IUPAC rules to name different organic compounds.	2
6	End unit assessment		1

Lesson 1: Classification of organic compounds as aliphatic

a) Learning objective

Classify organic compounds as aliphatic

b) Teaching resources

Smart board, chalkboard, textbooks

c) Prerequisites/Revision/Introduction

The student-teachers will learn better the content of this lesson if they have a good understanding on the inorganic compounds including those contain carbon atom

d) Learning activities 7.1

- Form group of four students and let them do activity 7.1 and supervise them to encourage the participation of every one
- Choose randomly three representatives of all groups to present their findings.
- Allow some other students to comment about the findings presented by their colleagues.
- Give your feedback highlighting how organic compounds are classified as aliphatic
- Through different small verbal questions, help the students to make the conclusion themselves.

Answers to activity 7.1

1. Aliphatic 2.aliphatic 3.aliphatic 4. Alicyclic 5.aromatic 6. Aliphatic 7. Alicyclic 8.aliphatic 9. Aromatic 10. aromatic

e) Application activities

Answers to application activity 7.1

Aliphatic: G, H, J, K   Alicyclic: B, C Aromatic: A, D, E, F

Lesson 2: Types of formulae for organic compounds

a) Learning objective

Determine different formulae for given organic compounds.

b) Teaching resources

Smart board, chalkboard, textbooks

c) Prerequisites/Revision/Introduction

The student-teachers will learn better the content of this lesson if they have understood the previous lesson

d) Learning activities 7.1

- Form group of four students , let them do activity 7.2, and supervise them to encourage the participation of every one
- Choose randomly three representatives of all groups to present their findings.
- Allow some other students to comment about the findings presented by their colleagues.
- Give your feedback highlighting the different ways to represent the structure of organic compounds and their relationship
- Through different small verbal questions, help the students to make the conclusion themselves.

Answers to activity 7.2

1→D   2→A   3→B   4→C

e) Application activities

Answers to application activity 7.2

1.

C	H	O
80%	6.7%	100-(80+6.7)=13.3
80/12=6.66	6.7/1=6.7	13.3/16=0.83
6.66/0.83=8.03	6.7/0.83=8.7	0.83/0.83=1

Empirical formula is C_8H_8O

n=120/120=1, hence the empirical formula is C_8H_8O

2. %C in CO_2= (12×17.8x100)/(18×7.5)=64.73%

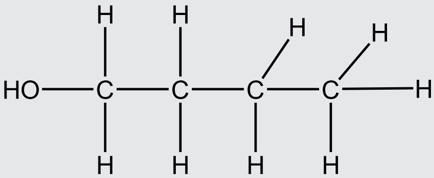
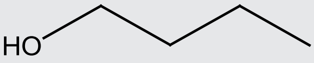
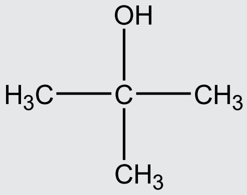
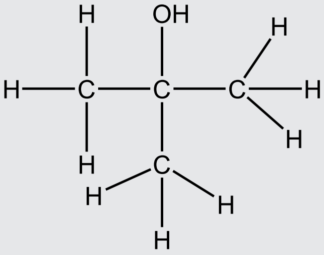
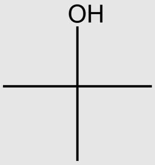
% H in H_2O= (2×9.27×100)/(18×7.5)=13.73%

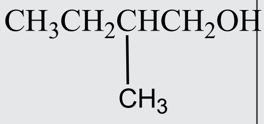
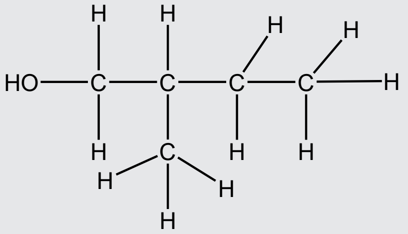
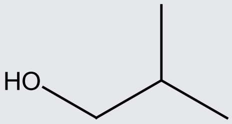
% O = 100-(64.73 + 13.73)= 21.54%

C	H	O
64.73%	13.73%	21.54
64.73/12=5.39	13.73/1=13.13	21.54/16=1.5
5.39/1.5=4	6.7/1.5=10	1.5/1.5=1

Empirical formula is $C_4H_{10}O$

n=74/74=1, hence the molecular formula is $C_4H_{10}O$

Condensed	Displayed	Skeletal
$CH_3CH_2CH_2CH_2OH$		
		

 $CH_3CH_2\underset{CH_3}{CH}CH_2OH$		

Lesson 3: Functional group and homologous series

a) Learning objective

Name different organic functional group and homologous series

b) Teaching resources

Smart board, chalkboard, textbooks

c) Prerequisites/Revision/Introduction

The student-teachers will learn better the content of this lesson if they have understood the previous lessons

d) Learning activities

- Form group of four students, let them do activity 7.3, and supervise them to encourage the participation of every one
- Choose randomly three representatives of all groups to present their findings.
- Allow some other students to comment about the findings presented by their colleagues.
- Give your feedback highlighting the common functional group and the concept of homologous series
- Through different small verbal questions, help the students to make the conclusion themselves.

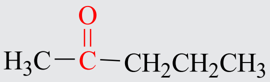
Answers to activity 7.3

Answers for learning activity 7.3

1 $H_2C{=}CHCH_2CH_2CH_3$

2 $HC{\equiv}CCH_2CH_2CH_3$

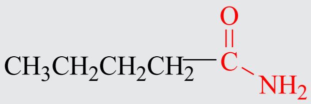
3



$$H_3C-\overset{\overset{\displaystyle O}{\|}}{C}-CH_2CH_2CH_3$$

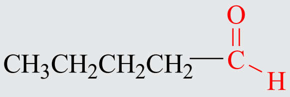
4 $CH_3CH_2CH_2CH_2-NH_2$

5



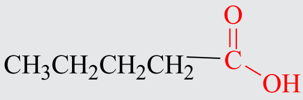
$$CH_3CH_2CH_2CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-NH_2$$

6



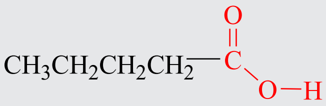
$$CH_3CH_2CH_2CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-H$$

7



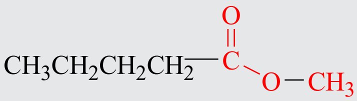
$$CH_3CH_2CH_2CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-OH$$

8



$$CH_3CH_2CH_2CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-O-H$$

9



$$CH_3CH_2CH_2CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-O-CH_3$$

Note : compound 7 and compound 8 are the same

The features that differentiate them are called function group

e) Application activities

Answers to application activity 7.3.1

1. See content in student's book
2. a) alkene b) alkyne c) ketone d) amine e) amide f)aldehyde g) carboxylic acid

   h) Carboxylic acid j) ester **Learning activity 7.3.2**

Similarities: all have carboxylic acid functional group except compound 8 which has ester function group

Differences: Numbers of carbon and hydrogen atoms are not equal

Application activity 7.3.2

1. Butane and isobutane related to the possession of the same functional group and they differ from that the chain of isobutene is branched while that of butane is not
2. a. Alkane

   b. hydroxyle

   c. carboxylic acid
3. a. i) Alkane ii) Alcohol

   b. methane, ethane, propane, butane.

   c. As the alkanes increase in chain length so does their surface area. This leads to stronger intermolecular forces and an increase in boiling point.

   d. As each hydroxyl group is added the strength of the intermolecular forces increases. The compound can form more hydrogen bonds. This leads to an increase in the boiling point.

Lesson 4: Isomerism in organic compounds

a) Learning objective

Describe the structural isomers of organic compounds.

b) Teaching resources

Smart board, chalkboard, textbooks

c) Prerequisites/Revision/Introduction

The student-teachers will learn better the content of this lesson if they have understood the previous lessons

d) Learning activities

Guidance for learning activities

- Form group of four students , let them do activity 7.4, and supervise them to encourage the participation of every one
- Choose randomly three representatives of all groups to present their findings.
- Allow some other students to comment about the findings presented by their colleagues.

- Give your feedback highlighting types of isomerism in organic compounds but telling them they are exploring only the types of structural isomers
- Through different small verbal questions, help the students to make the conclusion themselves.

Answers to learning activity 7.4

1. b and l

2. a, m, and n

b, g, j, and l

c, h, and k

f, and i

3. yes they are

4. – a (linear chain),m (one branch on the chain), n (two branches on the chain) : all have same number of carbon and hydrogen atoms

- b and l (OH at the 2nd C atom) , g (OH at the 1st C atom),j(O at two C atoms of the chain): all have same number of carbon, hydrogen and oxygen atoms.
- c (C-O double bond at the 1st C atom), h(C-O double bond at the 2nd C atom), k(C-C double bond and OH are present): all have same number of carbon, hydrogen and oxygen atoms.
- f(COO at the beginning of the chain) i(COO in the middle of the chain)

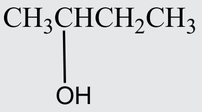
all have same number of carbon, hydrogen and oxygen atoms.

e) Application activity

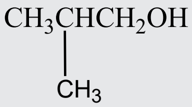
Answers to application activity 7.4

$C_4H_{10}O$

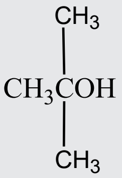
Position isomers



$CH_3\underset{\underset{OH}{|}}{C}HCH_2CH_3$

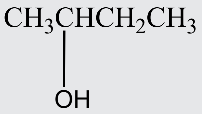


$CH_3\underset{\underset{CH_3}{|}}{C}HCH_2OH$



$CH_3\overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{C}}OH$

Functional isomers

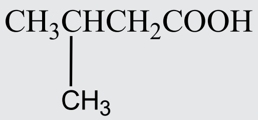


$CH_3\underset{\underset{OH}{|}}{C}HCH_2CH_3$

$CH_3CH_2OCH_2CH_3$

$C_5H_{10}O_2$

Position isomers $CH_3CH_2CH_2CH_2COOH$



$CH_3\underset{CH_3}{\underset{|}{C}}HCH_2COOH$

Functional isomers $CH_3CH_2COOCH_3$ $CH_3CH_2CH_2CH_2COOH$

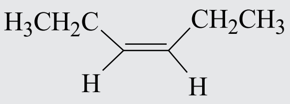
$C_5H_{10}O$

Position isomers $CH_3CH_2CH_2COCH_3$ $CH_3CH_2COCH_2CH_3$

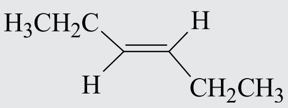
Functional isomers $CH_3CH_2COCH_2CH_3$ $CH_3CH_2CH_2CH_2CHO$

Answers to activity 7.4.2(a)

1. Compound o and p have same structural formula in terms of order of attachment of atoms but differ by spatial arrangement
2. Other example



and



Answers to the activity 7.4.2(b)

1. They are mirror images of one another
2. Presence of an asymmetric carbon atom i.e carbon with four different groups attached
3. They are enantiomers or optical isomers

Answers to the application activity 7.4.2

1. Isomers are compounds with the same molecular formula but different arrangements of atoms.
2. Structural isomers are compounds with the same molecular formula but different structural formulae. Stereoisomers are compounds with the same molecular formula but different spatial arrangement of some atoms. For the examples and the description of the sub-classes of isomers, see student book.
3. The rotation around the carbon-carbon double bond is restricted and therefore, substituents attached to the carbon atoms doubly bonded occupy fixed positions.
4. Hex-2-ene and hex-3-ene.
5. Compound c) because it contains an asymmetric carbon atom

Lesson 5: General rules of nomenclature of organic compounds according to IUPAC

a) Learning objective

Use IUPAC rules to name different organic compounds.

b) Teaching resources

Smart board, chalkboard, textbooks

c) Prerequisites/Revision/Introduction

The student-teachers will learn better the content of this lesson if they have understood the previous lessons

d) Learning activities

Guidance for learning activities

- Form group of four students , let them do activity 7.5, and supervise them to encourage the participation of every one
- Choose randomly three representatives of all groups to present their findings.
- Allow some other students to comment about the findings presented by their colleagues.

- Give your feedback highlighting the differences between systematic names and common names of organic compounds.
- Through different small verbal questions, help the students to make the conclusion themselves.

e) Application activity

Answers to application activity 7.5
1) IUPAC 2) Part of the functional group 3) a) 2,3-dimethylpentane b) n-decane c) 6-Ethyl-2,2,4-trimethylnonane d) 2-methylmethanal e) 4,7-dimethyldec-2-ene f) 4-methylhexan-1-ol g) hexanoic acid

7.6. Summary of the unit

Organic chemistry is the study of the structure and properties of carbon containing compounds.

Organic compounds are classified as aliphatic, alicyclic and aromatic. They may be represented by molecular or structural formulae. Structural formulae may be displayed, condensed or skeletal (line).

Organic compounds exhibit isomerism. **Isomerism** is the existence of compounds with the same molecular formula but different arrangement of atoms. Such compounds are referred as **isomers**.

A functional group is an atom or group of atoms which dictates the chemical behaviour of an organic compound.

A homologous series is a group of organic compounds having the same functional group.

Organic compounds are named following rules set by the International Union of Pure and Applied Chemistry. A name of an organic compound consists of three parts: a prefix that shows the nature and numbers of substituents, a root which indicate the size of the major chain and a suffix that indicate the homologous series.

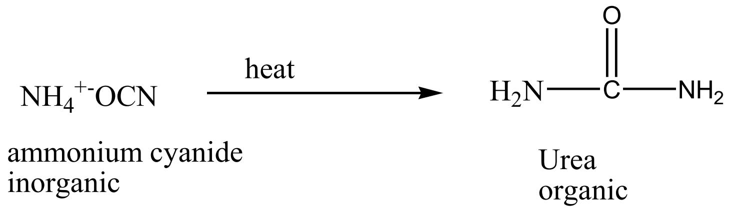
7.7. Additional Information for teachers

The Origins of Organic Chemistry

The modern definition of organic chemistry is *the chemistry of carbon compounds*. What is so special about carbon that a whole branch of chemistry is devoted to its compounds? Unlike most other elements, carbon forms strong bonds to other carbon atoms and to a wide variety of other elements. Chains and rings of carbon atoms can be built up to form an endless variety of molecules. It is this diversity of carbon compounds that provides the basis for life on Earth. Living creatures are composed largely of complex organic compounds that serve structural, chemical, or genetic functions.

The term **organic** literally means "derived from living organisms." Originally, the science of organic chemistry was the study of compounds extracted from living organisms and their natural products. Compounds such as sugar, urea, starch, waxes, and plant oils were considered "organic," and people accepted **Vitalism,** the belief that natural products needed a "vital force" to create them. Organic chemistry, then, was the study of compounds having the vital force. Inorganic chemistry was the study of gases, rocks, and minerals, and the compounds that could be made from them.

In the nineteenth century, experiments showed that organic compounds could be synthesized from inorganic compounds. In 1828, the German chemist Friedrich Wöhler converted ammonium cyanate, made from ammonia and cyanic acid, to urea simply by heating it in the absence of oxygen.



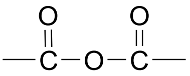
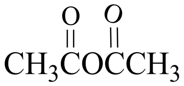
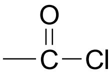
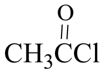
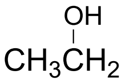
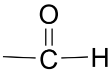
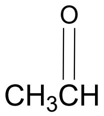
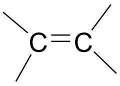
Urea had always come from living organisms and was presumed to contain the vital force, yet ammonium cyanate is inorganic and thus lacks the vital force. Some chemists claimed that a trace of vital force from Wöhler's hands must have contaminated the reaction, but most recognized the possibility of synthesizing organic compounds from inorganics. Many other syntheses were carried out, and the vital force theory was eventually discarded.

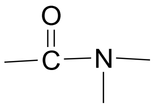
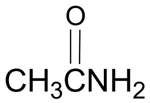
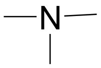
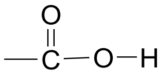
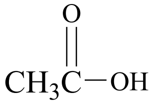
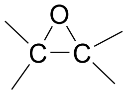
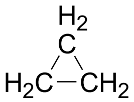
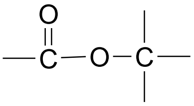
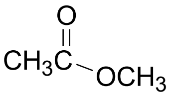
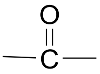
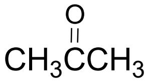
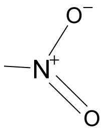
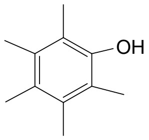
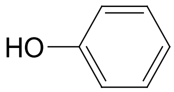
Even though organic compounds do not need a vital force, they are still distinguished from inorganic compounds. The distinctive feature of organic compounds is that they *all* contain one or more carbon atoms. Still, not all carbon compounds are organic; substances such as diamond, graphite, carbon dioxide, ammonium cyanate, and sodium carbonate are derived from minerals and have typical inorganic properties. Most of the millions of carbon compounds are classified as organic, however.

We humans are composed largely of organic molecules, and we are nourished by the organic compounds in our food. The proteins in our skin, the lipids in our cell membranes, the glycogen in our livers, and the DNA in the nuclei of our cells are all organic compounds. Our bodies are also regulated and defended by complex organic compounds.

Chemists have learned to synthesize or simulate many of these complex molecules. The synthetic products serve as drugs, medicines, plastics, pesticides, paints, and fibers. Many of the most important advances in medicine are actually advances in organic chemistry. New synthetic drugs are developed to combat disease, and new polymers are molded to replace failing organs. Organic chemistry has gone full circle. It began as the study of compounds derived from "organs," and now it gives us the drugs and materials we need to save or replace those organs.

More functional groups in organic compounds

	Functional group	**Example**	**IUPAC name**
Acid anhydride	 $-\overset{\overset{O}{\|}}{C}-O-\overset{\overset{O}{\|}}{C}-$	 $CH_3\overset{\overset{O}{\|}}{C}O\overset{\overset{O}{\|}}{C}CH_3$	Ethanoic anhydride
Acid chloride	 $-\overset{\overset{O}{\|}}{C}-Cl$	 $CH_3\overset{\overset{O}{\|}}{C}Cl$	Ethanoyl chloride
Alcohol	—OH	 $CH_3\overset{\overset{OH}{\|}}{C}H_2$	Ethanol (ethyl alcohol)
Aldehyde	 $-\overset{\overset{O}{\|}}{C}-H$	 $CH_3\overset{\overset{O}{\|}}{C}H$	Ethanal (acetaldehyde)
Alkane	…….	CH_3CH_3	Ethane
Alkene		$H_2C{=}CH_2$	Ethene (ethylene)
Alkyne	$-C{\equiv}C-$	$HC{\equiv}CH$	Ethyne(acetylene)

Amide	 $-\overset{O}{\overset{\|}{C}}-\underset{\|}{N}-$	 $CH_3\overset{O}{\overset{\|}{C}}NH_2$	Ethanamide (acetamide)
Amine, primary	$-NH_2$	$CH_3CH_2NH_2$	Ethylamine
Amine, secondary	$-NH-$	$(CH_3CH_2)_2NH$	Diethylamine
Amine, tertiary	 $-\underset{\|}{N}-$	$(CH_3CH_2)_3N$	Triethylamine
Carboxylic acid	 $-\overset{O}{\overset{\|}{C}}-O-H$	 $CH_3\overset{O}{\overset{\|}{C}}-OH$	Ethanoic acid
Disulfide	$-S-S-$	CH_3SSCH_3	methyldisulfide
Epoxide			Oxirane (ethylene oxide
Ester	 $-\overset{O}{\overset{\|}{C}}-O-\underset{\|}{\overset{\|}{C}}-$		Methyl ethanoate
Ether	$-O-$	CH_3OCH_3	Dimethyl ether
Haloalkane	$-X$ X=F,Cl,Br,I	CH_3CH_2Cl	Chloroethane (ethyl chloride)
Ketone	 $-\overset{O}{\overset{\|}{C}}-$	 $CH_3\overset{O}{\overset{\|}{C}}CH_3$	Propanone (acetone)
Nitrile	$-C{\equiv}N$	$H_3C-C{\equiv}N$	Ethanenitrile(acetonitrile)
Nitro		CH_3NO_2	Nitromethane
Phenol			Phenol
Sulfide	$-S-$	CH_3SCH_3	Dimethyl sulfide
Thiol	$-S-H$	CH_3CH_2SH	Ethanethiol

Guidance to skills Lab 7

- Make groups of 3 to 5 students (depending on the size of the class)
- Give clear instructions to the students
- Allow students to do a work and ask them to report both a written report and the product of shoes polish they have made.

End unit assessment

Answer to End unit assessment 7

1) a) functional group

b) Homologous series

2) True

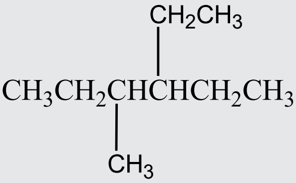
3) False

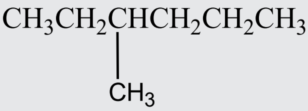
4) B

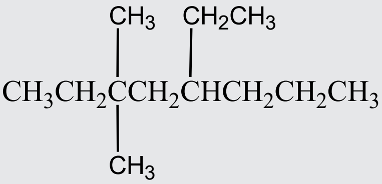
5) C

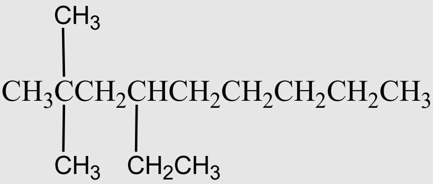
6) B

7)

(a)

$CH_3CH_2\underset{CH_3}{CH}\overset{CH_2CH_3}{CH}CH_2CH_3$

(b)

$CH_3CH_2\underset{CH_3}{CH}CH_2CH_2CH_3$

(c)

$CH_3CH_2\overset{CH_3}{\underset{CH_3}{C}}CH_2\overset{CH_2CH_3}{CH}CH_2CH_2CH_3$

(d)

$CH_3\overset{CH_3}{\underset{CH_3}{C}}CH_2\underset{CH_2CH_3}{CH}CH_2CH_2CH_2CH_2CH_3$

8) a)

%C	%H	%O
48/74×100= 64.73%	10/74×100=13.73%	16/74×100=21.54

b)

C	**H**	**O**
64.73/12=5.39	13.73/1=13.13	21.54/16=1.5
5.39/1.5=4	6.7/1.5=10	1.5/1.5=1

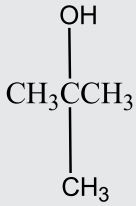
Empirical formula is $C_4H_{10}O$

c) n=74/74=1, hence the molecular formula is $C_4H_{10}O$

d) Isomers

(i) $CH_3CH_2CH_2CH_2OH$ (iv) $CH_3CH_2OCH_2CH_3$

(ii) $CH_3CH_2CHOHCH_3$ (v) $CH_3CH_2CH_2OCH_3$

(iii) 
$$CH_3\overset{\overset{\large OH}{|}}{\underset{\underset{\large CH_3}{|}}{C}}CH_3$$

e) IUPAC names (i) Butan-1-ol

(ii) butan-2-ol

(iii) 2-methylpropan-1-ol

(iv) 2-methylpropan-2-ol

(v) diethylether (vi) methoxypropane

f) Position isomers: (i) and (ii), (v) and (vi)

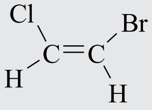
Chain isomers: (i) and (ii), (ii) and (iv)

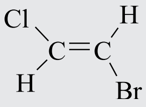
Functional isomers: (i) and (v) or (i) and (vi)

Compound which can exhibit optical isomerism: Compound (ii)

9. All four structures have a double bond and thus meet rule 1 for cis-trans isomerism.

a) This compound meets rule 2; it has two no identical groups on *each* carbon atom (H and Cl on one and H and Br on the other). It exists as both cis and trans isomers:

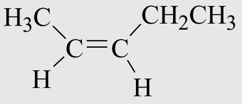


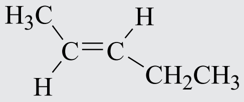


b) This compound has two hydrogen atoms on one of its doubly bonded carbon atoms; it fails rule 2 and does not exist as cis and trans isomers.

c) This compound has two methyl (CH_3) groups on one of its doubly bonded carbon atoms. It fails rule 2 and does not exist as cis and trans isomers.

d) This compound meets rule 2; it has two nonidentical groups on *each* carbon atom and exists as both cis and trans isomers:





10. Cis-trans isomers are compounds that have different configurations (groups permanently in different places in space) because of the presence of a rigid structure in their molecule. Alkenes and cyclic compounds can exhibit cis-trans isomerism.

11.

a) trans (the two hydrogen atoms are on opposite sides)

b) cis (the two hydrogen atoms are on the same side, as are the two ethyl groups)

c) cis (the two ethyl groups are on the same side)

d) neither (fliping the bond does not change the molecule. There are no isomers for this molecule)

7.8. Additional activities (Questions and answers)

7.8.1. Remedial activities

1) Say which of the following structures are functional isomers?

(i) $CH_3CH_2CH_2CHOHCH_3$

(ii) $CH_3CH_2CH_2OCH_2CH_3$

(iii) $CH_3CH=CHCO_2H$

Answer: The structure which may show optical isomerism is (i) alcohol and (ii)ether,

2) Name the following compounds according to IUPAC system.

(i) $CH_3CHOHCH_2CH_3$

(ii) $CH_3CH_2CH_2CH_2CH_3$

(iii) $CH_3CH(CH_3)CH_2CH_2CH_3$

Answer: (i) Butan-2-ol
(ii) n-pentane
(iii) 2-methylpentane

3) By giving 2 examples, explain the term homologous series.

Answer: A homologous series is a series of organic compounds with the same functional group but with each successive member differing by $–CH_2$-

Examples:

(i) for alkanes:

CH_3CH_3: Ethane

$CH_3CH_2CH_3$: Propane

$CH_3CH_2CH_2CH_3$: Butane

(ii) for alcohols:

CH_3CH_2OH: Ethanol

$CH_3CH_2CH_2OH$: Propan-1-ol

$CH_3CH_2CH_2CH_2OH$: Butan-1-ol

7.8.2. Consolidation activities

1) Give the names according to IUPAC of all possible isomers of C_6H_{14}.

Answer: (i) n-Hexane
(ii) 2-Methylpentane
(iii) 3-Methylpentane
(iv) 2,2-dimethylbutane
(v) 2,3-dimethylbutane

2) Write structural formulae for:

(i) n-Heptane

(ii) 2-Chloro-3-iodohexane

(iii) Hex-2-ene

(iv) Pentan-2-ol

Answer:

(i) $CH_3CH_2CH_2CH_2CH_2CH_2CH_3$

(ii) $CH_3CHClCHICH_2CH_2CH_3$

(iii) $CH_3CH=CHCH_2CH_2CH_3$

(iv) $CH_3CHOHCH_2CH_2CH_3$

7.9. Extended activities

1. Name the following compounds:

(i) $HC\equiv C\text{-}CH_2\text{-}CH=CH_2$

(ii) $CH_2=CH\text{-}C\equiv C\text{-}CO\text{-}CH_3$

(iii) $CF_3\text{-}CH_2\text{-}CH=CH\text{-}CHI\text{-}COOH$

Answer:

(i) Pent-1-en-4-yne

(ii) Hex-5-en-3-yn-2-one

(iv) 6,6,6-Trifluoro-2-iodo-3-pe ntenoic acid

UNIT 8

ALKANES

8.1. Key unit competence

Relate the chemical properties of alkanes to their reactivity and uses and explain their physical properties.

8.2. Prerequisite

Learners will understand better alkanes if they know:

- Chemical bonding and particularly molecular structures.
- Isomerism
- Classification of organic compounds
- General rules of nomenclature of organic compounds according to IUPAC.

8.3. Cross-cutting issues to be addressed:

a) Inclusive education:

This unit involves a number of formulae on organic compounds, the writing of formulae. This may be challenging to students with special educational needs especially students with visual impairment or visual difficulties. However, the teacher can make some arrangements like:

Grouping students. Students with special educational needs are grouped with others and assigned roles basing on individual student's abilities.

- If a teacher has students with visual difficulties, when writing on the blackboard, write in large, clear writing, especially when it comes to formulae. Read out what you are writing, for the benefit of those who are not able to see the blackboard clearly.
- If learners are sharing textbooks, try to arrange for those with visual difficulties to have their own copies, as far as this is possible.
- Give extra time for them to write summary notes or write down observations after experiments.
- Every important point is written and spoken.

- Remember to repeat the main points of the lessons.
- For students with visual impairment teacher can write of them a summary using the braille alphabet if possible.
- For learners with **hearing difficulties**, the teacher has to encourage them to sit closer to the front of the classroom. When teaching, often stop for a while to ask learners whether they have understood, or if they need you to repeat a point. s often. Encourage learners not to be afraid to ask questions. When teaching, speak clearly and ensure that all the learners can hear your voice. Avoid speaking hurriedly as this will make it difficult for learners with hearing difficulties to make sense of what you are saying.
- **Learners with mobility difficulties**: Encourage other learners to look out for and help their classmates. For example when working in the laboratory, ensure that they are able to participate, for example, making sure that they can reach the tables and other laboratory equipment comfortably.

b) Financial education: As the unit deals with the importance of alkanes in modern life, the teacher will draw the learners' attention on the economic impact of the making of common useful substances made using knowledge of chemistry.

c) Environment and sustainability: The growing awareness of the impact of the human race on the environment has led to recognition of the need to ensure our young people understand the importance of sustainability as they grow up and become responsible for the world around them. Hence Environment and Sustainability is a very important cross-cutting issue

Learners need skills and attitudes that will enable them in their everyday life to address the environment and climate change issue and to have a sustainable livelihood.

While teaching this unit concerning alkanes especially their reactivity, talk about the environment and its sustainability.

8.4. Guidance on introductory activity

Before introducing the lesson one of unit five, you will have to introduce the whole unit. Ask learners (in pairs) to attempt the introductory activity from student's book. This activity intends to relate the unit with learners' daily life and to capture their attention.

Ask learners to use library or internet (where is possible) in order to conduct this introductory activity very well. Learners may not be able to find the right answers but they are invited to predict possible solutions or answers.

Select some groups to share their findings to the whole class.

After presentation, give your comments showing them how alkanes are very important in our daily life.

It is not necessary to give them all answers of this introductory activity because they will study them in this unit. So, you can leave learners with the curiosity of knowing the correct answers.

8.5. List of lessons/sub-heading

	Lesson title	**Learning objectives**	**Periods**
1	Nomenclature of straight chain hydrocarbon alkanes (up to carbon 20) and branched hydrocarbons using IUPAC system.	• Name straight chain alkanes up to carbon 20 • Write the structural formula of alkanes • Use IUPAC system to name straight and branched alkanes	2 periods
2	Definition of homologous series and homologous series of alkanes	Define homologous series.	2 periods
3	Physical properties of straight and branched alkanes	Describe and explain the trend in physical properties of homologous series of alkanes.	2 periods
4	Laboratory preparation of alkanes by decarboxylation and other general methods.	Describe the preparation methods of alkanes.	2 periods
5	Uses of alkanes and chemical properties of alkanes (e.g. combustion, halogenations (photochemical reaction).	• State the physical properties and uses of alkanes. • Describe a photo-chemical reaction and free radical mechanism	2 periods
End unit assessment			2 periods

Lesson 1: Nomenclature of straight chain hydrocarbon alkanes

a) Prerequisite

Students will learn better the nomenclature of alkanes using IUPAC system if they have understanding on:

- General rules of naming organic compounds using IUPAC system (Year II unit 7)
- Covalent bonding and molecular structures (Year I)

b) Teaching resources

- Chemistry textbooks and other relevant chemistry books from the library
- Where possible use internet

c) Learning activities

Guidance

- Form groups (the number of groups and members will depend on your class size and the number of your resources or materials).
- Give learners activity 8.1 (from the student's book)
- Move around the class and check if all learners are working.
- Ask learners to present their findings.
- During their presentation ask some questions that lead to lesson objectives.
- Guide learners to make the summary of the lesson themselves. Make sure the following are emphasized on:
  - unbranched alkanes
  - Branched alkanes
- Make the final conclusion of the lesson.

After giving final conclusion, assess your learners using **application activity 8.1** (from student's book). Learners can do this application activity individually or in pairs. If you do not have enough time in your lesson, give it as individual home work.

Answers to activity 8.1:

1. The two elements are carbon and hydrogen. All the atoms in these compounds are covalently bonded.
2. Compound (D) and (E) have branches.
3. Compounds (D) and (E) are branched but (B) and (C) are linear.
4. **(A):** Methane **(B):** Propane **(C):** 2-methylpropane **(D):** 2,4-dimethylpentane

d) Application activities

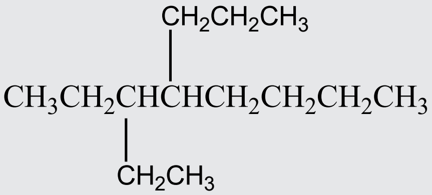
Answers to application activity 8.1.

1. a) 2,3-dimethylpentane

   b) 5-ethyl-8-methyltridecane

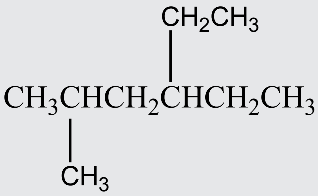
2.

(a)



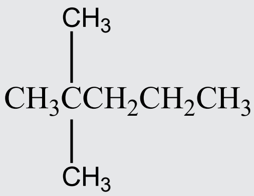
$CH_3CH_2\underset{CH_2CH_3}{CH}\overset{CH_2CH_2CH_3}{CH}CH_2CH_2CH_2CH_3$

(b)



$CH_3\underset{CH_3}{CH}CH_2\overset{CH_2CH_3}{CH}CH_2CH_3$

(c)



$CH_3\overset{CH_3}{\underset{CH_3}{C}}CH_2CH_2CH_3$

Lesson 2: Definition of homologous series and homologous series of alkanes

a) Prerequisites

Learners will understand better this lesson if they have understanding on the concept of introduction to organic compounds (year II, unit 7).

b) Teaching resources

- Chemistry textbooks
- Where possible use internet

c)Learning activities

Guidance :

- Give learners activity 8.2 (from the student's book).
- Ask learners to carry out this activity in pairs
- Move around the class and check if all learners are working.
- Ask learners to present their findings.
- Summarise the findings from students' work and give more examples which illustrate the content about definition of homologous series and homologous series of alkanes.
- Assess your learners using application activity 8.2 (from student's book).

Answers to the activity 8.2.

a)
- All these compounds are made of carbon and hydrogen only
- They are unbranched
- They are covalently bonded

b) A has 4 atoms of carbon and 10 hydrogen atoms but B has 5 atoms of carbon and 12 hydrogen atoms. They differ from $-CH_2-$ group.

c) The difference is only one $-CH_2-$ group.

d) All these compounds are composed only with carbon and hydrogen. Each one differs from the preceding by a methylene group $-CH_2-$. All these compounds are in the same homologous series.

d) Application activities

Answers to application activity 8.2.

CH_4 : Methane

CH_3-CH_3: Ethane

CH_3-CH_2- CH_3: Propane

CH_3-CH_2-CH_2-CH_3:Butane

CH_3-CH_2- CH_2-CH_2-CH_3:pentane

Lesson 3: Physical properties of straight and branched alkanes

a) Prerequisites

Students will learn better the physical properties of alkanes if they have understanding on covalent bonding and molecular structures.

b) Teaching resources

- Chemistry textbooks
- Where possible use internet

c) Learning activities

Guidance :

Use the guidance of activity 8.2 above.

Answers to activity 8.3.

1) (a) i) Methane, ethane, propane and butane

ii) It is in gaseous state

(b) The alkanes which are used as gasoline they have the number of carbon atoms between 5 and ten (C5- C10).

(c) The alkanes which are used to make candle wax, they have the number of carbon atoms which is above 18.

2) Gasoline is the one which is easily converted into vapours because it is made of alkanes with lower number of carbon atoms.

3) Gasoline does not dissolve in water because gasoline is made of non-polar compounds.

d) Application activities

Answers to Application Activity 8.3.

1. Hexane and heptane do not dissolve in water but they are soluble in organic solvents like carbon tetrachloride.
2. B has higher boiling point than A because straight chain isomers are closer packed than the branched chain isomers.

Lesson 4: Laboratory preparation of alkanes by decarboxylation and other general methods

a) Prerequisites

Students will learn better different methods of preparation of alkanes if they have understanding on types of reactions.

b) Teaching resources

Chemistry textbooks, stand and accessories, delivery tube, sodium hydroxide solid, sodium acetate solid, calcium oxide solid.

c) Learning activities

Guidance:

- Form groups
- Give learners the above resources
- Ask learners to carry out the activity **8.4** (from the student's book).
- Ask learners to present their observations and deductions to the whole class.
- During the presentation ask some questions that lead to lesson objectives.
- Summarise the findings from students' work and give more examples which illustrate the content about preparation of alkanes.
- Assess your learners using application activity 8.4 (from student's book). Learners can do this application activity individually.

Answers to activity 8.3.

Refer to student book unit 8

d) Application activities

Answers to Application Activity 8.4.

a) $CH_3CH_2COONa(s) + NaOH(s) \xrightarrow[\text{heat}]{\text{CaO(s)}} CH_3CH_3 + Na_2CO_3(s)$

b) $CH_3CH_2Br + H_2 \xrightarrow{\text{Pd}} CH_3CH_3 + HBr$

c) $CH_3CH{=}CHCH_2CH_3 + H_2 \xrightarrow[150^0C]{\text{Ni}} CH_3CH_2CH_2\ CH_2CH_3$

d) $CH_3CH_2CH_2Cl \xrightarrow{\text{Ethanol/Zn-Cu}} CH_3CH_2CH_3$

Lesson 5: Uses of alkanes and chemical properties of alkanes

a) Prerequisites

Students will learn better this lesson if they have understanding on physical properties of alkanes.

b) Teaching resources

- Chemistry textbooks
- Where possible use internet

c) Learning activities

Guidance:

- Form groups
- Ask learners to carry out the activity **8.5.1** and activity **8.5.2** (from the student's book).
- Ask learners to present their observations and deductions to the whole class.
- Guide learners to make the summary of the lesson themselves.
- Assess your learners using application activity 8.5 (from student's book).

Answers to Activity 8.5.1

Refer to the student book unit 8

Answers to Activity 8.5.2

The reaction that takes place is COMBUSTION and the equations are:

$2CH_3CH_3 + 7O_2 \longrightarrow 4CO_2 + 6H_2O$ (in the picture A)

$C_7H_{16} + 11O_2 \longrightarrow 7CO_2 + 8H_2O$ (in the picture B)

d) Application activities

Answers to Application Activity 8.5.

1. Refer to the student book unit 8
2. Refer to the student book unit 8
3. Carbon dioxide is one of the greenhouse gases. Greenhouse gases cause global warming.

8.6. Summary of the Unit

- **Alkanes** form the homologous series of general formula $C_nH_{2n+2.}$
- They show structural (chain, position), and in some cases optical, isomerism.
- They can be extracted from crude oil by fractional distillation.
- Alkanes are unreactive towards polar or ionic reagent. But, they react with reagents such as oxygen and halogens.
- The reaction with halogens follows a free radical mechanism. It is a free radical substitution.
- Alkane molecules break down to smaller molecules at high temperature or in the presence of a catalyst. The reaction called cracking. It is important the petrochemical industry.
- Their main use is as sources of energy by combustion; many of them are used as solvents.
- They react with chlorine and bromine in a **free radical substitution**

reaction, giving chloro or bromoalkanes.

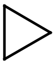
- There are three stages to a **radical chain reaction: initiation, propagation** and **termination.**

8.7. Additional information for tutors

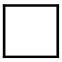
- **Nomenclature of cycloalkanes**

For naming cycloalkanes, the prefix "**cyclo"** is recommended, followed by the name of the alkanes of the same carbon number.

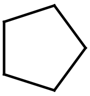
Examples:



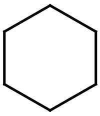
Cyclopropane



Cyclobutane



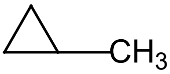
Cyclopentane



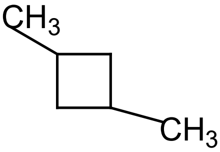
Cyclohexane

But in case of ramified cycloalkanes, the priority is for the ring.

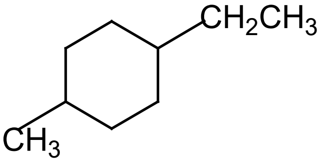
Examples:



methylcyclopropane



1,3-dimethylcyclobutane



1-ethyl-4-methylcyclohexane

Guidance on the Skills Lab 8

Ask learners to make a research on beeswax candles and make them.

End unit assessment

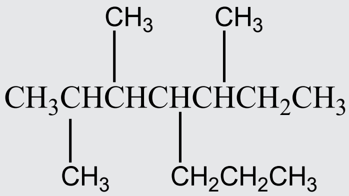
Answers to end unit assessment 8

1. a) True b) True

2.

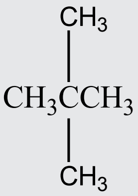
(a) $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$

(b)



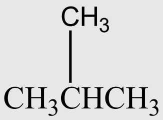
$$CH_3\underset{\substack{|\\ CH_3}}{CH}\overset{\substack{CH_3\\ |}}{CH}\underset{\substack{|\\ CH_2CH_2CH_3}}{CH}\overset{\substack{CH_3\\ |}}{CH}CH_2CH_3$$

(c)



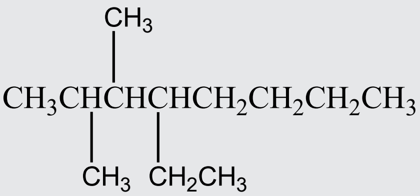
$$CH_3\overset{\substack{CH_3\\ |}}{\underset{\substack{|\\ CH_3}}{C}}CH_3$$

(d)



$$CH_3\overset{\substack{CH_3\\ |}}{CH}CH_3$$

(e)



$$CH_3\underset{\substack{|\\ CH_3}}{CH}\overset{\substack{CH_3\\ |}}{CH}\underset{\substack{|\\ CH_2CH_3}}{CH}CH_2CH_2CH_2CH_3$$

3. Refer to the student book unit 8

4. Refer to the student book unit 8

5.

a) $CH_3\text{-}Br + CH_3\text{-}CH_2\text{-}Br + 2Na \longrightarrow CH_3\text{-}CH_2\text{-}CH_3 + NaBr$

b) $CH_3\text{-}CH{=}CH\text{-}CH_3 + H_2 \xrightarrow{Pd} CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_3$

8.8. Additional activities

8.8.1. Remedial activities

1) Explain the following terms:

   a) Cracking

   b) Fractional distillation

Answers:

a) **Cracking** is the breaking down of long-chained saturated hydrocarbons to form a mixture of shorter-chained alkanes and alkenes.

b) **Fractional distillation** separates liquids from a mixture according to their different boiling points.

2) a) Write an equation for the combustion of hexane in a plentiful supply of oxygen.

   b) Which different products would be formed if the supply of oxygen were limited?

Answers:

a) $C_6H_{14} + O_2 \longrightarrow 6CO_2 + 7H_2O$

b) If the supply of oxygen were limited, carbon monoxide (CO) would be produced instead of carbon dioxide.

8.8.2. Consolidation activities

1) Name three greenhouse gases. For each gas, state the bonds that absorb infrared radiation.

Answers:

- **Carbon dioxide:** C=O bonds absorb infrared radiation.
- **Water vapour**: O-H bonds absorb infrared radiation.
- **Methane:** C-H bonds absorb infrared radiation

2) A deodorant contains a mixture of butane, 2-methylpropane and propane as propellant.

a) Suggest a property of these alkanes that makes them suitable as the propellant.

b) Why alkanes now being used as propellants in aerosol sprays?

Answers:

a) Liquid under pressure but vaporise when pressure is released.

b) Alkanes have replaced CFCs which cause damage to the ozone layer.

8.9. Extended activities

1) a) What are the constituents of crude oil?

b) Describe how they are separated.

c) Briefly explain cracking and state its use in petroleum industry

Answers:

a) Gas, petrol, kerosene, diesel oil, lubricating oil.

b) Crude petroleum is first freed from solid impurities by filtration. It is then first heated in a separate furnace to about 400°C after which the hot liquid is then passed into a fractionating tower. As the hot mixture of gases ascends the tower various vapours condense at different levels of the tower depending on their boiling points. These products are then separately tapped off.

c) Cracking is the process in the petroleum refinery where less volatile hydrocarbon of the kerosene or diesel fractions are converted to more volatile hydrocarbon (petrol) by application of heat. Cracking can be classified as thermal and catalytic. In thermal cracking the hydrocarbon fractions of long carbon chains (C_{12}-C_{18}) are broken down into shorter chains of petrol by heating to about 500°C under pressure of about 200 atmospheres.

UNIT 9

ALKENES AND ALKYNES

9.1. Key unit competence

Relate the chemical properties of alkenes and alkynes to their reactivity and uses and explain their physical properties

9.2. Prerequisite

Students will learn better the content related to alkenes and alkynes if they have understanding on:

- Chemical bonding,
- Concepts of isomerism
- General rules of naming organic compounds
- Types of reactions

Learners have the skills to use effectively the common laboratory apparatus and are aware of the safety precautions to take when working in a chemistry laboratory.

9.3. Cross-cutting issues to be addressed:

a) Inclusive education

This unit involves a number of formulae on organic compounds and experiments. This may be challenging to students with special educational needs especially students with visual and physical impairment or visual difficulties. However, the teacher can make some arrangements like:

i) Learners with visual difficulties

Students with special educational needs are grouped with others who can help them.

- If a tutor has students with visual difficulties, when writing on the blackboard, he/she may write in large and clear writing.
- If learners are sharing textbooks, try to arrange for those with visual difficulties to have their own copies, as far as this is possible.

- Give extra time for them to write summary notes or write down observations after experiments.
- Remember to repeat the main points of the lessons.
- For students with visual impairment teacher can write of them a summary using the braille alphabet if possible.

ii) **Learners with hearing difficulties**, the tutor has to encourage them to sit closer to the front of the classroom. Encourage learners not to be afraid to ask questions. When teaching, speak clearly and ensure that all the learners can hear you.

iii) **Learners with mobility difficulties**:

These include learners on crutches, in wheelchairs, or with walking difficulties. These learners can be helped by their classmates. Ask their fellow learners to help them with their notes, if their conditions hinder them from writing well.

iv) **Learners with reading difficulties:**

Learners with this kind of difficulties struggle to make sense of words or understand written work and take longer to read than other learners. Encourage them to pay careful attention during class time and participate for example by asking questions and answering questions, so that they can make the most of what they hear and observe. Instead of repeating word for word what is in the textbook, simplify the concepts to ease their understanding, so that when they have already understood.

b) Gender

During group activities try to form heterogeneous groups (with boys and girls) or when students start to present their findings encourage both (boys and girls) to present.

c) Financial education

As the unit deals with the importance of organic chemistry in modern life, the tutor will draw the learners' attention on the economic impact of the making of common items made using knowledge of chemistry.

When performing experiment they have to avoid waste of chemicals: they have to use the amounts that are just required.

d) Peace and values education

During group activities, the tutor will encourage learners to help each other and to respect opinions of colleagues.

e) Standardisation culture

Some lessons involve carrying out experiments. Learners have to always check if they are not using expired chemicals or defective apparatus.

In addition, when performing experiments learners have to record data accurately.

For tasks involving calculations, they have to always present accurate results.

f) Environment and sustainability

In order to avoid the environment pollution, before, during or after experiments learners have to not throw away chemicals anywhere.

Learners also have to be aware of the impacts of the use plastics on the environment.

9.4. Guidance on introductory activity

Before introducing the lesson one of unit nine, you will have to introduce the whole unit. Ask learners (in pairs) to attempt the introductory activity from student's book. This activity intends to relate the unit with learners' daily life and to capture their attention.

- Ask learners to use library or internet (where is possible) in order to conduct this introductory activity very well. Learners may not be able to find the right answers but they are invited to predict possible solutions or answers.
- Ask learners to present their findings.

During the presentation ask some questions that lead to lesson objectives.

9.5. List of lessons/sub-heading

#	Lesson title	Learning objectives	Periods
1	Definition and homologous series of alkenes, nomenclature and structure of alkenes	- Apply IUPAC rules to name alkenes. - Write the structural formulae of straight chain alkenes.	1 period
2	Structural and geometrical isomerism in alkenes.	Explain the existence of geometrical isomerism in alkenes.	1 period

3	Preparation methods of alkenes and chemical test for ethene.	- Describe the industrial process of preparing alkenes. - Carry out an experiment to prepare and test ethene gas.	2 periods
4	Physical properties of alkenes	Describe solubility and volatility of alkenes	1 period
5	Chemical properties of alkenes	- Explain the reactivity of alkenes in comparison to alkanes. - Apply Markovnikov's rule to predict the product of hydrohalogenaion of alkenes. - Propose the mechanisms for electrophilic addition reactions for alkenes	2 periods
6	Definition and homologous series, structure and nomenclature of straight and branched chain alkynes	- Apply IUPAC rules to name alkynes. - Write the structural formulae of straight and branched chain alkynes. - Classify alkynes as terminal and non-terminal alkynes using their different structures.	1 period
7	Physical properties and industrial preparation method of alkynes.	Describe the industrial process of preparing alkynes.	1 period
8	Chemical properties of alkynes	Explain the reactivity of alkynes	1 period
9	Uses of alkenes and alkynes	Appreciate the uses and dangers of addition polymers (polythene used for polythene bags, polypropene for plastic bottles etc.).	1 period
	End unit assessment		1 period

Lesson 1: Definition and homologous series of alkenes, nomenclature and structure of alkenes

a) Prerequisites

Learners will get a better understanding of the content of this lesson if they refer to the covalent bonding and molecular structures, general rules for naming organic compounds (year II, unit7 and unit 8).

b) Teaching resources

- Atomic models, flip charts, chemistry textbooks and other relevant chemistry books from the library,
- Where possible use internet

c) Learning activities

Before introducing the lesson one, let learners therefore attempt activity 9.1 which leads students to the first lesson of the unit.

Guidance:

- Form groups (the number of groups and members will depend on your class size and the number of your resources or materials).
- Give learners activity 9.1 (from the student's book)
- Move around the class and check if all learners are working.
- Ask learners to present their findings.
- During the presentation ask some questions that lead to lesson objectives.
- Guide learners to make the summary of the lesson themselves.
- Make the final conclusion of the lesson.
- After giving final conclusion, assess your learners using application activity 9.1 (from student's book).

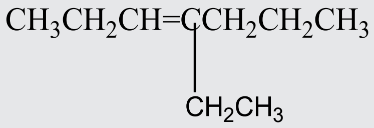
Answers to Activity 9.1

Refer to the student book unit 9

d) Application activities

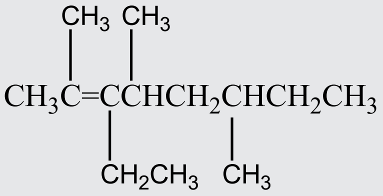
Answers to application activity 9.1.

1. a)



$CH_3CH_2CH{=}\underset{\underset{CH_2CH_3}{|}}{C}CH_2CH_2CH_3$

b)



$CH_3\overset{\overset{CH_3}{|}}{C}{=}\underset{\underset{CH_2CH_3}{|}}{C}\overset{\overset{CH_3}{|}}{C}HCH_2\underset{\underset{CH_3}{|}}{C}HCH_2CH_3$

c) $CH_2{=}C{=}CHCH_3$

2. a) Hept-2- ene
   b) 4,7-dimethyloct-3-ene
   c) 6-ethyl-3,8-dimethylnon-4-ene
   d) 6-butyl-10-methyldodec-3-ene

Lesson 2: Structural and geometrical isomerism in alkenes.

a) Prerequisites

Learners will get a better understanding of the content of this lesson if they refer to the covalent bonding, molecular structures and isomerism.

b) Teaching resources

Molecular models, flip charts or chalk board,

c) Learning activities

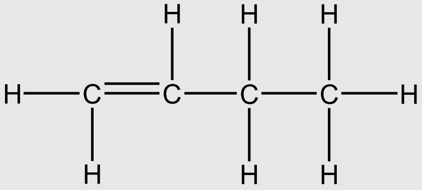
Guidance :

- Give learners activity 9.2 (from the student's book).
- Ask learners to carry out this activity in pairs
- Move around the class and check if all learners are working.
- Ask learners to present their findings.

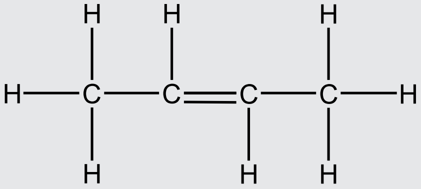
- Guide learners to make the summary of the lesson themselves.
- Make the final conclusion of the lesson.
- After giving final conclusion, assess your learners using application activity 9.2 (from student's book). Learners can do this application activity individually or in pairs.

Answers to the activity 9.2.

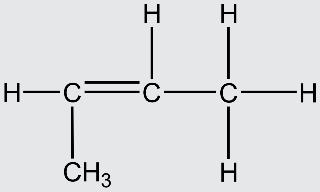
A)



B)



C)



All these three molecules have the same molecular formulae but their atoms are bonded differently and **C** is branched while others are linear.

d) Application activities

Answers to application activity 9.2.

1. Refer to the student book in the unit 9
2. It is B which can exhibit cis-trans isomerism. Each carbon doubly bonded is attached to two different groups.

Lesson 3: Preparation methods of alkenes and chemical test for ethene.

a) Prerequisites

For a better understanding of this lesson, learners will refer to:

- Chemical equations
- Types of reactions
- Covalent bonding
- Concept of reaction mechanism.

b) Teaching resources

Chemistry textbooks, internet (where possible), ethanol, aluminium oxide, lime water, mineral wool, boiling tube, rubber stopper with hole, delivery tube, test-tube rack, test tubes, spatula, bunsen burner, glass rod, matches.

c) Learning activities

Guidance :

- Form groups
- Give learners the above resources
- Ask learners to carry out the activity **9.3** (from the student's book).
- Ask learners to present their observations and deductions to the whole class.
- During the presentation ask some questions that lead to lesson objectives.
- Summarise the findings from students' work and give more examples which illustrate the content about preparation and test of alkenes.
- Assess your learners using application activity 9.3 (from student's book).

Answers to activity 9.3.

Refer to the student book unit 9

d) Application activities

Answers to Application Activity 9.3.

1) a) 2-methylpropene
   b) 2,3-dimethylbut-2-ene
   c) 2-methylbut-2-ene
2) a) 2-methylpropene
   b) 3-methylpent-2-ene
   c) 3-ehtylpent-2-ene
3) a) $(CH_3)_2CHCH=CHCH_3$
   b) $CH_3CH_2C(CH_3)=CHCH_2CH_3$
4) Refer to the student book unit 9

Lesson 4: Physical properties of alkenes

a) Prerequisites

Students will learn better the physical properties of alkenes if they have a good understanding on the chemical bonding, molecular structures and geometrical isomerism.

b) Teaching resources

Chemistry textbooks, internet (where possible), test tubes, cyclohexene, tetrachloromethane and water.

c) Learning activities

Guidance:

Give learners the above resources in pairs.

- Ask learners to carry out the activity **9.4** (from the student's book).
- Ask learners to present their observations and deductions to the whole class.
- During the presentation ask some questions that lead to lesson objectives.
- Summarise the findings from students' work and give more examples which illustrate the content about physical properties of alkenes.
- Assess your learners using application activity 9.4 (from student's book).

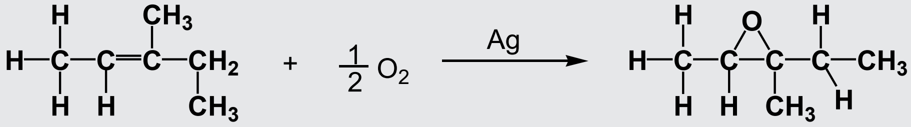
Answers to Activity 9.4

Refer to student book unit 9

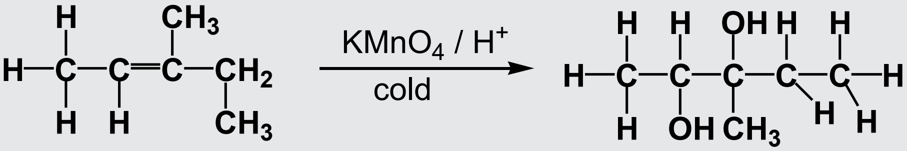
d) Application activities

Answers to Application Activity 9.4.

1) a)



b)



2) Refer to the student book unit 9

Lesson 5: Chemical properties of alkenes

a) Prerequisites

For better understanding the reactivity of alkenes and mechanisms related, learners have to review the concepts of:

- Types of reactions
- Covalent bonding

b) Teaching resources

Textbooks, internet connection (where possible), test tubes, droppers, ethene, bromine, lime water, matches, splints, stoppers

c) Learning activities

Guidance:

- Form groups,
- Ask learners to carry out the activity **9.4** (from the student's book).
- Ask learners to present their observations and deductions.
- During the presentation ask some questions that lead to lesson objectives.

- Summarise the findings from students' work and give more examples which illustrate the content about chemical properties of alkenes.
- Assess your learners using application activity 9.4 (from student's book).

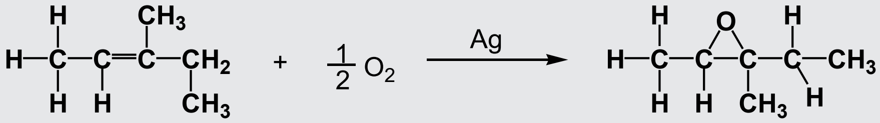
Answers to Activity 9.4

Refer to the student book unit 9

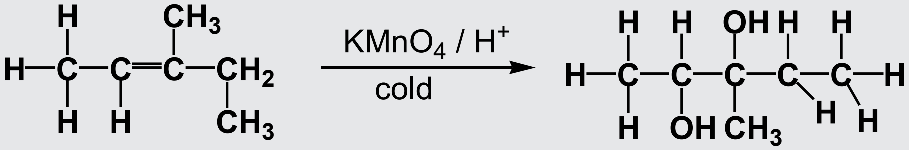
d) Application activities

Answers to Application Activity 9.5.

1) a)



b)



2) Refer to the student book unit 9

Lesson 6: Definition and homologous series, structure and nomenclature of straight and branched chain alkynes

a) Prerequisites

Students will learn better this lesson if they have a good understanding on covalent bonding and molecular structures, general rules of naming organic compounds.

b) Teaching resources

Chemistry textbooks, internet (where possible), flip charts/chalkboard.

c) Learning activities

Guidance:

- Give learners activity 9.6 (from the student's book).
- Ask learners to do it in pairs

- Move around the class and check if all learners are working.
- Ask learners to present their findings.
- Guide learners to make the summary of the lesson themselves.
- Make the final conclusion of the lesson.
- After giving final conclusion, assess your learners using application activity 9.6 (from student's book).

Answers to Activity 9.6

Refer to the student book unit 9

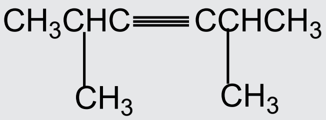
d) Application activities

Answers to Application Activity 9.6.

1) a) 4-methylhept-1-yne

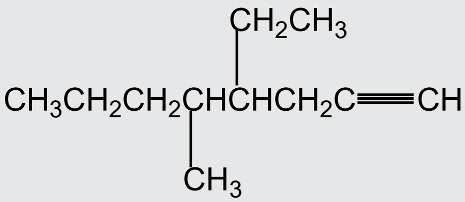
b) 6-ethyl-3-methylnon-4-yne

2) a)



$CH_3\underset{|\atop CH_3}{C}HC\equiv C\underset{|\atop CH_3}{C}HCH_3$

b)



$CH_3CH_2CH_2\underset{|\atop CH_3}{C}H\overset{CH_2CH_3\atop |}{C}HCH_2C\equiv CH$

Lesson7: Physical properties and industrial preparation method of alkynes.

a) Prerequisites

Students will learn better this lesson if they have a good understanding on the chemical bonding and preparation of different gases.

b) Teaching resources

Chemistry textbooks, internet (where possible), calcium carbide, conical flask, dropping funnel, water, test tube, bromine, trough, delivering tube, potassium manganate (VII).

c) Learning activities

Guidance:

- Form groups
- Give learners the above resources
- Ask learners to carry out the activity 9.7 (from the student's book).
- Ask learners to present their observations and deductions to the whole class.
- During the presentation ask some questions that lead to lesson objectives.
- Summarise the findings from students' work and give more examples which illustrate the content about physical properties and preparation methods of alkynes.
- Assess your learners using application activity 9.7 (from student's book).

Answers to Activity 9.7

Refer to the student book unit 9

d) Application activities

Answers to Application Activity 9.7.

1) Refer to the student book unit 9

2) Refer to the student book unit 9

3) Refer to the student book unit 9

4) a) $2CHCH + 2Na \longrightarrow 2CHCNa + H_2$

$CHCNa + CH_3Br \longrightarrow CHCCH_3 + NaBr$

b) $CHCH + 2Na \longrightarrow NaCHCNa + H_2$

$NaCCNa + 2CH_3Br \longrightarrow CH_3CC\ CH_3 + 2NaBr$

c) $2CHCH + 2Na \longrightarrow 2CHCNa + H_2$

$NaCCNa + 2CH_3CH_2Br \longrightarrow CH_3CH_2CCCH_2CH_3 + 2NaBr$

Lesson 8: Chemical properties of alkynes

a) Prerequisites

For a better understanding of chemical properties in alkynes learners have to review the concepts of types of reactions.

b) Teaching resources

Chemistry textbooks, internet (where possible), test tubes, droppers, bromine, potassium manganate (VII) and ethyne.

c) Learning activities

Guidance:

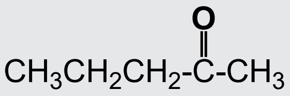
- Form groups
- Give learners the above resources
- Ask learners to carry out the activity 9.8 (from the student's book).
- Ask learners to present their observations and deductions to the whole class.
- During the presentation ask some questions that lead to lesson objectives.
- Summarise the findings from students' work and give more examples which illustrate the content about the chemical properties of alkynes.
- Assess your learners using application activity 9.8 (from student's book).

Answers to Activity 9.8

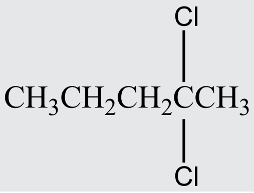
Refer to the student book unit 9

d) Application activities

Answers to Application Activity 9.8.

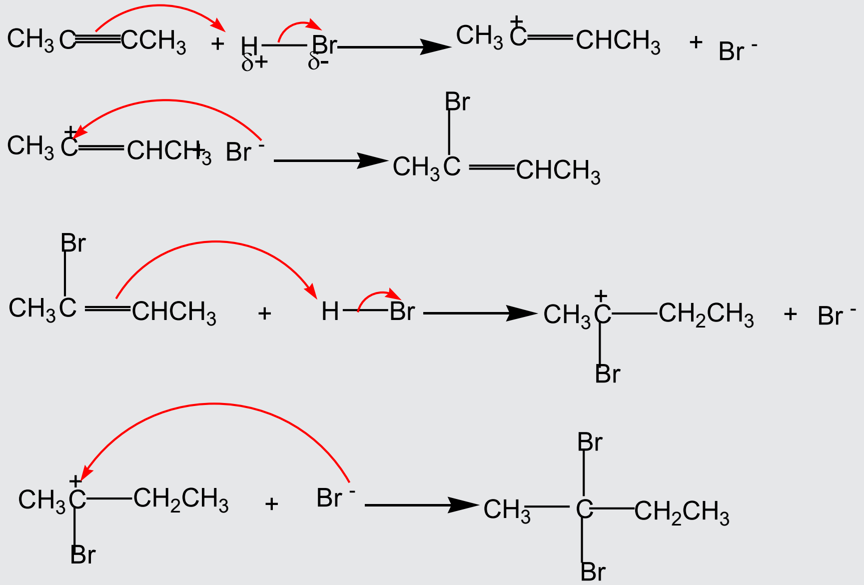
1) a) 

$CH_3CH_2CH_2\overset{\overset{O}{\parallel}}{C}CH_3$ pentan-2-one

b) 

$CH_3CH_2CH_2\underset{\underset{Cl}{|}}{\overset{\overset{Cl}{|}}{C}}CH_3$ 2,2-dichloropentane

2)



Lesson 9: Uses of alkenes and alkynes

a) Prerequisites

Students will learn better this lesson if they have a good understanding on the chemical bonding and types of reactions.

b) Teaching resources

Chemistry textbooks, internet (where possible)

c) Learning activities

Guidance:

- Form groups
- Give learners activity 9.9 (from the student's book)
- Move around the class and check if all learners are working.
- Ask learners to present their findings.
- During the presentation ask some questions that lead to lesson objectives.
- Guide learners to make the summary of the lesson.
- Make the final conclusion of the lesson.
- After giving final conclusion, assess your learners using application activity 9.9 (from student's book).

Answers to Activity 9.9

Refer to the student book unit 9

d) Application activities

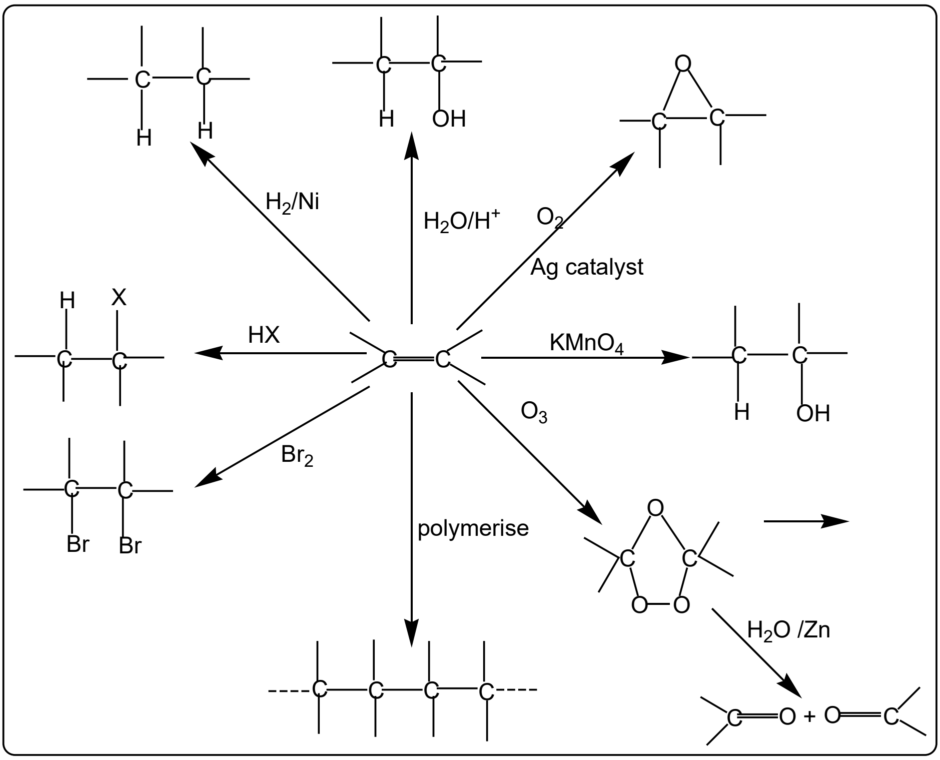
Answers to Application Activity 9.9

Refer to the student book unit 9

9.6. Summary of the Unit

- Alkenes are unsaturated hydrocarbons containing at list carbon-carbon double bond. They have the general formula C_nH_{2n}.
- As the rotation around the double bond is restricted, alkenes exhibit a cis-trans isomerism. The cis-trans isomers differ in the way their substituents are arranged around the double bond.
- They are widely present in the nature where the play many roles.
- For example ethene is a plant hormone in the fruit ripening, seed germination ...
- Alkenes are industrially obtained by cracking of large alkanes.
- They are also obtained by elimination reactions from alcohols, halogenoalkanes or partial hydrogenation of alkynes.
- As unsaturated hydrocarbon, they undergo addition reactions. Having a region of high density of electrons, they undergo electrophilic addition reactions.
- They form epoxides when they react with oxygen in the presence of silver catalyst.
- The unsaturated is tested using bromine water and/or potassium manganite (VII).
- Alkenes undergo addition polymerisation reactions to yield plastics having a wide range of applications.

- Some reactions of alkenes are summarised in the table below:



- Alkynes are unsaturated hydrocarbons with a carbon-carbon triple bond. Their general formula is C_nH_{2n-2}.
- There are two classes of alkynes: terminal and non-terminal alkynes.
- Alkynes are less volatile than alkenes because their linear structure allows them to pack together more closely than alkenes.
- Like other hydrocarbon alkynes are insoluble in water.
- Alkynes undergo addition reactions to give alkenes, alkene derivatives or alkanes.

9.7. Additional information for teachers

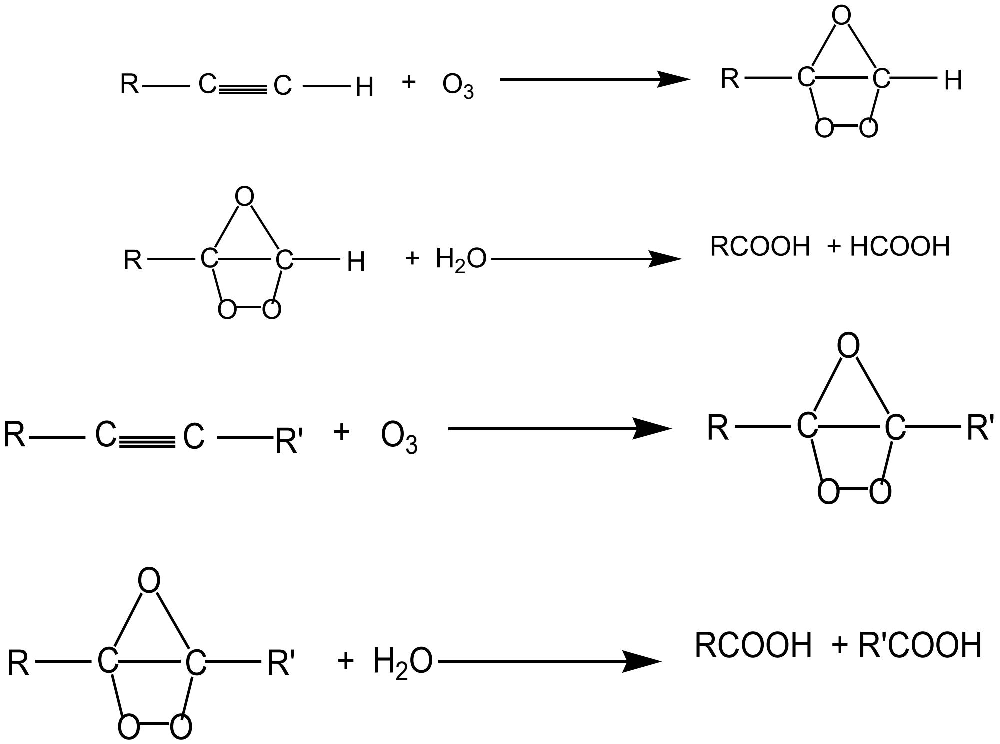
Oxidising agents that are effective against the carbon-carbon double bond are also effective against the carbon-carbon triple bond. But the carbon-carbon triple bond which is shorter than the carbon-carbon double bond is less reactive because electrons are more strongly attracted by the nuclei.

The oxidation of alkynes with hot alkaline potassium manganate (VII) cleaves the molecule at the site of the triple bond.

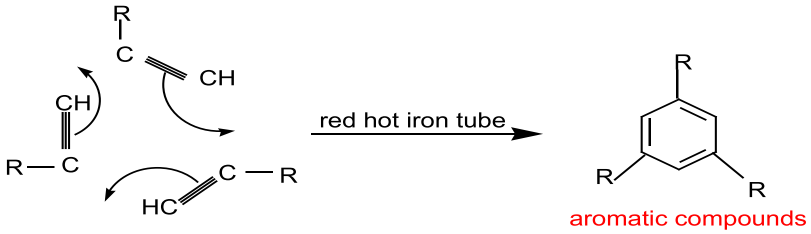
$$\text{R-C}\equiv\text{CH} \xrightarrow{\text{alkaline KMnO}_4} \text{R-COOH} + CO_2$$

$$R\text{-}C\equiv C\text{-}R' \xrightarrow{\text{alkaline } KMnO_4} R\text{-}COOH + R'COOH$$

Alkynes react with ozone to yield ozonides which on decomposition with water yield carboxylic acids:



When alkynes are passed through a red hot quartz or iron tube, they polymerise to yield aromatic compounds.



Skills Lab 9

Guidance on the Skills Lab:

Ask learners to make a research and design the following projects:

1) A project of making plastics which are biodegradable.

2) A project of recycling plastics.

End unit assessment

Answers to end unit assessment 9

I. Multiple choice questions. Choose the best answer in the following by noting the corresponding letter.

1) b

2) c

3) a

4) b

5) a

II. Open questions

6)

- Pent-1-ene
- Pent-2-ene
- 3-methylbut-1-ene
- 2-methylbut-1-ene
- 2-methylbut-2-ene

7)

$$CH_3CH{=}CH_2 + Br_2 \xrightarrow{CCl_4} CH_3CHBrCH_2Br$$

$$CH_3CHBrCH_2Br + KOH \xrightarrow{\text{ethanol/heat}} CH_3C{\equiv}\mathbf{CH} + 2KBr + 2H_2O$$

8)

D is $CH_3CH_2CH{=}CHCH_2CH_3$ **or** $CH_3CH_2CH_2CH{=}CHCH_3$

E is $CH_3CH_2CH_2CH_2CH{=}CH_2$

9) a) Alkenes such as ethene and propene have been described as the building blocks of the organic chemical industry because they can undergo addition polymerization to give a large range of plastics which have many applications.

Examples:

Polyethene (polyethylene) which is for making bags, cups, bottles, …

Polypropene which is used for wrapping, insulator, ropes, …

In addition ethene and propene are starting materials for the preparation of carbonyl compounds, carboxylic acids,.....

b) Presence of a double bond.

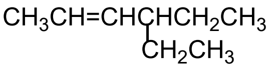
9.8. Additional activities

9.8.1. Remedial activities

1) Write the structural formula for:
   a) 4-ethylhex-2ene
   b) 3-ethyl-2,5-dimethylhept-3-ene
   c) 5-isopropyl dec-4-ene
   d) 5-propylnon-3-yne

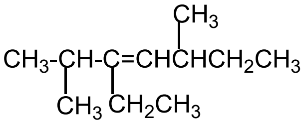
Answers:

a)



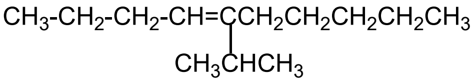
$CH_3CH{=}CH\underset{CH_2CH_3}{\underset{|}{C}}HCH_2CH_3$

b)



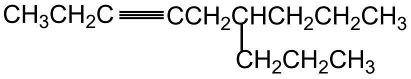
$CH_3\text{-}\underset{CH_3}{\underset{|}{C}}H\text{-}\underset{CH_2CH_3}{\underset{|}{C}}{=}CH\overset{CH_3}{\overset{|}{C}}HCH_2CH_3$

c)



$CH_3\text{-}CH_2\text{-}CH_2\text{-}CH{=}\underset{CH_3CHCH_3}{\underset{|}{C}}CH_2CH_2CH_2CH_2CH_3$

d)



$CH_3CH_2C{\equiv}CCH_2\underset{CH_2CH_2CH_3}{\underset{|}{C}}HCH_2CH_2CH_3$

2) Write the formula or the name of the product of the reaction between pent-1-yne and:
   a) Hydrogen bromide(excess)
   b) 2moles of hydrogen
   c) Sodium amide
   d) H_3O^+/Hg^{2+}
   e) Ammoniacal copper (I)chloride

Answers:

a) 2,2-dibromopentane
b) Pentane
c) $CH_3CH_2CH_2CC^-Na^+$
d) $CH_3CH_2CH_2COCH_3$

e) $CH_3CH_2CH_2CC^-Cu^+$

3) What the product of the ozonolysis of :

a) But-2-ene

b) 2-methylpent-2ene

Answers:

a) Ethanal

b) Propanone and propanal

9.8.2. Consolidation activities

1) a) Define the term "Electrophile"

b) Explain why alkenes and alkynes are readily attacked by electrophiles.

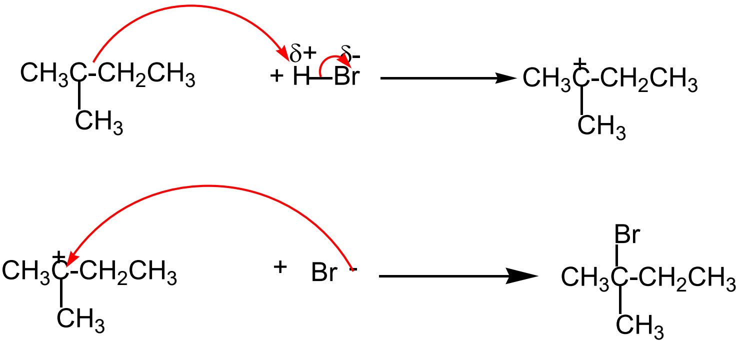
c) Outline the mechanism of the electrophilic addition of HCl on 2-methylbut-2-ene

Answers:

a) An electrophile is a chemical species which electron deficient.

b) Alkenes are readily attacked by electrophiles because the carbon-carbon double bond is an electron rich region.

c)



2) Give all structural formulae of alkynes with molecular formula C_6H_{10}.

Answers:

$CH_3CH_2CH_2CH_2C{\equiv}CH$

$CH_3CH_2CH_2C{\equiv}CCH_3$

$CH_3CH_2C{\equiv}CCH_2CH_3$

$(CH_3)_2CHCH_2C{\equiv}CH$

$(CH_3)_3CHC\equiv CCH_3$

3) Explain how, using chemical tests:
   a) propene could be differentiated propane
   b) propene could be differentiated from propyne
   c) propene could be differentiated from carbon dioxide

Answers:

   d) Propene decolourises bromine water but propane does not.
   e) Propyne reacts with sodium amide but propene does not.
   f) Carbon dioxide turns milky lime water but propene does not.

9.9. Extended activities

Using ethanol as the only starting organic substance and inorganic reagents, write equations to show how 5-methylhept-3-yne could be prepared.

Answer:

$$CH_3CH_2OH \xrightarrow[\text{heat}]{H_2SO_4} CH_2{=}CH_2 + H_2O$$

$$CH_2{=}CH_2 + Cl_2 \xrightarrow{CCl_4} CH_2ClCH_2Cl$$

$$CH_2ClCH_2Cl + 2KOH \xrightarrow{\text{heat}} CH\equiv CH + 2H_2O$$

$$CH\equiv CH + Na \xrightarrow{\text{liquid ammonia}} CH\equiv C^-Na^+ + 1/2H_2$$

$$CH_2{=}CH_2 + HCl \longrightarrow CH_3CH_2Cl$$

$$HC\equiv C^-Na^+ + CH_3CH_2Cl \longrightarrow CH_3CH_2C\equiv CH + NaCl$$

$$CH_3CH_2C\equiv CH + Na \xrightarrow{\text{liquid ammonia}} CH_3CH_2C\equiv C^-Na^+ + 1/2H_2$$

$$CH_3CH_2C\equiv CH + H_2 \longrightarrow CH_3CH_2CH{=}CH_2$$

$$CH_3CH_2CH{=}CH_2 + HCl \longrightarrow CH_3CH_2CHClCH_3$$

$$CH_3CH_2C\equiv C^-Na^+ + CH_3CH_2CHClCH_3 \longrightarrow CH_3CH_2C\equiv CCH(CH_3)CH_2CH_3 + NaCl$$

UNIT 10

HALOGENOALKANES (ALKYL HALIDES)

10.1. Key unit competence

Relate the physical and chemical properties of halogenoalkanes to their reactivity and uses.

10.2. Prerequisite

Students will learn better the formation of halogenoalkanes or alkyl halides if they have a good understanding on: alkanes, alkenes, hydrogen halides and concept of bonding.

10.3. Cross-cutting issues to be addressed:

a) Inclusive education

This unit involves a number of experiments on the properties of halogenoalkanes compounds. The experiments require assembling of apparatus and observation of the results. This may be challenging to students with special educational needs especially children with visual impairment. However, the tutor can make some arrangements like:

- Grouping students. Students with special educational needs are grouped with others and assigned roles basing on individual student's abilities.
- Providing procedure earlier before the experiment so that students get familiar with them. They can be written on the chalkboard or printed depending on available resources. If you have children with low vision remember to print in appropriate fonts.
- Every important point is written and spoken. The written points helps students with hearing impairment and speaking aloud helps students with visual impairment
- Remember to repeat the main points of the lessons.

b) Environment and sustainability

The growing awareness of the impact of the human race on the environment has led to recognition of the need to ensure our young people understand the importance of sustainability as they grow up and become responsible for the world around them. Hence Environment and Sustainability is a very important cross-cutting issue

Learners need skills and attitudes that will enable them in their everyday life to address the environment and climate change issue and to have a sustainable livelihood.

While teaching this unit concerning halogenoalkanes especially their uses, talk about the environment and its sustainability. For instance:

- CFCs (Chlorofluorocarbons) are very important but they destroy ozone layer;
- DDT (Dichlorodiphenyltrichloroethane) used, especially in the past, for killing insects but nowdays is no longer used because it is harmful to crops.

10.4. Guidance on introductory activity

Before introducing the first lesson of this unit, let learners attempt introductory activity.

This activity intends to:

1) Relate the unit with learners' daily life to capture their attention.
2) Assess learners understanding of the concept of halogens and alkanes.

Ask leaners to use library or internet (where is possible) in order to conduct this introductory activity very well. Learners may not be able to find the right answers but they are invited to predict possible solutions or answers.

Select some groups to share their findings to the whole class.

After presentation, give your comments showing them how alkanes are very important in our daily life.

It is not necessary to give them all answers of this introductory activity because they will study them in this unit. So, you can leave learners with the curiosity of knowing the correct answers.

10.5. List of lessons/sub-heading

#	Lesson title	Learning objectives	Periods
1	Definition, homologous series, nomenclature of halogenoalkanes	• Define halogenoalkanes and homologous series. • Draw displayed structural formulae of halogenoalkanes and give names using IUPAC system. • Classify halogenoalkanes according to developed formula as primary, secondary and tertiary.	2 periods
2	Classification, isomerism and physical properties of halogenoalkanes	• Explain the physical properties of halogenoalkanes. • Classify halogenoalkanes according to developed formula as primary, secondary and tertiary.	3 periods
3	Preparation of halogenoalkanes	Describe preparation methods for halogenoalkanes.	2 period
4	Chemical reactions of halogenoalkanes	• Explain the reactivity of halogenoalkanes. • Write reaction mechanisms of halogenoalkanes as SN1, SN2, E1 and E2. • Explain different mechanisms in halogenoalkanes	3 periods
5	Uses of halogenoalkanes and dangers associated with CFCs	Explain the uses and dangers associated with halogenoalkanes	3 periods
End unit assessment			2 periods

Lesson 1: Definition, homologous series, nomenclature of halogenoalkanes

a) Prerequisites

Students will learn better this lesson if they have understanding on halogen halides and alkanes.

b) Teaching resources

- Chemistry textbooks and other relevant chemistry books from the library
- Where possible use internet

c)Learning activities

Guidance :

- Form groups (the number of groups and members will depend on your class size and the number of your resources or materials).
- Give learners activity 10.1 (from the student's book)
- Move around the class and check if all learners are working.
- Ask learners to present their findings.
- During their presentation ask some questions that lead to lesson objectives.
- Guide learners to make the summary of the lesson themselves.
- Make the final conclusion of the lesson.
- After giving final conclusion, assess your learners using application activity 10.1 (from student's book). Learners can do this application activity individually or in pairs. If you do not have enough time in your lesson, give it as individual home work.

Answers to Activity 10.1

Refer to the student book unit 8, 9 and 10.

d) Application activities

Answers to Application Activity 10.1

1. a) 2-iodopentane

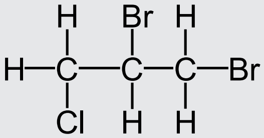
   b) 1,1-dichloropropane

   c) Tetrachloromethane

   d) Trichloromethane

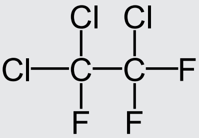
   e) 2-bromo-2-methylpropane

2. a)



$CH_2ClCHBrCH_2Br$

b)



CCl_2FCClF_2

Lesson 2: Classification, isomerism and physical properties of halogenoalkanes

a) Prerequisites

Students will learn better this lesson if they have understanding on isomers and electronegativity.

b) Teaching resources

- Chemistry textbooks and other relevant chemistry books from the library
- Where possible use internet

c) Learning activities

Guidance:

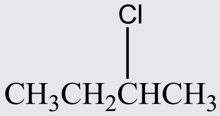
- Give learners activity 10.2 (from the student's book).
- Ask learners to carry out this activity in pairs
- Move around the class and check if all learners are working.
- Ask learners to present their findings.

- Summarise the findings from students' work and give more examples which illustrate the content about classification, isomerism and physical properties of halogenoalkanes.
- Assess your learners using application activity 10.2 (from student's book).

Answers to Activity 10.2

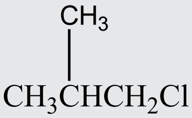
(1) a) 1st $CH_3CH_2CH_2CH_2Cl$

2nd



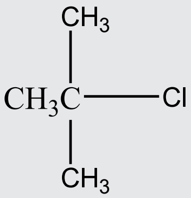
$CH_3CH_2CH(Cl)CH_3$

3rd



$CH_3CH(CH_3)CH_2Cl$

4th



$CH_3C(CH_3)_2Cl$

b) The first and the third isomers are primary halogenoalkanes

The second isomer is secondary halogenoalkane

The fourth isomer is tertiary halogenoalkane.

c) The first isomer and the second one, they are positional isomers,

The third and the fourth or the first and the third are chain isomers.

(2) The melting and boiling temperatures of chloroalkanes are higher than those of bromoalkanes of similar molecular mass due to the higher electronegativity of chlorine.

d) Application activities

Answers to Application Activity 10.2

1) $CH_2BrCHClCH_3$, $CH_3CH_2CHBrCl$, $CH_3CHClCH_2Br$

2) a) Tribromomethane > dibromomethane > bromomethane>chloromethane

b) 1-chlorobutane > 2-chloro-2-methylpropane > 1-chloropropane

This is because with the increase in size and mass of halogen atom, the magnitude of van der Waal forces increases.

3. Propane has a smaller molar mass and, it is a hydrocarbon. Chloropropane, not only has a higher molar mass but also it is polar and therefore it has stronger intermolecular forces than hydrocarbons.

Lesson 3: Preparation of halogenoalkanes

a) Prerequisites

Students will learn better this lesson if they have understanding on reactivity of alkenes, alkanes with halogens.

b) Teaching resources

Chemistry textbooks, internet (where possible), water, ice, concentrated sulphuric acid, ethanol, solid potassium bromide, condenser, distillation flask, conical flask and matches.

c) Learning activities

Guidance

- Give learners activity 10.3 (from the student's book).
- Ask learners to carry out this activity in groups
- Move around the class and check if all learners are working.
- Ask learners to present their findings.
- Guide learners to make the summary of the lesson.
- Make the final conclusion of the lesson.
- After giving final conclusion, assess your learners using application activity 10.3 (from student's book).

Answers to Activity 10.3

Refer to the student book unit 10

d) Application activities

Answers to Application Activity 10.3

1) a. $CH_2=CH_2 + HCl \longrightarrow CH_3-CH_2Cl$

b. $CH_3CH_3 + Cl_2 \longrightarrow CH_3CH_2Cl + HCl$

c. $CH_3CH_2-OH + HBr \longrightarrow CH_3CH_2Br_{(aq)} + H_2O_{(l)}$

d. $CH_3-CH_2CH_2OH + PCl_5 \longrightarrow CH_3CH_2CH_2Cl + POCl_3 + HCl$

e. $CH_3CH_2-OH + SOCl_2 \longrightarrow CH_3CH_2Cl + SO_2 + HCl$

f. $3CH_3CH_2CH_2-OH + 3PCl_3 \longrightarrow 3CH_3CH_2CH_2Cl + 3H_3PO_3$

2) $CH_3CH_2CH_2OH + HBr \xrightarrow{H_2SO_4} CH_2BrCH_2CH_3 + H_2O$

Lesson 4: Chemical reactions of halogenoalkanes

a) Prerequisites

Students will learn better this lesson if they have understanding on types of reactions like substitution and elimination.

b) Teaching resources

Chemistry textbooks, internet (where possible), nitric acid, water, dilute sodium hydroxide solution, 1-bromobutane, test tubes, droppers and source of heat.

c) Learning activities

Guidance :

- Give learners activity 10.4 (from the student's book).
- Ask learners to carry out this activity in groups
- Move around the class and check if all learners are working.
- Ask learners to present their findings.
- Guide learners to make the summary of the lesson.
- Make the final conclusion of the lesson.

After giving final conclusion, assess your learners using application activity 10.4 (from student's book).

Answers to Activity 10.4

Refer to the student book unit 10

d) Application activities

Answers to Application Activity 10.4

1\. a) $(CH_3)_2CHCH_2Br + NaOH \xrightarrow[\text{heat}]{\text{Ethanol}} (CH_3)_2C{=}CH_2 + NaBr + H_2O$

b) $CH_3CH_2CHBrCH_2CH_3 + NaOH(aq) \longrightarrow CH_3CH_2CH(OH)CH_2CH_3 + NaBr(aq)$

2\) a) $CH_3CH_2\text{-}CH_2\text{-}I + NH_3 \longrightarrow CH_3CH_2\text{-}CH_2\text{-}NH_2 + HI$

b) $(CH_3)_3CCl + H_2O \longrightarrow (CH_3)_3COH + HCl$

Lesson 5: Uses of halogenoalkanes and dangers associated with CFCs

a) Prerequisites

Students will learn better this lesson if they have understanding on reactivity of halogenoalkanes and their physical properties.

b) Teaching resources

Chemistry textbooks, internet (where possible).

c) Learning activities

Guidance:

- Form groups
- Give learners activity 10.5 (from the student's book)
- Move around the class and check if all learners are actively working
- Ask learners to present their findings.
- During the presentation ask some questions that lead to lesson objectives.
- Guide learners to make the summary of the lesson.
- Make the final conclusion of the lesson.

- After giving final conclusion, assess your learners using application activity 10.5 (from student's book

Answers to Activity 10.5

Refer to the student book unit 10

d) Application activities

Answers to Application Activity 10.5

Refer to the student book unit 10

10.6. Summary of the Unit

- **Halogenoalkanes** contain a δ+ carbon atom
- Their most common reaction is **nucleophilic substitution.** They also undergo **elimination** reaction to give alkenes.
- They reactivity increases in order CF< CCl < CBr <CI.
- Fluoroalkanes and chloroalkanes are used as solvents, aerosol propellants and refrigerants. CFCs damage the ozone layer by being photolysed to chlorine atoms, which initiate chain reactions destroying ozone.

Halogenoalkanes can be made from alkanes and alcohols. **Key Reactions :**

- Elimination:

$$R\text{-}CH_2\text{-}CH_2\text{-}Br + OH^- \xrightarrow[\text{ethanol}]{\text{heat with NaOH in}} R\text{-}CH{=}CH_2 + H_2O + Br^-$$

- Nucleophilic substitutions:

$$R\text{-}Br + OH^- \xrightarrow{\text{heat with NaOH in water}} R\text{-}OH + Br^-$$

$$R\text{-}Br + 2NH3 \xrightarrow{NH_3 \text{ in ethanol under pressure}} R\text{-}NH_2 + NH_4Br$$

- $R\text{-}Br + CN^- \xrightarrow{\text{heat with NaCN in ethanol}} R\text{-}C{\equiv}N + Br^+$

10.7. Additional information for teachers

Preparation of Grignard reagents

This is an alkyl magnesium bromide or iodide prepared by refluxing an alkyl or iodide with magnesium turnings in the presence of dry ether.

i.e $\mathrm{R\text{-}Br + Mg \xrightarrow{ether/heat} R\text{-}MgBr}$

Example: $\mathrm{CH_2CH_2\text{-}Br + Mg \xrightarrow{Heat/ether} CH_3CH_2MgBr}$

$\mathrm{CH_3CH_2CH_2\text{-}I + Mg \xrightarrow{Ether/\ heat} CH_3CH_2CH_2MgI}$

Skills Lab

Guidance on the Skills Lab:

Ask learners to make a research and synthesise the chemicals to replace the CFCs (Chlorofluorocarbons).

End unit assessment

Answers to end unit assessment

1) **b**

2) Halogenoalkanes compounds are compounds in which the halogen atoms like chlorine, bromine, **iodine** or fluorine are attached to a hydrocarbon chain or an aromatic ring. When the halogen atom is attached to a hydrocarbon chain the compound is called an **alkyl halide** or **halogenoalkane**.

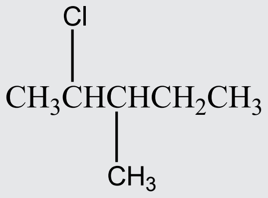
3) a. True b. True c. true d. false e. true f. true

4. a) 2-chloro-3-methylbutane

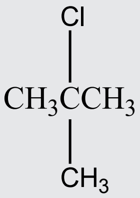
b) 1-iodo-2,2-dimethylbutane

c) 1-bromo-2,2-dimethylpropane

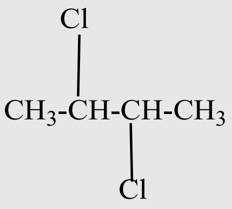
d) 2-bromo-3-methylbutane

5) a) 

$\mathrm{CH_3\overset{Cl}{C}H\underset{CH_3}{C}HCH_2CH_3}$

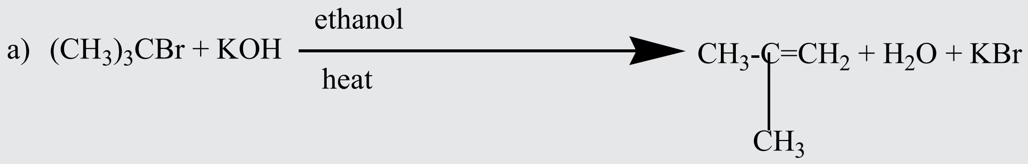
b) 

$\mathrm{CH_3\underset{CH_3}{\overset{Cl}{C}}CH_3}$

c) 

$\mathrm{CH_3\text{-}\overset{Cl}{C}H\text{-}\underset{Cl}{C}H\text{-}CH_3}$

6)



a) $(CH_3)_3CBr + KOH \xrightarrow[heat]{ethanol} CH_3\text{-}\underset{\displaystyle CH_3}{\underset{|}{C}}{=}CH_2 + H_2O + KBr$

b) $CH_3CH(Br)CH_2CH_3 + NaOH \xrightarrow{water} CH_3CHOHCH_2CH_3 + NaBr$

c) $CH_3CH_2CH_2OH + SOCl_2 \longrightarrow CH_3CH_2CH_2Cl + SO_2 + HCl$

d) $CH_3CH_2CH{=}CH_2 + HBr \xrightarrow{peroxide} CH_3CH_2CH_2CH_2Br$

10.8. Additional activities

10.8.1. Remedial activities

1. Using suitable examples, define the terms:

   a) Nucleophile

   b) Substitution

Answers:

a) A **nucleophile** is an electron pair donor.

b) **Substitution** is reaction in which an atom or group of atoms is replaced by another atom or group of atoms.

2. 1-bromobutane is refluxed with aqueous potassium hydroxide to form an alcohol. Write a balanced equation for this reaction and name the alcohol formed.

Answer:

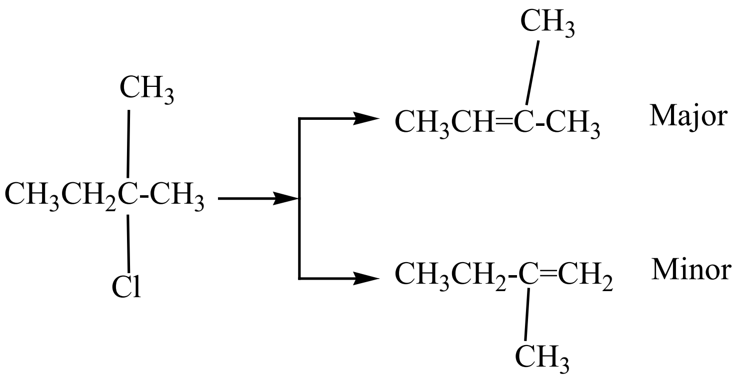
$$CH_3CH_2CH_2CH_2Br + KOH \longrightarrow CH_3CH_2CH_2CH_2OH + KBr$$

Alcohol formed is butan-1-ol

10.8.2. Consolidation activities

1. Suggest the structural formulae of the possible alkenes produced when 2-chloro-2-methylbutane is treated with hot KOH in ethanol. Which of the possible products will be found in greatest yield? Explain your answer.

Answer:



The major product is obtained following Zaitsev' rule.

2. Why are halogenoalkanes attacked by nucleophiles?

Answer: The halogenoalkanes contain a slightly positive carbon atom, part of the carbon-halogen bond. This carbon atom can be attacked by an electron-rich nucleophile.

10.9. Extended activity

Use of CFCs has been declining due to concern over the possible effects on the environment. It is thought that this damage is a result of a light catalysed radical process involving chlorine radicals.

a) State one possible type of damage caused by CFCs to the environment.

b) Explain what is meant by a radical.

c) Give an equation for the formation of a radical from the chlorofluorocarbon CCl_2F_2

Answers:

a) CFCs deplete the ozone layer

b) A radical is a species with an unpaired electron.

c) $CCl_2F_2 \longrightarrow CF_2Cl\bullet + Cl\bullet$

UNIT
11
ALCOHOLS AND ETHERS

11.1. Key unit competence

Compare the physical and chemical properties of alcohols and ethers and explain their preparation methods, reactivity and uses

11.2. Prerequisite

The students will learn better this unit if they have knowledge on alkenes and halogenoalkanes.

11.3. Cross-cutting issues to be addressed:

a) Standardization culture

The students will be taught about the standard of the alcoholic drinks and other beverages by giving them the example of how none standardized things are harmful to organism, give them the examples on how some local beers are prepared in unknown way and how the government fight non- standardised drinks.

b) Gender

The students in their groups guided by the tutor will be taught about gender violence as the cause of alcohol abuse when drunk in non-controlled way the women or men can be violated due to the alcohol abuse.

c) Peace and values

Self-respect even while taking the alcohol not to be directed by it but also to have self-control while drinking and take the amount just needed to quench their thirst and if possible advise them to leave it completely.

d) Financial education:

While discussing in their groups or while harmonizing the work, you have to reinforce on the finance of alcohols, how alcohols bring money for the sellers and distributors of beer.

11.4. Guidance on introductory activity

Before introducing the lesson one of this unit, you will have to introduce the whole unit. Ask learners (in pairs) to attempt the introductory activity from student's book. This activity intends to relate the unit with learners' daily life and to capture their attention.

Ask learners to use library or internet (where is possible) in order to conduct this introductory activity very well. Learners may not be able to find the right answers but they are invited to predict possible solutions or answers.

Ask learners to present their findings.

After presentation, give your comments showing them how alcohols are very important in our daily life.

It is not necessary to give them all answers of this introductory activity because they will study them in this unit. So, you can leave learners with the curiosity of knowing the correct answers.

11.5. List of lessons/sub-heading

#	Lesson title	Learning objectives	Periods
1	Definition, homologous series, nomenclature, isomerism and classification of alcohols	- Write and name alcohols according to IUPAC system. - Classify alcohols as primary, secondary and tertiary. - Explain isomers in alcohols from	2 periods
2	Physical properties of alcohols	Describe the physical properties of alcohols	1 periods
3	Preparations of alcohols	Describe the preparation methods of alcohols	2 periods
4	Local preparation of ethanol by fermentation	Recall the steps involved in fermentation process.	2 periods

5	Chemical properties of alcohols	- Carry out an experiment to compare the oxidation reactions of primary, secondary and tertiary - Explain the mechanism of dehydration of alcohols and that reaction with hydrogen chloride - Perform iodoform test to distinguish between the methyl and non- methyl alcohols.	2 periods
6	Nomenclature, physical properties and isomers of ethers	Describe the physical properties of ethers	1 period
7	Preparation reactions of ethers	Describe the preparation of ethers	1 period
8	Chemical properties of ethers	Describe the chemical properties of ethers	1 period
9	Uses of alcohols and ethers	State the uses of alcohols and ethers	1 periods
	End unit assessment		1 periods

Lesson 1: Definition, homologous series, nomenclature, isomerism and classification of alcohols

a) Prerequisites

The learning of this lesson will be better if the students have knowledge on:

Functional groups, rules of naming organic compound, isomerism in organic chemistry.

b) Teaching resources:

- Chemistry textbooks and other relevant chemistry books from the library
- Where possible use internet

c) Learning activities

Guidance :

- Form groups (the number of groups and members will depend on your class size and the number of your resources or materials).

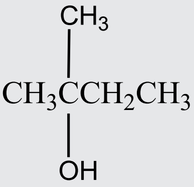
- Give learners activity 11.1 (from the student's book)
- Move around the class and check if all learners are actively working.
- Ask learners to present their findings.
- During their presentation ask some questions that lead to lesson objectives.
- Guide learners to make the summary of the lesson.
- Make the final conclusion of the lesson.
- After giving final conclusion, assess your learners using application activity 11.1 (from student's book). Learners can do this application activity individually or in pairs. If you do not have enough time in your lesson, give it as individual home work.

Answers to Activity 11.1

Refer to the student book unit 7, 8, 9 and 10

d) Application activities

Answers to Application Activity 11.1

$CH_3CH_2CH_2CH_2CH_2OH$	pentan-1-ol
$CH_3CH_2CH_2CH(OH)CH_3$	pentan-2-ol
$CH_3CH(CH_3)CH(OH)CH_3$	3-methylbutan-2-ol
$CH_3CH(CH_3)CH_2CH_2OH$	3-methylbutan-1-ol
$CH_3C(CH_3)_2CH_2OH$	2,2-dimethylpropan-1-ol
 $CH_3\overset{\overset{\displaystyle CH_3}{\vert}}{\underset{\underset{\displaystyle OH}{\vert}}{C}}CH_2CH_3$	2-methylbutan-2-ol

Lesson 2: Physical properties of alcohols

a) Prerequisites

Learners will understand better this lesson if they have understanding on the concept of chemical bonding.

b) Teaching resources

- Chemistry textbooks and other relevant chemistry books from the library
- Where possible use internet

c) Learning activities

Guidance

- Give learners activity 11.2 (from the student's book).
- Ask learners to carry out this activity in pairs
- Move around the class and check if all learners are working.
- Ask learners to present their findings.
- Summarise the findings from students' work and give more examples which illustrate the content about Physical properties of alcohols.
- Assess your learners using application activity 11.2 (from student's book).

Answers to Activity 11.2

Refer to the student book unit 8 and 11

d) Application activities

Answers to Application Activity 11.2

Refer to the student book unit 8 and 9

Lesson 3: Preparations of alcohols

a) Prerequisites

Learners will understand better this lesson if they have understanding on the concept of reactivity of alkenes and reactivity of halogenoalkanes.

b) Teaching resources

- Chemistry textbooks and other relevant chemistry books from the library
- Where possible use internet

c) Learning activities

Guidance

- Give learners activity 11.3 (from the student's book).
- Ask learners to carry out this activity in xpairs
- Move around the class and check if all learners are working.
- Ask learners to present their findings.
- Harmonize the findings from students' work and give more examples which illustrate

  the content about Preparations of alcohols.
- Assess your learners using application activity 11.3 (from student's book).

Answers to Activity 11.3

Refer to the student book unit 9 and 10

d) Application activities

Answers to Application Activity 11.3

1. a) From alkenes

$$CH_3CH_2CH{=}CH_2 + H_2O \xrightarrow{H_2SO_4} CH_3CH_2CH(OH)CH_3$$

b) From a halogenoalkane

$$CH_3CH_2CH(Cl)CH_3 + KOH \xrightarrow{\text{water}} CH_3CH_2CH(OH)CH_3 + KCl$$

2. a) $CH_3CH_2CH_2CH{=}CHCH_3 + H_2O \xrightarrow{H_2SO_4} CH_3CH_2CH_2CH_2CH(OH)CH_3$

b) $(CH_3)_2C{=}CHCH_3 + HCl \longrightarrow (CH_3)_2CClCH_2CH_3 \xrightarrow{NaOH\ (aq)} (CH_3)_2COHCH_2CH_3$

Lesson 4: Local preparation of ethanol by fermentation

a) Prerequisites

Learners will understand better this lesson if they have understanding on the concept of fermentation.

b) Teaching resources

- Chemistry textbooks and other relevant chemistry books from the library
- Where possible use internet

c) Learning activities

Guidance

- Give learners activity 11.4 (from the student's book).
- Ask learners to carry out this activity in pairs
- Move around the class and check if all learners are working.
- Ask learners to present their findings.
- Harmonize the findings from students' work and give more examples which illustrate

  the content about local preparation of ethanol.

Assess your learners using application activity 11.4 (from student's book)

Answers to Activity 11.4

Refer to the student book unit 11

d) Application activities

Answers to Application Activity 11.4

Refer to the student book unit 11

Lesson 5: Chemical properties of alcohols

a) Prerequisites

Learners will understand better this lesson if they have understanding on the concept of preparation of alkenes and preparation of halogenoalkanes.

b) Teaching resources

- Chemistry textbooks, internet (where possible), methanol, ethanol, 2M sulphuric acid, potassium dichromate solution, test tubes, burner, droppers, propan-2-ol and 2-methylpropan-2-ol.

c) Learning activities

Guidance on the activity

- Form groups
- Give learners activity 11.5 (from the student's book).
- Ask learners to carry out this activity
- Move around the class and check if all learners are working.
- Ask learners to present their findings.
- Summarise the findings from students' work and give more examples which illustrate

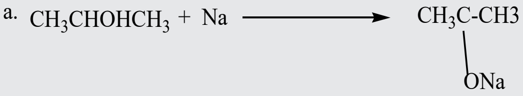
  the content about chemical properties of alcohols.
- Assess your learners using application activity 11.5 (from student's book).

Answers to Activity 11.5

Refer to the student book unit 11

d) Application activities

Answers to Application Activity 11.5



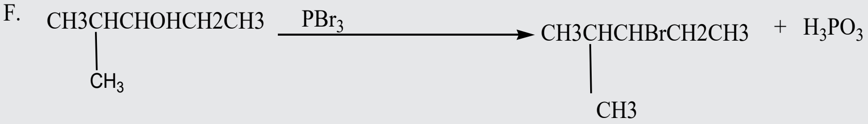
a. $CH_3CHOHCH_3 + Na \longrightarrow \underset{\displaystyle ONa}{CH_3C\text{-}CH3}$

b. $CH_3CHOHCH_3 + HBr \longrightarrow CH_3CHBrCH_3$

c. $CH3OH + CH3CH2COOH \longrightarrow CH_3COOCH_2CH_3$

d. $CH_3CH_2CH_2CH_2OH + PCl_5 \longrightarrow CH_3CH_2CH_2CH_2Cl + POCl_3 + HCl$

e. $CH_3CH_2CH_2CH_2OH + SOCl2 \longrightarrow CH_3CH_2CH_2CH_2Cl + SO_2 + HCl$



F. $\underset{\displaystyle CH_3}{CH3CHCHOHCH2CH3} \xrightarrow{PBr_3} \underset{\displaystyle CH3}{CH3CHCHBrCH2CH3} + H_3PO_3$

Lesson 6: Nomenclature, physical properties and isomers of ethers

a) Prerequisites

Learners will understand better this lesson if they have understanding on the concept of naming organic compounds, chemical bonds and isomers.

b) Teaching resources

- Chemistry textbooks and other relevant chemistry books from the library
- Where possible use internet

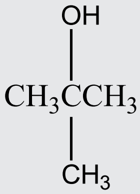
c) Learning activities

Guidance

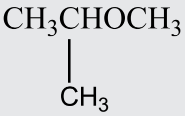
- Give learners activity 11.6 (from the student's book).
- Ask learners to carry out this activity in pairs
- Move around the class and check if all learners are working.
- Ask learners to present their findings.
- Guide learners to make the summary of the lesson.
- Make the final conclusion of the lesson.
- After giving final conclusion, assess your learners using application activity 11.6 (from student's book). Learners can do this application activity individually or in pairs.

Answers to Activity 11.6

1) (a) $CH_3CH_2CH_2CH_2OH$ (b) $CH_3CH_2CH(OH)CH_3$ (e) $CH_3CH_2OCH_2CH_3$

(c)

$CH_3\overset{OH}{\underset{CH_3}{C}}CH_3$

(d) $CH_3CH_2CH_2OCH_3$

(f)

$CH_3\underset{CH_3}{CH}OCH_3$

2) Refer to the student book unit 11

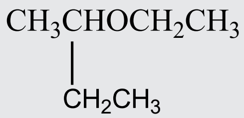
d) Application activities

Answers to Application Activity 11.6

1. a) Ethoxybutane or butyl ethyl ether

   b) 2-methoxypropane

2) a) $CH_3CH_2CH_2OCH_2CH_2CH_3$ dipropyl ether



$CH_3\underset{CH_2CH_3}{\underset{|}{CH}}OCH_2CH_3$ 2-ethoxybutane

b) They are isomers because they have the same molecular formula

c) Dipropyl ether is the one which has higher boiling point because is unbranched.

Lesson 7: Preparation reactions of ethers

a) Prerequisites

Learners will understand better this lesson if they have understanding on the concept of reactivity of alcohols and reactivity of halogenoalkanes.

b) Teaching resources

- Chemistry textbooks and other relevant chemistry books from the library
- Where possible use internet

c) Learning activities

Guidance

- Form groups
- Give learners the above resources
- Ask learners to carry out the activity 11.7 (from the student's book).
- Ask learners to present their observations and deductions to the whole class.
- During the presentation ask some questions that lead to lesson objectives.

- Summarise the findings from students' work and give more examples which illustrate

  the content about preparation of ethers.
- Assess your learners using application activity 11.7 (from student's book).

Answers to Activity 11.7

Refer to the student book unit 11

d) Application activities

Answers to Application Activity 11.7

a) $CH_3CH_2O^-Na^+ \quad + \quad CH_3CH_2Cl \longrightarrow CH_3CH_2OCH_2CH_3 + NaCl$

b) $2CH_3CH_2CH_2CH_2OH \xrightarrow{H_2SO_4\ /140^0C} CH_3CH_2CH_2CH_2OCH_2CH_2CH_2CH_3 + H_2O$

Lesson 8: Chemical properties of ethers

a) Prerequisites

Learners will understand better this lesson if they have understanding on the concept of:

- Polarity of chemical bonds
- Reactivity of alcohols as the reactivity alkyl halides.

b) Teaching resources

- Chemistry textbooks and other relevant chemistry books from the library
- Where possible use internet

c) Learning activities

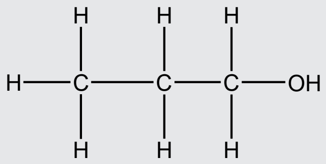
Guidance

- Give learners activity 11.8 (from the student's book).
- Ask learners to carry out this activity in pairs
- Move around the class and check if all learners are actively working.
- Ask learners to present their findings.
- Guide learners to make the summary of the lesson.

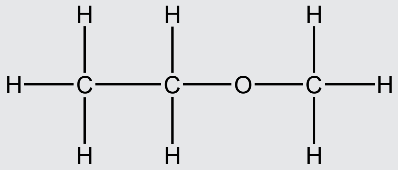
- Make the final conclusion of the lesson.
- After giving final conclusion, assess your learners using application activity 11.8 (from student's book). Learners can do this application activity individually or in pairs.

Answers to Activity 11.8

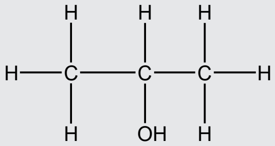
A:



B:



C:



The only one which does not react with sodium metal is **B.**

d) Application activities

Answers to Application Activity 11.8

Refer to the student book unit 11

Lesson 9: Uses of alcohols and ethers

a) Prerequisites

Learners will understand better this lesson if they have understanding on the concept of chemical bonds and physical properties of alcohols and ethers.

b) Teaching resources

- Chemistry textbooks and other relevant chemistry books from the library
- Where possible use internet

c) Learning activities

This lesson contains two activities 11.9. (a) and 11.9. (b):

Guidance

- Form groups
- Give learners the above resources
- Ask learners to carry out the activities 11.9.(a) and 11.9.(b) (from the student's book).
- Ask learners to present their observations and deductions to the whole class.
- During the presentation ask some questions that lead to lesson objectives.
- Summarise the findings from students' work and give more examples which illustrate the content about preparation of ethers.
- Assess your learners using application activity 11.9 (from student's book).

Answers to Activity 11.9.(a)

a) Banana wine (urwagwa), sorghum beer (ikigage), etc.
b) Kanyanga is prohibited in Rwanda, because it is toxic.

Answers to Activity 11.9.(b)

Refer to the student book unit 10

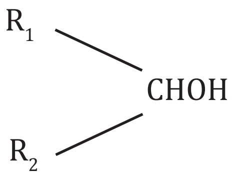
d) Application activities

Answers to Application Activity 11.9

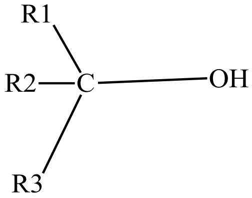
Refer to the student book unit 11

11.6 Summary of the Unit

- Alcohols are aliphatic compounds containing the OH group. They are named using the suffix **–ol.**
- Primary alcohols are of the form RCH_2OH;
- Secondary alcohol are of the form:



- Tertiary alcohols are of the form:



- The physical properties of alcohols, especially the early members of the series are strongly influenced by Hydrogen bonding
- Alcohol act as proton donor but are weaker acid than water.
- Alcohols act as bases becoming protonated on the oxygen atom. This lead to the formation of carbocation and subsequent dehydration.
- Primary alcohols can be oxidized to aldehydes, then acids;
- Secondary alcohols are oxidized to ketones; tertiary alcohols are **not** oxidized.
- Some alcoholic drinks are sometimes prepared using traditional methods.
- **Ethers** are organic compounds in which two carbon groups are connected to single oxygen.
- The general formula of ether is R-O-R'. Based on the general structure of ether, they are classified as symmetrical, unsymmetrical and epoxide.
- Ethers can be named by naming each of the two carbon groups as a separate word followed by a space and the word ether. The -OR group can also be named as a substituent using the group name, **alkox.**
- Ethers are functional isomers of alcohols.

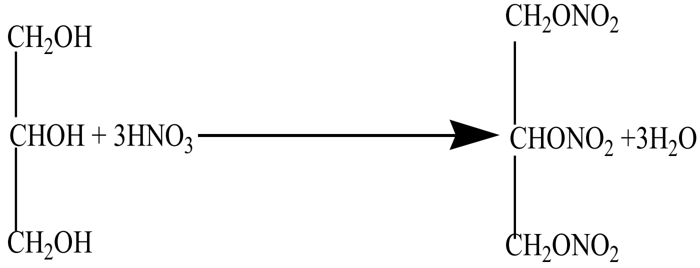
11.7. Additional information for teachers

Polyhydric alcohols

Those are the molecules of alcohols which are characterised by the presence of many OH groups, the IUPAC system of naming them is started with the prefix di, tri… depending to the number of hydroxyl group, where as their common name is glycols since they have a sweet taste.

Formula	Common Name	IUPAC Name
$HOCH_2CH_2OH$	Ethylene glucol	1,2-ethanediol
$HOCH_2CH(OH)CH_3$	Propylene glycol	1,2-propanediol
$HOCH_2CH_2CH_2OH$	Trimetylen glycol	1,3-propanediol

Glycerol is a by-product in the manufacture of soaps by alkaline hydrolysis of fats. It is used in the manufacture of the esters which it forms with nitric acid, propane-1, 2,3-triyltrinitrate or glyceryltrinitrate



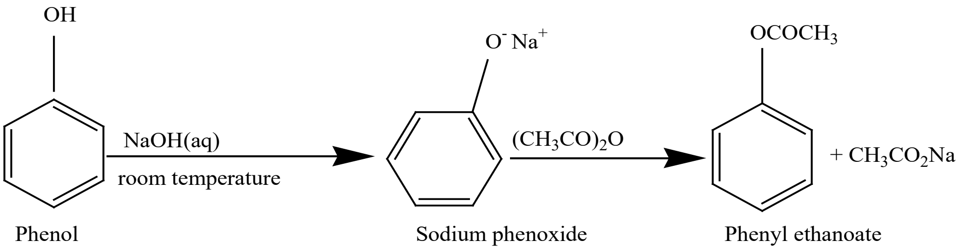
$$\begin{matrix} CH_2OH \\ | \\ CHOH + 3HNO_3 \\ | \\ CH_2OH \end{matrix} \longrightarrow \begin{matrix} CH_2ONO_2 \\ | \\ CHONO_2 + 3H_2O \\ | \\ CH_2ONO_2 \end{matrix}$$

Propane-1,2,3-triol (glycerol) — Propane-1,2,3-triyl trinitrate (glyceryl trinitrate)

This ester, also called *nitro-glycerine* is an explosive which is detonated by shock. When nitroglucerol is in contact with clay of the type kieselguhr, it is called dynamite. It is still powerful explosive but it is less sensitive to shock.

Phenols

Phenols are characterised by the presence of OH or hydroxyl group located on the benzene ring. Phenols react differently from the alcohols and they are acidic. They are able to react with NaOH.



Guidance to skills Lab 11

As a tutor asks learners to make a research and prepare concentrated ethanol from banana wine or sorghum beer.

End unit assessment

Answers to end unit assessment 11

I. Multiple choice questions

1. B

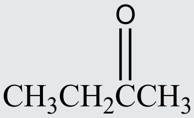
2. A

3. A

II. Open questions

4) (a) Butan-1-ol, butan-2-ol and 2-methylpropan-2-ol

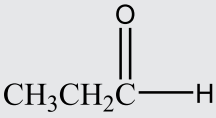
b) i) $CH_3CH_2CH(OH)CH_3$

ii) 

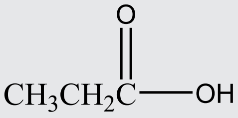
$CH_3CH_2\overset{\overset{O}{\|}}{C}CH_3$

5)

A: $CH_3CH{=}CH_2$

B: 

$CH_3CH_2\overset{\overset{O}{\|}}{C}—H$

C: 

$CH_3CH_2\overset{\overset{O}{\|}}{C}—OH$

D: $CH_3CH_2CH_2Br$

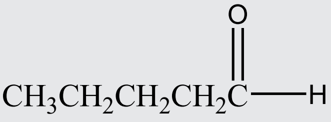
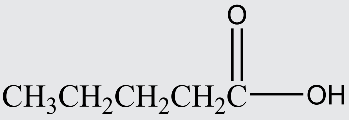
E: $CH_3CH_2CH_2Cl$

F: $CH_3CH_2CH_2ONa$

6) a) Pentan-1-ol

b) X is a primary alcohol

c) Hydrogen bonds

d)  and 

$CH_3CH_2CH_2CH_2\overset{\overset{O}{\|}}{C}—H$ and $CH_3CH_2CH_2CH_2\overset{\overset{O}{\|}}{C}—OH$

11.8. Additional activities

11.8.1. Remedial activities

1. What is the general formula of alcohols?

Answer: $C_nH_{2n+1}OH$ or **R-OH**

2. Give at least 2 methods of preparing alcohols

Answer:

i) Hydration of alkenes in presence of sulphuric acid; mechanism see student book

ii) Addition of water to an halogen alkane, this is a substitution reaction where the OH group from water replaces the halogen atom of halide (mechanism see student book).

3. Describe the method of alcoholic fermentation.

Answer: Refer to the student book

4. Compare the fermentation process and the direct hydration of ethylene

Answer: Refer to student book (section about alcoholic fermentation)

11.8.2. Consolidation activities

1. Propanol can be forms by the hydration of an alkene in presence of a suitable catalyst.

(a) Suggest the catalyst used in the reaction

(b) Establish the mechanism of reaction

Answers:

(a) The catalyst used is concentrated sulphuric acid

(b) Mechanism: see student book

11.9. Extended activities

A compound (**A**) $C_6H_{14}O$ liberate H gas when treated with sodium metal, A doesn't react with NaOH, gives positive Lucas test in several minutes. When **A** treated with PBr_5 the compound (**B**) $C_6H_{13}Br$ is formed when B is treated with alcoholic KOH compound (**C**) and (**D**)both having the formula of $C_6H_{12}$are formed (C) is the major reaction product while (D) is the minor product. When (C) is treated with ozone, followed by hydrolysis only a single ketone is obtained. This ketone can be shown to be identical to the compound produced by hydration of propyne in presence of sulphuric acid and mercuric sulphate.

From the information deduce and write the names and structural formula of (A) to (D).

Answer:

Because the molecule $C_6H_{14}O$ liberate the hydrogen gas when reacted with Na, shows that it is an alcohol, but also because of its behaviour when it is identified by Lucas test, that shows that this alcohol is a tertiary alcohol

(A) **is 2,3 dimethylbutan-2-ol** or any tertiary alcohol

to the molecule of (A), the addition of PBr_5 show a substitution reaction, so the molecule

(B) **is 2-bromo 2,3 dimethyl butane**

the addition of alcoholic KOH compound is added to (B), there is an elimination reaction

(C) **is 2, 3 dimethyl but-2-ene (cis or trans)**

(**D) is 2,3 dimethylbut-1-ene**

UNIT 12

CARBONYL COMPOUNDS

12.1. Key unit competence

Compare the chemical nature of carbonyl compounds to their reactivity and uses.

12.2. Prerequisite

Students will learn better the content related to carbonyl compounds if they have understanding on:

- Introduction to organic chemistry (unit 7, year II)
- Alkenes (unit 8, year II)
- Alcohols (unit 11, year II)

Learners have the skills to use effectively the common laboratory apparatus and are aware of the safety precautions to take when working in a chemistry laboratory.

12.3. Cross-cutting issues to be addressed:

a. Environment protection: Environment protection, polymers formed from aldehyde for example bakelite is harmful to environment but materials formed by cellulose, trees, are not harmful to environment.

b. Standardization culture: the students will be taught about the standard of the table sugar and how some local beers are oxidized in aldehyde and carboxylic acids when are exposed on air.

12.4. Guidance on introductory activity

Before introducing the lesson one of unit twelve, you will have to introduce the whole unit. Ask learners (in pairs) to attempt the introductory activity from student's book. This activity intends to relate the unit with learners' daily life and to capture their attention.

- Ask learners to use library or internet (where is possible) in order to conduct this introductory activity very well. Learners may not be able to find the right answers but they are invited to predict possible solutions or answers.
- Ask learners to present their findings.
- During the presentation ask some questions that lead to lesson objectives.

12.5. List of lessons/sub-heading

	Lesson title	Learning objectives	Periods
1	Nomenclature and isomerism in carbonyl compounds	Write and name carbonyl compounds and isomers of ketones and aldehydes	1 period
2	Physical properties of aldehydes and ketones	State the physical properties of aldehydes and ketones.	1 period
3	Preparation methods of aldehydes and ketones	• Describe the preparation reactions of ketones and aldehydes. • Prepare ketones from secondary alcohols by oxidation reaction.	4 periods
4	Chemical reactions of carbonyl compounds	• Describe the reactivity of carbonyl compounds • Write equations for the reactions of carbonyl compounds with other substances.	4 periods
5	Uses of carbonyl compounds	Describe the uses of carbonyl compounds.	1 period
End unit assessment			2 periods

Lesson 1: Nomenclature and isomerism in carbonyl compounds

a) Prerequisites

The learning of this lesson will be better if the students have knowledge on: Functional groups, rules of naming organic compound and isomerism in organic chemistry.

b) Teaching resources

- Chemistry textbooks and other relevant chemistry books from the library,
- Where possible use internet

c) Learning activities

Guidance to Activity 12.1:

- Form groups (the number of groups and members will depend on your class size and the number of your resources or materials).
- Give learners activity 12.1 (from the student's book)
- Move around the class and check if all learners are working.
- Ask learners to present their findings.
- During the presentation ask some questions that lead to lesson objectives.
- Guide learners to make the summary of the lesson themselves.
- Make the final conclusion of the lesson.
- After giving final conclusion, assess your learners using application activity 12.1 (from student's book).

Answers to Activity 12.1

1. A and D are isomers to each other.

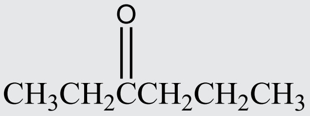
   B and E are also isomers.

2. Refer to the student book unit 7 and 12

d) Application activities

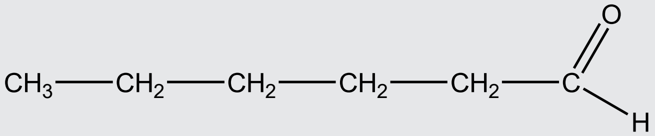
Answers to Application Activity 12.1

1) A: Butanal
   B: Butanone
   C: Hexanal
   D: pentan-2-one

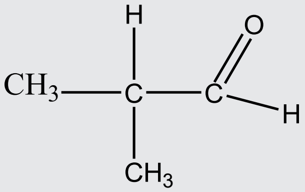
2) 

$CH_3CH_2\overset{\overset{O}{\|}}{C}CH_2CH_2CH_3$ hexan-3-one

The isomer of hexan-3-one is hexanal

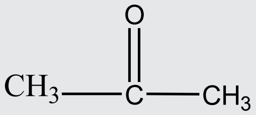


Hexanal

3) 

2-methylpropanal

The isomer of 2+methylpropanal which is a ketone is propanone.



$CH_3-\overset{\overset{O}{\|}}{C}-CH_3$ Propanone or acetone

Lesson 2: Physical properties of aldehydes and ketones

a) Prerequisites

Students will learn better the physical properties of aldehydes and ketones if they have a good understanding on the chemical bonding, molecular structures and geometrical isomerism.

b) Teaching resources

Chemistry textbooks, internet (where possible), beakers, ethanal, butanal and propanone (or acetone).

c) Learning activities

Guidance on the Activity 12.2:

- Give learners the above resources in pairs.
- Ask learners to carry out the activity 12.2 (from the student's book).
- Ask learners to present their observations and deductions.
- During the presentation ask some questions that lead to lesson objectives.
- Summarise the findings from students' work and give more examples which illustrate the content about physical properties of aldehydes and ketones.
- Assess your learners using application activity 12.2 (from student's book).

Answers to Activity 12.2

Refer to the student book unit 12

d) Application activities

Answers to Application Activity 12.2

Refer to the student book unit 12

Lesson 3: Preparation methods of aldehydes and ketones

a) Prerequisites

Students will understand better this lesson if they have a good understanding on oxidation reactions of alkenes and alcohols.

b) Teaching resources

Chemistry textbooks, internet (where possible), ethanoic acid, round-bottomed flask, water, concentrated sulphuric acid, anti-bumping granules, distillation apparatus, tap funnel, ice, ethanal, sodium dichromate (VI), beaker, ethanol, conical flasks, heating source(hot plate with magnetic stirrer) , calcium acetate, condenser, stirrer bar.

c) Learning activities

This lesson contains two activities 12.3 (a) and 12.3 (b)

Guidance to the Activities:

- Form groups,
- Ask learners to carry out the two activities (from the student's book).
- Ask learners to present their observations and deductions.
- During the presentation ask some questions that lead to lesson objectives.
- Summarise the findings from students' work and give more examples which illustrate the content about chemical properties of alkenes.
- Assess your learners using application activity 9.4 (from student's book).

Answers to Activity 12.3.(a)

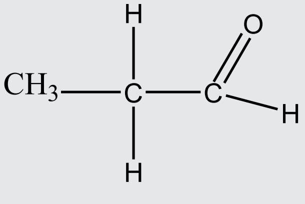
Refer to the student book unit 12

Answers to Activity 12.3.(b)

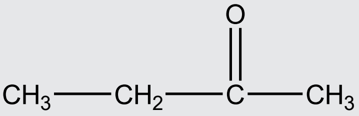
Refer to the student book unit 12

d) Application activities

Answers to Application Activity 12.3

1) i) 

ii) $CH_3CH_2CH(CH_3)CHO$

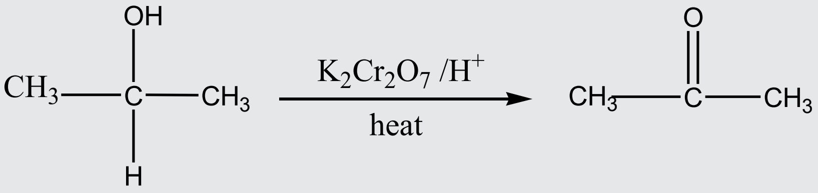
iii) 

$$CH_3-CH_2-\overset{\overset{O}{\|}}{C}-CH_3$$

2) i) $CH_3CH(OH)CH_2CH_2CH_3$

ii) $CH_3CH_2CH_2CH_2OH$

3)



$$CH_3CH(OH)CH_3 \xrightarrow[\text{heat}]{K_2Cr_2O_7\,/H^+} CH_3COCH_3$$

Lesson 4: Chemical reactions of carbonyl compounds

a) Prerequisites

Students will understand better this lesson if they have a good understanding on oxidation, reduction and addition reactions.

b) Teaching resources

Chemistry textbooks and internet (where possible), propanal, propanone, ethanol, glucose, test tubes, water bath, heating source, beakers, droppers, potassium dichromate (VI) solution, dilute sulphuric acid, Tollens' reagent, 6M sodium hydroxide, KI_3 and distilled water.

c) Learning activities

This lesson has five activities:

Guidance to the Activity:

- Form groups,
- Ask learners to carry out the activity 12.4. (a) (from the student's book).
- Ask learners to present their observations and deductions.
- During the presentation ask some questions that lead to lesson objectives.
- Summarise the findings from students' work and give more examples which illustrate the content about chemical properties of aldehydes and ketones.
- Assess your learners using application activity 12.4.(a) (from student's book).

Note: For the guidance of other activities of this lesson, use the same guidance.

Answer to activity 12.4

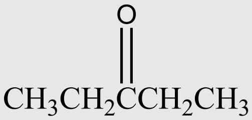
For answers of the activities of this lesson, refer to the student book unit 12.

d) Application activities

Answers to Application Activity 12.4

1) **A is** $CH_3CH_2CH(OH)CH_2CH_3$

B is



$CH_3CH_2\overset{\overset{O}{\|}}{C}CH_2CH_3$

C is $CH_3CH{=}CHCH_2CH_3$

2) If you add a few drops of an unknown compound to Brady’s reagent and get a bright orange or yellow precipitate, the compound is an aldehyde or ketone.

Lesson 5: Uses of carbonyl compounds

a) Prerequisites

Learners will understand better this lesson if they have understanding on the concept of chemical properties and physical properties of aldehydes and ketones.

b) Teaching resources

Chemistry textbooks and internet (where possible).

c) Learning activities

Guidance to the Activity 12.5:

- Give learners activity 12.5 (from the student’s book).
- Ask learners to carry out this activity in pairs
- Move around the class and check if all learners are working.
- Ask learners to present their findings.
- Guide learners to make the summary of the lesson.
- Make the final conclusion of the lesson.
- After giving final conclusion, assess your learners using application activity 12.5 (from student’s book).

Answers to Activity 12.5

Refer to the student book unit 12

d) Application activities

Answers to Application Activity 12.5

Refer to the student book unit 12

12.6. Summary of the Unit

The carbonyl group, C=O, is present in aldehyde and ketone. In aldehyde is in a terminal position in the carbon chain. In ketone is in a non-terminal position.

Aldehydes and ketones are named using the suffixes **“al”** and **“one”,** respectively.

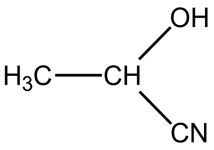
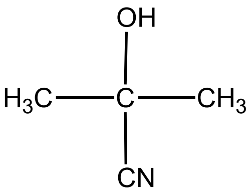
The carbonyl group undergoes nucleophilic addition. This is sometimes followed by the elimination of a small like water, resulting in a condensation reaction.

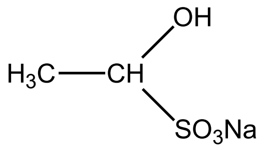
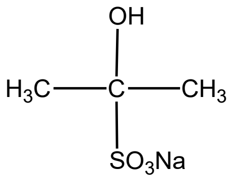
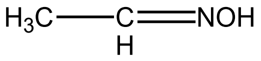
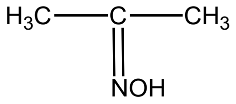
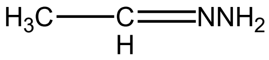
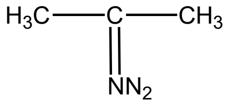
Aldehydes are generally more reactive than ketones. Aldehyde can be oxidized by to carboxylic acids by variety reagents like acidified potassium chromate, Tollens reagent, Fehling reagent. Ketones are not readily oxidized.

Carbonyl group activates the methyl hydrogen on neighbouring carbon atoms, making them more readily substituted than those in alkanes.

Aldehydes are prepared by oxidizing primary alcohol and ketones are prepared by oxidizing secondary alcohol.

The following table represents important reactions of aldehyde and ketone

Reagent	**Reaction type**	**Product from ethanal**	**Product from Propanone**
HCN	Addition		

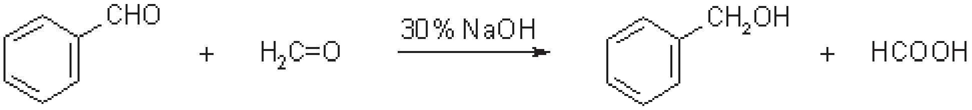
$NaHSO_3$	Addition		
NH_2OH	Condensation	 $H_3C-CH=NOH$	 $H_3C-C(=NOH)-CH_3$
NH_2NH_2	Condensation	 $H_3C-CH=NNH_2$	 $H_3C-C(=NN_2)-CH_3$
2.4-Dinitrophenylhydrazine	Condensation	Yellow precipitate of combination ethanal and 2.4-Dinitrophenylhydrazine	Yellow precipitate of combination ethanal and 2.4-Dinitrophenylhydrazine
Tollens reagent	Oxidation	CH_3COOH	No reaction
Fehling reagent or Benedict's reagent	Oxidation	CH_3COOH	No reaction
I_2/OH^-	Iodoform reaction	Yellow precipitate of CHI_3	Yellow precipitate of CHI_3

12.7. Additional information for teachers

a. The Cannizzaro reaction

The Cannizzaro reaction is an example of **Disproportionation reaction** in which two molecules of an aldehyde are reacted to produce a primary alcohol and a carboxylic acid in presence of base like NaOH or KOH.

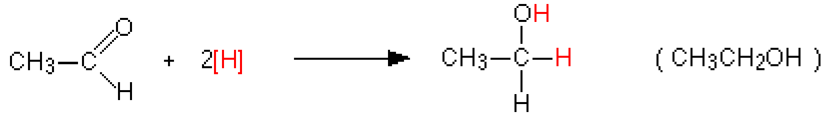
Example;



b. The reduction of an aldehyde

Reducing agent used are tetrahydridoaluminate or sodium tetrahydridoborate.

For example

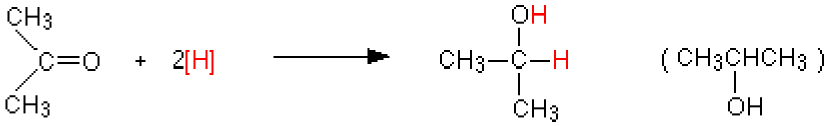
- 

Where [H] is "hydrogen from a reducing agent"; tetrahydridoaluminate or sodium tetrahydridoborate. In general terms, reduction of an aldehyde leads to a ***primary alcohol***.

c. The reduction of a ketone

Reduction of a ketone leads to a ***secondary alcohol***. The product is the same whichever of the two reducing agents you use.

For example



d. The reduction of a carboxylic acid

The reaction takes place in two stages:

1st an aldehyde is formed and **2nd** a primary alcohol. Because lithium tetrahydridoaluminate reacts rapidly with aldehydes, it is impossible to stop reaction at the aldehyde. This reason why aldehydes don't be prepared by reduction of carboxylic acid method, equation for reaction is:

$$RCOOH + 4[H] \longrightarrow RCH_2OH + H_2O$$

Where [H] represent "hydrogen from a reducing agent"; tetrahydridoaluminate; the sodium tetrahydridoborate isn't reactive enough to reduce carboxylic acids.

Skills Lab 12

As a tutor ask learners to make a research and prepare formalin from banana or from sorghum.

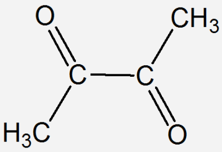
End unit assessment

Answers to end unit assessment

1. a) C

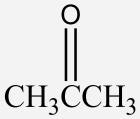
   b) B

2.



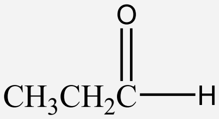
Butane-2,3-dione

3. **F:**



$CH_3\overset{\overset{O}{\parallel}}{C}CH_3$

G:



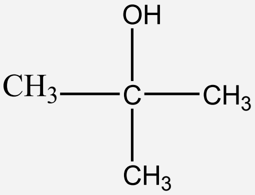
$CH_3CH_2\overset{\overset{O}{\parallel}}{C}-H$

4. X is a carbonyl compound (adds 2,4-Dinitrophenylhydrzine). X contains a CH_3CO- group (gives positive iodoform test). It is not an aldehyde. It has no C=C bond (does not react with bromine). Hydrogen must reduce C=O group to CHOH.

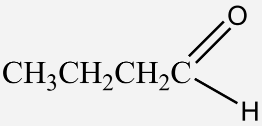
X is $CH_3COCH_2CH_{3,}$ Y and Z are stereoisomers with the formula: $CH_3CHOCH_2CH_3$.

5. **A:** $CH_3CH_2CH_2CH_2OH$ **B:** $CH_3CH_2CH(OH)CH_3$

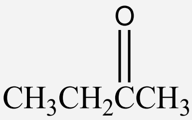
C:



D:



F:



$CH_3CH_2\overset{\overset{O}{\parallel}}{C}CH_3$

12.8. Additional activities

12.8.1. Remedial activities

1. Which of the following compounds will react with Tollens reagent?

A: CH_3-CHO

B: CH_3-COOH

C: CH_3-CH-CH_3

D: CH_3-CO-CH_2-CH_3

Answer: A

2. Primary alcohol is gently heated to produce aldehyde in presence of solution of acidified:

A: hydroxide

B: dichromate

C: ethanol

D: all of them

Answer: B

4. Which of the following substances does not give iodoform test?

A: Methyl alcohol
B: Ethanal
C: Propanone
D: Propanal

Answer: D

5. Which of the following will have the highest boiling point?

A: Methanol
B: Propanal
C: Ethanol
D: hexanone

12.8.2. Consolidation activities

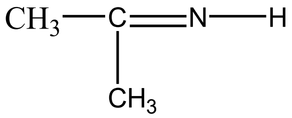
1) a) Draw the structure of hydroxylamine.

b) Draw the structure of the organic product of the reaction between hydroxylamine and propanone.

Answer:

a) $H_2N\text{-}OH$

b)



$CH_3-\underset{\displaystyle CH_3}{\underset{|}{C}}=N-H$

2) The reaction is done by shaking a ketone containing at least one methyl group or any aldehyde with a saturated solution of sodium hydrogensulphite in water.

a) What would you see if a reaction occurred?

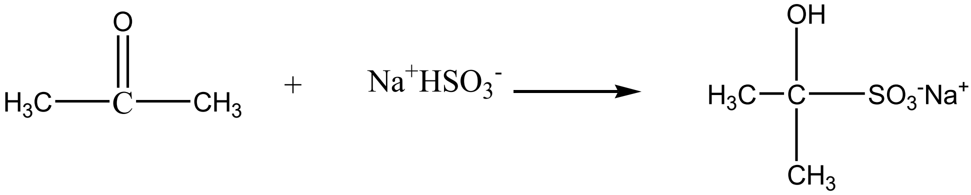
b) Write the equation for the reaction between propanone and sodium hydrogensulphite showing the essential structure of the product. You don't need to show the structure of the sulphur-containing group.

c) How can this reaction be used during the purification of an aldehyde?

Answers:

a) A white crystalline precipitate.

b)



$$H_3C-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3 \quad + \quad Na^+HSO_3^- \longrightarrow H_3C-\underset{\underset{\displaystyle CH_3}{|}}{\overset{\overset{\displaystyle OH}{|}}{C}}-SO_3^-Na^+$$

c) Shake the impure aldehyde with sodium hydrogensulphite solution to produce the crystals. Filter and wash the crystals, and then add a dilute acid or alkali to regenerate the aldehyde.

12.9. Extended activities

An organic compound, A, of molecular formula $C_2H_4O_2$ contains two functional groups.

a) The first functional group was tasted as follows:

(i) The dry compound, A, reacts with sodium to give hydrogen gas and a compound of molecular formula $C_2H_3O_2Na$.

(ii) When A was heated with ethanoic acid and a few drops of concentrated sulphuric acid, the product B of molecular formula $C_2H_6O_3$ is formed with evolution of a sweet smell.

- Give the name of the first functional group.
- Give the formula and name of the functional group formed in (a) (ii).

b) The second functional group was tasted as follows:

(i) a few drops of A were added to 2,4-dinitrophenylhydrazine which gave a yellow/orange precipitate.

(ii) one drop of A was mixed with a solution containing $[Ag(NH_3)_2]^+$ (Tollens' reagent) and warmed. A deposit of silver was formed on the inner sides of the test tube. Give the name and the formula of the second functional group.

c) Give the structural formula for compound A.

d) Give the structural formulae of two possible geometric isomers of molecular formula $C_2H_4O_2$

e) Compound A is oxidized to give an acid of the molecular formula $C_2H_2O_4$. Give the structural formula of $C_2H_2O_4$

f) Compound A is reduced to give a compound of molecular formula $C_2H_6O_2$. Give the structural formula of $C_2H_6O_2$.

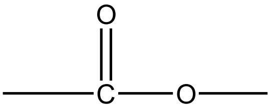
g) Suggest the formula of the compound formed by reacting $C_2H_6O_2$ with excess HBr.

h) Give the structural formula of possible compound formed when one mole of $C_2H_6O_2$ reacts with 2 moles of ethanoic acid.

Answers:

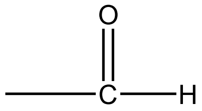
a) The first functional group is alcohol

In (ii), an ester is formed:

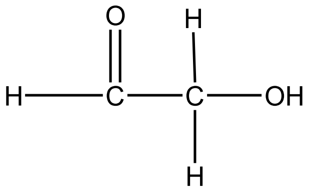


Ester

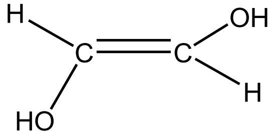
b) Aldehyde



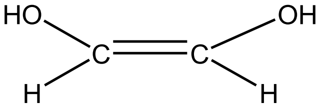
c)



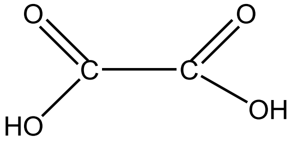
d)



and

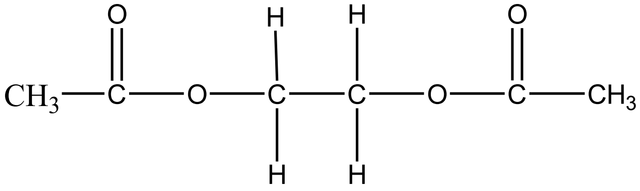


e)



f) $HO\text{-}CH_2\text{-}CH_2\text{-}OH$

g) $Br\text{-}CH_2\text{-}CH_2\text{-}Br$

h) 

$$CH_3-\overset{\overset{\displaystyle O}{\|}}{C}-O-\underset{\underset{\displaystyle H}{|}}{\overset{\overset{\displaystyle H}{|}}{C}}-\underset{\underset{\displaystyle H}{|}}{\overset{\overset{\displaystyle H}{|}}{C}}-O-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3$$

UNIT
13

CARBOXYLIC ACIDS AND ACYL CHLORIDES

13.1. Key unit competence

Compare the chemical nature of the carboxylic acids and acid halides to their reactivity

13.2. Prerequisite

In general, the study of carboxylic acids acyl chlorides will require the prior knowledge about general IUPAC rules that are used in the nomenclature of organic compounds, types of formulae that are used to represent organic compounds, inductive effects of different atoms and group of atoms, diverse ways of bond fission and types of reaction mechanism.

13.3. Cross-cutting issues to be addressed

The cross-cutting issues that can be addressed in this unit are specifically:

- **Gender**

The teacher has always to mind about the gender balance in assignment of roles during learning activities. He/she must make sure that both genders are represented and avoid using examples that minimize/praise any of them (boys or girls).

- **Financial education**

In the lesson 13.2 about uses of carboxylic acids, the teacher must emphasize on industrial applications of carboxylic acids, where they are used to manufacture many more useful products such as pharmaceuticals, foods and drinks which are sources of income for many business owners. This cross-cutting issue should be addressed at the end of the lesson 7.9, not as the focus of the lesson. It has also to be underlined that in the laboratory students should avoid wasting chemicals. They must use them economically.

13.4. Guidance on introductory activity

This activity has the objective of making students think critically about the phenomenon and the observations they always encounter in their daily life.

Then they try to interpret those observations by using scientific concepts. To help the students in this regard, the teacher will start by challenging the students with the questions given in introductory activity as a way of awakening their curiosity. Here students will give diverse opinions, but at the end the teacher will guide them towards a collective understanding.

Answers to introductory activity

1. Fresh juice taste is sweet, but after some time the taste changes to sour, the same is observed for milk. The explanation is that after some time in either juice or fresh milk glucose undergoes fermentation that forms ethanol which gets oxidized by oxygen in air to form acetic acid. It is the one responsible for the sour taste.
2. a) The ants' sting causes an injury of the part of the body affected.

   b) Ants inject formic acid (methanoic acid) in the part their stings and it is that acid that is responsible for the swelling and painful sensation.
3. a) They are used to burn the vegetables so that they can be a little bit soft and to change the vegetables' taste.

   b) They burn the vegetables because of their acidity and the same property is responsible for their sour taste.

   c) They all have carboxylic functional group -COOH, in their structure.

13.5. List of lessons

Lesson No	Lesson title	Learning objectives	Number of periods
1	- Nomenclature and isomerism - Nomenclature of carboxylic acids and acyl chlorides	- Apply the IUPAC rules to name different carboxylic acids - Write the structural formula and isomers of the carboxylic acids.	**1**
2	- Physical properties of carboxylic acids, acyl chlorides and uses of carboxylic acids	- Explain the physical properties and uses of the carboxylic acids and acyl chlorides. - Compare the physical properties of the carboxylic acids to those of alcohols.	**2**

3	- Acidity of carboxylic acids.	- Describe the inductive effect on the acidity of the carboxylic acids.	**1**
4	Preparation methods carboxylic acids and acyl halides	- Prepare carboxylic acids from oxidation of aldehydes or primary alcohols - Prepare acyl chlorides from carboxylic acids	**1**
5	- Reactions of carboxylic acids (with metals, sodium hydroxide, sodium carbonate/ hydrogencarbonates, phosphorus pentachloride/ thionylchloride, esterification, reduction reactions, reaction with halogens	- Explain the reactions of the carboxylic acids - Outline the mechanisms of esterification. - Distinguish between the carboxylic acids from other organic compounds using appropriate chemical test.	**2**
6	Reactions of acyl chlorides with water, strong base, Grignard reagents, alcohols, ammonia and amines, salts of carboxylic acid and reduction of acyl halides.	- Outline the mechanisms of esterification of reaction of acyl chlorides with ammonia, amines and alcohols	**2**
7	End unit assessment		**1**

Lesson 1: Nomenclature of carboxylic acids, acyl chlorides and isomerism (40minutes)

a) Prerequisites

Carboxylic acids consist of organic compounds that are characterized by the carboxyl functional group in their structure. The study of carboxylic acids requires a prior knowledge of:

- IUPAC general rules of naming organic compounds that will help student in the nomenclature of carboxylic acids. This was studied in senior 5 unit 7.
- Application of IUPAC general rules to name acyl chlorides
- Isomerism and types of isomerism in organic compounds that was seen in senior 5, unit 7.
- Different formulae that are used to represent organic compounds discussed in senior 5, unit 7 are important to represent diverse molecules of carboxylic acids.

b) Teaching resources

The teaching and learning resources that are needed for this lesson are:

- Student's textbooks
- Chalk board and pieces of chalk

c) Learning activities

Guidance

- Since it is not their first time to deal with nomenclature and isomerism of organic compounds, start by giving students the questions in activity 13.1.1 and 13.1.2.for them to discuss in small groups of five or six students.
- Students should apply general rules of naming organic compounds in naming carboxylic acids given and identify the types of isomers that are possible in carboxylic acids.
- After discussion, students will be asked to suggest their answers from which the teacher will build his/her whole lesson by simply emphasizing on the points where students demonstrated some difficulties.
- Focus on the fact that the side branches and substituents on the carboxylic longest carbon chain are given position by starting from the carboxylic functional group/acyl chloride group
- Clearly explain how optical isomers arise in carboxylic acids/acyl chlorides and how to distinguish them by using plane polarized light in a polarimeter.

Answers to activity 13.1.1

1. A. Ethanoic acid

B.2-Methylpropanoic acid

C.Methanoic acid

D. Ethanedioic acid

C.2-Methylbutanoic acid

2. a)$CH_3C(CH_2)_3COOH$

3. b) $CH_3CH\ (CH_3)\ CH_2COOH$

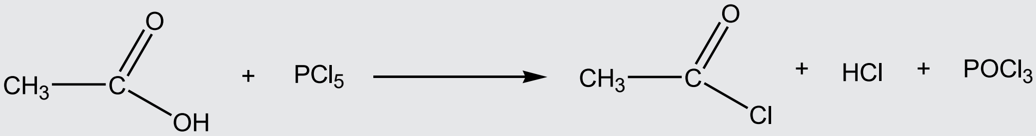
$C_3H_6O_2$:$HOCH_2CH_2CHO$:1-hydroxy propanal
:$CH_3CHOHCHO$:2-hydroxy propanal
:CH_3CH_2COOH :propanoic acid
:CH_3COOCH_3 :methyl ethanoate
:$HOCH=CHCH_2OH$:1-propene-1,3 diol
:$HOCH=CH(OH)CH_3$:1-propene-1,2 diol

4. a.One is the mirror-image of the other and they are non-superimposable like right and left hands.

b.They can be distinguished using a polarimeter, where L-lactic acid rotates plane polarized light to left and D-lactic acid rotates plane polarized light to the right.

Answers to activity 13.1.2

a.



b)The functional group is acyl chloride

c) The compound is called ethanoyl chloride

d) Replace '-ic acid' by '-yl chloride'

d) Application activities

The teacher will give the evaluation questions in application activity 13.1 and 13.1.2 to individual students and finally ask them to exchange their exercise book for peer marking. This will be done about what they will have corrected on the chalk board, together as a whole class.

Answers to application activity 13.1

1.

a)$CH_3CH_2C(CH)_3CH_2COOH$

b)$HOOC\ \text{-}CH(CH_3)CH_2CH_2CH_2COOH$

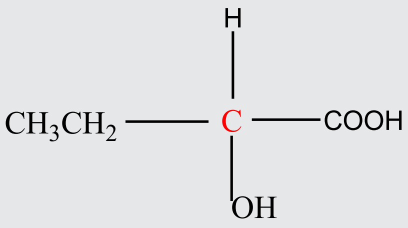
2. a)6-Methylhept-4-enoic acid

b) 3-Hydroxybutanoic acid

3. a) Functional group isomers

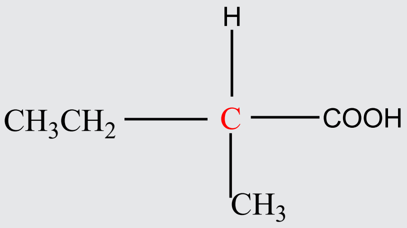
b) Chain isomers

4.



$$\mathrm{CH_3CH_2-\underset{OH}{\overset{H}{C}}-COOH}$$

and



$$\mathrm{CH_3CH_2-\underset{CH_3}{\overset{H}{C}}-COOH}$$

are optically active because they have asymmetric carbon (in red)

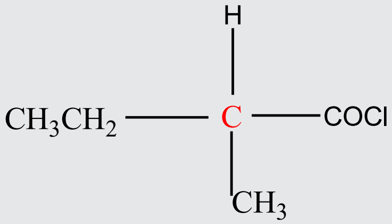
Answers to application activity 13.1.2

1)

a)	b)	c)
CH_3CH_2COCl	$CH_3CH_2CH_2COCl$	$CH_3CH_2(CH_3)CH_2CH_2COCl$

2) a) False The functional group is given priority, it should take the lowest position possible.

b)True. The following molecule of acyl chloride has a chiral carbon and it can show optical isomerism.



The name is: 2-methylbutanoyl chloride

Lesson 2: Physical properties of carboxylic acids, acyl chlorides and uses of carboxylic acids (80minutes)

a) Prerequisites

Physical properties of chemical substances in general are determined either by the chemical bonds, the structure or the intermolecular forces. To understand the physical properties of carboxylic acids requires a prior knowledge of:

- Chemical bonding and structure of molecules which were studied in unit 3 and 4 of year 1
- Type of intermolecular forces learnt in year 1

Acyl chlorides consist of discreet polar molecules and do not have hydrogen bonds, they interact by Van der Waals forces.

- Chemical bonding and structure of molecules which were studied in year 1
- Type of intermolecular forces learnt in year 1.

In groups learners will make research, discuss and make presentation about the uses of carboxylic acids after observing and answering questions in activity 13.2.3.The tasks should be given to learners as homework by the end of the previous lesson.

b) Teaching resources

The teaching and learning resources that are needed for this lesson are:

- Student's textbooks
- Chalk board and pieces of chalk
- Samples of carboxylic acids such as acetic acid/vinegar

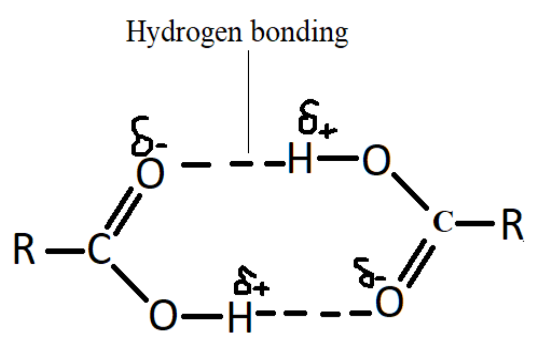
c) Learning activities

Guidance

- Start the lesson by asking students to brainstorm the answers and their ideas about the questions in activity 13.2.1and 13.2.2 The questions are asked to the class and students can give their own ideas.
- Put the focus on the fact that molecules held together by strong intermolecular forces are likely to be liquids and solids, they also have high melting and boiling points.
- Use the answers given to compare the boiling and melting points of carboxylic acids with those of alcohols and other homologous series learnt in the previous units.
- Emphasize on the dimeric structure of molecules of carboxylic acids because of double hydrogen bonds. Highlight that this fact makes carboxylic acids have higher boiling and melting points than alcohols even though they all interact by hydrogen bonding as intermolecular forces.
- Emphasize to the uses of carboxylic acids in everyday life(industry, medicine,…),

Answers to activity 13.2.1

1. Consider the ideas that the balls held together strong metallic wire are hard to be separated. They require more energy.
2. Carboxylic acids have high melting and boiling points because their hydrogen bonds enhance the possibility of bringing two acid molecules together by forming a kind of **dimer**.



Dimeric structure of carboxylic acid molecules

3. Refer to student's book

Answers to activity 13.2.2

Acyl chlorides molecules are loosely held together by weak Van der Waals forces, whereas carboxylic acids are held together by double strong hydrogen bonds in a dimeric structure. This results in that carboxylic acids have higher melting and boiling points than acyl chlorides. Since carboxylic acids can form hydrogen bonds with molecules of water they also more soluble in water than carboxylic acids.

Answer to activity 13.2.3

The carboxylic may not be the only chemical that is used in making these materials, but it is also used in the process. Refer to student's book, section 13.2.3 about uses of carboxylic acids.

d) Application activities

Ask students to discuss the questions in application activity 13.2. The activity will be conducted in a way that students work in pairs to ensure that there are active discussions among students. Then collect different answers from diverse groups and after the groups will exchange the worksheets for peer marking with reference to answers the whole class has agreed on. This will help the teacher to evaluate the achievement of his/her objectives by seeing how conversant the students are with doing these questions.

Answers to application activity 13.2

I. Carboxylic acids

1. Octadecanoic acid has higher melting point because it has greater molecular mass (greater size) than that of hexadecenoic acid. Van der Waals forces become stronger as the molecular mass of the molecule increases.
2. Butanoic acid has higher boiling point than that of pentan-2-one because of two main reasons:
    - Butanoic acid molecules interact with strong hydrogen bonds while pentan-2-one molecules interact with Van der Waals forces (dipole-dipole interactions) that are weaker.
    - Butanoic acid has greater molecular mass than that of pentan-2-one, which also favor the stronger Van der Waals forces in butanoic acid.

3. Yes, butanoic acid has higher solubility in water than butan-1-ol because carboxylic acids form stronger hydrogen bonds with the molecules of water.

II. Acyl chlorides

4. Acyl chlorides are slightly soluble in water due to their small dipole that can interact with the polarity of water molecule. They cannot be said to be soluble in water because they readily react with water. It is impossible to have a simple aqueous solution of acyl chlorides; rather we have the products of their reaction with water.
5. Their characteristic strong smell is caused by hydrogen chloride gas that is produced when they get in contact with moisture for example; the strong smell of ethanoyl chloride is a mixture of vinegar odour and the acrid smell of hydrogen chloride gas.
6. Acyl chloride molecules interact by Van der Waals forces whose strength increases with the increase in molecular masses of the compounds.

The boiling and melting points of acyl chlorides increases as their molecular masses rise. They have lower boiling and melting points than alcohols and carboxylic acids of the same number of carbon atoms, because they lack hydrogen bonds.

Answer to application activity 13.2.3

For this application activity group students appropriately in 5. Then provide them clear instruction on topics to research on. After research allow each group to present their findings.

Answers: Refer to student book, 13.2.3

Lesson 3: Acidity of carboxylic acids (40minutes)

a) Prerequisites

Acidity is one of the important chemical properties of carboxylic acids which can easily be understood after that the following concepts have been covered because they are prerequisite knowledge of this lesson:

- Acid-base theories in year 1.
- Positive and negative inductive effects of diverse atoms or group of atoms.

b) Teaching resources

The teaching and learning resources that are needed for this lesson are:

- Student's textbooks
- Chalk board and pieces of chalk
- Samples of carboxylic acids such as acetic acid/vinegar
- Methyl orange indicator/litmus paper
- Strong mineral acids (HCl or H_2SO_4)

c) Learning activities

Guidance

- To effectively conduct this activity, the teacher starts by asking students to tell the characteristics of an acidic substance as in question 1 of activity 13.3. He/she allows students to brainstorm what they think about an acidic substance.
- For the practical activity, the teacher groups the students appropriately; a group of more than 6 students would be very large. The group should be heterogeneous in a way that boys and girls, brilliant and slow learners are mixed.
- The teacher provides students with indicated apparatus and chemicals; and asks them to follow the procedure suggested in the student's book while carrying out activity 13.3. After that diverse groups have presented their findings, ask the students to evaluate the productions; the teacher judges the logic of the students' products, corrects those which are false, completes those which are incomplete, and confirms those which correct.
- It must also be explained that the strength of the acidity depends on the atoms or group atoms that are in the molecule, if they have a positive inductive effect or a negative inductive effect. Here relevant examples are needed to explain this concept (see student's book, lesson 13.3).

Answers to activity 13.3.

1. Carboxylic acids:

- Have a sour test
- Have ionizable hydrogen
- Can release hydrogen ions in aqueous solution
- Accepts lone pair of electrons
- Are proton donors
- Have effect on indicators

2.
   a) Arrhenius acid releases hydrogen ions in aqueous solution
   b) Bronsted-Lowry acid is a proton donor
   c) Lewis acid is lone pair of electrons acceptor
3. Both theories well define the acidity of carboxylic acids:

$$\underset{\text{Acid}}{\text{R-COOH(aq)}} + \underset{\text{base}}{H_2O(l)} \rightleftharpoons \underset{\text{base}}{\text{R-COO}^-\text{(aq)}} + \underset{\text{acid}}{H_3O^+\text{(aq)}}$$

4. For this activity, group students appropriately, a group of more than 6 students would be very large. Then provide them with indicated apparatus and chemicals; and ask them to follow the procedure suggested. Emphasize on the following points:

- Carboxylic acids have acidic properties as mineral acids. Their solutions, all change blue litmus/methyl orange indicator to red
- Carboxylic acids are weaker acids than most of mineral acids. The intensity of the colour is different.

e) Application activities

The teacher asks students to do questions in application activity 13.3. The activity will be conducted in a way that two or three students work together to ensure that there are active discussions among students. Then the teacher will collect different answers from diverse groups and after the groups will exchange the worksheets for peer marking with reference to answers that the whole class has agreed on.

Answers to application activity 13.3.

1. Refer to student book, about electron resonance in carboxylate ion.
2.
   a) Refer to student book section 13.3 about positive inductive effect of alkyl groups.
   b) Refer to student book section 13.3 about negative inductive effect of halogens.

The increasing order of the acidity strength follows the same order of increasing acid dissociation constant, as:

Butanoic acid < 4-chlorobutanoic acid < 3-chlorobutanoic acid < 2-chlorobutanoic acid

The explanation by using the location of the chloro-group which has negative inductive effect can also be used.

Lesson 4: Preparations of carboxylic acids and acyl chlorides (40 minutes)

a) Prerequisites

Carboxylic acids are commonly prepared from the oxidation of alcohols and aldehydes or by hydrolysis of diverse acids' derivatives such acyl chlorides, acid anhydrides, and esters.

- Oxidation of alcohols seen in unit11, year 2.
- Oxidation of aldehydes seen in unit 12, year 2.
- Reactions of organomagnesium with carbon dioxide followed by hydrolysis in acidic medium.
- Hydrolysis of nitriles in acidic/alkaline medium.
- Cleavage oxidation of alkenes seen in unit 9,year 2.
- Reactions of carboxylic acids with PCl_5,PCl_3 and $SOCl_2$ to prepare acid chlorides

b) Teaching resources

The teaching and learning resources that are needed for this lesson are:

- Student's textbooks
- Chalk board and pieces of chalk

c) Learning activities

Guidance

- This activity 13.4 can be carried out in a way that the teacher starts developing an awareness of the students about the need of preparing carboxylic acids by asking them question 1 of activity 13.4.
- He continues by guiding them to realize that they might already know some methods of preparation of carboxylic acids that they learnt in previous units. He/she asks them to have discussions in their groups and come up with some answers about question 2 of the activity 13.4.

- Ask students to present the results of their group discussions to the whole class.
- Then to the methods that students will have suggested during presentations add more others which are in the student's book, lesson 13.4. Emphasize on the fact that in case of carboxylation of organomagnesium compound or reaction of metal cyanides with alkyl halides, the carboxylic acid formed has one carbon atom more than those of the starting organic compound.

Answers to activity 13.4.1

1. There is no specific correct answer, accept any relevant opinion of the student.
2. Refer to the student book section 13.4 about preparation of carboxylic acids. The students may suggest some of the methods given this content (specifically oxidation of alcohols and aldehydes seen in unit 11 and 12).

c) Application activity

The questions in the application activity 13.4 which are found in student's book are given to students and they are asked to do them individually in their exercises books. The role of the teacher in this activity will be to assist those who prove the difficulties.

Answers to application activity 13.4.1

1.

Two stages preparation of propanoic acid from bromoethane.

$$CH_3CH_2Br \xrightarrow{Mg\ /\ ether} CH_3CH_2CO_2MgBr \xrightarrow{H_2O\ /\ H^+(aq)} CH_3CH_2CO_2H$$

Or

$$CH_3CH_2Br \xrightarrow{NaCN\ /\ ethanol} CH_3CH_2CN \xrightarrow{H_2O\ /\ H^+(aq)} CH_3CH_2COOH$$

$$CH_3CH_2OH \xrightarrow{PCl_5} CH_3CH_2Cl \xrightarrow{NaCN\ /\ ethanol} CH_3CH_2CN \xrightarrow{H_2O\ /\ H^+(aq)} CH_3CH_2COOH$$

Or

$$CH_3CH_2OH \xrightarrow{PCl_5} CH_3CH_2Cl \xrightarrow{Mg\ /\ ether} CH_3CH_2CO_2MgCl \xrightarrow{H_2O\ /\ H^+(aq)} CH_3CH_2COOH$$

2. Banana beer tastes sour after some time because ethanol in banana beer gets oxidized by oxygen into ethanoic acid which responsible for the sour taste.

Lesson 5: Reactions of carboxylic acids (80minutes)

a) Prerequisites

The reactions of carboxylic acids are classified into three main categories depending on the part of carboxylic acid that reacts: the reactions that break the O-H bond, the reactions that break the C-O bond and the reaction that concerns the carbonyl group. The reactions of carboxylic acids require the prior knowledge of:

- Acid-base reactions (neutralization reactions) .
- Reactions of alcohols (reaction with PCl_5, $SOCl_2$ and esterification reaction) seen in unit 11, year 2.

b) Teaching resources

The teaching and learning resources that are needed for this lesson are:

- Student's textbooks
- Chalk board and pieces of chalk
- Chemicals: sodium carbonate, lime water and acetic acid
- Apparatus: test tubes, rubber stopper and delivery tubes

c) Learning activities

Guidance

- This activity 13.5starts by the teacher who creates an awareness of the students about the usefulness of the reactions of carboxylic acids in synthesis of many more useful materials (question 1 and 2 of activity 13.5).
- The teacher asks the students to discuss question 3 of activity 13.5 in groups of 5 or 6 students. Here the objective is to give students the opportunity of using the knowledge they have acquired in previous units as it was indicated in prerequisite knowledge.

- Students will present the results of the group discussions from which the teacher will build her/his lesson.
- The emphasis should be put on the mechanism of esterification of alcohols and on the fact that the reaction of carboxylic acids with carbonates and bicarbonates is used a chemical test to distinguish carboxylic acids from other functional groups, especially phenols.

Answers to activity 13.5.

1. Carboxylic acids can be transformed into other more useful substances because they can undergo chemical reactions. The property that is exploited in this case is their reactivity.
2. It is possible because fatty acids can react with appropriate reagents, under appropriate conditions to form soap.
3. Refer to student's book, section 13.4 about reactions of carboxylic acids.

d) Application activity

The questions in the application activity 13.5 which are found in student's book are given to students and they are asked to do them individually in their exercises books. The role of the teacher in this activity will be to assist those who are struggling with finding answers.

Answers to application activity 13.5

1. a) Sodium hydroxide reacts with carboxylic acids in a neutralization reaction, but there is no reaction of sodium hydroxide with alcohols.

   b) During the process potassium hydroxide was neutralized by acetic acid. Since the equimolar amount of the base and the acid were mixed there was complete neutralization.

2. Refer to student's book, lesson 7.5

3. a) The student is asked to take a sample from each of the liquids and test them either using solution of sodium carbonate or methyl orange indicator. Emphasis should be put on acidic nature of carboxylic acid (Ethanoic acid), unlike alcohol (2-methylpropan-2-ol

   b) Use sodium carbonate as a chemical test that will give a positive test with carboxylic acid, but there is no observable change in case of a phenol. Note that the indicator is not appropriate because it would give similar observations in both compounds.

Lesson 6: Reactions of acyl chlorides (80minutes)

a) Prerequisites

The chemistry of acyl chlorides is dominated by nucleophilic substitutions where the chlorine atom is replaced by another nucleophile. The reactivity of acyl chlorides requires the prior knowledge of:

- Types of chemical reactions in organic chemistry (especially nucleophilic substitution reaction).
- Reaction of carboxylic acids especially those that break the bonds between C-O

b) Teaching resources

The teaching and learning resources that are needed for this lesson are:

- Student's textbooks
- Chalk board and pieces of chalk

c) Learning activities

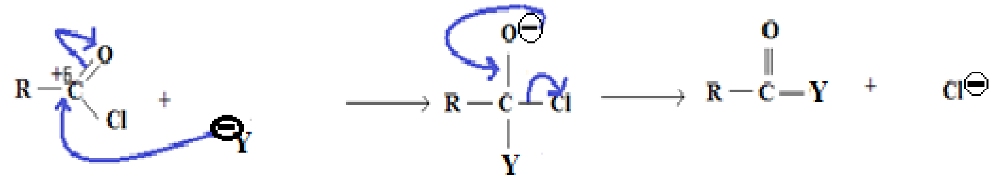
Guidance

- The fact that the content of this lesson is closely related to the other lessons discussed previously, especially reaction of carboxylic acid with alcohols; the activity 13.6 is given to students so that they can discuss it in groups by using the information of what they studied in the previous lessons of this unit.
- Allow students to present the results of their discussions. From the information given by students, explain all the types of reactions of acyl chlorides by focusing on the mechanisms of nucleophilic substitution reactions.

Answers to activity 13.6

1 a)The mechanism is called nucleophilic substitution

b)The mechanism is as follows:



The incoming atom Y^- should have a pair of electrons to donate and must have higher electronegativity than that of chlorine so that it can form stronger bond with carbon (C-Y) than that of chlorine with carbon C-Cl.

d) Application activity

The questions in the checking up activity 13.6 which are found in student's book are given to students and they are asked to do them individually in their exercises books. The role of the teacher in this activity will be to assist those who have difficulties and are struggling with finding the correct answers.

Answers to application activity 13.6

1. Tertiary amines do not react with acyl chlorides because their lone pair is stabilized by positive inductive effect of many alkyl groups (they do not easily give their lone pair of electrons) and they lack hydrogen on the nitrogen atom.
2. Acyl chlorides are acid derivatives because they are obtained from carboxylic acids by substituting -OH group by Cl-atom.
3.

d) The carbon atom in acyl group is very deficient in electrons due to O-atom and Cl-atom attached to it. It has a greater pulling force on the electron lone pairs of water molecules than the carbon which bears halogen in alkyl halides.

e) Acyl chlorides have a better leaving group Cl-atom than that of carboxylic acids -OH group, because oxygen has greater electronegativity than chlorine.

13.6. Summary of the unit

- Carboxylic acid is a class of organic compounds that are characterized by the presence of carboxyl group in their chemical formula.
- Carboxylic acids naturally occur in different substances that we normally encounter in our daily life and are also used to make various useful materials.
- Carboxylic acids are named by following the general rules of naming organic compounds, where the suffix '**oic acid'** is added to the stem name of the longest carbon chain that contains the acid functional group.
- For diacids, the suffix of the IUPAC name becomes **'dioic acid'.** They have a general formula of $HOO\text{-}C_nH_{2n}\text{-}COOH$.
- Unsaturated acids (alkenoic acids) are systematically named by changing the stem suffix **'-an'** to **'-en'.**

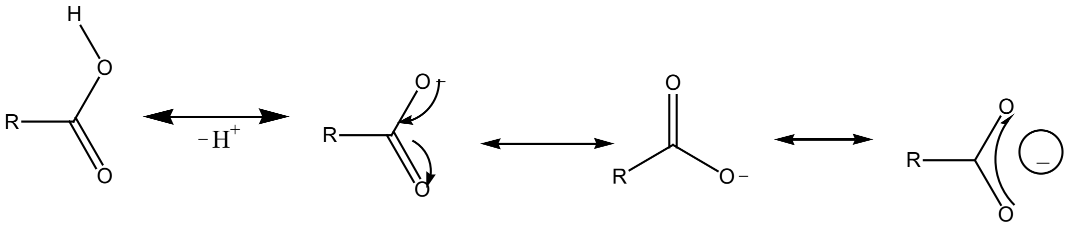
- Hydroxy-acids are named by considering -hydroxyl group as a substituent on the longest carbon chain that contains carboxylic functional group.
- Carboxylic acids show diverse types of isomers either among themselves or with other compounds that have different functional groups. The common isomers are chain isomers, functional isomers, and optical isomers.
- Carboxylic acids are polar molecules that interact by double strong hydrogen bonds in a dimeric structure. Many carboxylic acids are colourless liquids with disagreeable odours at room temperature and pressure.
- Carboxylic acids have high melting and boiling points which increases as the molecular weight increases, because the molecules interact by strong hydrogen bonds.
- The boiling and melting points of carboxylic acids are higher than those of their alcohols counterparts due the formation of a strong dimer by carboxylic molecules.
- They are generally soluble in water because they form hydrogen bonds with molecules of water.
- Carboxylic acids are acidic because they have ionizable hydrogen and they dissociate in water to release very few hydrogen ions. They are weak acids.
- The presence of a group with positive inductive effect in the structure of the molecule reduces the acidity strength, whereas the group with a negative inductive effect increases their acidity strength.
- Carboxylic acids are common and vital functional group; found in amino acids, fatty acids etc. and provide the starting raw material for acid derivatives such as acyl chlorides, amides, esters and acid anhydrides.
- Different carboxylic acids can be prepared by oxidation of either primary alcohols or aldehydes. In the process, the mixture of alcohol is heated under reflux with an oxidizing agent such acidified potassium permanganate or potassium dichromate.
- Carboxylic acids can be prepared from oxidation of either primary alcohols or aldehydes by oxidizing agent such acidified potassium permanganate or potassium dichromate.
- Hydrolysis of nitriles in acidic or alkaline conditions forms carboxylic acids.

- Carboxylation of Grignard reagents leads to formation of carboxylic acid with one carbon atom more than the number of carbon atoms in the original organic compound.
- Hydrolysis of diverse derivatives of carboxylic acids also form the parent carboxylic acid.
- Reactions that break the bond between O-H bond are typical reactions of a carboxylic acid compound as an acid (reaction with metals and bases).
- Reactions that break the C-O bond are considered as nucleophilic substitution reactions (esterification, reaction with ammonia and amines, PCl_5, $SOCl_2$...)
- Reducing agents such as $LiAlH_4$ in dry ether or H_2 in the presence of nickel catalyst yields primary alcohols.
- Carboxylic acids occur naturally in fats, acidic dairy and citrus fruits, they are mainly used in food industry, pharmaceutical and other industries directly or as the starting material to synthesize other materials that are used in those industries.

13.7 Additional information for the teacher

13.7.1 Acidity of carboxylic acids

The acidity of carboxylic acids can be explained by the fact that the carboxylate ion formedwhen the acid releases hydrogen ion is stable. The carboxylate ion formed by ionization of the acid is more stable than the acid because it has many resonance structures.



I II III

Structures I, II, III are results of the resonance of the carboxylate ion, where the carbon-oxygen bond lengths are equal and C-O length is between than of C-O and pure C=O.

The values of acid dissociation constant, Ka, express the acidity strength. The greater the Ka value, the stronger the acid and vice versa. On the other hand,

p^{Ka} which is defined as the negative log of Ka, as its value becomes smaller if the acid is stronger and vice versa.

Table: Dissociation constants of some carboxylic acids

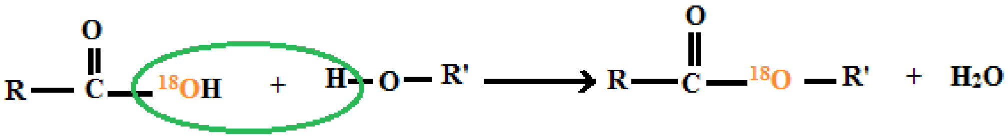
Molecule	**K_a value**	$pK_a = -\log K_a$
H-COOH	1.77×10^{-4}	3.80
CH_3-COOH	1.75×10^{-5}	4.75
CH_3CH_2-COOH	1.8×10^{-5}	4.90
$CH_3CH_2CH_2$-COOH	1.5×10^{-5}	5.20
$ClCH_2$-COOH	1.36×10^{-3}	2.9
Cl_2CH-COOH	4.5×10^{-2}	1.25
Cl_3C-COOH	2.2×10^{-1}	0.70
HOOC-COOH	1.47×10^{-4}	1.2
F_3C-COOH	3.0×10^{-1}	0.52

For example, methanoic acid with bigger K_a value is stronger acid than ethanoic acid whose smaller Ka value.

Different Ka values given in the above table can be explained by **inductive effect** which is the tendency of an atom or group of atoms to either donate or withdraw electrons from the atom they are attached to.

13.7.2. Reaction of carboxylic acids with alcohols (80minutes)

To understand the mechanism of esterification they used an alcohol with oxygen-18 isotope and in carboxylic acid oxygen-16 isotope and after the reaction the ester was found to contain oxygen-18 and in water there was oxygen-16. The conclusion about these observations was that in esterification reaction the acid loses -OH while the alcohol loses H-atom.



Guidance to skills lab 13

The teacher collects the required materials and chemicals in each question of the skills lab.

The learners are given instructions and the procedures to carry out the chemical test for in laboratory.

The learners are given the opportunity to perform the experiment, deduce and interpret the results.

Q1. The learners will perform the experiment to develop the spirit and self-confidence of working in laboratory ,develop a sense of analysis and to respect diverse opinions when discussing

Q2. IDEM AS Q1

Q3.The teacher will give the opportunity to discuss diverse ideas and he/she will harmonise after

a. The wine has a sour taste
b. Alcohol in wine oxidises to carboxylic acid
c. The PH is in acidic medium

End unit assessment

Answers to end unit assessment 13

Multiple choice questions

A , A , D, B, A

Open questions

6. Increasing order of the boiling point is: Propanal< propan-1-ol < Propanoic acid

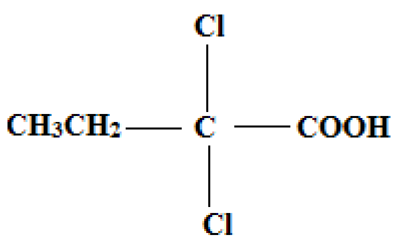
Propanal: Has low boiling point because molecules interact by weak Van der Waals

Propan-1-ol: molecules interact with strong hydrogen bonding

Propanoic acid: has the highest boiling point because molecules interact by double hydrogen bonding that leads to formation of dimeric structure.

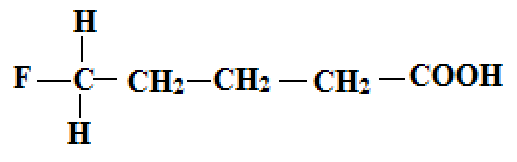
7.

The strongest acidic isomer of dichlorobutanoic acid is



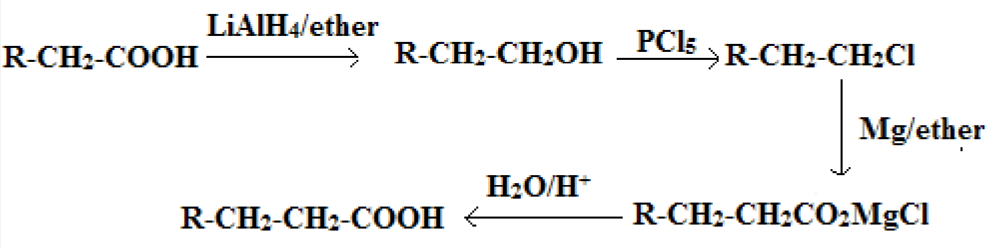
$CH_3CH_2-CCl_2-COOH$

The least acidic isomer fluoropentanoic acid is



$F-CH_2-CH_2-CH_2-CH_2-COOH$

8.



9.

The names and the formula of compounds:

A.CH_3COCl: Ethanoyl chloride

B.CH_3CONH_2: Ethanamide

C.$CH_3COOCH_2CH_3$: Ethyl ethanoate

Refer to the student's book, section 13.6 about reaction of acyl chlorides.

10. Use the idea that the boiling point increases as the molecular mass increases

Formula	Boiling point (^0C)
$CH_3—CO_2H$	141^0C
$CH_3(CH_2)_{10}—CO_2H$	299^0C
$CH_3(CH_2)_3—CO_2H$	186^0C
$CH_3CH_2—CO_2H$	118^0C

11. a. Refer to student's book, lesson 6 about reactions of carboxylic acids.

    b.Refer to student's book, lesson 6 about preparations of carboxylic acids.

12.Given the samples of A and B, after the tests and the observations noted;

   a) A is an acyl chloride because it the derivative of carboxylic acid that produces white fumes of HCl when it is reacted with water.

   b) B is a carboxylic acid because it is the organic compound that reacts with carbonates or bicarbonates and effervescence is observed.

13.8 Additional activities

13.8.1 Remedial activities

These remedial activities are given to students that are struggling with the understanding of the concepts learnt in the lesson. They are to help those learners to catch up with what they did not well understood.

Questions

1. Give the systematic names of the following organic compounds
   - a) CH_3-CH(CH_3)-CH_2-CH(CH_3)-COOH
   - b) CH_3-CH(OH)-CH_2-CH_2-COOH
   - c) HOOC-CH_2-CH_2-COOH
2. Explain the following observations:
   - a) Propanoic acid has lower boiling point than that of pentanoic acid
   - b) Ethanol is much more volatile than ethanoic acid
   - c) The palmitic acid forms two layer with water when they are mixed, but acetic acid mixes with water in all proportions.

3. Acetic acid, unlike ethanol, readily reacts with ammonia solution to form ammonium and acetate ion. Explain the property that acetic acid has which makes it behave in this way.

4. Complete the following reactions:

   a) $CH_3\text{-}CH_2\text{-}CH_2\text{-}COOH$
   b) $CH_3COOH + CH_3CH(OH)CH_3$
   c) $CH_3COOH\ (aq) + NaHCO_3(aq) \rightarrow$

5. Describe how you can prepare;

   a) Propanoic acid from propan-1-ol

   b) Acetic acid from bromomethane

Answers

1.

   a) 2,4-dimethylpentanoic acid
   b) 4-hydroxypentanoic acid
   c) Butanedioic acid

2.

   a) Propanoic acid has lower boiling point than pentanoic acid because pentanoic acid has stronger Van der Waals forces due to its higher molecular mass than that of propanoic acid.
   b) Ethanol is in more volatile than ethanoic acid because the hydrogen bonds in ethanol are weaker. Ethanoic acid molecules form double hydrogen bonds that result in the formation of dimeric structure, and this makes it less volatile.
   c) The solubility of carboxylic acids decreases as the molecular size increases. This causes the Van der Waals forces between hydrophobic parts of the molecule to dominate hydrogen bonds between molecules of water. Palmitic acid being a large molecule is less soluble in water than acetic acid that is very small.

3. Acetic acid readily reacts with ammonia solution because it has acidic properties, where it readily donates a proton to ammonia which is a base.

4. Complete the following reactions:

   a) $CH_3\text{-}CH_2\text{-}CH_2\text{-}COOHCH_3\text{-}CH_2\text{-}CH_2\text{-}COCl + SO_2 + HCl$
   b) $CH_3COOH + CH_3CH(OH)CH_3CH_3COOCH(CH_3)_2 + H_2O$
   c) $CH_3COOH\ (aq) + NaHCO_3(aq) \rightarrow CH_3COONa\ (aq) + H_2O(l) + CO_2(g)$

5.

a) $CH_3CH_2CH_2OH + KMnO_4(aq) \longrightarrow CH_3CH_2COOH + K^+(aq) + Mn^{2+}(aq) + H_2O(l)$

b) $CH_3Br \xrightarrow{Mg/ether} CH_3MgBr \xrightarrow{CO_2} CH_3CO_2MgBr \xrightarrow{H_2O/H^+} CH_3COOH$

13.8.2 Consolidation activities

These are additional activities given to all students for more practice about all the lessons learnt.

Questions

1. Complete the following reactions and identify the compounds represented by the bold letters:

   a) $CH_3CH_2Br + CO_2(g)$ **A B** + $Mg(OH)Br$

   b)

   $$\boxed{C} + \boxed{C_2H_4O_2} \underset{}{\overset{H^+(aq)}{\rightleftharpoons}} \boxed{CH_3COOC(CH_3)_3} + \boxed{H_2O}$$

   c) $CH_3CH_2COOH \;\; (CH_3CH_2CO)_2O$

2. Use the following experiment information to answer related questions:

Formula	Molar mass (g/mol)	Melting point (^0C)	Boiling point (^0C)
$HCOOH$	46	8	100.5
CH_3COOH	60	17	118
CH_3OH	36	-98	65
CH_3CH_2OH	46	-114.1	78.4

a) How is the boiling point of ethanoic acid greater than that of methanoic acid?

b) Explain why the boiling point of methanoic acid is greater than that of ethanol despite of their molecular masses that are the same.

Answers

1.

a) A: $CH_3CH_2CO_2MgBr$ **and** **B:** CH_3CH_2COOH

b) C: $(CH_3)_3COH$

c) D: P_2O_5

2.

a) The boiling point of carboxylic acids increases as the molecular mass increases. Since ethanoic acid has greater molecular mass than that of methanoic acid, it has greater boiling point.

b) Methanoic acid molecules interact by stronger double hydrogen bonds in dimeric structure, which is not formed in ethanol.

13.9. Extended activities

Questions

1. a) Suggest a series of reactions by which ethanol can be converted to 2-hydroxypropanoic acid. For each reaction specify the reagents and conditions necessary.

   b) Explain whether the solution of 2-hydroxypropanoic acid, made in this way, would have any effect on plane polarized light.

   c) 2-hydroxypropanoic acid reacts with lithium tetrahydridoaluminate (III), $LiAlH_4$. State the conditions necessary for this reaction and give the structure of the organic product formed.

2. Esters are products of the reaction between carboxylic acids and alcohols.

   a) Draw the structure of the organic product of the reaction between propan-2-ol with propanoic acid

   b) Explain the alternative way this ester can be prepared by using another reagent in place of propanoic acid.

3. Describe how the following pairs of compounds can be distinguished by a chemical test.

a) CH_3COOH and CH_3COCl

b) Propanoic acid and propan-2-ol

Answers

1.

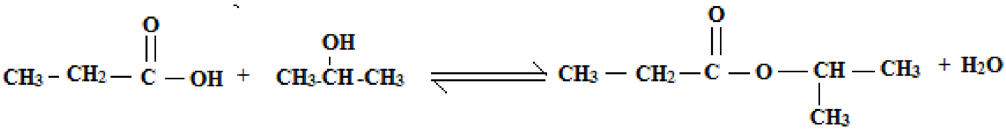
a) CH_3 CH_2OH CH_3CHO $CH_3CH(OH)CN$

b) $CH_3CH\ (OH)\ COOH$

c) Refer to student's book, lesson 7.1 about nomenclature and isomerism

d) This reaction takes place in dry ether. The organic product formed is propan-1,2-diol: $CH_3CH(OH)CH_2OH$

2. a)



$$CH_3-CH_2-\overset{O}{\overset{\|}{C}}-OH + CH_3\text{-}\overset{OH}{\overset{|}{C}H}\text{-}CH_3 \rightleftharpoons CH_3-CH_2-\overset{O}{\overset{\|}{C}}-O-\underset{CH_3}{\underset{|}{CH}}-CH_3 + H_2O$$

b) The same ester can be prepared by using propanoyl chloride.

3.

a) The chemical test that can be used is Sodium carbonate (Na_2CO_3).

With ethanoic acid, there is formation of carbon dioxide that results in effervescence

With ethanoyl chloride, there is no effervescence

b) Acidified potassium permanganate/dichromate can be used.

With propan-2-ol, orange/purple colour turns to green/colourless colour

With propanoic acid, there is observable change.

Or

The chemical test that can be used is Sodium carbonate (Na_2CO_3).

With propanoic acid, there is formation of carbon dioxide that results in effervescence

With propan-2-ol, there is no effervescence

UNIT 14

ESTERS, ACID ANHYDRIDES, AMIDES AND NITRILES

14.1. Key unit competence

Relate the functional groups of esters, acid anhydrides, amides and nitriles to their reactivity, preparation methods and uses.

14.2. Introduction

Students will learn better esters, acid anhydrides, amides and nitriles if, in the previous units, they have understood chemical bonding (Year 1), chemistry of alcohols (Year 2) and chemistry of carboxylic acids (Year 2: unit 13). You will use various techniques such as discussions, you will help learners to recap the above concepts before you start unit 14.

14.3. Cross-cutting issues to be addressed

a) Inclusive education: This unit will involve the physical and chemical properties of acid derivatives and their uses in our everyday life and then, the use of molecular structures and many practical activities is obvious. This may be challenging to students with special educational needs especially students with visual and upper and lower limb impairment. However, these students can be catered for in every lesson by using different techniques which are explained in the general introduction. Refer to the general introduction of this book for more information.

b) Gender: You should always remember that there is no activity reserved for boys only or girls only. Try to involve both of them in each and every learning activity.

c) Financial education: This unit tackles the chemistry and uses of esters, acid anhydrides, amides and nitriles, the teacher will explain how processes such as saponification are income generating. S/He shall also indicate various manufactures which use acid derivatives and that can make a good starting point for young entrepreneurs.

d) Peace and values education: During group activities, you will encourage learners to help each other and to respect other's opinions.

e) Standardization culture

You should remind learners to always check if they are not using expired chemicals or defective apparatus.

In addition, they must be trained to record data accurately and present accurate results.

f) Environment and sustainability

In order to avoid the environment pollution, before, during or after experiments learners have to not throw away chemicals anywhere.

During the lesson of saponification you will tell learners the impacts of using soap less detergents on the environment.

14.4. Guidance on the introductory activity

Introductory activity 15 minutes

- Help learners to form groups of four members, explain what is to be done, and then let them work out the introductory activity.
- You must be sure that all group members are participating.
- Each group will note down the observations made from the pictures in the activity and write answers for the given questions in their books.
- Randomly, you will choose 2 to 3 groups to present the outcomes of their work to the others. Here you should take note of the key points from presentations as they help you to know what to add, what to correct…

After presentations, you have to engage the class into exploitation of the students' productions. They discuss on the presentations to decide if they are correct, complete and if more information is needed. Here you will act as a moderator but you will also have to add, correct or remove some information. After harmonization you will provide a short summary of the activity and start the new unit.

Answers for the questions in the introductory activity

1. Nylon textile is used to make umbrella because it is impermeable
2. Urea is synthesized by reacting ammonia and carbon dioxide. It can also be prepared from calcium carbide.
3. Since the beginning of production of artificial esters which have fruity smells, the food industry has become able to make artificial drinks with fruity flavours. To the sugary liquid they prepare, they add flavours of various fruits.

4. The pain killer drug, aspirin, is manufactured by a reaction between salicylic acid and ethanoic anhydride. It is an example of one of the methods of preparing esters.
5. Chemicals which give fragrances to perfumes are esters.

14.5. List of lessons

Lesson n°	Lesson title	Learning objectives	Number of periods
1	• Nomenclature, structure of esters. • Physical properties of esters and uses.	• Apply IUPAC rules to name esters • Compare physical properties of esters to those of alcohols and carboxylic acids • State uses of esters	2
2	• Preparation and Chemical properties of esters.	• Describe the chemical properties of esters	2
3	• Saponification and detergents	• Make soap and compare its properties with those of soapless detergents.	1
4	• Structure and nomenclature of acid anhydrides.	• Apply IUPAC rules to name acid anhydrides	1
5	• Physical and chemical properties, preparations of acid anhydrides. • Uses of acid anhydrides.	• Describe the physical properties and chemical properties of acid anhydrides • Describe the and preparation methods of acid anhydrides • State and explain the uses of acid anhydrides	2

6	• Structure and nomenclature of amides. • Physical properties of amides. • Uses of amides like urea in chemical industry, medicine, niche, agriculture etc	• Classify amides as primary, secondary and tertiary • Apply IUPAC rules to name amides • Describe the physical properties of amides • State and explain the uses of amides	3
7	• Preparations of amides • Chemical properties of amides (reduction reaction, reaction with water / acid, Hoffman degradation reaction and reaction with nitrous acid, dehydration reaction and alcohols).	• Describe the preparation methods of acid amides • Compare the reactivity of amides to that of esters and acid chlorides • Describe the chemical properties of amides	3
8	• Structure ,nomenclature, Physical properties and uses of some nitriles.	• Apply IUPAC rules to name nitriles • Describe the physical properties of nitriles • State the uses of nitriles	1
9	• preparation methods of nitriles. • Reactions of nitriles (hydrolysis and reduction).	• Describe the preparation methods of nitriles • Describe the chemical properties of nitriles	1
10	End unit assessment		1

Lesson 1: Nomenclature, structure, physical properties and uses of Esters (80 minutes)

a) Prerequisites

This lesson will be well delivered if students have a good understanding of how to draw structures of organic compounds and the reactions of carboxylic acids. You should find a way of testing the understanding level of your learners. You can use an exercise or a short discussion.

b) Teaching resources

Student book and reference books from library or internet, basic organic chemicals and apparatus

c) Learning activities

You will have to introduce briefly the unit. After that learners will attempt the introductory activity first and then activity 14.1.

Guidance

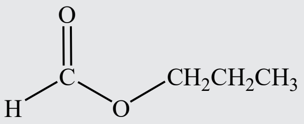
As a facilitator, the teacher is expected to guide learners through the following steps:

- In groups learners used in the introductory activity, they will discuss on questions in activity 14.1 answer them. The discussion will be done in groups but let each learner write answers in her/his exercise book. The teacher must be sure that all learners are involved in the activity. Each group must have a leader who will be moderator and a secretary who writes the report and will present findings of the group.
- Move around the class, listening to students as they discuss and provide support where needed.
- Have a sample group present their findings to the class.
- Valuing learners' presentations(judgment and discovery of possible mistakes by students)
- This is diagnostic activity; the next step will greatly depend on your judgment. If your class can not correctly answer the question, extra explanations and exercises are necessary. But if they are correctly answered then the teacher can proceed and give a summary of the first part of the lesson. A summary of the content must be written on the board.

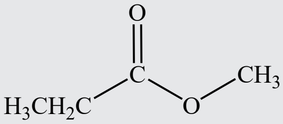
Answers to activity 14.1

Acid derivatives	**Carboxylic acids**	**Alcohols**	**Carbonyl compounds**
$CH_3CH_2CH_2CONHCH_3$ $CH_3CH_2CH_2COOC(CH_2)_2CH_3$ $CH_3CH_2CH_2CONH_2$ $CH_3CH(CH_3)CN$	$CH_3CH_2CH_2COOH$ $CH_3CH(CH_3)COOH$	$CH_3CH_2CH_2CH_2OH$ $CH_3CHOHCH_2CH_3$	$CH_3CH_2COCH_3$ $CH_3CH_2CH_2COH$

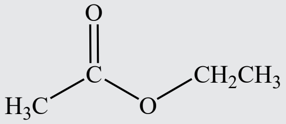
Isomers of molecular formula $C_4H_8O_2$



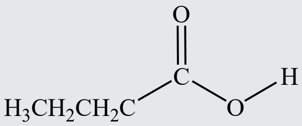
A



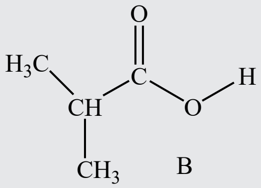
A



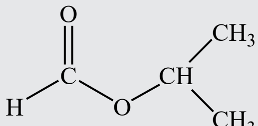
A



B



B



A

Experiment.

- As the second part involves an experiment this lesson must be taught in the school laboratory.
- The teacher will prepare necessary apparatus and chemicals. ***Note***: It is always better for the teacher to carry out the experiment before you bring learners in the laboratory.
- Learners will work in groups. Here groups can be changed to help students with special educational needs who may be present. Learners with visual or mobility impairment must be with colleagues who can help them. These students will not manipulate but they can be allowed to give instructions of how to proceed.
- Each group performs the experiment and record the results.
- When time is up, the teacher will choose some groups to present their observations.
- All students will take time to discuss, guided by the teacher, the inferences of each observation.

- The teacher must provide the necessary extra information and explanations.
- A summary of the second part of the lesson should be written next to that of the first part on the board.

Findings for the experiment in lesson 14.1.

Refer to the student's book. Conclusion of activity 14.1

Answers to application activity 14.1.

1. Names

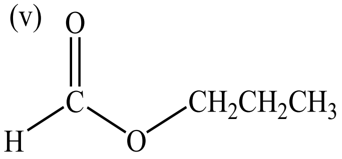
(i) methyl propanoate

(ii) ethyl propanoate

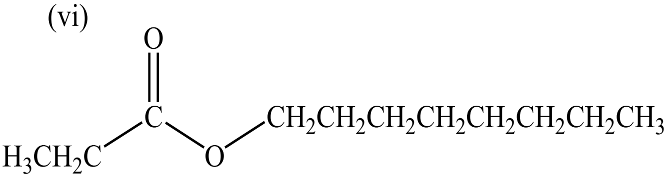
(iii) propyl propanoate

(iv) isopropylmethanoate

(v)

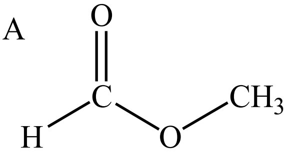


(vi)

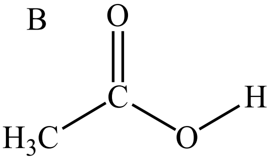


2. Like all organic compounds esters are insoluble in water but soluble in organic solvents. However lower esters are slightly soluble in water because they can form hydrogen bond with water molecules but this solubility decreases as the size of the hydrocarbon part increases.
3. Esters are used in food industry to give fruity flavours various products. They are also used in perfume industry because of their pleasant odours…
4. Compound A is an ester, it lacks hydrogen bond. Compound B is a carboxylic acid with strong hydrogen bond.

A



B



These compounds are functional group isomers. This is because they have same molecular formula but belong to different homologous series. Mark the work of learners to evaluate the achievement of your objectives.

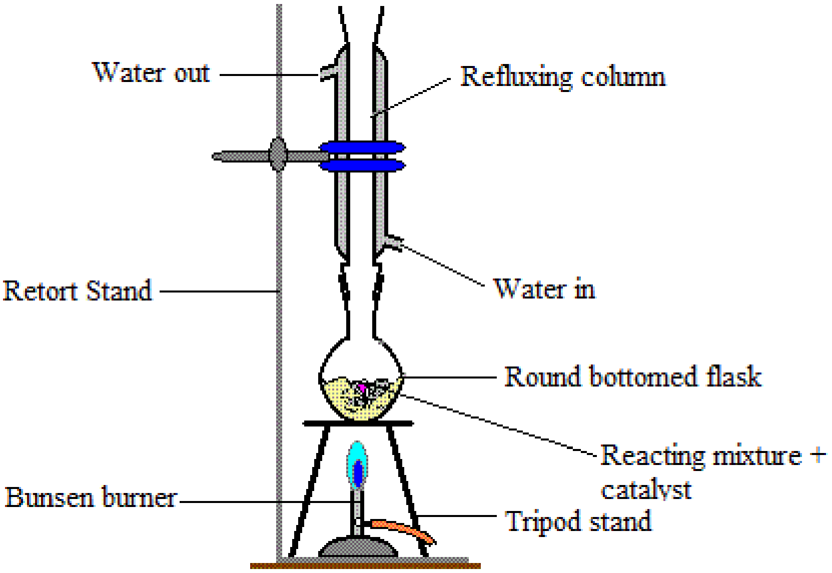
Lesson 2: Preparation and Chemical properties of Esters (80 minutes)

a) Prerequisites

This lesson will be well delivered if students have a good understanding of how to draw structures of organic compounds and reactions of carboxylic acids with alcohols as well as the preparation of alcohols or carboxylic acids from esters, covered in unit 11 and unit 14. Give some exercises to help learners recap reactions of alcohols and carboxylic acids.

b) Teaching resources

Student book, reference books or internet, ethanol, ethanoic acid and concentrated sulphuric acid and the set up shown below:



c) Learning activities

Briefly explain what students are going to do and let them carry out the experiment described on point number 4 of activity 14.2 in the student's book.

Guidance

As a facilitator, the teacher is expected to guide learners through the following steps:

- You will prepare necessary apparatus and chemicals, help learners make groups and give a brief explanation of what is to be done.
- ***Note***: It is always better for the teacher to carry out the experiment **before**

you bring learners in the laboratory. You should also find ways of helping learners with various special needs.

- For points 1, 2 and 3 of the activity the discussion will be done in groups and the report will be written by the secretary of the group. However, you should encourage all group members to keep a copy of the report in their own exercise books.
- Point number 4 of this activity is practical. Learners will prepare ethyl ethanoate guided by the teacher. Each group will need an esterification set up (shown in the teaching activity above), 20ml of acetic acid and 20ml of ethanol and 3drops of concentrated sulphuric acid. They will mix them carefully and heat the mixture for ten minutes. The mixture will then be poured into cold water and students will smell the resulting solution. You should remind learners to be careful when handling concentrated sulphuric acid.
- Move around the class, listening to students as they discuss and help groups which may have difficulties in starting the activity.
- Choose 2 to 3 groups to present their findings to other students.
- After presentation, engage learners in a discussion on the answers given by different groups provide necessary complementary information and explanations. From this discussion a summary of the lesson must be given to students.
- Before closing your lesson, should reserve some minutes to discuss with students the environmental impacts of acidic wastes.

Answers to activity 14.2.

1.(i) Physical method:

Mixing different available esters to produce a new odour which is an intermediate of the odours of the mixed esters.

(ii) Chemical method.

Produce new esters chemically by reacting alcohols and carboxylic acids to produce new esters. Use available esters and transform them chemically by reacting them with alcohols through trans Esterification.

2. Organic compounds used are: ethanol and propanoic acid.

$$CH_3CH_2OH + CH_3CH_2COOH \xrightleftharpoons[\text{Reflux}]{H_2SO_4\text{ conc}} CH_3CH_2OCOCH_2CH_3 + H_2O$$

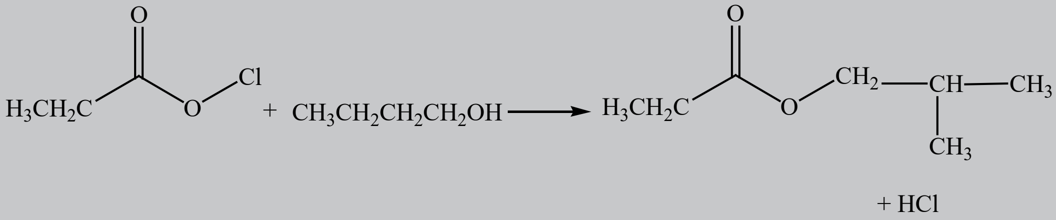
For questions 3, 4 and 5 refer to the student's book unit 8, summary of lesson 4.

Learners will attempt application activity 14.2 to assess the achievement of your learning objectives.

d) Application activity

Answers to application activity 14.2.

1.



Name of the product: Isobutyl propanoate

2.

a

$$CH_3CH_2CH_2OH \xrightarrow[\text{Reflux}]{Cr_2O_7^{=}\ /\ H^{+}} CH_3CH_2COOH$$

$$CH_3CH_2COOH + HOCH_2CH_2CH_3 \xrightleftharpoons[\text{Reflux}]{H_2SO_4\ \text{conc}} CH_3CH_2COOCH_2CH_2CH_3 + H_2O$$

b

$$CH_3CHO \xrightarrow[\text{Reflux}]{MnO_4^{-}\ /\ H^{+}} CH_3COOH$$

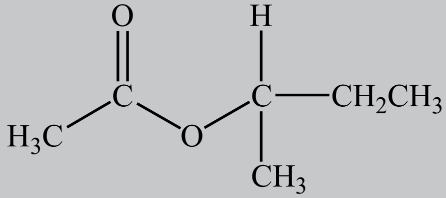
$$CH_3CHO \xrightarrow[\text{Ether}]{LiAlH_4} CH_3CH_2OH$$

$$CH_3COOH + CH_3CH_2OH \xrightarrow[\text{Reflux}]{H_2SO_4\ \text{conc}} CH_3COOCH_2CH_3 + H_2O$$

3. (a)Structure of the alcohol

$CH_3CH_2CHOHCH_3$

(b) Structure of the ester

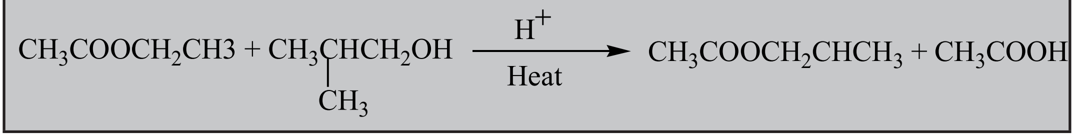


4. a. $CH_3CH_2COOCH_3 + NaOH \rightarrow CH_3CH_2COONa + CH_3OH$

b. $CH_3CH_2OOCH + CH_3NH_2 \rightarrow HCONHCH_3 + CH_3CH_2OH$

c. $CH_3COOCH_3 + 2CH_3MgCl \rightarrow CH_3C(CH_3)_3OH + IMgOH + CH_3OMgI$

5. Conditions for reaction 1.a: NaOH must be in aqueous solution and heat must be provided.
6. This reaction produces amides but with a small yield and therefore it is not preferred. Instead acid chlorides are used for the same purpose as they give more yield. Esters react faster with acid chlorides than with amines.
7. Given ethyl ethanoate to prepare isobutyl ethanoate you can carry out a trans-esterification using 2-methylpropan-1-ol.



$$CH_3COOCH_2CH3 + CH_3\underset{\displaystyle CH_3}{\underset{|}{C}}HCH_2OH \xrightarrow[\text{Heat}]{H^+} CH_3COOCH_2CHCH_3 + CH_3COOH$$

Find an appropriate method of marking the work of learners to find out how the lesson was understood.

Lesson 3: Saponification and Detergents (40 minutes)

a) Prerequisites

This lesson will be well delivered if students have a good understanding of alkaline the knowledge of triglyceride structures and esters will also help much. This lesson is linked to biology (lipids). Find a way of checking the understanding of your learners.

b) Teaching resources

Student book, NaOH, cooking oil, ethanol, NaCl, heater and glassware.

c) Learning activities

Give a brief introduction on the lesson and explain the objective of the experiment (the practical part of the activity). You should set up instructions and a protocol which will guide learners during the practical work.

Notice that the process will continue as Skill Lab to allow learners to deepen the topic

Guidance

As a facilitator the teacher is expected to guide learners through the following steps:

- The activity 14.3 is similar to activity 14.2 and you may refer to it for an appropriate preparation. However, in addition to the guidance provided in activity 14.2, you will provide to each group some cooking oil and concentrated aqueous caustic soda.
- They will mix the two liquids and add some ethanol to facilitate dissolution of oil. The resulting mixture will be heated for ten minutes in a borosilicate beaker. The mixture will then be poured into cold water and students will smell the resulting solution. From the smell they will try to identify the product.
- Choose sample groups to present their findings to other students and after presentation, engage learners in a discussion on the answers given by different groups provide necessary complementary information and explanations. From this discussion you will give a summary of the lesson.
- Before closing your lesson, should reserve some minutes to discuss with students the environmental impacts of acidic wastes.
- Saponification is an economically important reaction and time should be provided to discuss about the benefits of knowing this reaction and being able to make soaps. You should also discuss about the dangers of using soapless detergents.

Answers to activity 14.3.

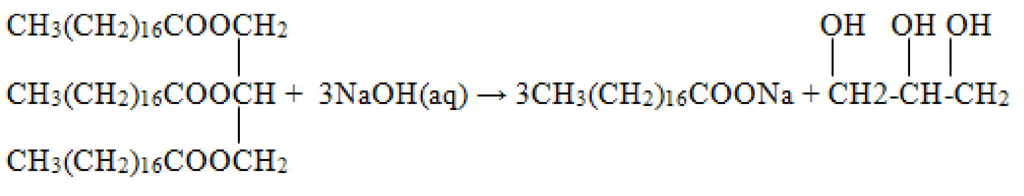
1. Soaps and detergents are used in our everyday life for cleaning.
2. Their molecule has two parts: the hydrophobic part which is insoluble but soluble in oil and the hydrophilic part which is soluble in water.
3. Soaps are manufactured by reacting oil of fat with a strong base such as NaOH or KOH. Detergents are prepared by using petroleum derivatives (which have hydrophobic and hydrophilic parts) and NaOH.
4. Both have cleaning properties and molecules made of two parts cited above. Detergents are not prepared by saponification because we do not use oil or fat. Detergents are more effective than soaps because they do not form scum with water. Their magnesium and calcium salts are soluble in water. They foam very easily so that they are used in small quantity.
5. Take some oil mix with NaOH (aq) and heat the mixture. It is better to add some ethanol to facilitate dissolution of oil. After heating, pour the mixture in a concentrated solution of NaCl to precipitate out the salt.

Application activity

To assess your lesson, let students work out application activity 14.3.

Answers to application activity 14.3.

1.(a)



$$\begin{matrix} CH_3(CH_2)_{16}COOCH_2 \\ | \\ CH_3(CH_2)_{16}COOCH \\ | \\ CH_3(CH_2)_{16}COOCH_2 \end{matrix} + 3NaOH(aq) \rightarrow 3CH_3(CH_2)_{16}COONa + \overset{\overset{OH}{|}}{CH2}\text{-}\overset{\overset{OH}{|}}{CH}\text{-}\overset{\overset{OH}{|}}{CH_2}$$

(b) Molecular mass of propyl tristearate: 891g/mol

From the balanced equation 819g of oil react with 120g of NaOH

4000g will react with = (4000x120):891 = 538.72g of NaOH

Mass of soap produced:

From the balanced equation 891g of oil produce 918g of soap.

4000g will produce= (4000x918):891= 4121.21g of soap

2. Liquid soap is produced by reacting oil or fat with KOH but solid soap is prepared by reacting oil or fat with NaOH. Electrostatic forces between the hydrophilic part of soap and sodium cation are stronger than with potassium cation.

3. Soap is prepared by using oil or fat but detergent are prepared using other chemicals such as sulfonic acids.

4. Detergents are more effective than soaps because they do not form scum with hard water. Their calcium or magnesium salts are soluble in water. They produce foam easily so that they are used in smaller quantity than normal soap in hard water.

5. Refer to the student's book point 8.3.

6. Soaps and detergents are cleaning agents that help us getting rid of dirt, harmful microorganisms. However they may also be a source of pollution. Most detergents are non-biodegradable.

Note: the teacher should consider answers of students with the same information as the one given here but written in other words. Mark the work of learners or make a correction and ask them to correct one another to find out how the lesson was understood

Lesson 4: Structure and nomenclature of Acid anhydrides(40 minutes)

a) Prerequisites

This lesson will be well delivered if students have a good understanding of how to draw structures of organic compounds and reactions of carboxylic acids. Find a way of checking the understanding of your learners.

b) Teaching resources

Student's book, reference books or internet

c) Learning activities

After checking the prerequisites of your learners, you will let them work out activity 14.4.

Guidance

You are expected to guide learners through the following steps:

- Organize the class in groups for the activity. Provide necessary instructions and let them discuss. After discussion you will choose sample groups and invite their representatives to present the findings. Remember to help learners with disabilities
- Move around the class, listening to students as they discuss and help groups which may have difficulties in starting the activity.
- After presentation you will ask learners to evaluate the given answers. They must will decide which results are correct, incorrect, poor, …
- After learners' evaluation, you will summarize the knowledge and give some examples which illustrate the content learnt.
- Before closing your lesson, should reserve some minutes to discuss with students the need of standardization culture. One of the uses of acid anhydrides is to synthesize aspirin. Based this use, remind learners to always check the expiry dates on medicines.

Answers to activity 14.4

1. Acetic anhydride or ethanoic anhydride
2. Preparing aspirin using ethanoic acid would require an acidic catalyst which also catalyses the reverse reaction, hydrolysis of the produced ester hence reducing the yield.
3. $CH_3COOOCCH_3$
4. It is prepared by dehydration of acetic acid using P_2O_5 or $SOCl_2$.

Application activity

Tell students to attempt individually application 14.4.

Answers to application activity14.4

1.$C_6H_{10}O_3$

2.$CH_3CH_2COOOCCH_2CH_3$(A) or $CH_3COOOCCH_2CH_2CH_3$(B) Straight isomers

3.$CH_3CH(CH_3)COOOCCH_3$ (C) Branched isomer

A: propanoic anhydride B: butanoic ethanoic anhydride C: ethanoic 2-methylpropanoic anhydride. You can mark the work of learners or make a correction and ask them to correct one another to find out how the lesson was understood

Lesson 5: Preparation, chemical properties and uses of acid anhydrides

This lesson has 80 minutes (2periods). It will describe different methods of preparing acid anhydrides and their reactions.

a) Prerequisites

A good understanding of reactions of carboxylic acids and preparation methods of esters will help learners in this lesson. You should then organize a short discussion to help them recall those two points.

b) Teaching resources

Internet or reference books and student's book

c) Learning activities

Invite students to try to answer questions in activity 14.5.

Guidance

In this lesson you will guide learners through the following steps:

Follow the methodological steps used in activity 14.4 and in addition to that remind your learners the need of proper waste disposal for environmental sustainability.

Answers to activity 14.5

1. This is because in addition to the desired acid anhydride, two symmetrical acid anhydrides of the parent acids used in the preparation will be produced.

2. A better method of preparing mixed acid anhydrides is to use a salt of one carboxylic acid and an acid chloride of another acid.

$CH_3COCl + CH_3CH_2COONa \rightarrow CH_3COOOCCH_2CH_3 + NaCl$

3. Refer to the student's book. Lesson 8.5.1

4. Refer to the student's book. Lesson 8.5.2

Next will be the assessment time. They will attempt all questions in activity 14.5.

d) Application activity

Answers to application activity 14.5

1. a)

$$CH_3CH_3OH \xrightarrow[\text{Heat}]{MnO_4^- / H^+} CH_3COOH$$

$$2\,CH_3COOH \xrightarrow{P_2O_5} CH_3COOOOCCH_3 + H_2O$$

b)

$$CH_3CH_2OH + HCl \xrightarrow{ZnCl_2} CH_3CH_2Cl + H_2O$$

$$CH_3CH_2Cl + Mg \xrightarrow{\text{Dry ether}} CH_3CH_2MgCl$$

$$CH_3CH_2MgCl + CO_2 \xrightarrow{H_2O} CH_3CH_2COOH + ClMgOH$$

$$2CH_3CH_2COOH \xrightarrow{P_2O_5} CH_3CH_2COOOCCH_2CH_3 + H_2O$$

c) The preparation of ethanoic acid and propanoic acid is shown in (a) and (b) in addition to those preparations the reaction below is used

$$CH_3COOH + CH_3CH_2COOH \xrightarrow{SOCl_2} CH_3COOOCCH_2CH_3 + H_2O$$

2. Group A made a better choice. This is because this method will produce the desired acid anhydride only. Dehydration would produce butanoic anhydride and propanoic anhydride in addition to butanoic propanoic anhydride.

3. $(CH_3CH_2CO)_2O + NH_3 \rightarrow CH_3CH_2CONH_2 + CH_3CH_2COOH$

$CH_3CH_2COOOCCH_2CH(CH_3)_2 \xrightarrow{LiALH_4} CH_3CH_2CH_2OH{+}CH_3CH(CH_3)CH_2CH_2OH$

4. $CH_3CH_2COO^{18}OCCH^3 + H_2O \xrightarrow{H^+} CH_3CH_2COOH + CH_3CH_2{}^{18}OH$

5. $CH_3CH_2COOC(CH_3)_3 + CH_3COOH$

6. Chemicals: salicylic acid and ethanoic anhydride, conditions: concentrated sulfuric acid to speed up the reaction and heat.

7. Esters can be prepared by using an acid chloride or an acid anhydride with an alcohol. The reaction with an acid chloride is very fast at room temperature but that of the anhydride is slow and must be speeded up by heating. Though the reaction involving the acid chloride is faster it is not preferred by chemists simply because it produces huge amounts of gaseous hydrochloric acid making working conditions bad.

Lesson 6: Structure, nomenclature, physical properties and uses of amides (120minutes)

a) Prerequisites

Students need to have a good understanding of the reactions and preparation methods of carboxylic acids.

b) Teaching resources

Student's book, reference books and charts

c) Learning activities

Learners will work out activity 8.6. You are supposed to give them a brief introduction to make clear what they have to do.

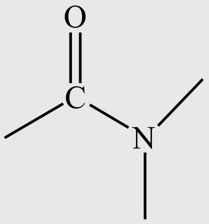
Guidance

You will guide learners through the following steps:

For the methodological steps follow, refer to activity 14.4. Remember to talk about gender education and the application of inclusive education as explained in the general introduction.

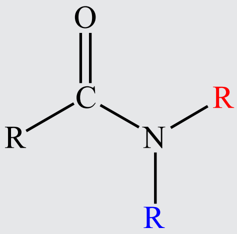
Answers to activity 14.6

1.



Amide group

2.



R, R and R may be hydrogen atoms or alkyl groups(identical or different). General molecular formula: CnH2n+1ON

3. Natural polymer: proteins, Artificial: nylon
4. They would have relatively higher boiling points than esters of the same mass because of hydrogen bonding except tertiary amides.
5. It is Nylon-6,6, a polyamide.

d) Application activity

Learners have to attempt application activity 14.6. to assess their understanding.

Answers to application activity 14.6

1. $C_6H_{13}NO$
2. $CH_3CH_2CH_2CONH_2$ (A), $CH_3CH(CH_3)CONH_2$ (B), $CH_3CH_2CONHCH_3$ (C), $CH_3CONHCH_2CH_3$ (D), $HCONHCH_2CH_2CH_3$ (E), $CH_3CON(CH_3)_2$ (F), $HCON(CH_3)CH_2CH_3$ (G)

A: butanamide, B:2-methylpropanamide, C:N-methylpropanamide, D:N-ethylethanamide, E :N-propylmethanamide, F :N,N-dimethylethanamide, G :N-ethyl-N-methylmethanamide

3. Butanamide is more soluble in water than N,N-dimethylethanamide because it forms more hydrogen bonding with water molecules due to the hydrogen atoms it has on nitrogen. The other compound does not have any hydrogen atom and this reduce the magnitude of hydrogen bonds it can make with water molecules.

4. Solubility of amides decreases with an increase in molecular mass because the size of hydrocarbon part increases and it is insoluble.

5. Ethanol.

   It will have a higher boiling point because the hydrogen bonding involving oxygen atom is stronger than that involving nitrogen atom due to the lower electronegativity of nitrogen.

6. Animal urine can be used as a fertilizer as it contains urea, a source of nitrogen. This must be slightly diluted before being used as it may make plants wither. Too much application causes an accumulation of sodium (Na) and/or nitrogen (N) in soil and eventually inhibits plant growth. Urine can also be a source of water pollution as it may be containing harmful microorganism from the animal body.

Lesson 7: Preparation and chemical properties of amides (120 minutes)

a) Prerequisites

Learners need to have a good understanding of the chemical properties of carboxylic acids and reactions of acyl chlorides. You will find a way of helping your learners recall these points.

b) Teaching resources

Reference books, internet and student's book

c) Learning activities

Briefly explain what students are going to do and let discuss on activity 14.7 and answer the asked questions.

Guidance

During the lesson you will provide guidance to your learners through the following steps:

Make reference to activity 14.4 and the general introduction for methodological steps and cross-cutting issues to be addressed.

Answers to activity 14.7

1.$CH_3CH_2CONH_2$

2. Propanamide can be prepared by reacting propanoic acid and ammonia.

   $CH_3CH_2COOH + NH_3 \rightarrow CH_3CH_2CONH_2 + H_2O$

   Conditions: Heat

3.$CH_3COCl + CH_3NH_2 \rightarrow CH_3CONHCH_3 + HCl$

4. Refer to the student's book. Point 14.7.1.

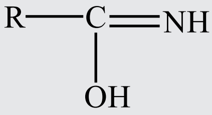
5. $LiAlH_4$/ether or H_2/Pd

d) Application activity

Let students attempt application activity 14.7 individually.

Answers to application activity 14.7

1.



$R-\overset{\displaystyle}{\underset{\displaystyle OH}{\underset{|}{C}}}=NH$

2. A: CH_3CH_2Br, B: CH_3CH_2MgBr, C: CH_3CH_2COOH, D: $CH_3CH_2CONHCH_2CH_3$, E: $CH_3CH\ (CH_3)\ COOH$, F: $CH_3CH\ (CH_3)COCl$

3. (a) Use Hofmann degradation.

   Reagents: NaOH and Br_2 Observation: colorless gas which turns milky lime water, CO_2 for the amide but no observation for the ester.

   (b) Use any aqueous acid (a) strong acid is better. For Na_2CO_3 (aq) one will observe an effervescence caused by the evolution of CO_2 gas. For the amide there will be formation of a soluble salt (no observable change).

4 (a)

$$CH_3CH_2CH_2OH \xrightarrow[\text{Heat}]{KMnO_4\ /\ H^+} CH_3CH_2COOH$$

$$CH_3CH_2COOH + NH_3 \xrightarrow[\text{Heat}]{} CH_3CH2CONH_2 + H_2O$$

$$CH_3CH_2CONH_2 \xrightarrow{P_2O_5} CH_3CH_2CN + H_2O$$

(b)

$$CH_3CHO \xrightarrow[\text{Heat}]{K_2Cr_2O_7 / H^+} CH_3COOH$$

$$CH_3COOH + NH_3 \xrightarrow[\text{Heat}]{} CH_3CONH_2 + H_2O$$

$$CH_3CONH_2 + NaOBr \longrightarrow CH_3NH_2 + CO_2 + NaBr$$

Lesson 8: Structure, nomenclature physical properties and uses of nitriles (80 minutes)

a) Prerequisites

Nitriles are acid derivatives and for a better understanding of their chemistry, learners need to know reactions of amides and preparation methods of carboxylic acids. Find a way of checking if they remember these points.

b) Teaching resources

Molecular structure Charts, Reference books, student’s book or internet.

c) Learning activities

Give a brief introduction of the activity to be done and give time to learners to work collaboratively on the activity 14.8

Guidance

You will guide learners through the following steps:

Refer to activity 14.4 and the general introduction for methodological steps and cross-cutting issues to be addressed.

Answers to activity 14.8

1. CH3C≡N
2. Nitriles
3. C2H3N
4. General structure: R-C≡N , General Molecular formula: CnH2n-1N
5. These compounds are liquids or solids at room temperature even though they lack hydrogen bonding because they have strong dipole-dipole forces. The C≡N bond is highly polar.

d) Application activity

Answers to application activity 14.8

1. (a) $CH_3CH_2CH_2CN$ (b) $CH_3CH_2CH(CH_3)CH_2CN$

2. (a) 2-methylpentanenitrile (b) 2,3-dimethylbutanenitrile

3. $CH_3CH_2CH_2CN$: butanenitrile, $CH_3CH (CH_3) CN$: 2-methylpropanenitrile

Lesson 9: Preparation and chemical properties of nitriles

This lesson has 80 minutes (2periods). It will describe the preparation methods, reduction and hydrolysis of nitriles.

a) Prerequisites

This lesson will be well delivered if students have understood the preparation of carboxylic acids and the meaning of reduction. They also need to know nucleophilic substitution of alkyl halides. As a facilitator you are supposed to find an appropriate method of helping your learners recall all of these points.

b) Teaching resources

Reference books, student's book or internet, Nitrile substances available

c) Learning activities

Briefly explain the task assigned to the learners and allow them to work on activity 8.9. in groups.

Guidance

You will guide learners through the following steps:

Refer to activity 14.4 and the general introduction for methodological steps and cross-cutting issues to be addressed.

Answers to activity 14.9

1. Halogenoalkanes react with –CN (aq) to produce nitriles. The halogen is substituted by the –CN ion.

2. The reaction mechanism for reaction in (1) is called ***nucleophilic substitution***.

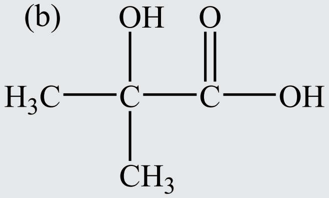
3.$CH_3CH_2Cl + KCN(aq) \rightarrow CH_3CH_2CN + KCl(aq)$

d) Application activity

Answers to application activity 14.9

1. (a) $LiAlH_4$ / Ether

(b)

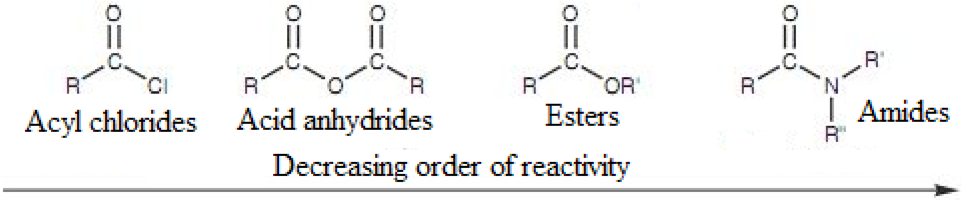


$$H_3C-\overset{OH}{\underset{CH_3}{\overset{|}{\underset{|}{C}}}}-\overset{O}{\overset{||}{C}}-OH$$

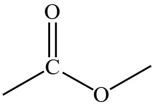
2. Hydrolysis is a chemical breakdown of a compound as a result of reacting with water.
3. This is because they undergo hydrolysis to produce a carboxylic acid.

14.6. Summary of the unit

In this unit you learnt esters, amides, acid anhydrides and nitriles. The figure below compares the reactivity of these compounds.

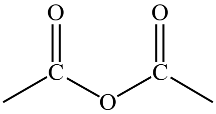


Esters contain the group



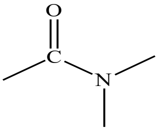
and they are known for their pleasant smells. They are prepared by a reaction of a carboxylic acid and an alcohol. They react with sodium hydroxide to produce a salt and an alcohol (this reaction is known as saponification and when oils and fats are used soap is produced). Esters are reduced to alcohols and hydrolysed to acids and alcohols.

Acid anhydrides contain the group



and they are prepared by dehydration of carboxylic acids. They are hydrolyzed to produce parent carboxylic acids. They react with alcohols and ammonia/ amines to produce esters and amides respectively. Ethanoic anhydride is very important in the manufacture of aspirin.

Amides contain the group



They are hydrolyzed to carboxylic acids, dehydrated to nitriles reduced by $LiAlH_4$ to amines and degraded to amines by NaOBr.

They are prepared from carboxylic acids and other acid derivatives when they react with ammonia or primary and secondary amines. Nylon textile is a polyamide.

Nitriles are also considered to be acid derivatives because they undergo hydrolysis to produce carboxylic acids. They are prepared by dehydrating amides and by nucleophilic substitution of the halogen in alkyl halides by CN- from NaCN or KCN. In addition to hydrolysis, they are also reduced to amines.

14.7. Additional information for the teacher

a. Some carboxylic acids containing the hydroxyl group can undergo esterification to produce cyclic esters. The later are called lactones. Eg: 5-hydroxypentanoic acid.

b. Oils and fats are both esters. Oils are less saturated and are liquids at rtp while fats are solids because they are more saturated. Saturation favours generation of strong intermolecular forces, Van der Waals forces.

c. Saponification produces soap and glycerol. However, most soap factories do not produce glycerol because its separation is expensive. They mix oil and the base to get the soap without separating it with glycerol. The glycerine sold on market in the country is imported.

d. Polyesters are polymers containing the ester functional group. They are used to make a variety of products. An example of this polymer is Terylene.

e. There are two types of nylon: nylon-6 and nylon-6,6. Nylon-6 is produced by joining molecules of $H_2N(CH_2)_5COOH$ and nylon-6,6 is made by reacting

$H_2N(CH_2)_6NH_2$ and $HOOC(CH_2)_4COOH$

Guidance to skills lab 14

The learners are guided to perform experiment either in laboratory or try it at home. After identifying all the required materials learners are given instructions for a better manipulation of chemicals

Q1 .The procedure is given to learners, they perform experiment in laboratory and they are tasked to use the same procedure to produce the soap using local material in their area but by providing them the chemicals that they cannot find at home or by guiding them to a probable supply from the market.

Q2.The learners will perform the experiment to develop the spirit and self-confidence of working in laboratory ,develop a sense of analysis and to respect diverse opinions when discussing

End unit assessment

Answers to end unit assessment 14

Part I: Objective questions

1.C   2.C   3.D   4.C   5.C   6.D   7.A   8.D   9.C   10.B

Part II: Structured questions

11. Preparation of compounds

a.

$CH_3CH_2COOH + NH_3 \quad CH_3CH_2CONH_2 + H_2O$

$CH_3CH_2CONH_2 + NaOBr\ CH_3CH_2NH_2 + CO_2 + H_2O$

b.

$$CH_3CH_2OOCCH_2CH_3 \xrightarrow{LiAlH_4/Ether} CH_3CH_2OH + CH_3CH_2CH_2OH$$

$$CH_3CH_2OH \xrightarrow[Heat]{KMnO_4\,/\,H^+} CH_3COOH$$

$$CH_3COOH + NH_3 \xrightarrow[Heat]{} CH_3CONH_2 + H_2O$$

c.

$$CH_3CH_2COOH \xrightarrow{P_2O_5} CH_3CH_2COOOCCH_2CH_3 + H_2O$$

d.

$$CH_3CH_2CH_2CN \xrightarrow{H_3O^+} CH_3CH_2CH_2CONH_2$$

$$CH_3CH_2CH_2CONH_2 + NaOBr \longrightarrow CH_3CH_2CH_2NH_2 + NaBr + CO_2$$

e.

$$CH_3CH_2COOH + PCl_5 \xrightarrow[\text{Heat}]{} CH_3CH_2COCl + POCl_3 + HCl$$

$$CH_3CH_2COOH \xrightarrow{NaBH_4} CH_3CH_2CH_2OH$$

$$CH_3CH_2CH_2OH + HBr \longrightarrow CH_3CH_2CH_2Br + H_2O$$

$$CH_3CH_2CH_2Br + NH_3 \longrightarrow CH_3CH_2CH_2NH_2 + HBr$$

$$CH_3CH_2CH_2NH_2 + CH_3CH_2COCl \longrightarrow CH_3CH_2CH_2NHCOCH_2CH_3 + HCl$$

12. **A**: CH_3CH_2COCl, **B**: $CH_3CH_2CONH_2$, **C**: CH_3CH_2OH, **D**:$CH_3CH_2COOCH_3$, **E: $CH_3CH_2COOCH_3$**, **X**:NAOH/Br_2 or NAOBr, **Y**:HNO_2 or $NaNO_2$/HCl , **Z**:CH_3OH

13. **(a)** CH_3CH_2OH, **(b)**CH_3CH_2Br, **(c)**CH_3CH_2MgBr, **(d)**CH_3CH_2COOH, **(e)**CH_3CH_2COONa, **(f)**CH_3CH_2COCl, **(g)**$CH_3CH_2COOOCCH_2CH_3$

14. a.methyl propanoate, b.N-methylpropanamide, c.ethanoic propanoic anhydride, d.propanenitrile, e.N,N-dimethylethanamide

15. a. $CH_3ClCONH_2$, b.$CH_3OOCCH_2CH_2CH_2CH_3$, c.$(CH_3CH_2CH_2CO)_2O$,
    d. CH_3CH_2COCl,
    e. $CH_3CH_2CH_2CON(CH_2CH_3)CH_2CH_2CH_3$

16. a.$CH_3CH_2CONH_2$, b.CH_3OOCCH_3, c.$CH_3CH_2CH_2COOH$, d.$CH_3CH_2NH_2$, e.$CH_3CH_2OOCCH_2CH_3$

17. a.reagent:P_2O_5 or $SOCl_2$, b.reagent:NH_3, condition:heat, c.reagent:ethanol conditions: strong acidic medium and heat

18.Ethanamide contains strong intermolecular forces, hydrogen bonding, which are absent in the acid anhydride.

19. Refer to the student's book lesson 8.1.2

20.(a)$CH_3COCl + CH_3CH_2OH \rightarrow CH_3CH_2OOCCH_3 + HCl$

(b) Terylene is polyester (condensation polymer). The ester groups in this polymer are hydrolyzed aqueous sodium hydroxide (caustic soda) destroying it. Polythene is an addition polymer which does not react with NaOH.

21. (a) $CH_3(CH_2)_6CH_2\text{-}CH=CHCH_2(CH_2)_6COOH$

(b) $C_7H_{15}CH_2\text{-}CH=CHC_7H_{15}COOH + C_2H_5OH \rightarrow C_7H_{15}CH=CHC_7H_{15}COOC_2H_5 + H_2O$

(c) From the triglyceride oleic acid can be prepared by acidic hydrolysis.

22. (a) Carbon: 49.4/12=4.116

Hydrogen: 9.6/1=9.6

Nitrogen: 19.1/14=1.3643

Simplest ratio

C=3 , H=7 , N=1

Empirical formula= C_3H_7NO

Molecular formula

$(C_3H_7NO)n=73$

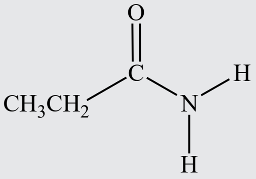
$((12x3) + 7 +14 + 16)n=73$

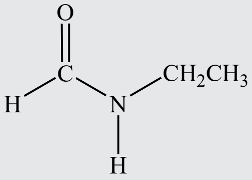
$73n=73$

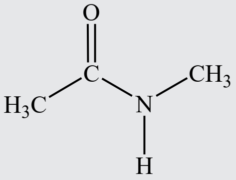
$n=1$

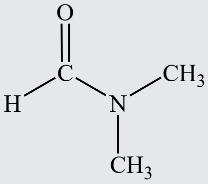
Molecular formula is $(C_3H_7NO)x1 = C_3H_7NO$

(ii)









(b) i. Ethanoic acid and HCl

ii. Isopropyl ethanoate and HCl

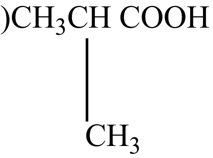
iii. Ethanamide and HCl or $CH_3CONH_3^+Cl^-$

iv. Ethanoic anhydride and NaCl

14.8. Additional activities

14.8.1 Remedial Activities

1. Consider the following compounds:

A) 
$CH_3\underset{\substack{|\\ CH_3}}{CH}\,COOH$

B) $CH_3OOCCH_2CH_3$

C) $HOOC\text{-}CH_2CH_2COOH$

D) $CH_3CH_2COOCOCH_2CH_3$

a. Which is an ester?

b. Which is a dibasic acid?

c. Which is an acid anhydride?

d. Name each compounds.

e. Which would be almost insoluble in water, but would slowly dissolve when boiled with sodium hydroxide solution?

f. Which would form a pleasant smelling liquid when warmed with ethanol and concentrated sulphuric acid?

Answers

a. **B**

b. **C**

c. **D**

d. **A**: methylpropanoic acid, **B**: methyl propanoate, **C**: butanedioic acid, **D**:Propanoic anhydrid

e. **B**

2. Esters are derivatives of carboxylic acids and occur widely in nature.

   a. Draw the structure of the ester formed when ethanol reacts with 2-methyl propanoic acid.

   b. Name an alternative reagent which may be used in place of methylpropanoic acid to produce the ester.

Answers

   a. $CH_3CH_2OOCCH(CH_3)_2$

b. Methyl propanoyl chloride

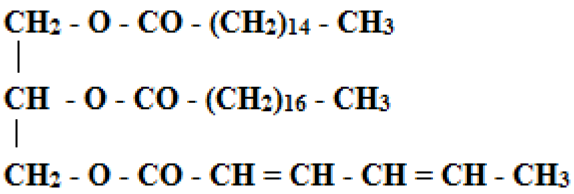
3. a. A triglyceride represented by letter A is an ester derived from glycerol and 3 fatty acids: hexadecanoic acid, octadecanoic acid and 2,4-hexadienoic acid. Write the structural formula of the triglyceride.

b. (i) Write the equation of reaction between the triglyceride above and sodium hydroxide.

(ii) What is the importance of this reaction?

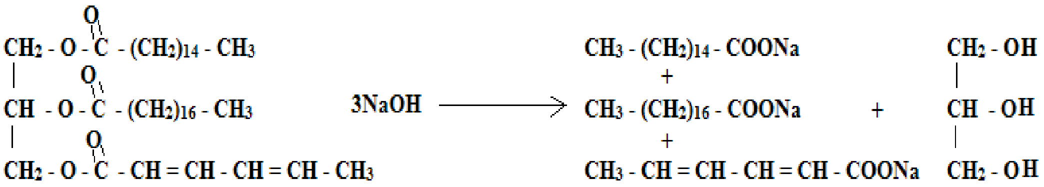
Answers:

a.



$$\begin{array}{l} CH_2-O-CO-(CH_2)_{14}-CH_3\\ |\\ CH\ -O-CO-(CH_2)_{16}-CH_3\\ |\\ CH_2-O-CO-CH=CH-CH=CH-CH_3 \end{array}$$

b. (i)



$$\begin{array}{l} CH_2-O-\overset{O}{\overset{\|}{C}}-(CH_2)_{14}-CH_3\\ |\\ CH\ -O-\overset{O}{\overset{\|}{C}}-(CH_2)_{16}-CH_3\\ |\\ CH_2-O-\overset{O}{\overset{\|}{C}}-CH=CH-CH=CH-CH_3 \end{array} \quad 3NaOH \longrightarrow \begin{array}{c} CH_3-(CH_2)_{14}-COONa\\ +\\ CH_3-(CH_2)_{16}-COONa\\ +\\ CH_3-CH=CH-CH=CH-COONa \end{array} + \begin{array}{l} CH_2-OH\\ |\\ CH\ -OH\\ |\\ CH_2-OH \end{array}$$

(ii) This reaction is used in making soap.

4. Describe how you can distinguish the compounds below. Include relevant observations in your answer.

a. CH_3CH_2COCl and $CH_3CH_2CH_2Cl$

b. CH_3CONH_2 and $CH_3CH_2NH_2$

c. CH_3CH_2CN and $CH_3CH_2COOCH_3$

Answers

a. Dissolve both compounds separately in some water and test the acidity of resulting solutions. CH_3CH_2COCl solution will be acidic but the other one will be neutral.

b. React both compounds with NaOBr separately. CH_3CONH_2 produces a colorless gas which turns milky lime water but for the amine there is no observable change.

c. Hydrolyze while heating both compounds and test the evolved vapors with litmus papers. CH_3CH_2CN would produce ammonia which turns red litmus paper blue.

5. a. Write an equation for the reaction of ethanoyl bromide with CH_3MgCl.

b. Explain why animal urine is used as a fertilizer

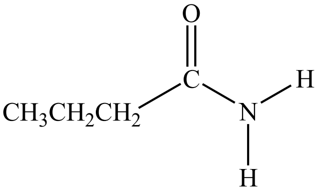
Answers

a. $CH_3COCl + CH_3MgCl \quad CH_3C(OH)(CH_3)_2$

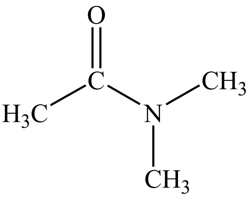
b. Animal urine contains urea, a substance which has high nitrogen content. It is used to provide nitrogen to plants.

6. Draw the structural formulae of all possible isomers with molecular formula C_4H_9NO and name them.

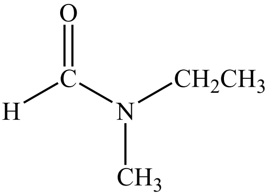
Answers



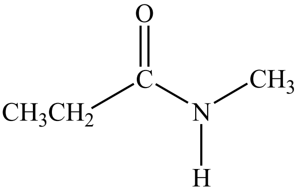
butanamide



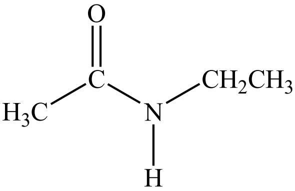
N,N-dimethylethanamide



N-ethyl-N-methylmethanamide



N-methylpropanamide



N-ethylethanamide

7. Compare the boiling points of ethanoic acid, ethyl ethanoate and ethanamide. Explain your reasoning.

Answers

Ethanoic acid has highest boiling point because it has more and stronger hydrogen bonding. Ethanol will be next to the acid because hydrogen bonds between oxygen and hydrogen are stronger than those involving nitrogen. This is because of small electronegativity of nitrogen.

8. Complete the equations below

Answers

a. $CH_3CH_2OOCCH_3$ + NaOH → ***$CH_3COONa + CH_3CH_2OH$***

b. $CH_3COCl + CH_3NH_2$ → ***$CH_3CONHCH_3 + HCl$***

c. $CH_3CN + H_2$ → **$CH_3CH_2NH_2$**

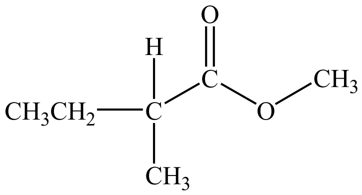
d. $CH_3CH_2COOOCCH_3 + H_2O$ → **$CH_3CH_2COOH + CH_3COOH$**

e. $HCOOCH_3$ → **$2CH_3OH$**

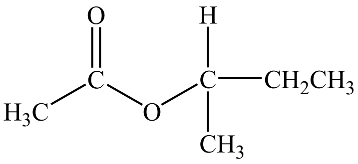
14.8.2 Consolidation activities

1. Two esters, A and B, have molecular formula $C_6H_{12}O_2$. Both show optical isomerism. When heated with aqueous sodium hydroxide, A gives sodium ethanoate and another product, and B gives methanol and another products. Write the structural formulae for A and B and name them.

Answers



Methyl-2-methylbutanoate:**B**

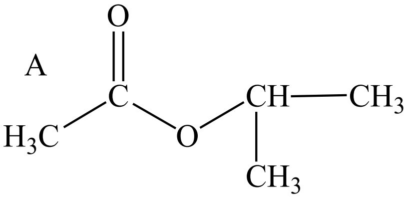


1-methylpropylethanoate: **A**

2. A liquid **A** of molecular formula $C_5H_{10}O_2$ was reduced by $LiAlH_4$ to a mixture of two alcohols **B** and **C.** Both alcohols reacted with iodine in alkaline solution to give a pale yellow crystalline solid **D**. The liquid A is insoluble in cold, dilute aqueous sodium hydroxide but on boiling the mixture gradually becomes one layer. Given that the boiling point of **B** is higher than that of **C**, identify and draw structural formulae of **A**, **B**, **C** and **D.** Give your reasoning

Answers

A



B $CH_3CHOHCH_3$

C CH_3CH_2OH

D CHI_3

Alcohols which react with iodine in alkaline solution must be ethanol or methyl alcohol. A is an ester because it is insoluble cold aqueous NaOH but dissolves on boiling because of being hydrolyzed. B has higher boiling point because it has bigger molecular mass.

3. State and explain the conditions necessary for converting an aldehyde into a cyanohydrin.

Answers

An aldehyde reacts with HCN in the presence of a strong base or aqueous KCN. The strong base or KCN is used to facilitate the release of CN^- ions as HCN is a weak base.

4. The nitrile group can be introduced into a molecule by dehydration of an amide. Outline a reaction scheme, giving names or formulae for the reagents, for the preparation of ethanenitrile from ethanal.

Answer

$$CH_3CHO \xrightarrow[\text{Heat}]{K_2Cr_2O_7 / H_2SO_4} CH_3COOH$$

$$CH_3COOH + NH_3 \xrightarrow[\text{Heat}]{} CH_3CONH_2 + H_2O$$

$$CH_3CONH_2 \xrightarrow{P_2O_5} H_3C{-}C{\equiv}N + H_2O$$

5. (a) What do you think would be formed when soap is heated with soda lime?

(b) Suggest explanations for the following observations.

(i) Butane, propan-1-ol, propanal and ethanoic acid all have approximately the same relative molecular mass, but their boiling points are 273K, 371K, 322K and 391K, respectively.

(ii) When dilute hydrochloric acid is added to an aqueous solution of soap, a white insoluble substance is formed.

Answers

(a) A hydrocarbon with one less carbon to the number of carbon atoms of the soap. A decarboxylation of a sodium salt of a carboxylic acid will take place.

(b) (i) These compounds have different intermolecular forces. Butane has weakest intermolecular forces (Van der Waals forces) and propanal has weak dipole-dipole forces. Propan-1-ol has strong hydrogen bonding as well as ethanoic acid, but their magnitude in the acid is bigger.

(ii) Salts of carboxylic acids react with mineral acids to regenerate the parent acid. Soap is a carboxylic salt which will react to regenerate the parent fatty acid which is insoluble in water, the white substance.

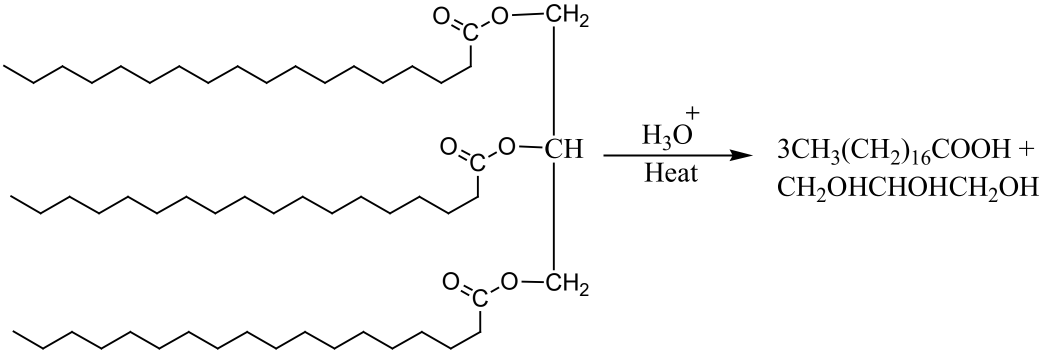
14.9. Extended activities

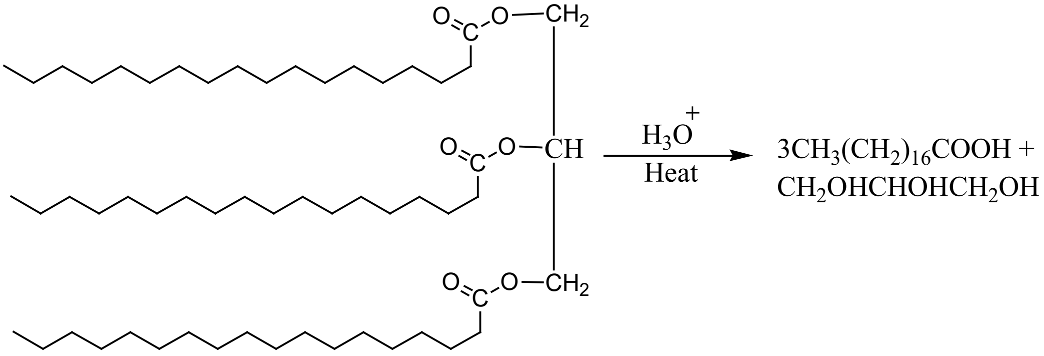
1. Naturally occurring fats and oils are esters of acids with an even number of carbon atoms. Acids with an odd number of carbon atoms are rare. Suggest a method of producing a fatty acid and increasing its length by one carbon atom from propyl tristearate. Include equations in your answer.

Answers

Method: Hydrolyze propyl tristearate; reduce the produced acid to an alcohol, substitute the OH group by a halogen, convert the produced alkyl halide into a Grignard reagent and carboxylate it.

Equations:





a) What are the products of the reactions of $CH_3CH{=}CHCH_2CO_2C_2H_5$ with:

a. NaOH, Heat

b. H_2, Ni

c. Br_2

d. O_3 followed by H_2O

e. $LiAlH_4$

Answers

a. $CH_3CH=CHCH_2COONa + HOC_2H_5$

b. $CH_3CH_2CH_2CH_2CO_2C_2H_5$

c. $CH_3CHBrCHBrCH_2CO_2C_2H_5$

d. $CH_3CH=O + O=CHCH_2CO_2C_2H_5 + H_2O_2$

e. $CH_3CH_2CH_2CH_2CH_2OH + CH_3CH_2OH$

b) The complete hydrolysis of 1.76g of an ester of a monocarboxylic acid and a monohydric alcohol required $2.0X10^{-2}$mol of sodium hydroxide. Deduce its molecular formula, and write the names and structural formulae of all the esters with this molecular formula.

Answer

1mol of NaOH reacts with 1mol of the ester (the ester is produced from a monohydric alcohol)

$2.0X10^{-2}$mol of NaOH will react with $2.0X10^{-2}$ mol of the ester.

n=m/Mm

Mm=m/n=1.76/0.02=88g/mol

$C_nH_{2n}O_2=88$

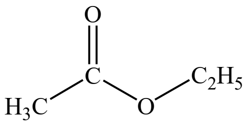
12n+2n=88-32

14n=56

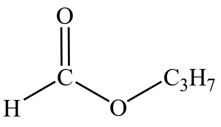
n=56/14= 4

Molecular formula is $C_4H_8O_2$

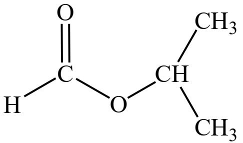
Structures and names



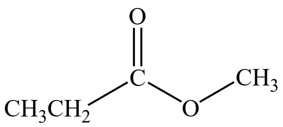
Ethyl ethanoate



propyl methanoate

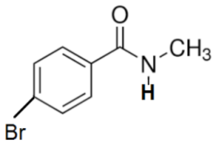


isopropyl methanoate

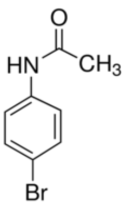


methyl propanoate

c) A and B are two isomeric amides which can be hydrolyzed in acidic medium.



A



B

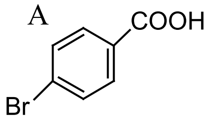
a. Draw the structures of the products formed from hydrolysing A and B.

b. What is the structure of the compound produced when A reacts with sodium hypobromite?

c. Write an equation for the reaction of B with ethanoyl chloride.

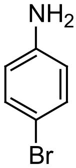
Answers

a. A



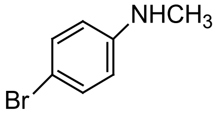
+ CH_3NH_2

B

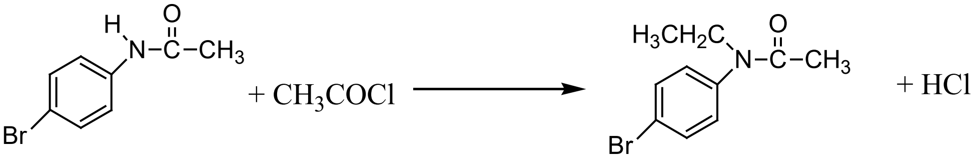


+ CH_3COOH

b.



c.



d) Three chlorine-containing compounds can be prepared from acetic acid (A) by the following routes:

$$\begin{tikzcd}
\underset{A}{CH_3COOH} \arrow[r, "I"] \arrow[d, "II"'] & \underset{B}{CH_2ClCOOH} \arrow[r] & \underset{C}{CHCl_2COOH} \\
\underset{D}{CH_3COCl} & &
\end{tikzcd}$$

a. Suggest reagents and conditions for reactions I and II.

b. When D reacts with ethanol, steamy fumes are evolved and a fruity smelling liquid is produced. Write a balanced equation for this reaction.

c. When compounds A, B and D (not necessarily in that order) are added to separate portions of water, solutions are found to have pH values of 0.5, 2.5 and 3.0. When aqueous silver nitrate is added to these three solutions, two show no reaction but the third one produces a thick white precipitate. Suggest, with explanations, which pH value is associated with each of A, B and D. Explain the formation of the white precipitate.

d. Predict, with a reason, the likely pH value of an aqueous solution of compound C.

Answers

a. I: Cl_2 in the presence of UV light, II: PCl_5 at room temperature

b. $CH_3COCl + CH_3CH_2OH \rightarrow CH_3COOCH_2CH_3 + HCl$

c. A=3.0, B=2.5, D=0.5

Explanation

Acid A is a weak acid but when the hydrogen atom in alpha position is substituted by chlorine its acidity increases reason why B has a lower pH. The O-H bond in B is weaker so that more H^+ ions are released in aqueous solution. D hydrolyzes in water to produce HCl, a strong acid, giving a pH of 0.5.

d. Its pH will be lower than 2.5 because its O-H bond is more weakened due to the presence of 2 chlorine atoms in alpha position. But it will not be lower than 0.5 because still it is an organic acid.

UNIT
15

AMINES AND AMINO ACIDS

15.1 Key unit competence

Relate the chemical nature of the amines and amino acids to their properties, uses and reactivity

15.2 Prerequisites

For learning contents of this unit 15 (amines and amino acids), each learner should have enough knowledge in organic chemistry: Introduction to organic chemistry, Alkanes, Alkenes and alkynes, Halogenoalkanes, Alcohols and Ethers, Carbonyl compounds, Carboxylic acids and acyl halides as well as Esters, acid anhydrides, amides and nitriles.

For each of those mentioned topics, the students should be confident in their identification, nomenclature, physical properties, natural occurrence, their preparation, chemical properties, and usage.

15.3 Cross-cutting issues to be addressed

For this unit 9 (amines and amino acids), three cross cutting issues should be addressed in some or all lessons. You should note that you can integrate cross cutting issues other than the one proposed in this teacher's guide, depending on your class.

a. Peace and Values Education

This cross cutting issue ***is compulsory for the Chemistry subject***: you are advised to address this cross cutting issue frequently. Laboratory activities, group work, discussions in the classroom and many other interactions in the learning process should help to create a peaceful society, and it is your responsibility to make sure that in each lesson of the unit 15, this cross cutting issue is addressed. You must encourage learners to help each other and to respect opinions of colleagues. National values should be also emphasized on politeness, generosity …

b. Standardisation Culture

This cross cutting issue ***is compulsory for the Chemistry subject***: you are advised to address this cross cutting issue frequently. IUPAC (International Union of Pure and Applied Chemistry) has set a number of rules related to nomenclature of organic and inorganic compounds. Respecting those standards of nomenclature as well as standards in writing formulas, using international recognised units … are one of the ways to address the standardisation culture as cross cutting issue. You must train students on the respect of those standards and many others.

c. Inclusive Education

This cross cutting issue ***is compulsory for the Chemistry subject***: you are advised to address this cross cutting issue frequently. Make sure that all learners are engaged in education regardless their age, sex, physical appearance, physical and/or mental impairment, special gifts/talents … and make sure that all of those learners are well welcomed by other students so that everyone can achieve their potential. You should make sure that no learner will be left behind, frustrated or ignored. If there is any group work, heterogeneous groups should be formed and activities should be relevant to each category of students depending on their abilities.

In case there is no student who needs special attention (like in a boy's school or girl's school where there is no student with impairment or special talent), you should make sure that you engage discussions on the issue, depending the type of today's lesson.

To be successful, inclusive education as cross cutting issue involves a range of issues including teacher's positive attitudes, adapting the learning resources, variation of teaching and learning methods and working together.

15.4 Guidance on introductory activity

At the beginning of this unit, a reflection question is provided in the learner's book. The following instructions should be followed:

- The activity should be done individually, ***in less than 10 minutes***.
- Each student tries to answer to the questions individually. All the three questions should be answered.
- No answers should be provided for this activity. Learners will discover step by step the answers for this activity.
- The expected answers for this activity are the following:

Answers to introductory activity

1. DNA and proteins have in common the amino acids which are their building blocks.
2. See learners book.
3. If protein molecules are made essentially of Carbon, Hydrogen, Oxygen, Nitrogen and amino acid side chains (figure C):

a. Covalent bonds C–C , C–H, C–O, C–N, N–H, H–O, …

Note that proteins undergo acid related reactions (due to the presence of –COOH function) and base related reactions (due to the presence of –NH_2 function) in amino acids

All of them have a nasty smell like that of ammonia or a fishy smell. This smell is due to the presence of amines (Ex: cadaverine and putrescine)

c) Eggs, fishes, milk, beans are all made up of proteins as body building food

15.5 List of lessons

The unit 15 (amines and amino acids) should be taught in 11 periods. All activities, contents and assessments should be done in that period of time.

#	Lesson title	Learning objectives	Number of periods
1	Nomenclature and classification of amines	Apply IUPAC rules to name primary, secondary and tertiary amines them.	1
2	Physical properties, natural occurrences and uses of amines	Describe the physical properties and uses of amines.	1
3	Preparation of amines	Describe the preparation methods of the amines.	1
4	Chemical properties of amines	Recognise and apply chemical properties of amines	1
5	General structure of amino acids and some common examples	Apply the general structure of amino acids and some common examples	1

#	Lesson title	Learning objectives	Number of periods
6	Comparison of physical properties amino acids to those of carboxylic acids and amines	Compare the physical properties of the amino acids to those of the carboxylic acids and amines.	1
7	Chemical properties of amino acids	Describe the reactions of amino acids and amines with other substances.	1
8	Optical isomers of amino acids	Write the optical isomers of the amino acids.	1
9	Peptides and polypeptides	Appreciate the importance of amino acids as the building blocks for proteins in our bodies.	1
10	Summative assessment	To relate the chemical nature of the amines and amino acids to their properties, uses and reactivity	1

Lesson 1: Nomenclature and classification of amines (40minutes)

a) Prerequisites

Students to learn this lesson, they should have learned nomenclature and classification of alcohols the nucleophilic substitution reaction involving ammonia. The activity 15.1 in learners book will be used as introductory or revision activity. Since this lesson has only 40 minutes, the revision should take less than 7 minutes of time.

The box below shows answers for the given activity.

b) Teaching resources

You should avail the following resources: molecular models, chalkboard and chemistry books (learners books and reference books). A periodic table of elements and access to internet may also be necessary, basic organic chemicals and apparatus.

c) Learning activities

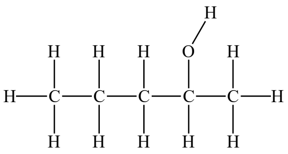
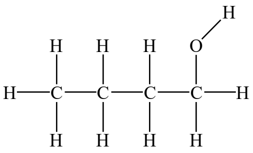
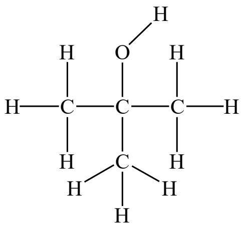
Guidance

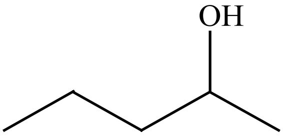
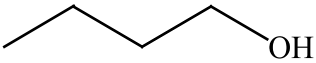
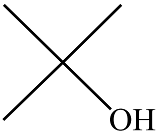
The learning activities for this lesson will be designed so as to help learners to develop competencies. You are advised to choose which activities suit the best to his class.

- Helps learners to form groups of 4-5 students.
- ***In groups***, students revise about alcohols using the activity proposed in the learner's book (activity 15.1).
- The duration for this activity should not exceed ***5 minutes***.
- Introduce the new lesson and make relevant explanations, based in the learners' findings in activity 15.1. ***This activity will help learners to discover that alcohols and amines have almost same way of classification but different way of nomenclature (primary, secondary & tertiary amines or alcohols),it will help also to discover that amines are derivatives of ammonia in its different reaction of*** SN_2
- While explaining, ask to learners relevant application questions to involve them in the teaching and learning activities.
- Students should have their textbooks, and access to reference books is necessary.
- Individually, learners do self-evaluation exercises proposed in learner's book on (application activity 15.1)
- Discuss and present their finding in plenary.

Answers to activity 15.1

a.

	Pentan-2-ol	butan-1-ol	2-methylpropan-2-ol
molecular formula	$C_5H_{11}OH$ *or* $C_5H_{12}O$	C_4H_9OH *or* $C_4H_{10}O$	C_4H_9OH *or* $C_4H_{10}O$
structural formula	$CH_3CH_2CH_2CHOHCH_3$	$CH_3CH_2CH_2CH_2OH$	$CH_3COH(CH_3)_2$
displayed formula			

skeletal formula			
class	secondary	Primary	tertiary alcohol

General formula that is used to represent alcohols: $C_nH_{2n+1}OH$

C.Butan-1-ol and 2-methylpropan-2-ol. Structural isomers.

d. $CH_3CH_2COH\ (CH_3)_2$.: 2-methylbutan-2-ol

2. a) a reaction in which a positive seeking reactant (nucleophile) replaces a negatively charged leaving group.

b) SN1: takes place in two steps;

the reaction rate is determined by the concentration of one molecule.

Example: $(CH_3)_3CBr + H_2O \longrightarrow (CH_3)_3COH + HBr$

SN2: takes place in one step;

the reaction rate depends on the concentration of the nucleophile and the concentration of R-X

Example: $R\text{-}CH_2\text{-}I + NH_3 \rightarrow R\text{-}CH_2\text{-}NH_2 + HI$

c) The reaction between ammonia and alkyl halide is a SN2,it requires both ammoniia and alkyl halide and the mechanism of the reaction takes one step

d) Reaction of alkyl halide (ex:ethyl iodide) with concentrated ammonia produces a mixture of amines.

The alkyl amine (ex:ethyl amine) produced can then react with a molecule of alkyl iodide to produce a series of substituted amines as shown in the reactions below:

$$CH_3-CH_2-I+CH_3-CH_2NH_2 \rightarrow (CH_3-CH_2)_2NH+HI$$

Diethyl amine

$$(CH_3-CH_2)_2NH+CH_3-CH_2-I \rightarrow (CH_3-CH_2)_3N+HI$$

Triethyl amine

$$(CH_3-CH_2)_3N+CH_3-CH_2-I \rightarrow (CH_3-CH_2)_4N^+I^-$$

Tetra ethyl ammonium iodide

Note: due to limited time allocated to this lesson, homework should be provided to learners. It should be composed by a series of exercises related to nomenclature and classification of amines

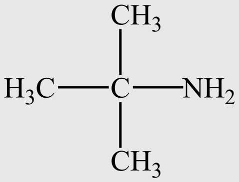
d) Application activities

Application activities 15.1 are provided in learners' book. The box below shows their answers.

Answers to application activity 15.1

1.

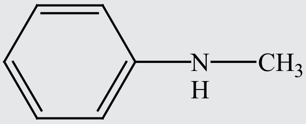
a



$H_3C-\overset{CH_3}{\underset{CH_3}{C}}-NH_2$

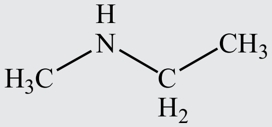
Primary amine

c



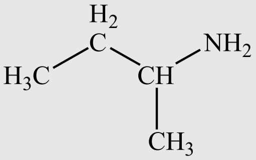
Secondary amine

e



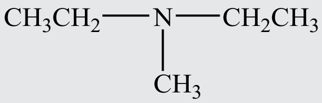
Secondary amine

b



Primary amine

d



$CH_3CH_2-\underset{CH_3}{N}-CH_2CH_3$

Tertiary amine

2.

	IUPAC name
CH_3NH_2	Methylamine
$CH_3CH_2CH_2NH_2$	Propylamine
$CH_3CHNH_2CH_3$	Isopropylamine
$CH_3NHCH_2CH_3$	Ethyl-methyl-amine
$CH_3CH_2N(CH_3)CH_2CH_2CH_3$	Ethyl-methyl-propyl-amine

3.

i) 1-methylethylamine or propan-2-amine ***(primary amine)***

ii) Propan-1-amine ***(primary amine)***

iii) N-methyl-2-methylethylamine or N-methylpropan-2-amine ***(secondary amine)***

iv) 2-methylpropan-2-amine ***(primary amine)***
v) N-methylbenzenamine or N-methylaniline ***(secondary amine)***
vi) N-Ethyl-N-methylethanamine ***(tertiary amine)***

Lesson 2: Physical properties, natural occurrences and uses of amines (40 minutes)

a) Prerequisites

Students to learn this lesson, they should be confident with physical properties of common organic compounds. The activity 15.2 in learner's book is about calculation of the molecular weight of given products and justification of the difference between boiling points of given amines, alkanes and alcohols. It will be used as introductory activity of the lesson. Since this lesson has only 40 minutes, the revision should take less than 10 minutes of time. The learners should have knowledge about intermolecular forces (hydrogen bonding and Van Der Waals forces)

The box below shows answers for the given activity.

Answers to activity 15.2

Name	Molecular mass	Boiling point
Methanol (CH_3OH)	31.06 g/mol	65°C
Methylamine (CH_3NH_2)	30.07 g/mol	−6°C
Ethane (CH_3CH_3)	32.04 g/mol	−89°C
1-propanol ($CH_3CH_2CH_2OH$)	60.1 g/mol	97°C
Propyl Amine ($CH_3CH_2CH_2NH_2$)	59.1 g/mol	48°C
Ethylmethylamine ($CH_3NHCH_2CH_3$)	59.1 g/mol	36°C
Trimethylamine $N(CH_3)3$	59.1 g/mol	2.9°C
Butane ($CH_3CH_2CH_2CH_3$)	58.1 g/mol	-0.5°C
Butylamine (n-$C_4H_9NH_2$)	73 g/mol	77.65°C
Diethyl-amine [$(C_2H_5)2NH$]	73 g/mol	56.15°C
Ethyl-dimethyl-amine [$C_2H_5N(CH_3)2$]	73 g/mol	37.35°C
2-Methyl-butane [$C_2H_5CH(CH_3)2$]	72 g/mol	27.65°C
Butan-1-ol (n-C_4H_9OH)	74 g/mol	117.15°C

Based on the molecular weights and boiling points of given molecules, we can deduce that primary and secondary amines boil at higher temperatures than alkanes and tertiary amines, but at lower temperatures than alcohols of comparable molar mass.

b) Teaching resources

You should avail the following resources: molecular models, chalkboard and chemistry books (learners books and reference books). A periodic table of elements and access to internet may also be necessary.

c) Learning activities

Guidance

The learning activities for this lesson will be designed so as to help learners to develop competencies. You are advised to choose which activities suit the best to his class.

- Help learners to form groups of 4-5 students.
- ***In groups***, students perform the activity proposed in the learner's book (activity 9.2), about comparison of boiling points of amines, alcohols and alkanes of same molecular weights.
- The duration for this activity should not exceed ***10 minutes***.
- Introduce the new lesson and make relevant explanations, based in the learners' findings in activity 15.2.
- While explaining, ask to learners relevant application questions to involve them in the teaching and learning activities.
- Individually, learners do self-evaluation exercises proposed in learner's book (Checking up 15.2).
- Discuss and present their finding in plenary.

Note: You can alternatively to the activity 9.2 (introduction to physical properties of amines), let learners perform an experiment for identification of physical properties of amines which is proposed in the section "Consolidation activities" of this teacher's guide.

d) Application activities

Application activities 15.2 are provided in learner's book.

Answers to application activity 15.2

1.
   a) Butylamine because the N–H bonds can engage in hydrogen bonding; pentane cannot engage in hydrogen bonding
   b) $CH_3CH_2CH_2CH_2CH_2NH_2$ because it has a greater molar mass than CH_3NH_2
2. $CH_3CH_2NH_2$ because amines can engage in hydrogen bonding with water; alkanes cannot engage in hydrogen bonding

Lesson 3: Preparation of amines (40minutes)

a) Prerequisites

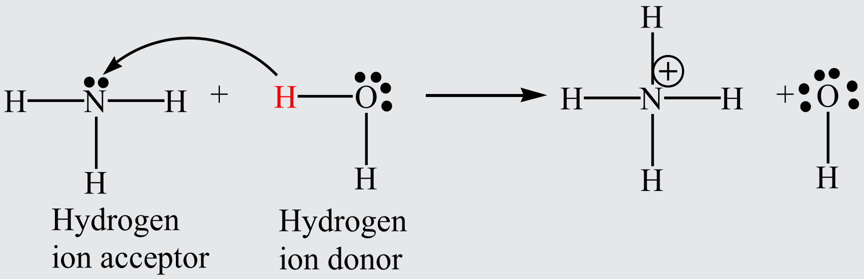
To learn this lesson, learners should be confident in explaining physical properties of common organic compounds. The activity 15.3 in learner's book is about reaction of ammonia with water. It will be used as learning activity of the lesson. Since this lesson has only 40 minutes, the revision should take less than 4 minutes of time.

The box below shows answers for the given activity.

Answers to activity 15.3

Ammonia and water molecules are reactants, while the ammonium ion and the hydroxide ion are products: $NH_{3(aq)} + H_2O_{(\ell)} \rightarrow NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

What has happened in this reaction is that the original water molecule has donated a hydrogen ion to the original ammonia molecule, which in turn has accepted the hydrogen ion. We can illustrate this as follows:



b) Teaching resources

You will avail the following resources: molecular models, chalkboard and chemistry books (learners books and reference books). A periodic table of elements and access to internet may also be necessary.

c) Learning activities

Guidance

The learning activities for this lesson will be designed so as to help learners to develop competences. You are advised to choose which activities suit the best to his class.

- Invite students to work ***individually*** on the activity proposed in the learner's book (activity 15.3).
- The duration for this activity should not exceed ***4 minutes***.

- Introduce the new lesson and make relevant explanations, based in the learners' findings in activity 15.3.
- While explaining, ask to learners relevant application questions to involve them in the teaching and learning activities.
- Individually, learners do self-evaluation exercises proposed in learner's book on (Checking up 15.3)
- Discuss and present their finding in plenary.

Note: A practical experiment for preparation of amines is proposed in the section "Consolidation activities" of this teacher's guide; it should be done before or during the lesson itself.

d) Application activities

Application activities 15.3 are provided in learner's book. The box below shows their answers.

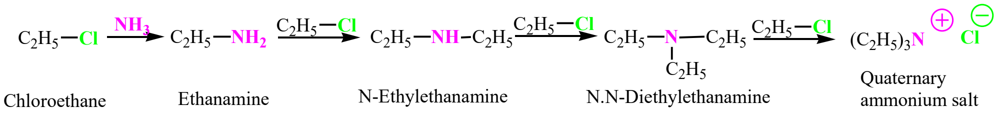
Answers to application activity 15.3

1. a) $LiAlH_4$ and H_2 with a platinum, palladium or nickel catalyst. ($NaBH_4$ does not work.)

   b) For $LiAlH_4$ the reaction takes place in ethoxyethane solution. With catalyst and H_2 the nitile is heated with H_2 in the presence of the metal.

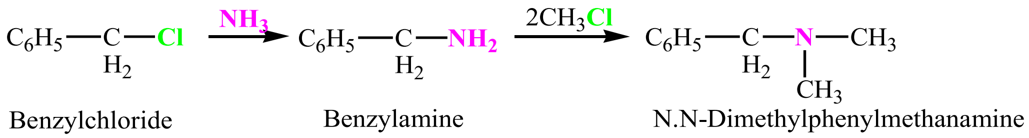
2.

a.



$$C_2H_5-Cl \xrightarrow{NH_3} C_2H_5-NH_2 \xrightarrow{C_2H_5-Cl} C_2H_5-NH-C_2H_5 \xrightarrow{C_2H_5-Cl} C_2H_5-\underset{\large C_2H_5}{N}-C_2H_5 \xrightarrow{C_2H_5-Cl} (C_2H_5)_3N^{\oplus}\ Cl^{\ominus}$$

b.



$$C_6H_5-\underset{H_2}{C}-Cl \xrightarrow{NH_3} C_6H_5-\underset{H_2}{C}-NH_2 \xrightarrow{2CH_3Cl} C_6H_5-\underset{H_2}{C}-\underset{\large CH_3}{N}-CH_3$$

Lesson 4: Chemical properties of amines (40minutes)

a) Prerequisites

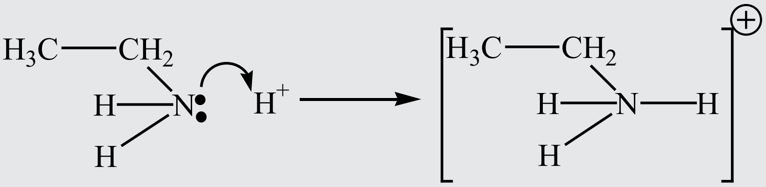
To learn this lesson, students should be confident with physical properties of amines. The activity 15.4 in learner's book is about reaction of ethylamine at room temperature, with hydrochloric acid and excess of sodium hydroxide. It will be used as the learning activity of the lesson. Since this lesson has only 1 period – 40 minutes, the experiment take less than 20 minutes of time.

The box below shows expected results of the experiment.

Answers to activity 15.4

Observations: The solution of ethylamine has a characteristic smell (A). When dilute hydrochloric acid is added in the solution (B), the temperature raises and the smell disappears (C). When excess of sodium hydroxide is added in the solution (D), the smell of amine returns (E).

Interpretation: like ammonia, the ethylamine carries a lone pair of electrons on its nitrogen atom. This enables it to form a dative bond to hydrogen ion from HCl:



Ethylamine is therefore a base like ammonia: when an acid is added to a solution of ethylamine, a salt is formed, *ethylammonium chloride* ($CH_3CH_2NH_3^+$ Cl^-). Like all salts, it is involatile and therefore has no smell.

When NaOH (strong base) is added to this salt, protons are removed from it. This reforms the free amine (ethylamine). $CH_3CH_2NH_3^+{}_{(aq)} + OH^-{}_{(aq)} \rightarrow CH_3CH_2NH_{2\ (aq)} + H_2O_{\ (l)}$

b) Teaching resources

You should avail the following resources: beakers, thermometer, hydrochloric acid, sodium hydroxide, molecular models, chalkboard and chemistry books (learners books and reference books). A periodic table of elements and access to internet may also be necessary.

c) Learning activities

The learning activities for this lesson will be designed so as to help learners to develop competencies. You are advised to choose which activities suit the best to his class.

- Helps learners to form groups of 4-5 students.
- ***In groups***, students perform the activity proposed in the learner's book (activity 15.4), about the reaction between ethylamine and HCl as well as with NaOH.

- The duration for this activity should not exceed ***20 minutes***.
- Introduce the new lesson and make relevant explanations, based on the learners' findings in activity 15.3.
- While explaining, ask learners relevant application questions to involve them in the teaching and learning activities.
- Individually, learners do self-evaluation exercises proposed in learner's book (Application activities 15.3)
- Discuss and present their finding in plenary.

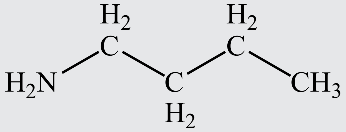
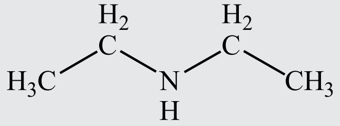
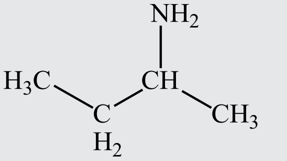
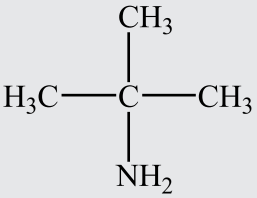
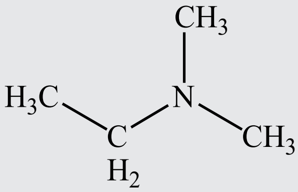
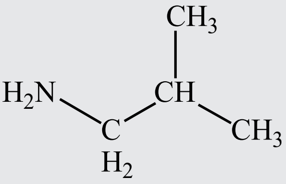
Note: due to limited time allocated to this lesson, homework should be provided to learners. It should be composed by a series of exercises related to chemical properties of amines and their reactivity.

d) Application activities

Application activities 15.4 are provided in learner's book. Their answers are given in the box below. Because of the lesson has only one period the teacher should give application activities in form of homework

Answers to application activity 15.4

1.

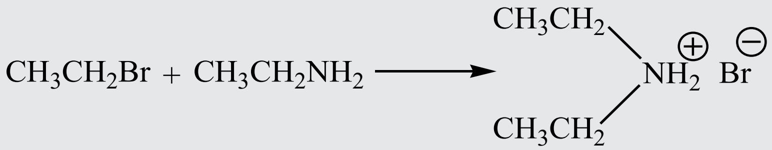
 n-Butylamine	 Diethylamine	 sec-Butylamine
 tert-Butylamine	 Dimethylethylamine	 Isobutylamine

2. a) $(CH_3)_2NH + H_2O \rightleftharpoons (CH_3)_2\overset{\oplus}{N}H_2 + OH^{\ominus}$

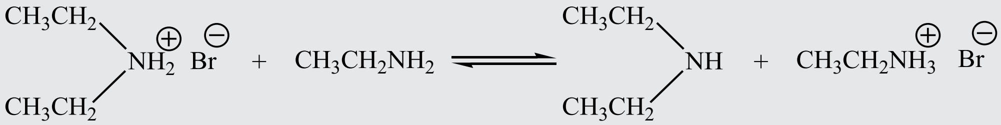
b) $(CH_3)_3\overset{\oplus}{N}H \quad \overset{\ominus}{Cl}$

3. Acidify the amine with dilute hydrochloric acid and then add sodium or potassium nitrite solution.

4. a)

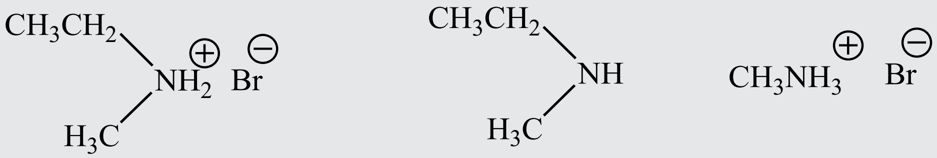


In the first reaction, the bromine is pushed off the ethyl group as a bromide ion, and is replaced by the whole of the amine to form an ammonium-like ion. The product is diethylammonium bromide.

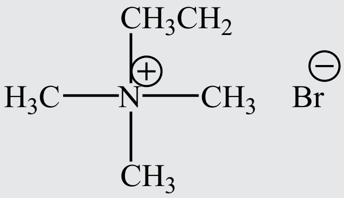


In the second reaction, equilibrium is set up involving a reaction between another ethylamine molecule which removes a hydrogen ion from the diethylammonium ion and forms the free diethylamine. In the process, ethylammonium bromide is formed. A similar reaction can happen between the two compounds on the right-hand side of the equation, reversing the reaction.

b.



c)



It doesn’t matter how you have positioned the hydrocarbon groups around the nitrogen in this or the similar example in part (c).

If you got these last three parts right, very well done! Having two different hydrocarbon groups involved makes the whole process seem much more difficult than it already is.

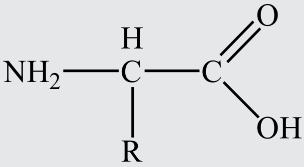
Lesson 5: General structure of amino acids and some common examples

a) Prerequisites

To learn this lesson, students should be confident with general structure of amines and carboxylic acids. The activity 15.5 in learner's book is about prediction of a general structure (displayed formula) of a molecule that contains an ***amino group*** and ***a carboxyl group*** on an aliphatic chain. It will be used as the learning activity of the lesson. The box below contains expected answer for that activity:

Answers to activity 15.5

General structure (displayed formula) of a molecule that contains an ***amino group*** and ***a carboxyl group*** on an aliphatic chain:



b) Teaching resources

You should avail the following resources: molecular models, chalkboard and chemistry books (learners books and reference books). A periodic table of elements and access to internet may also be necessary.

c) Learning activities

Guidance

The learning activities for this lesson will be designed so as to help learners to develop competencies. You are advised to choose which activities suit the best to his class.

- Invite students to work ***individually*** on the activity proposed in the learner's book (activity 15.5).
- The duration for this activity should not exceed ***4 minutes***.
- Introduce the new lesson and make relevant explanations, based in the learners' findings in activity 15.5.
- While explaining, ask learners relevant application questions to involve them in the teaching and learning activities.
- Individually, learners do self-evaluation exercises proposed in learner's book on (Application activity 15.5)

- Discuss and present their findings in plenary.

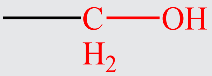
Note: Homework should be provided to learners. It should be composed by a series of exercises related to general structure of amino acids and some common amino acids. Elements of nomenclature of amino acids should be also incorporated (see teachers guide – Additional information for the teacher.

d) Application activities

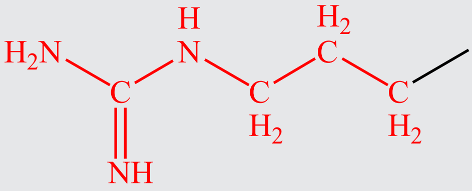
Application activities are provided in learner's book. The box below shows their answers.

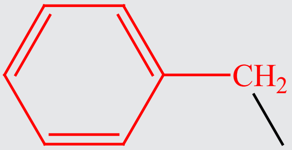
Answers to application activity 15.5

1.

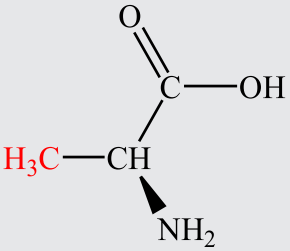
a) The side chain of serine: 

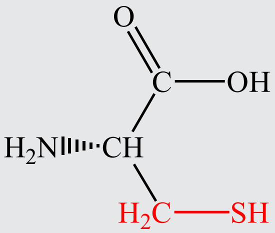
$-\underset{H_2}{C}-OH$

b) The side chain of arginine: 

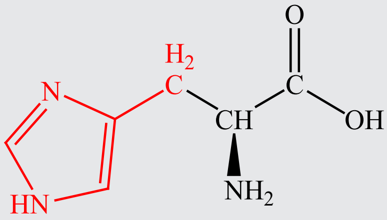
c) The side chain of phenylalanine: 

2.

a) The structure for alanine: 

b) The structure for cysteine: 

c) The structure for histidine:



3.

a) The amino acids whose side chain contain an amide functional group are ***asparagine or glutamine***

b) The amino acids whose side chain contain an aromatic ring are ***phenylalanine, tyrosine, or tryptophan***

c) The amino acids whose side chain contain a carboxyl group are ***aspartic acid or glutamic acid***

Lesson 6: Comparison of physical properties amino acids to those of carboxylic acids and amines

a) Prerequisites

To learn this lesson, learners should be confident with general structure of amines and carboxylic acids. The activity 15.6 in learner's book is about characteristic odour of Amines, Carboxylic acids and Amino acids. It will be used as a learning activity of the lesson. Since this lesson has only 40 minutes, the activity should be done in less than 5 min.

The box below contains expected results of the activity.

Answers to activity 15.6

Refer to table 15.6 in Learners' book.

b) Teaching resources

You should avail the following resources: molecular models, chalkboard and chemistry books (learners books and reference books). A periodic table of elements and access to internet may also be necessary.

c) Learning activities

Guidance

The learning activities for this lesson will be designed so as to help learners to develop competencies. You are advised to choose which activities suit the best to his class.

- Invite students to work ***individually*** on the activity proposed in the learner's book (activity 15.6).
- The duration for this activity should not exceed ***5 minutes***.
- Introduce the new lesson and make relevant explanations, based in the learners' findings in activity 15.6.
- While explaining, ask learners relevant application questions to involve them in the teaching and learning activities.
- Individually, learners do self-evaluation exercises proposed in learner's book on (application activity 15.6)
- Discuss and present their findings in plenary.

Note: Homework should be provided to learners. It should be composed by a series of exercises related to Comparison of physical properties amino acids to those of carboxylic acids and amines**.**

d) Application activities

Application activities 15.6 are provided in learner's book. It is about comparison of the solubility of amino acids, amines and carboxylic acids The box below shows their answers.

Answers to application activity 15.6

Refer to table 15.6 in Learners' book.

Lesson 7: Chemical properties of amino acids

a) Prerequisites

To learn this lesson, students should be confident with acidic and basic characters of amino acids. The activity 15.7 in learner's book is about reactivity of amino acids with acids and with bases. It will be used as introductory activity of the lesson. Since this lesson has only 40 minutes, the activity will be done in less than 4 minutes of time.

The box below shows expected results of the activity.

Answers to activity 15.7

1. $CH_3(CH_3)_2CH_3NH_2 + HCl \rightarrow CH_3(CH_3)_2CH_3NH_3^+Cl^-$
2. $CH_3CH_2COOH + NaOH \rightarrow CH_3CH_2COONa + H_2O$

b) Teaching resources

You should avail the following resources: molecular models, chalkboard and chemistry books (learners books and reference books). A periodic table of elements and access to internet may also be necessary.

c) Learning activities

Guidance

The learning activities for this lesson will be designed so as to help learners to develop competences. You are advised to choose which activities suit the best to his class.

- Invite students to work ***individually*** on the activity proposed in the learner's book (activity 15.7).
- Invite some students to present their findings.
- The duration for this activity should not exceed ***4 minutes***.
- Introduce the new lesson and make relevant explanations, based in the learners' findings in activity 15.7.
- While explaining, ask learners relevant application questions to involve them in the teaching and learning activities.
- Individually, learners do self-evaluation exercises proposed in learner's book (application activity 15.7)
- Discuss and present their finding in plenary.

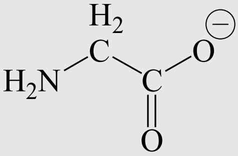
Note: Homework should be provided to learners. It should be composed by a series of exercises related chemical properties of amino acids.

d) Application activities

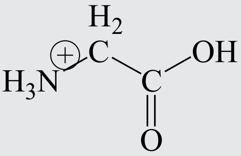
Application activities 15.7 are provided in learner's book. It is about reaction of glycine (and other amino acids) with acids and bases. The box below shows answers to that activity.

Answers to application activity 15.7

1. The base removes H^+ from the protonated amine group.



The acid adds H^+ to the carboxylate group.



2. Glycine is neutral and optically inactive amino acid. According to isoelectric point concept, the given formula will be applied

   The isoelectric point of the Glycine is 6.1

3. Lysine is basic amino acids (diamino monocarboxylic acid). According to isoelectric point concept, the given formula will be applied

   The isoelectric point of the Lysine is 9.7

Lesson 8: Optical isomers of amino acids

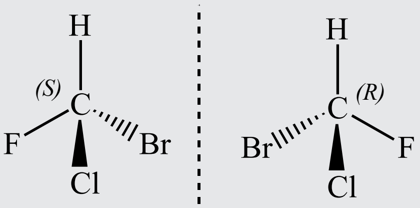
a) Prerequisites

Learners should be confident with isomerism in organic compounds to better understand this lesson. The activity 15.8 in learner's book is about revision on optical isomerism. It will be used as learning activity of the lesson. Since this lesson has only 40 minutes, the activity will be done in less than 5 minutes of time.

The box below shows expected results of the activity.

Answers activity 15.8

Optical isomers for CHBrClF



b) Teaching resources

You should avail the following resources: molecular models, chalkboard and chemistry books (learners books and reference books). A periodic table of elements and access to internet may also be necessary.

c) Learning activities

Guidance

The learning activities for this lesson will be designed so as to help learners to develop competences. You are advised to choose which activities suit the best to his class.

- Invite students to work ***individually*** on the activity proposed in the learner's book (activity 15.8).
- The duration for this activity should not exceed ***5 minutes***.
- Introduce the new lesson and make relevant explanations, based in the learners' findings in activity 15.8.
- While explaining, ask learners relevant application questions to involve them in the teaching and learning activities.
- Individually, learners do self-evaluation exercises proposed in learner's book on (application activity 15.8)
- Discuss and present their findings in plenary.

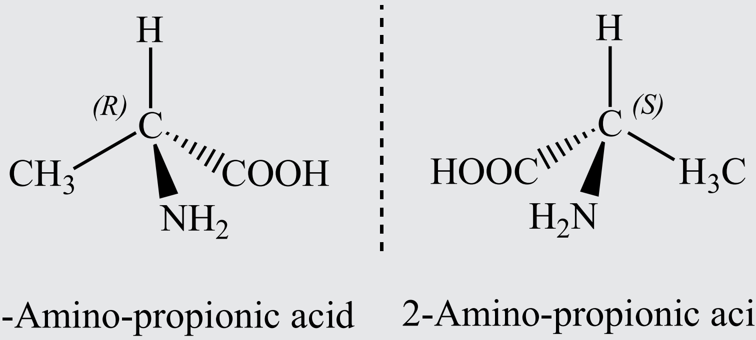
Note: Homework should be provided to learners. It should be composed by a series of exercises related to optical isomers of amino acids.

d) Application activities

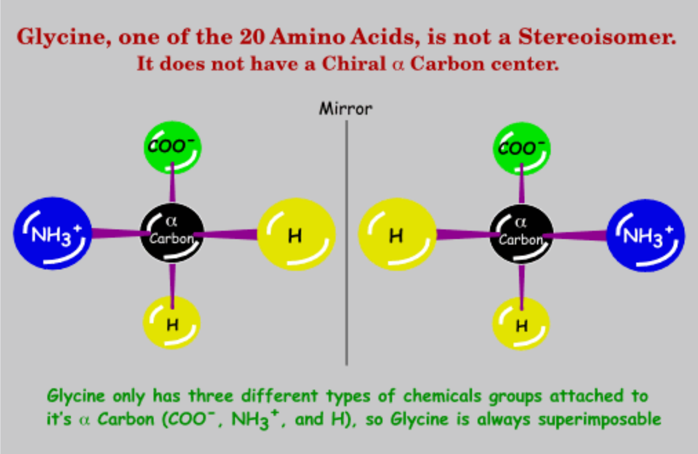
Application activities (15.8) are provided in learner's book. It is about optical isomerism and chirality. The box below shows answers to that activity.

Answers to application activity 15.8

1.



2. All amino acids, except glycine, are chiral because there are four different groups around the asymmetric C. In the case of glycine, there is no asymmetric carbon since there are two hydrogen atoms attached to it and therefore the four substituents are not different(see picture below). In conclusion, glycine is not chiral, instead it is achiral molecule.



Lesson 9: Peptides and polypeptides

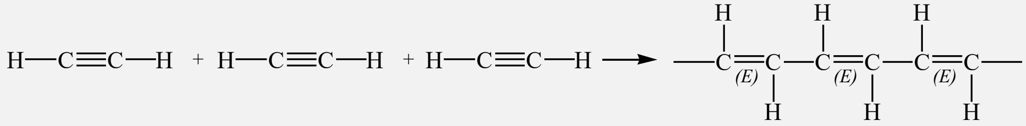
a) Prerequisites

Learners should be confident with polymerisation reactions to better understand this lesson. The activity 15.9 in learner's book is about revision on polymerisation of ethyne. It will be used as introductory activity of the lesson. Since this lesson has only 40 minutes, the activity will be done in less than 5 minutes of time.

The box below shows expected results of the activity.

Answers to activity 15.9

Reaction of polymerisation of ethyne:



$$H{-}C{\equiv}C{-}H + H{-}C{\equiv}C{-}H + H{-}C{\equiv}C{-}H \longrightarrow {-}\overset{H}{C}\underset{(E)}{=}\underset{H}{C}{-}\overset{H}{C}\underset{(E)}{=}\underset{H}{C}{-}\overset{H}{C}\underset{(E)}{=}\underset{H}{C}{-}$$

Hexa-1,3,5-triene

b) Teaching resources

You should avail the following resources: molecular models, chalkboard and chemistry books (learners books and reference books). A periodic table of elements and access to internet may also be necessary

c) Learning activities

Guidance

The learning activities for this lesson will be designed so as to help learners to develop competences. You are advised to choose which activities suit the best to your class.

- Invite students to work ***individually*** on the activity proposed in the learner's book (activity 15.9).
- The duration for this activity should not exceed ***5 minutes***.
- Introduce the new lesson and make relevant explanations, based in the learners' findings in activity 15.9.
- While explaining, ask learners relevant application questions to involve them in the teaching and learning activities.
- Individually, learners do self-evaluation exercises proposed in learner's book on (Application activity 15.9)
- Discuss and present their findings in plenary.

Note: Homework should be provided to learners. It should be composed by a series of exercises related to peptides and polypeptides.

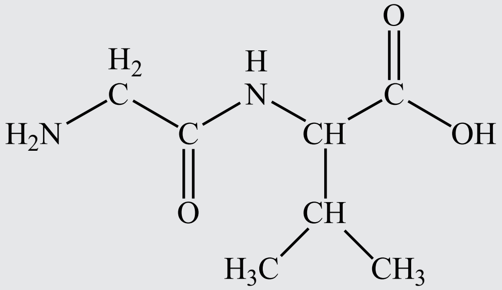
d) Application activities

Application activities (15.9) are provided in learner's book. The box below shows answers to that activity.

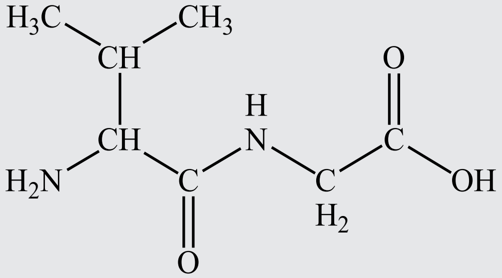
Answers to application activity 15.9

1. The N– terminal end is the end of a peptide or protein whose amino group is free (not involved in the formation of a peptide bond), while the C– terminal end has a free carboxyl group.
2. A peptide is composed of two or more amino acids. Amino acids are the building blocks of peptides.
3. Amide bond

a.



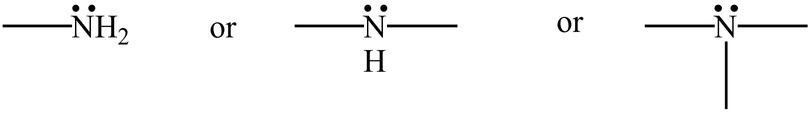
b.



4. C-terminal amino acid: cys; N-terminal amino acid: lys

15.6 Summary of the unit

- An amine is a derivative of ammonia in which one, two, or all three hydrogen atoms are replaced by hydrocarbon groups. The amine functional group is as follows



$-\ddot{N}H_2$ or $-\ddot{N}(H)-$ or $-\ddot{N}(-)-$

- Amines are classified as primary, secondary, or tertiary based on the number of hydrocarbon groups attached to the nitrogen atom.
- In IUPAC system, amines are named by naming the alkyl groups attached to the nitrogen atom, followed by the suffix ***-amine***.
- Primary and secondary amines have higher boiling points than those of alkanes or ethers of similar molar mass because they can engage in intermolecular hydrogen bonding. Their boiling points are lower than those of alcohols and carboxylic acids because they have hydrogen atoms bonded to an oxygen atom, which is more electronegative.

- The boiling points of tertiary amines, which cannot engage in hydrogen bonding because they have no hydrogen atom on the nitrogen atom, are comparable to those of alkanes and ethers of similar molar mass.
- Because all three classes of amines can engage in hydrogen bonding with water, amines of low molar mass are quite soluble in water.
- The chemistry of amines is mainly related to the basic nature of nitrogen atom. Amines can react with strong acids, nitrous acid, carboxylic acid as well as with Acyl chlorides and acid anhydrides.
- Reaction of alkyl halides with ammonia produces a mixture of primary, secondary or tertiary amines along with quaternary ammonium salts.
- Reduction of nitriles, amides and nitro compounds gives amines having the same number of carbon atoms.
- In Hofmann bromamide reaction, the amine formed has one carbon less than the starting amide.
- Like ammonia, amines behave as bases. Because of the lone pair of electrons on their nitrogen atom, they can readily accept protons (H^+ ions), reacting to form salts.
- Both aliphatic and aromatic amines are basic in nature. But aromatic amines are less basic and aliphatic amines are more basic than ammonia. An aliphatic secondary amine is more basic than primary and tertiary amines.
- Amides can be hydrolysed by aqueous alkali or acid. With aqueous alkali the products are the salt of a carboxylic acid and a primary amine.
- There are about 20 naturally occurring amino acids (2-amino-carboxylic acids) with the general formula $RCH(NH_2)COOH$, where R may be H, CH_3 or another organic group.
- The physical properties of amino acids, amines and carboxylic acids are strongly related and comparable.
- Amino acids react with both acids and bases to form salts.
- The amino group of one amino acid can react with the carboxyl group on another amino acid to form a peptide bond that links the two amino acids together. Additional amino acids can be added on through the formation of addition peptide (amide) bonds.
- A sequence of amino acids in a peptide or protein is written with the –N terminal amino acid first and the C– terminal amino acid at the end (writing left to right).

- Two amino acids react together in a condensation reaction, bonding together by a peptide (amide) link to form a dipeptide and water. Three amino acids form a tripeptide, and repetition of this condensation reaction many times leads to the formation of polypeptides and proteins.

15.7 Additional Information for teachers

15.7.1 Nomenclature of amino acids

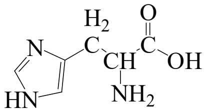
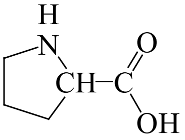
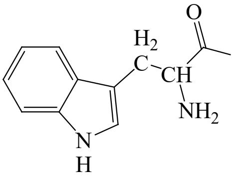
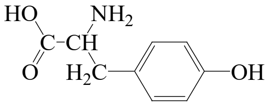
1. Names of common α-amino acids

The trivial names of the α-amino acids that are commonly found in proteins and are represented in the genetic code, together with their symbols, systematic names and formulas, are given in the learner's book.

The systematic names and formulas given refer to hypothetical forms in which amino groups are unprotonated and carboxyl groups are undissociated. This convention is useful to avoid various nomenclatural problems but should not be taken to imply that these structures represent an appreciable fraction of the amino-acid molecules.

Table 1. α-Amino acids incorporated into protein under mRNA direction.

Trivial name[a]	Symbols[b]		Systematic name[c]	Formula
Alanine	Ala	A	2-Aminopropanoic acid	$CH_3-CH(NH_2)-COOH$
Arginine	Arg	R	2-Amino-5-guanidinopentanoic acid	$H_2N-C(=NH)-NH-[CH_2]_3-CH(NH_2)-COOH$
Asparagine	Asn[d]	N[d]	2-Amino-3-carbamoylpropanoic acid	$H_2N-CO-CH_2-CH(NH_2)-COOH$
Aspartic acid	Asp[d]	D[d]	2-Aminobutanedioic acid	$HOOC-CH_2-CH(NH_2)-COOH$
Cysteine	Cys	C	2-Amino-3-mercaptopropanoic acid	$HS-CH_2-CH(NH_2)-COOH$
Glutamine	Gln[d]	Q[d]	2-Amino-4-carbamoylbutanoic acid	$H_2N-CO-[CH_2]_2-CH(NH_2)-COOH$
Glutamic acid	Glu[d]	E[d]	2-Aminopentanedioic acid	$HOOC-[CH_2]_2-CH(NH_2)-COOH$

Trivial name[a]	**Symbols**[b]		**Systematic name**[c]	**Formula**
Glycine	Gly	G	Aminoethanoic acid	$CH_2(NH_2)$-COOH
Histidine	His	H	2-Amino-3-(1*H*-imidazol-4-yl)-propanoic acid	
Isoleucine	Ile	I	2-Amino-3-methylpentanoic acid	C_2H_5-$CH(CH_3)$-$CH(NH_2)$-COOH
Leucine	Leu	L	2-Amino-4-methylpentanoic acid	$(CH_3)_2CH$-CH_2-$CH(NH_2)$-COOH
Lysine	Lys	K	2,6-Diaminohexanoic acid	H_2N-$[CH_2]_4$-$CH(NH_2)$-COOH
Methionine	Met	M	2-Amino-4-(methylthio)butanoic acid	CH_3-S-$[CH_2]_2$-$CH(NH_2)$-COOH
Phenylalanine	Phe	F	2-Amino-3-phenylpropanoic acid	C_6H_5-CH_2-$CH(NH_2)$-COOH
Proline	Pro	P	Pyrrolidine-2-carboxylic acid	
Serine	Ser	S	2-Amino-3-hydroxypropanoic acid	HO-CH_2-$CH(NH_2)$-COOH
Threonine	Thr	T	2-Amino-3-hydroxybutanoic acid	CH_3-CH(OH)-$CH(NH_2)$-COOH
Tryptophan	Trp	W	2-Amino-3-(l*H*-indol-3-yl)- propanoic acid	
Tyrosine	Tyr	Y	2-Amino-3-(4-hydroxyphenyl)-propanoic acid	
Valine	Val	V	2-Amino-3-methylbutanoic acid	$(CH_3)_2CH$-$CH(NH_2)$-COOH

The trivial name refers to the L or D or DL-amino acid; for those that are chiral only the L-amino acid is used for protein biosynthesis.

a) Use of the one-letter symbols should be restricted to the comparison of long sequences.

b) The fully systematic forms ethanoic, propanoic, butanoic and pentanoic may alternatively be called acetic, propionic, butyric and valeric, respectively. Similarly, butanedioic = succinic, 3-carbamoylpropanoic = succinamic, pentanedioic = glutaric, and 4-carbamoylbutanoic = glutaramic.

c) The symbol Asx denotes Asp or Asn; likewise B denotes N or D. Glx and Z likewise represent glutamic acid or glutamine or a substance, such as 4-carboxyglutamic acid, Gla, or 5-oxoproline, Glp, that yields glutamic acid on acid hydrolysis of peptides.

2. Formation of semisystematic names for amino acids and derivatives

a) Principles of Forming Names

Semisystematic names of substituted α-amino acids are formed according to the general principles of organic nomenclature, by attaching the name of the substituent group to the trivial name of the amino acid. The position of the substitution is indicated by locants. The configuration, if known, should be indicated.

New trivial names should not be coined for newly discovered α-amino acids unless there are compelling reasons. When they are needed (e.g. because the substance is important and its semisystematic name is cumbersome), the name should be constructed according to the general principles for naming natural products, including either some element of its chemical structure or reference to its biological origin. It is important to use no elements in the trivial name that imply an incorrect structure; when a new trivial name is used, it is essential that it be defined by a correctly constructed systematic or semisystematic name. A number of existing trivial names are given in the Appendix, and an extensive list has been published previously.

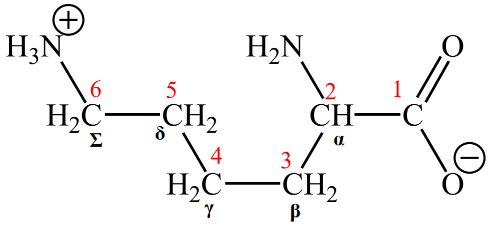
b) Designation of Locants

Note. The atom numbering given below is the normal chemical system for designating locants. A somewhat different system has been recommended for describing polypeptide conformations, in which Greek letters are used irrespective of the nature of the atom (unless it is hydrogen), so that in lysine N-6 becomes N^{ζ}, and in phenylalanine C-l, C-2 and C-6 become $C^{\delta 1}$ and $C^{\delta 2}$ respectively.

i) Acyclic Amino Acids

In acyclic amino acids, the carbon atom of the carboxyl group next to the carbon atom carrying the amino group is numbered 1. Alternatively, Greek letters may be used, with C-2 being designated α. This practice is not encouraged for locants, although terms like 'α-amino acids' and 'α-carbon atom' are retained. Example:

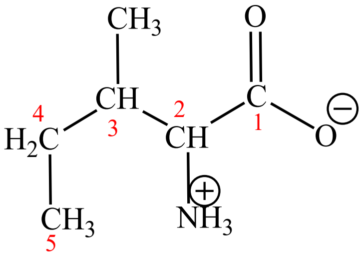
lysine



A heteroatom has the same number as the carbon atom to which it is attached, e.g. N-2 is on C-2. When such numerals are used as locants they may be written as N^6- or as 6-*N*, e.g. N^6-acetyllysine.

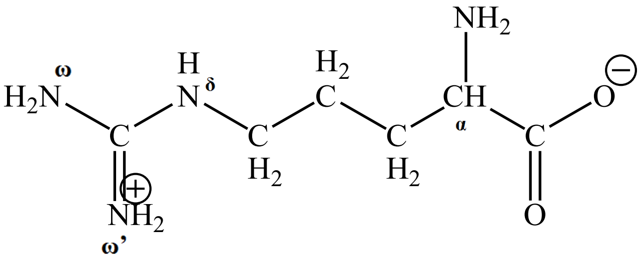
The carbon atoms of the methyl groups of valine are numbered 4 and 4'; likewise those of leucine are 5 and 5'. Isoleucine is numbered as follows:

isoleucine



The word 'methyl' can be italicized for use as a locant for substitution on (or isotopic modification of) the methyl group of methionine, e.g. [*methyl*-^{14}C] methionine. The nitrogen atoms of arginine are designated as shown for the arginine (1+) cation:

arginine

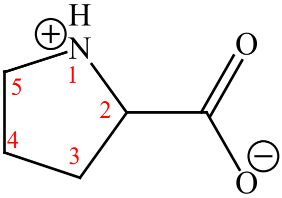


It should be noted that the ω and ω' atoms of this cation are equivalent because of resonance. The carbon atom in the guanidino group may be called guanidino-C (it may be needed as a locant for isotopic replacement although it cannot carry a substituent).

ii) Proline

The carbon atoms in proline are numbered as in pyrrolidine, the nitrogen atom being numbered 1, and proceeding towards the carboxyl group.

proline

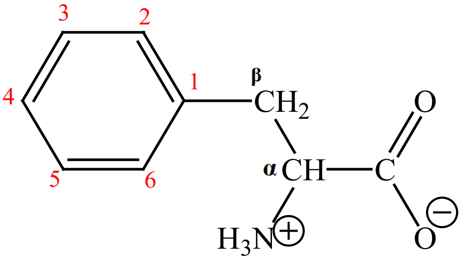


iii) Aromatic Rings

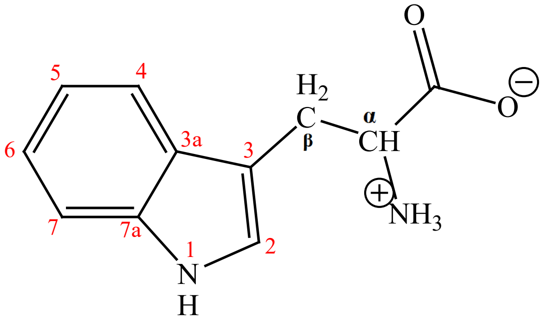
The carbon atoms in the aromatic rings of phenylalanine, tyrosine and tryptophan are numbered as in systematic nomenclature, with 1 (or 3 for tryptophan) designating the carbon atom bearing the aliphatic chain. The carbon atoms of this chain are designated α (for the carbon atom attached to the amino and carboxyl groups) and β (for the atom attached to the ring system).

Note. This numbering should also be used for decarboxylated products (e.g. tryptamine).

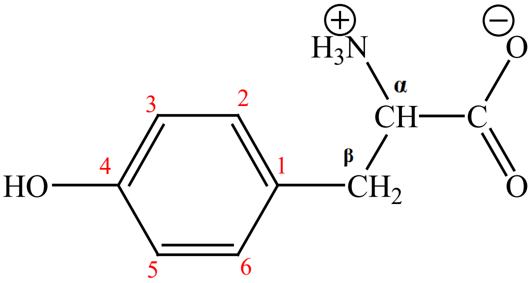
phenylalanine



tryptophan



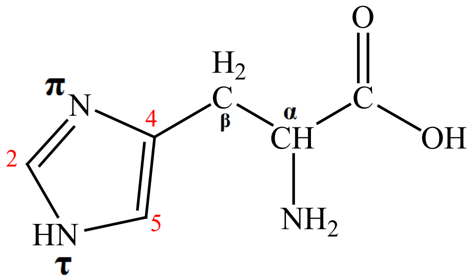
tyrosine



iv) Histidine

The nitrogen atoms of the imidazole ring of histidine are denoted by *pros* (‹near›, abbreviated π) and *tele* (‹far›, abbreviated τ) to show their position relative to the side chain. This recommendation arose from the fact that two different systems of numbering the atoms in the imidazole ring of histidine had both been used for a considerable time (biochemists generally numbering as 1 the nitrogen atom adjacent to the side chain, and organic chemists designating it as 3). The carbon atom between the two ring nitrogen atoms is numbered 2 (as in imidazole), and the carbon atom next to the τ nitrogen is numbered 5. The carbon atoms of the aliphatic chain are designated α and β as seen above. This numbering should also be used for the decarboxylation product histamine and for substituted histidine.

histidine

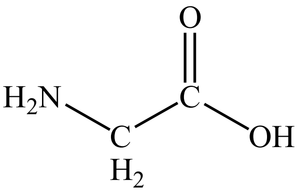


v) Definition of Side Chain

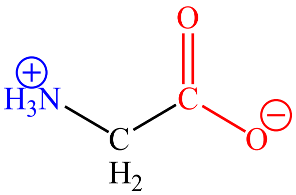
When amino acids are combined in proteins and peptides, C-l, C-2 and N-2 of each residue (the numbering being that of aliphatic amino acids) form the repeating unit of the main chain (‘backbone’) and the remainder forms a ‘side chain’. Hence the words ‘side chain’ refer to C-3 and higher numbered carbon atoms and their substituents.

15.7.2 Acid–base properties of amino acids

As the name suggests, amino acids are organic compounds that contain both a carboxylic acid group and an amine group. Amino acids are crystalline, high melting point (>200°C) solids. Such high melting points are unusual for a substance with molecules of this size — they are a result of internal ionisation. Even in the solid state, amino acids exist as ***zwitterions*** in which a proton has been lost from the carboxyl group and accepted by the nitrogen of the amine group:



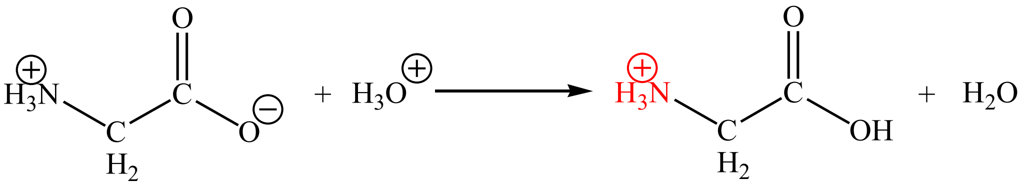
Glycine



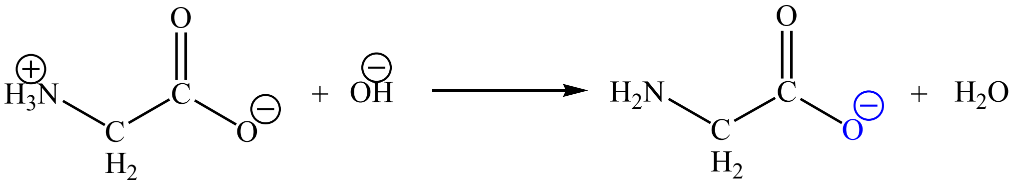
Zwitterion of glycine

So instead of hydrogen bonds between the amino acid molecules there are stronger ionic (electrovalent) bonds. This is reflected in the relative lack of solubility of amino acids in non- aqueous solvents compared with their solubility in water.

Zwitterions exhibit acid–base behaviour because they can accept and donate protons. In acidic medium a proton is accepted by the carboxylic acid anion, forming a unit with an overall positive charge:



In alkaline medium the reverse occurs with the loss of a proton from the nitrogen atom:



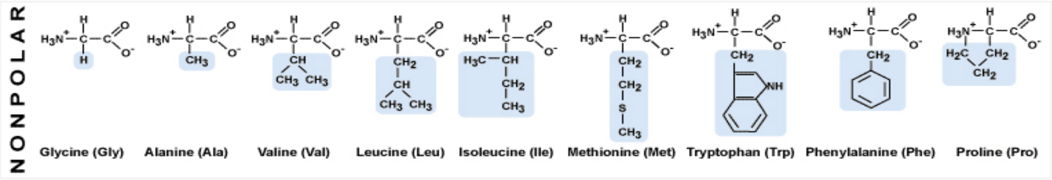
The species present in a given solution depends on the pH of the solution.

Carboxylic acids have acidic properties and react with bases. Amines have basic properties and react with acids. It therefore follows that amino acids have both acidic and basic properties.

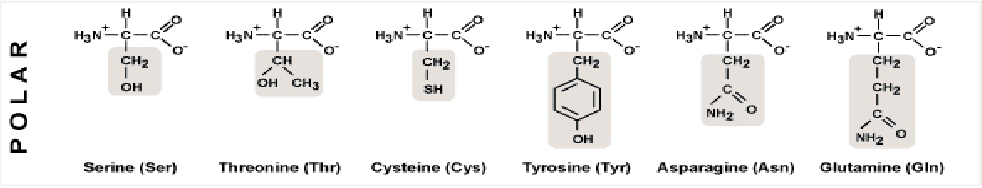
15.7.3 Polarity of amino acids

Amino acids can be divided into four different groups depending on their R group and overall structure: non-polar, polar, acidic, and basic, as described below:

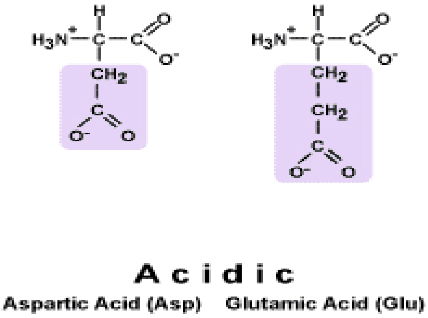
Nonpolar amino acids have R groups which have either attached aliphatic or aromatic side chains. As a result, these amino acids tend to be hydrophobic (water-fearing) in nature. Examples of this group are glycine, alanine, valine, leucine, isoleucine, methionine, tryptophan, phenylalanine, and proline.



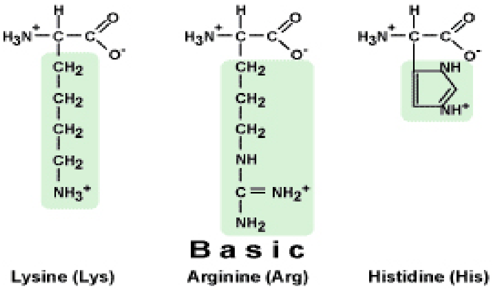
Polar amino acids. The distinguishing characteristic of this next group of amino acid is having at least one atom of nitrogen, oxygen, or sulfur, which is readily available to pair with water, hence making them polar. Examples of this group are serine, threonine, cysteine, tyrosine, asparagine, and glutamine.



Acidic amino acids. As their names suggests, aspartic acid and glutamic acids are the two examples of an acidic amino acid. The presence of a carboxylic acid on one side of the amino acid gives them the acidic property.



Basic amino acids. Last but not the least are lysine, arginine, and histidine which all fall under basic amino acids. These amino acids have a basic R group, hence the name. We can observe that most amino acids are hydrophilic (includes polar, acidic, and basic) in nature. Hence, they make an ideal component of globular proteins in solutions.



GUIDANCE TO SKILLS LAB 15

The tutor will avail laboratory chemicals $CuSO_4$, NaOH for biuret test
Ethanol for test for lipids or oils

1. for the biuret test milk will turn blue solution of $CuSO_4$ mixed with NaOH to violet
2. Ethanol will give an emulsion with milk

The learners are allowed to perform the experiment so as to help them develop the skills of working in laboratories, team work spirit, sharing diverse opinions

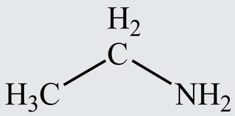
End unit assessment

The end unit assessment (summative assessment) for unit 15 is provided in the learner's book. This ***40 minutes*** assessment is composed of 3 questions which have some sub questions, and cover the content for the whole unit. Answers to those questions are provided below:

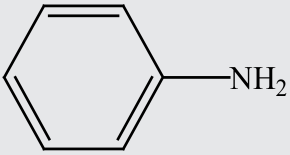
Answers to end unit assessment 15

1.

a.



ethylamine



phenylamine

b. E.g. $C_2H_5NH_2 + HCl \rightarrow C_2H_5NH_3^+Cl^-$

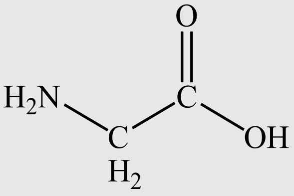
c .Lone pair on nitrogen

2.

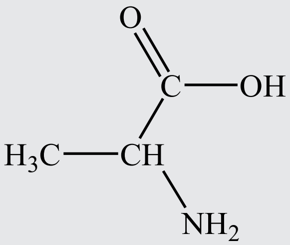
a.

i. glycine: aminoethanoic acid (2-aminoethanoic acid);
alanine: 2-aminopropanoic acid

2 ii.



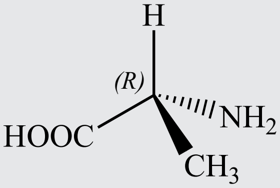
glycine ,

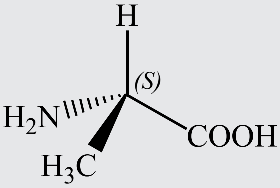


alanine

b . Alanine can exist as two stereoisomers.

i.



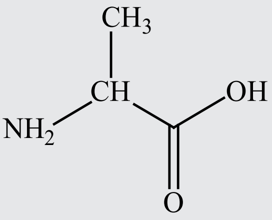


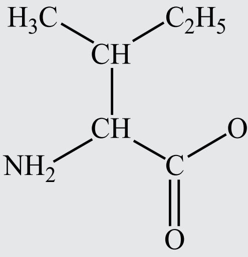
ii. It does not have a chiral carbon (a carbon with four different groups/ atoms attached), so no optical isomers; and it does not have a C=C double bond, so no geometrical (*cis*/*trans*) isomers.

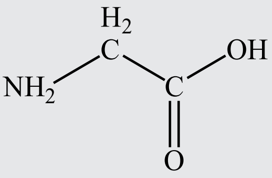
3 .

a.

i.







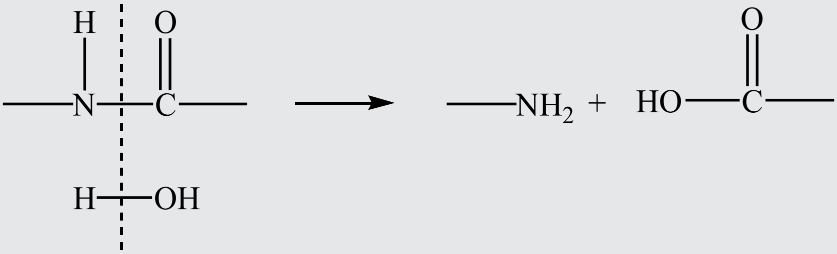
ii. The second one in the diagram above

b.

i. –CO–NH– / amide/peptide bond/link

ii. Hydrolysis means splitting of a bond / breaking down a compound using water.

iii.



15.8 Additional activities

15.8.1 Remedial activities

1. The table below shows the boiling points of a number of amines.

Type	Formula	Boiling point (°C)
Primary	CH_3NH_2	-6.3
Primary	$CH_3CH_2NH_2$	16.6
Primary	$CH_3CH_2CH_2NH_2$	48.6
Secondary	$(CH_3)_2NH$	7.4
Tertiary	$(CH_3)_3N$	3.5

a) What intermolecular forces are present in the primary amines?

b) Considering only the primary amines shown, explain why the boiling points increase as they do.

c) The secondary amine shown is an isomer of the primary amine, ethylamine (aminoethane). Why is its boiling point slightly less?

d) The tertiary amine shown is an isomer of the primary amine 1-aminopropane. Why is the boiling point much less?

e) Why are all the amines in this table soluble in water?

f) Why does the solubility become less with longer chain lengths?

2.

a) To make a primary amine like ethylamine you can react a halogenoalkane like bromoethane with ammonia. State the conditions for this reaction.

b) The equations for the reaction are:

$$CH_3CH_2Br + NH_3 \rightarrow CH_3CH_2NH_3^+ Br^-$$

$$CH_3CH_2NH_3^+ Br^- \leftrightarrow CH_3CH_2NH_2 + NH_4^+ Br^-$$

Describe in words what is happening in these two equations.

c) Unfortunately the reaction doesn't stop there, and you end up with a mixture of several organic products rather than the two (the amine salt and the free amine) shown above. By writing equations like the ones in part (b), show what happens to make the next lot of products from those in the reactions above.

d) The reaction wouldn't stop there either. There are three further organic products that you could get. Draw their structures.

e) What would your major product be if you had a large excess of bromoethane in the original reaction mixture?

f) What would your major product be if you had a large excess of ammonia in the original reaction mixture?

3. Primary amines can be made from nitriles avoiding the complicated mixtures formed above. The reaction can be done with either lithium tetrahydridoaluminate (lithium aluminium hydride), or hydrogen in the presence of a metal catalyst.

a) Give the conditions for the reaction involving $LiAlH_4$.

b) This reaction is a reduction, and the equation is commonly given using the symbol [H] for the reducing agent. Write the equation for the reduction of CH_3CH_2CN using LiAlH4.

c) Suggest a suitable catalyst for the reduction of CH_3CH_2CN with hydrogen gas.

d) Write the equation for that reduction.

Answers

1.

a) Van der Waals dispersion forces, dipole-dipole attractions and hydrogen bonds.

b) As the molecules get bigger, the potential for van der Waals dispersion forces increases, and so more energy is needed to boil the amine.

c) The dispersion forces and hydrogen bonding will be much the same, but with the nitrogen in the middle of the molecule rather than at the end, the permanent dipole a rather smaller, and so the dipole-dipole attractions will be a bit weaker.

d) A molecule of a tertiary amine can't form hydrogen bonds with other tertiary amine molecules. Hydrogen bonding needs a hydrogen atom attached to an electronegative element, and in a tertiary amine, there aren't any hydrogens attached to the nitrogen.

e) They can all form hydrogen bonds with water (including the tertiary amines). When the amine dissolves, hydrogen bonds between amine molecules and between water molecules have to be broken, but are replaced by similar strength hydrogen bonds between amine molecules and water molecules. In the case of a tertiary amine, you can get a hydrogen bond between the lone pair on the nitrogen and a slightly positive hydrogen atom from the water.

f) You have to break increasing numbers of hydrogen bonds in the water as the bigger amines fit between the water molecules, but these are only replaced by hydrogen bonds involving the single nitrogen atom. It becomes energetically unprofitable.

2.

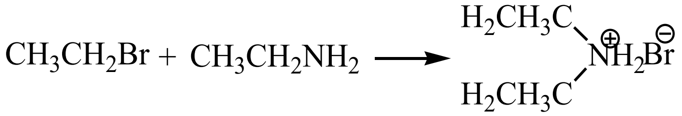
a) Heat a mixture of bromoethane and a concentrated solution of ammonia in ethanol in a sealed tube.

b) $CH_3CH_2Br + NH_3 \rightarrow CH_3CH_2NH_3^+ Br^-$

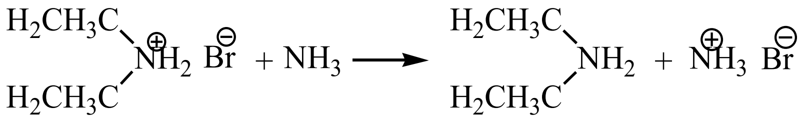
In the first equation the ammonia reacts with the bromoethane, breaking the bond between the ethyl group and the bromine atom. The product is the ionic salt, ethylammonium bromide.

$CH_3CH_2NH_3^+ Br^- + NH_3 \leftrightarrow CH_3CH_2NH_2 + NH_4^+ Br^-$

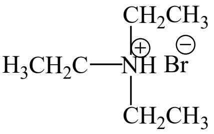
In the second reaction another ammonia molecule removes a hydrogen ion from the nitrogen in the salt to leave the free amine and produce the ammonium ions which form ammonium bromide. This reaction is reversible, and so you end up with a mixture of everything in the equation.

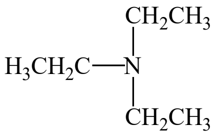


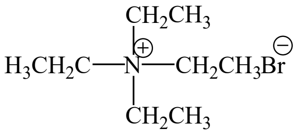
c)



d)







These are probably easier to see if you write them in a more condensed form:

$(CH_3CH_2)_3NH^+ Br^-$ $(CH_3CH_2)_3N$ $(CH_3CH_2)_4N^+ Br^-$

It is certainly easier to see their relationship with ammonia and ammonium salts if you write them like this.

e) $(CH_3CH_2)_4N^+ Br^-$

f) $CH_3CH_2NH_2$

15.8.2 Consolidation activities

This section embraces a series of experiments which should be performed to consolidate what has been learned in this unit. You are asked to prepare them and let learners perform them before or after the concerned lessons.

Pre-laboratory questions

1. Draw the structure of the following organic molecules. For ionic compounds simply give the chemical formula.
2. For each of the amines and amides in the preceding question label them as primary, secondary or tertiary.

Experiment 15.1 Solubility of Amines in Water and Acid

1. Perform the following in the fumehood.
2. Add 5 drops of each amine (*1-hexanamine, diethylamine, triethylamine and N-methylaniline*) to a separate test tube.
3. Carefully detect the odor of all the compounds by carefully wafting. Record your observations.
4. Add 2 mL of water to each test tube. Stir vigorously. Record your observations.
5. Wait 2-3 minutes and record your results.
6. Determine the pH of each solution using a stirring rod and pH paper.
7. Add 10% HCl drop-wise to each solution until the solution is acidic to blue litmus paper. Record your results. Note any color changes or odors.
8. Write a balanced chemical reaction for each neutralization that occurred in the previous step.
9. Dispose of the contents of the test tubes in the waste bottle labelled *"Experiment 15.1 Waste"*.

Results – Solubility of Amines in Water and Acids

The following table will be used in recording data, for the first experiment:

	1-hexanamine	**diethylamine**	**Triethylamine**	**N-methylaniline**
Odour				
Initial Solubility in Water				
Solubility in Water after 2-3 minutes				
pH				
Reaction Products for Amine + H_2O				
Observations after addition of HCl (Odor, Color, Solubility)				
Reaction product after addition of HCl				

Experiment 15.2 Distinguishing Primary, Secondary and Tertiary Amines

1. Perform the following in the fumehood. Dissolve 0.5 mL of the amine (*1-hexanamine, diethylamine, triethylamine and N-methylaniline*) in 2.5 mL of water. Carefully (drop-wise) add 1.5 mL of concentrated HCl.
2. Cool the resulting solution in an ice-water bath for 5 minutes.
3. In a separate test tube dissolve 2.0 g of sodium nitrite in 10.0 mL of water.
4. Add 2.5 mL if the sodium nitrite solution (made in the previous step) 5 drops at a time to the test tube containing the amine to be tested. Keep the test tube immersed in the ice water bath at all times except to briefly mix

the solution between adding drops. Test for the formation of nitrous acid after each addition of sodium nitrite by placing a drop of the solution on starch-iodide paper, a blue colour indicates the formation of nitrous acid. Continue the addition until the mixture gives a positive test for nitrous acid.

5. Remove 2.0 mL of the resulting solution and slowly warm it to room temperature in a water bath. Record your observations.
6. Dispose of the contents of the test tubes in the waste bottle labelled *“Experiment 15.2 Waste”*.

Results – Primary, Secondary and Tertiary Amines

	1-hexanamine	**Diethylamine**	**Triethylamine**	**N-methylaniline**
Initial Observations				
Observations on addition of sodium nitrite (in ice water)				
Observations on warming to room temperature				
Conclusion: *Primary, Secondary or Tertiary Amines*				

After-laboratory questions

1. Which amines were soluble in water?
2. Which amines were insoluble in water?
3. What conclusion(s) can you make relating amine structure and solubility in water?
4. Amines are responsible for the nasty odor of many substances including the odor of fish. Explain why lemon juice might remove the odor of fish.

15.9. Extended activities

After the deep understanding of the content on amines and amino acids, students should be able to relate what they have learnt in previous units with the content of this unit. For that, you are asked to prepare and give those kinds of questions. Sample activities are provided below:

Questions

1. You have 3 unknown solutions: a carboxylic acid, an ester, and an amine. Describe how you might distinguish between them.
2. Primary amines can be made from nitriles avoiding the complicated mixtures formed above. The reaction can be done with either lithium tetrahydridoaluminate (lithium aluminium hydride), or hydrogen in the presence of a metal catalyst.
    a) Give the conditions for the reaction involving $LiAlH_4$.
    b) This reaction is a reduction, and the equation is commonly given using the symbol [H] for the reducing agent. Write the equation for the reduction of CH_3CH_2CN using LiAlH4.
    c) Suggest a suitable catalyst for the reduction of CH_3CH_2CN with hydrogen gas.
    d) Write the equation for that reduction.

Answers

1. See learner's book.
2.
    a) The nitrile reacts with the lithium tetrahydridoaluminate in solution in ethoxyethane (diethyl ether, or just "ether") followed by treatment of the product of that reaction with a dilute acid.
    b) $CH_3CH_2CN + 4[H] \rightarrow CH_3CH_2CH_2NH_2$
    c) Palladium, platinum or nickel. There are undoubtedly other similar catalysts, but stick with one of the commonly quoted ones.

$CH_3\ CH_2\ CN + 2H_2 \rightarrow CH_3CH_2CH_2NH_2$

UNIT 16

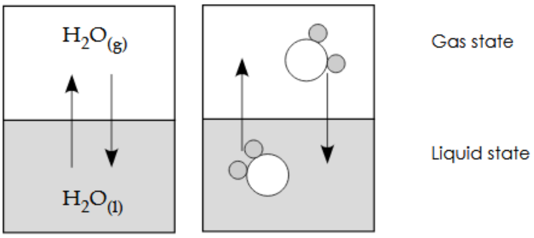
FACTORS THAT AFFECT CHEMICAL EQUILIBRIUM

16.1. Key unit competence

Deduce how concentration, pressure, catalyst and temperature affect the chemical processes in industry.

16.2. Prerequisite knowledge and skills

As a teacher you need to a simple example boiling water, water (H_2O (l)) is in equilibrium with its vapor (H_2O (g)). The rate of evaporation is equal to the rate of condensation in a closed container at a constant temperature. At the particulate level, for every one molecule of water (H_2O (l)) that evaporates, another water vapor molecule (H_2O (g)) condenses to the liquid state. This is an example of a reversible reaction for a physical equilibrium. At least many of your students could have boiled water. This example is used to conceptualize reversible.



In addition to the above, learners need to remember the concept of limiting reactants studied in ordinary level and moles.

16.3. Cross-cutting issues to be addressed

Gender studies:

People fighting for gender equality are feminists. Actuality, gender equality concerns every single person in society, both males and females. People who fight for gender equality have to fight to females, who have been oppressed in the male-dominated-and-favoured society that we live in and who is at a disadvantage due to this particular perception. It isn't that people favour women over men, it simply is that women deserve the same opportunities that men receive and the same respect that men receive. Advocates of gender equality aren’t fighting for women to get better treatment; they just want them to be regarded with respect as men. This brings balance/equilibrium in the society or families and foster peace.

16.4. Guidance on introductory activity

Before introducing the first lesson of this unit learners should look at the diagram in the introductory activity and attempt the questions in groups. Let learners attempt activity 16.1. The introductory and learning activities are intended to:

- Relate the unit with learners’ daily life to capture their attention.
- Assess learners’ understanding of the concept of reversible and irreversible reactions or reactions that undergo completion.
- Explain how the equilibrium can be disturbed

The figures in the introductory activity show that when two teams pull on a rope with equal force. The resulting force is equal in magnitude and equal to zero and the rope does not move, the system is said to be in equilibrium. ***Students on in figure (a) represent a system in equilibrium. The equal and opposite forces on both ends of the seesaw are balancing. If, instead one force is greater in magnitude than the other, the system is not in equilibrium [figure (b)]***

16.5. List of lessons:

Lesson nº	Lesson title	objectives	No of periods
1	• Complete versus reversible reactions • Concept and characteristics of a dynamic equilibrium	• Distinguish between complete and reversible reactions. • Explain dynamic equilibrium. • State the characteristics of dynamic equilibrium.	1
2	- Factors that affect equilibrium position (concentration, temperature, pressure and catalyst). Use Le Chatelier’s principle.	• Explain the factors that affect the position of the equilibrium in a reversible reaction. • Apply Le Châtelier’s principle to explain the effects of changes in the temperature, concentration and pressure on a system in equilibrium.	2

3	- Application of those factors on industrial processes (contact process and Haber process)	• Recognize the importance of Le Châtelier's principle in Haber and Contact processes. • Compare and contrast theoretical and actual optimal conditions in the industrial processes. • Relate the effect of concentration, temperature, pressure and catalyst to the amount of products in the manufacturing industries.	1
End of unit assessment			1

Lesson 1: Difference between complete and incomplete reactions (reversible versus irreversible reactions, concept of equilibrium (dynamic equilibrium) and their Characteristics

a) Prerequisites/Revision/Introduction:

Students will learn better the concept of reactions that undergo completion and those do not go to completion when they have knowledge about the concept of equilibrium learnt in physics and any factor in our daily life that can disturb the state of equilibrium

b) Teaching resources:

- Use the illustrations in the learners' book or draw them on a manila paper or a black board may be enough.

c) Learning activities:

Task1

Provide the exercise 16.1 from a student book or you can write it on a black board or on pieces of paper.

Ask the learners to do activity 16.1(task1) individually in their exercise books.

Allow some learners to present their answers on the black/white board

Learners compare the equations written on the black/white board and make conclusion

Task 2

Provide the ropes and ask learners to go out of the classroom

Divide learners into two groups (you can create many other groups if learners are many)

Note that the number of learners should be equal to create the equilibrium.

Provide the instructions about the tug-of-war game.

Provide learners with activity 16.1 (task 2) and allow them to do activity.

Select the learners to read the answers to the whole class when the corrections are made.

Ask learners to comment and relate the game with the lesson about concept of equilibrium

Ask learners to answer the activity 16.1 in students' book

Answers to activity 16.1

1. A complete reaction is a reaction which proceeds in only *one direction,* in other words, the reactants are completely transformed into products. Example:

$$AB\ (s) \longrightarrow A\ (s) + B(g)$$

2.An incomplete reaction proceeds in both direction and indicated by placing two half arrows pointing in opposite directions between the reactants and products. The forward reaction is indicated by an arrow oriented from left to right and the reverse reaction from right to left.

$$AB \rightleftharpoons A+B$$

3. Refer to student's book 16.1

4.Refer to student's book 16.1. sub title c)

5. Refer to student's book 16.1 sub title b)

6. Three and four learners discuss in groups, make presentation and the teacher collect all the answer for harmonisation

d) Application activity 16.1

Answers to application activity 16.1

1.(a)$HCl + NaOH \longrightarrow NaCl + H_2O$ **(irreversible)**

(b) $BaCl_2 + 2\ AgNO_3 \longrightarrow 2\ AgCl + Ba(NO_3)_2$**(irreversible)**

(c)$CaCO_3 + 2\ HCl \longrightarrow CaCl_2 + H_2CO_3$ **(irreversible)**

(d)$4NH_{3(g)} + 5O_{2(g)} \rightleftharpoons 4NO_{(g)} + 6H_2O_{(g)}$ **(reversible)**

(e)$2SO_{3(g)} \rightleftharpoons 2SO_{2(g)} + O_{2(g)}$**(reversible)**

(f)$N_{2(g)} + O2_{(g)} \rightleftharpoons 2NO_{(g)}$**(reversible)**

(g)$2H_2O_{(g)} + 2SO_{2(g)} \rightleftharpoons 2H_2S_{(g)} + 3O_{2(g}$ (reversible)

(h)Irreversible

(i) Irreversible

(j) Irreversible

(k) Reversible

2. -The rate of the forward reaction is equal to the rate of the reverse reaction
   - Microscopic processes (the forward and reverse reaction) continue in a balance which yields no macroscopic changes (nothing appears to be happening.)
   - The system is closed and the temperature is constant and uniform throughout.
   - The equilibrium can be approached from the left (starting with reactants) or from the right (starting with products)

3. Homogeneous reaction has reactants and products in the same phase. For example:

   (i) $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$

   (ii) $4NH_{3(g)} + 5O_{2(g)} \rightleftharpoons 4NO_{(g)} + 6H_2O_{(g)}$

While in heterogeneous, the reactants and products are in different phases. For example:

(i) $S_{(s)} + H_2SO_{3(aq)} \rightleftharpoons H_2S_2O_{3(aq)}$

(ii) $2ZnS_{(s)} + 3O_{2(g)} \rightleftharpoons 2ZnO_{(s)} + 2SO_{2(g)}$

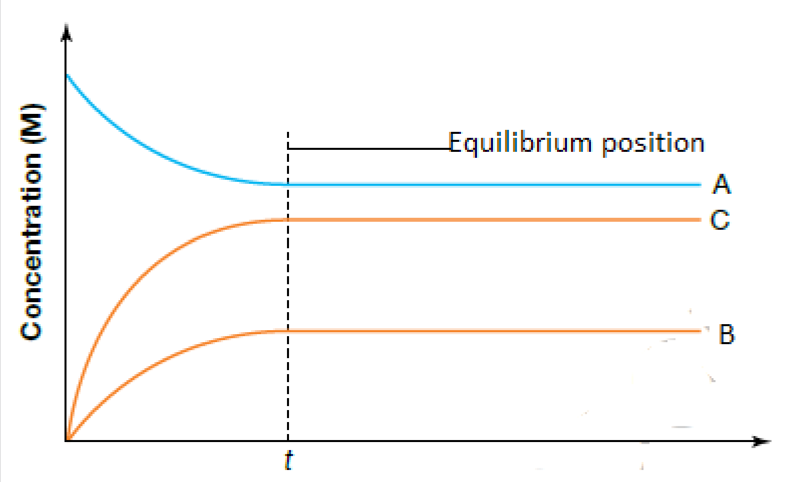
4. A dynamic equilibrium is a process where the forward and reverse reactions proceed at the same rate and after a period of time, the concentrations of reactants and products remain constant (do not change).

Example: $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$

5. When a chemical reaction takes place in a container which prevents the entry or escape of any of the substances involved in the reaction, the quantities of these components change as some are consumed and others are formed. The system is then said to be in its equilibrium state.

6. For $A \rightleftharpoons C + B$

During a reversible reaction towards the equilibrium concentration of reactants decrease while that of products increase. When the equilibrium is attained, the concentration of reactants is equal that of products.



Lesson 2: Factors that affect the reactions in equilibrium and Le Châtelier's principle (2 periods)

a) Prerequisites/Revision/Introduction:

This lesson will be well delivered if students have a good understanding of collision theory of matter in relation with the temperature studied in senior 1, ideal gas law in relation with the pressure learnt in senior 2, effect of concentration, catalysts,pressure and temperature on the reaction rate studied in senior 3

b) Teaching resources:

Student book, reference book from library or internet

c) Learning activities

- Students will discuss on questions in activity 16.2.1, activity 16.2.2, activity16.2.3and activity 16.2.4 and answer them. The discussion will be done in groups but let each learner write answers in her/his exercise book. The teacher must be sure that all learners are involved in the activity. Each group must have a leader who will be moderator and a secretary who writes the report and will present findings of the group.
- Move around the class, listening to students as they discuss and provide support where needed.
- Each group will make presentation of their findings
- Valuing learners' presentations(judgment and discovery of possible mistakes by students)
- This is diagnostic activity; the next step will greatly depend on your judgment. If your class can not correctly answer the question, extra explanations and exercises are necessary. But if they are correctly answered then the teacher can proceed and give a summary of the first part of the lesson. A summary of the content must be written on the board.
- Because the lesson requires 2 periods the teacher will provide one period to the effect of temperature and pressure ,another period will be allocated to the effect of concentration and catalyst

Answers to activity 16.2

1. When cooking beans it is required to use water as cooking liquid, fire for heating, the use of catalyst(ex:hydrogen carbonate/igikukuru) to accelerate the process

2. a) $N_2(g)+3H_2(g) \rightleftharpoons 2NH_3(g)$

b) Temperature 350-400^{o}c, Pressure=150-300 atm

c) Catalyst and promoters are used to accelerate the rate of reaction and to reduce the energy of activation

Answer to activity 16.2.1

1. By dissolving sulphuric acid in water the walls of the container feel hot. It is not allowed to pour water in sulphuric acid to avoid explosion.The reaction releases heat energy and is termed as exothermic reaction

2.a)Endothermic :reaction which absorbs energy

b) Exothermic: which releases energy

Answers to activity 16.2.2

If we add either N_2 or H_2, the collisions between N_2 and H_2 are increased and more products NH_3 are formed. It means that the equilibrium shifts from left to right. However, if more NH_3 are added, the concentration of NH_3 is increased. As a result, some NH_3 decomposes and forms more reactants. The equilibrium shifts from right to left.

Answers to activity 16.2.3

1. Molecules of CO_2 in (b) are less than that in (a)
2. The cause is the exerted pressure in (b)
3. You should reduce the pressure
4. The equilibrium will shift to right i.e. the direction of decreasing the number of gaseous molecules

Answers to activity 16.2.4

1. An enzyme is a biological catalyst that allows the breaking of biological molecules
2. A catalyst is a substance that speeds up the rate of a reaction and remains unchanged after the reaction.

   in the Haber process :Fe

   in contact process :V_2O_5
3. The breaking down and digestion of polymer molecules in food will not occur
4. The **processes** will go slowly or either will be stopped

d) Application activities

After each period in learning activities the teacher will provide the application activities 16.2.1,16.2.2,16.2.3 and 16.2.4 for which the answers are given below:

Answers to application activity 16.2.1

1) $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2\ SO_{3(g)}$; $\Delta H^o = -180$ kJ **(low temperature)**

2) $CO_{(g)} + H_2O_{(g)} \rightleftharpoons CO_{2(g)} + H_{2(g)}$; $\Delta H^o = -46$ kJ **(low temperature)**

3) $CO_{(g)} + Cl_{2(g)} \rightleftharpoons COCl_{2(g)}$; $\Delta H^o = -108$ kJ **(low temperature)**

4) $N_2O_{4(g)} \rightleftharpoons 2\ NO_{2(g)}$; $\Delta H^o = +57$ kJ **(high temperature)**

Answers to application activity 16.2.2

(1) Le Châtelier's Principle, when the temperature, pressure or concentration of a reaction in equilibrium is changed, the reaction shifts in the direction where the effect of these changes is reduced.

2. Concentration, temperature, pressure and catalyst.

3. Increasing the concentration of any one of the reactants shifts the equilibrium to right to reduce the concentration. On the other hand removing any one of the reactants or reducing the concentration of the reactants will shift the equilibrium to left to replace the removed species and maintain the equilibrium.

4. a) If H_2 is added, there is now more reactant, so the reaction will shift toward products to reduce the added H_2.

$2Ga(s)+6H_2O(l)+2OH^-(aq) \longrightarrow 3H_2(g)+2Ga(OH)_4^-(aq)$ NH_3 is added, there is now more products, so the reaction will shift toward reactants to reduce the added NH_3.

c) If NH_3 is removed, there is now fewer products, so the reaction will shift toward products to replace the product removed.

Answers to application activity 16.2.3

1) $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2\ SO_{3(g)}$ **(high pressures)**

2) $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$ **(low pressures)**

3) $CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)}$ **(high pressures)**

4) $N_2O_{4(g)} \rightleftharpoons 2\ NO_{2(g)}$ **(low pressures)**

5) $H_{2(g)} + F_{2(g)} \rightleftharpoons 2\ HF_{(g)}$ **(no effect)**

6. (a) According to Le Châtelier's principle, if the pressure is increased, the equilibrium shifts to the side with the fewer number of moles of gas. This particular reaction shows a total of 4 mol of gas as reactants and 2 mol of gas as products, so the reaction shifts toward the products side.

(b) Reaction shifts towards the reactant

Answers to application activity 16.2.4

1. a. The position of the equilibrium always moves forward to increase the yield of SO_3.

   b. Increase in temperature would reduce the production of SO_3 whereas the increase in pressure would increase the production of SO_3

   c. No effect on the production of SO_3

   d. To favour the formation of the product since the equilibrium will always move forward.

   e. Higher temperature (more than 450°C) would reduce the production by shifting the equilibrium to the left. However, the temperature lowers than 450°C would slow the reaction.

   f. Higher pressures would be increase the yield as it favours the forward reaction. Since the foreward reaction proceeds by reduction in moles/volume. However, it is very expensive to maintain.

   g. It is very expensive

2. a) The reaction will shift in the direction of increasing the removed substance hydrogen(backward reaction)

   b) Increasing pressure of gases by decreasing the volume will shift the reaction in the direction of reducing the number of gaseous molecules (forward reaction)

   c) The reaction will reach the dynamic equilibrium

   d) The increase of temperature will favour the endothermic reaction (the backward one)

   e) The catalyst will reduce the activation energy so that the reaction will go forward

3. When the concentration of water is increased, the equilibrium shifts toward right (formation of products)

Lesson 3: Application of factors that affect the equilibrium on industrial processes

a) Prerequisites

This lesson will be well delivered if students have a good understanding of collision theory of matter in relation with the temperature studied in senior 1, ideal gas law in relation with the pressure learnt in senior 2, effect of concentration, catalysts, pressure and temperature on the reaction rate studied in senior 3

b) Teaching resources:

Student book, reference book from library or internet

c) Learning activities

- Students will discuss on questions in activity 16.3, and answer them. The discussion will be done in groups but let each learner write answers in her/his exercise book. The teacher must be sure that all learners are involved in the activity. Each group must have a leader who will be moderator and a secretary who writes the report and will present findings of the group.
- Move around the class, listening to students as they discuss and provide support where needed.

- Each group will make presentation of their findings
- Valuing learners' presentations(judgment and discovery of possible mistakes by students)
- This is diagnostic activity; the next step will greatly depend on your judgment. If your class can not correctly answer the question, extra explanations and exercises are necessary. But if they are correctly answered then the teacher can proceed and give a summary of the first part of the lesson. A summary of the content must be written on the board.

Answers to activity 16.3

1. Refer to student book 16.3. point c
2. Refer to student book 16.2

d) Application activity

Answers to application activity 16.3

In the Contact process, sulphur dioxide is catalytically oxidized to sulphur trioxide according to the equation:

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)\ \Delta H < 0$

The rate of SO_3 production can be improved by:

Increasing the concentration of O_2 and SO_2

Employing catalyst V_2O_5

increasing the temperature

In practice a compromise temperature of 4500c is chosen for economical reason (reducing the fuel cost and avoiding corrosion of reaction chambers with rising temperature

16.6. Summary of the Unit

The factors that affect the equilibrium state of a reaction:

1. Temperature
2. Pressure
3. Concentration of reactants and products
4. Catalyst

The effect of these factors on chemical equilibrium can be understood with the help of **Le Châtelier's principle**.

The statement of Le Châtelier's principle: When the temperature, pressure or concentration of a reaction in equilibrium is changed, the reaction shifts in the direction where the effect of these changes is reduced.

$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g)$

Effect of change in temperature: For exothermic **reactions** and **Endothermic reactions.**

Consider a reversible in Haber process; $N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3$

(g)

Increase in temperature $\xrightarrow[\text{the direction of}]{\text{shifts the equilibrium in}}$ Endothermic reaction

Decrease in temperature $\xrightarrow[\text{the direction of}]{\text{shifts the equilibrium in}}$ Exothermic reaction

Effect of pressure

According to Le Châtelier's principle, an increase in pressure will favor the reaction in the direction where the volume of reactants is reduced and the decrease in pressure will favor the reaction in thedirection where the volume of reactants is increased.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

1 unit of volume 3unit of Volume 2 unit of volume

In this reaction the volume of reactants is 4 units while the volume of products is 2 units. So according to Le Châtelier's principle, an increase in pressure of this reaction will favour the forward reaction to form more ammonia while a decrease in pressure of the reaction will favour the backward reaction to form more nitrogen and hydrogen. Thus,

Increase in pressure $\xrightarrow[\text{the direction of}]{\text{shifts the equilibrium in}}$ decreased volume

Decrease in pressure $\xrightarrow[\text{the direction of}]{\text{shifts the equilibrium in}}$ increased volume

Effect of change in concentration

1. Effect of change in concentration of reactants: consider the reversible reaction:

$$N_2\ (g) + 3H_2\ (g) \rightleftharpoons 2NH_3\ (g)$$

1 Unit of volume 3 Unit of volume 2 Unit of volume

2. Effect of change in concentration of products

Increase in concentration of reactants $\xrightarrow[\text{the direction of}]{\text{shifts the equilibrium in}}$ forward direction

Increase in concentration of products $\xrightarrow[\text{the direction of}]{\text{shifts the equilibrium in}}$ backward direction

Effect of catalyst

A catalyst has no effect on equilibrium state of a reaction. It is added into the reaction mixture only to achieve the equilibrium state quickly because the addition of a catalyst increases the rate of both the forward and backward reactions equally.

16.7. Additional information

Effect of adding an inert gas in the equilibrium mixture

The effect of adding an inert gas depends on whether it is added at constant pressure or constant volume.

(a) Addition inert gas at constant volume

At constant volume, the presence of an inert gas has no effect on the position of equilibrium or value of equilibrium constant, since it does not take part in the reaction.

(b) Addition at constant pressure

The introduction of an inert gas at constant pressure results in dilution effect on the system which reduces the partial pressure of the component. This favors the dissociation. The equilibrium position shifts to the side with large number of molecules.

For instance, $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2\ (g)$

Introducing an inert gas to the system would dilute it and reduce the partial pressure of the components. As a result, PCl_5dissociates and the equilibrium shift from left to the right so as to maintain the equilibrium.

Consider the following equilibrium reaction: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

GUIDANCE ON THE SKILLS LAB 16

The teacher provide all the chemicals and laboratory apparatus

The learners will themselves perform the experiments, discuss and exchange opinions about the facts.

The teacher will monitor the work of learners to help them develop self confidence in manipulating chemicals

EXPERIMENT I

The learners will investigate the effect of a catalyst to reduce the activation energy and the high cost in temperature

They will interpret the results in form of graphic.

EXPERIMENT 2

Answers to study questions

1.a) Fe^{3+}

b)the equilibrium shifts to right(forward reaction)

c) the concentration of SCN^- decreases

d) the concentration of $FeSCN^{2+}$ will increase

2.a) SCN

b) to right

c) the concentration of Fe^{3+} decreases

d) d) the concentration of $FeSCN^{2+}$ will increase

3.a) SCN

b) itsconcetration decreases

c) to left

4. Nothing will happen.No one of ions in $NaNO_3$ can cause the stress in the reaction

Considering the equilibrium $Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$

If the concentration of either Fe3$^+$ or SCN^- is increased, the equilibrium shifts to right to reduce the concentration of the added reactant. Similarly, if $FeSCN^{2+}(aq)$ is added to the equilibrium, the position of the equilibrium will shift to the left to reduce the concentration of $FeSCN^{2+}(aq)$ according to Le Châtelier's principle.

Note that if silver nitrate solution is added to the equilibrium, it supplies silver ions (Ag^+) which removes cyanide ions (SCN^-) and causes the equilibrium to shift from right to left to replace the cyanide ion

End unit assessment

Answers to end unit assessment

1. The answers to question (a) and (b) are the same. If we add eitherN_2 or H_2, we increase the collisions between N_2 and H_2, thereby forming more product NH_3. This is how the equilibrium counteracts the applied stress; **we say the equilibrium shifts from left to right.**

(c) If we add more NH_3, we increase the concentration of NH_3. As a result, some NH_3 decomposes and forms more reactants. **We say the equilibrium shifts from right to left.**

(d) and (e). The answers to question (d) and (e) are the same. If we remove either N_2 or H_2, now there is less concentration of N_2 and H_2. To offset the applied stress, the **equilibrium shifts from right to left.**

(f) If we remove some NH_3, **the equilibrium shifts from left to right** to counteract the applied stress.

2. When the concentration of CO_2 (g) increases, the system responds by reducing the change.

The position of equilibrium of the first system will shift to the right.

The concentration of CO_2 (aq) will increase.

When the concentration of CO_2 (aq) increases, the position of equilibrium of the second system will shift to the right. The concentration of hydrogen ions will increase.

Thus, the pH of the water at the ocean surface will decrease.

(c) Slight cooling of the water saturated with carbon dioxide can reduce the solubility of carbon dioxide.

Some carbon dioxide bubbles out of the solution and the concentration of carbon dioxide decreases.

The system responds by reducing the change.

The position of equilibrium of the system represented by equation (3) shifts to the left, resulting in the precipitation of calcium carbonate.

3. An increase in pressure will bring about a net reaction that decreases the number of moles of gas. This helps to reduce the pressure.

A net backward reaction will occur. Thus, the yield of hydrogen will decrease.

OR

A decrease in pressure will bring about a net reaction that increases the number of moles of gas. This helps to increase the pressure.

A net forward reaction will occur. Thus, the yield of hydrogen will increase.

- When the temperature is increased, the system will respond by reducing the temperature.

As the production of hydrogen is endothermic, the system will undergo a net forward reaction. Thus, the yield of hydrogen will increase.

OR

When the temperature is decreased, the system will respond by raising the temperature.

As the production of hydrogen is endothermic, the system will undergo a net backward reaction. Thus, the yield of hydrogen will decrease.

- The yield of hydrogen is not affected by a catalyst.

A catalyst increases the rates of both the forward reaction and the backward reaction to the same extent.

4. (a) Le Châtelier's principle states that if the conditions of a system in equilibrium is changed, the position of equilibrium will shift so as to reduce that change.

(b) Decreasing the pH of the chlorinated water means increasing the concentration of hydrogen ions.

The system will respond by reducing this change.

The position of equilibrium will shift to the left.

More hypochlorous acid will form.

OR Increasing the pH of the chlorinated water means decreasing the concentration of hydrogen ions.

The system will respond by reducing this change.

The position of equilibrium will shift to the right.

More hypochlorite ions will form.

(d) When sodium hydroxide solution is added, the hydroxide ions react with the hydrogen ions to form water. Thus, the concentration of hydrogen ions decreases.

The system responds by reducing this change. A net backward reaction occurs to produce more hydrogen ions. Thus, the concentration of chlorine will decrease.

(5) (a) Case A

An increase in pressure will bring about a net reaction that decreases the number of moles of gas. This helps to reduce the pressure.

A net forward reaction occurs.

Thus, a high pressure will increase the yield of SO_3(g).

When the temperature is decreased, the system will respond by raising the temperature.

As the forward reaction is exothermic, the system will undergo a net forward reaction.

Thus, a low temperature will increase the yield of SO3(g).

(b) Case D

Air is readily available and cheap.

At lower pressure, the cost of building and running the plant is lower.

At lower temperature, the cost of energy is lower / less fuel is required.

6. (a) Rate of forward reaction = rate of backward reaction

- Concentration of the reactants and product remain constant.

(b) (i) The percentage conversion increases with pressure.

An increase in pressure will bring about a net reaction that decreases the number of moles of gas. This helps to reduce the pressure.

The position of equilibrium will shift to the side of the equation with a fewer number of moles of gas, i.e. shift to the right.

(ii) When the temperature is increased, the percentage conversion decreases.

It can be deduced that when the temperature is increased, the system will undergo a net backward reaction so as to lower the temperature.

Hence the backward reaction should be an endothermic reaction / the forward reaction should be an exothermic reaction.

The sign of the enthalpy change for the forward reaction should be negative.

(c) Using excess steam will shift the position of equilibrium to the right.

(a) (i) An increase in pressure will bring about a net reaction that decreases the number of moles of gas. This helps to reduce the pressure.

A net forward reaction occurs.

Thus, the percentage yield of ammonia increases.

(ii) Too expensive to generate. / The cost of building and running the plant is too high.

(b) (i) The yield of ammonia increases.

When the temperature is decreased, the system will respond by raising the temperature.

As the forward reaction is exothermic, the system will undergo a net forward reaction.

(ii)The rate of production of ammonia is higher.

(iii) 723 K is a balance between rate and yield.

7. (a) equilibrium shifts to the left

(b) To the right

(c) (No change on the equilibrium position

(d) To the left

(e) No change on the position of equilibrium

8. (a) refer to learners book

(b) (i) Equilibrium shift to right to replace sulphurdioxide

(ii) Equilibrium shift to left

(iii) No effect on the position of Equilibrium

(iv) Equilibrium shift to left

(c) Refer to learner's book .

(d) Removing hydrogen from equilibrium will shift the equilibrium to left to replace it thus reducing the concentration of products

16.8. Additional activities

16.8.1. Remedial activities

Multiple choice Questions

1. In a reversible reaction, the catalyst:

(a) Decreases activation energy of forward reaction

(b) Increases activation energy of forward reaction

(c) Decreases activation energy of both forward and backward reactions

(d) Increases activation energy of backward reaction

2. The chemical equilibrium of a reversible reaction is not influenced by:

(a) Temperature

(b) Pressure

(c) Catalyst

(d) Concentration

4. The reaction: $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ is in equilibrium. If the equilibrium concentration of $PCl_3(g)$ is doubled then concentration would become:

(a) 1/2 of its initial value

(b) 1/4 of its initial value

(c) Four times of its initial value

(d) Two times of its initial value

5. Which of the following reactions will be favoured at low pressure?

(a) $N_2 + 3H_2 \rightleftharpoons 2NH_3(g)$

(b) $H_2I_2 \rightleftharpoons 2HI$

(c) $PCl_4 \rightleftharpoons 2PCl_3 + Cl_2$

(d) $N_2 + O_2 \rightleftharpoons 2NO$

6. For equilibrium reaction:, $2NO_2(g) \rightleftharpoons N_2O_4(g)$ $\Delta H = -58KJ.mol^{-1}$ increase in temperature would:

(a) Favour the formation of N_2O_4

(b) Stop reaction

(c) Favour the decomposition of N_2O_4

(d) Not alter the equilibrium

7. in the reaction: $H_2 + I_2 \rightleftharpoons 2HI$ at equilibrium, some I_2 is added. What happens to the equilibrium?

(a) It gets shifted to the right

(b) It remains unchanged

(c) It gets shifted to the left

(d) First (b), then (c)

8. Which of the following changes will shift the reaction in forward direction?
$I_2(g) \leftrightharpoons 2I(g)$Take $\Delta H^0 = +150$

(a) decrease in concentration of I_2

(b) decrease in total volume

(c) Decrease in concentration of I_2

(d) Increase in temperature

9. Which of the following equilibria, in gaseous phase, would be unaffected by an increase in pressure?

(a) $N_2 + 3H_2 \rightleftharpoons NH_3$

(b) $N_2 + O_2 \rightleftharpoons 2NO$

(c) $N_2O_4 \rightleftharpoons 2NO$

(d) $CO + ½\ O_2 \rightleftharpoons CO_2$

10. A reversible reaction is said to have attained *equilibrium*, when:

(a) A backward reaction stops
(b) Both backward and forward reactions take place at equal speed
(c) Both backward and forward reactions stop
(d) Concentration of each of the reactants and products becomes equal

11. The equilibrium between water and its vapor, in an Open—vessel:
    (a) Can be achieved
    (b) Depends upon pressure
    (c) Cannot be achieved
    (d) Depends upon temperature

12. Chemical equilibrium is dynamic in nature, because:
    (a) The equilibrium is maintained rapidly
    (b) The concentration of reactants and products is constant but different
    (c) The concentration of reactants and products becomes same at equilibrium.
    (d) Both forward and backward reactions occur at all times with same speed

ANSWERS TO MULTIPLE CHOICE QUESTIONS

1C, 2C , 3C, 4C, 5C, 6C, 7A, 8D, 9B, 10B, 11C, 12D,

16.8.2. Consolidation activities

1. In the Haber process, ammonia is synthesized by the exothermic reaction of nitrogen and hydrogen.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

The table shows the percentage yield of ammonia, under different conditions of pressure and temperature, when the reaction has reached equilibrium.

Temperature/ K	600	800	1000
% yield of ammonia at 100 atmospheres	50	10	2
% yield of ammonia at 200 atmospheres	60	16	4
% yield of ammonia at 50000 atmospheres	75	25	7

a) i) Explain why, at a given temperature, the percentage yield of ammonia increases with an increase in pressure.

ii) Give a reason why a high pressure of 500 atmospheres is NOT normally used in the Haber process.

b) Many industrial ammonia plants operate at a compromise temperature of about 723 K.

i) State one advantage, other than cost, of using a temperature lowers than 723 K. Explain your answer.

ii) State the major advantage of using a temperature higher than 723 K.

iii) Hence explain why 723 K is referred to as a compromise temperature.

Answer

(a) (i) According to Le Châtelier's principle, increasing the pressure shifts the equilibrium to the right, increasing the yield of ammonia (The pressure favours a reaction that occurs with the decrease of number of moles in the reaction)

(ii) High pressure is very expensive

(b) Very high temperature shifts the equilibrium to the left since the reaction is exothermic however; a lower temperature slows the reaction. Therefore, optimum temperature should be used.

(i) It favours the exothermic direction thus increasing the yield of ammonia.

(ii) It increases the speed of the reaction

(iii) It favours the formation of ammonia at a moderate rate.

2. When bromine is dissolved in water, the following equilibrium system is established

$$\underset{\text{Yellow-brown}}{Br_2(l) + H_2O(l)} \rightleftharpoons \underset{\text{colorless}}{H^+(aq) + Br^-(aq) + HOBr(aq)}$$

In an experiment, dilute sodium hydroxide solution and then dilute hydrochloric acid are added to the system. The observations made listed below

Step	Procedure	observation
I	Adding dilute sodium hydroxide solution	A colourless solution is formed

II	Adding dilute hydrochloric acid to the resulting solution	A yellow brown solution is formed.

Explain the observations made from the table above using Le Châtelier's principle.

Answer

In step I: addition of sodium hydroxide to the equilibrium above removes hydrogen ions and shifts the equilibrium to replace hydrogen ions.

In step II: addition of dilute hydrochloric acid increases the concentration of hydrogen ions thus shifting the equilibrium to the left.

3. Each of the following equilibrium systems is disturbed by increasing the pressure as a result of decreasing the volume of the reaction vessel. Decide whether the number of moles of reaction product(s) will increase, decrease, or remain the same. Explain your answer in each case.

   a) $2CO_2(g) \rightleftharpoons 2CO(g) + O_2(g)$ **(increase)**

   b) $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$ **(no change)**

   c) $Si(s) + 2Cl_2(g) \rightleftharpoons SiCl_4(g)$ **(decrease)**

4. Does the number of moles of reaction products increase, decrease, or remain the same when each of the following equilibria is subjected to a decrease in pressure by increasing the volume?

   (a) $CaO(s) + CO_2(g) \rightleftharpoons CaCO_3(s)$ **(decrease)**

   (b) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ **(increase)**

   (c) $3\ Fe(s) + 4\ H_2O(g) \rightleftharpoons Fe_3O_4(s) + 4\ H_2(g)$ **(no change)**

5. In the first step of the Ostwald process for the synthesis of nitric acid, ammonia is oxidized to nitric oxide by the reaction

$$4\ NH_3\ (g) + 5\ O_2\ (g) \rightleftharpoons 4\ NO(g) + 6\ H_2O(g) \quad \Delta H° = -901.2\ kJ$$

How does the equilibrium amount of NO vary with an increase in temperature?

Answer:

The amount of NO decrease since the reaction shifts to the endothermic direction (backward)

6. Consider the equilibrium $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ $\Delta H^0 = 58.0kj$

In which direction will the equilibrium shift when (a) N_2O_4 is added , (b) NO_2 is removed , (c)the total pressure is increased by addition of N_2 gas , (d) the volume is increased , (e) the temperature is increased.

(a) N_2O_4 is added : equilibrium shifts to the forward

(b) NO_2 is removed: equilibrium shifts to the forward

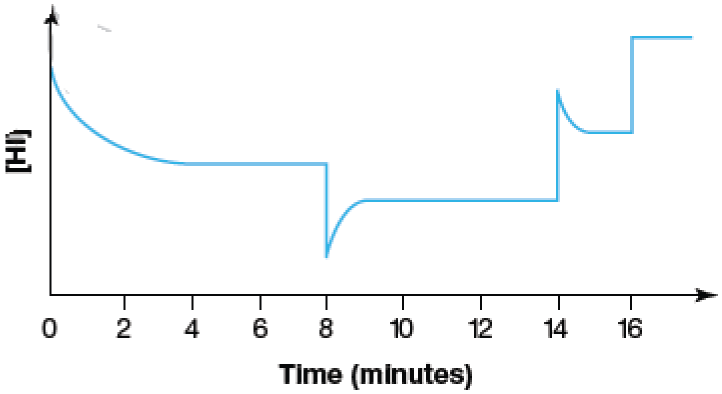
(c) the total pressure is increased by addition of N_2 gas: **no change on equilibrium position**

(d) the volume is increased: **equilibrium shifts to the forward**

(e) the temperature is increased: **equilibrium shifts to the forward**

7. In an investigation of the decomposition of hydrogen iodide, represented by the equation:

$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$ the concentration versus time graph shown in the figure below was obtained.



(a) Describe what happened during the first 2 minutes of the experiment.

(b) Describe what was happening from the 4- to 8-minute marks.

(c) Give an explanation for the cause of the dip in the graph at the 8-minute mark.

(d) What do you think might have happened at the 14-minute mark?

(e) What do you think might have happened at the 16-minute mark?

(f) Did the change occurring at the 16-minute mark affect the equilibrium or not? Explain.

Answer

(a) Decrease in concentrating of hydrogen iodide

(b) The concentration of hydrogen iodide remains the same.

(c) Equilibrium shifts to the right reducing the concentration of hydrogen iodide.

(d) Either hydrogen gas or iodine could have been added to thus shifting the equilibrium to left increasing the concentration of hydrogen iodide.

(f) It did affect the equilibrium since the concentration of hydrogen iodide increase

(e) Equilibrium shifts to the left thus increasing the concentration of hydrogen iodide

8. Account for the increase in reaction rate brought about by a catalyst.

Answer

In the presence of a catalyst, both the forward and reverse reaction rates will speed up equally, thereby allowing the system to reach equilibrium faster. However, it is very important to keep in mind that the addition of a catalyst has *no effect on* the final equilibrium *position* of the reaction. It simply makes the reaction faster.

9. Consider this scenario and answer the following questions: Chlorine atoms resulting from decomposition of chlorofluoromethanes, such as CCl_2F_2, catalyze the decomposition of ozone in the atmosphere. One simplified mechanism for the decomposition is:

$$O_3 \xrightarrow{\text{Sunlight}} O_2 + O$$

$$O_3 + Cl \longrightarrow O_2 + ClO$$

$$ClO + O \longrightarrow Cl + O_2$$

(a) Explain why chlorine atoms are catalysts in the gas-phase transformation:

$$2O_3 \longrightarrow 3O_2$$

(b) Nitric oxide is also involved in the decomposition of ozone by the mechanism:

$$O_3 \xrightarrow{\text{Sunlight}} O_2 + O$$

$$O_3 + NO \longrightarrow NO + O_2$$

$NO + O \longrightarrow NO + O_2$

Is NO a catalyst for the decomposition? Explain your answer.

10) The general mode of action for a catalyst is to provide a mechanism by which the reactants can unite more readily by taking a path with a lower activation energy. The rates of both the forward and the reverse reactions are increased, leading to a faster achievement of equilibrium.

(a) Chlorine atoms are a catalyst because they react in the second step but are regenerated in the third step. Thus, they are not used up, which is a characteristic of catalysts.

(b) NO is a catalyst for the same reason as in part (a).

11) Does the number of moles of reaction products increase, decrease, or remain the same

when each of the following equilibria is subjected to a decrease in pressure by increasing the volume?

(a) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

(b) $CaO(s) + CO_2(g) \rightleftharpoons CaCO_3(s)$

(c) $3\ Fe(s) + 4\ H_2O(g) \rightleftharpoons Fe_3O_4(s) + 4\ H_2(g)$

(a) Because the forward reaction converts 1 mol of gas to 2 mol of gas, net reaction will go from reactants to products, thus increasing the number of moles of PCl_3 and Cl_2.

(b) Because there is 1 mol of gas on the reactant side of the balanced equation and none on the product side, the stress of a decrease in pressure is relieved by net reaction from products to reactants. The number of moles of $CaCO_3$ therefore decreases.

(c) Because there are 4 mol of gas on both sides of the balanced equation, the composition of the equilibrium mixture is unaffected by a change in pressure. The number of moles of Fe_3O_4 and H_2 remains the same.

12. In the first step of the Ostwald process for the synthesis of nitric acid, ammonia is oxidized to nitric oxide by the reaction

$4\ NH_3\ (g) + 5\ O_2(g) \rightleftharpoons 4\ NO(g) + 6\ H_2O(g)\quad \Delta H° = -901.2\ kJ$

How does the equilibrium amount of NO vary with an increase in temperature?

Because the oxidation of ammonia is exothermic, we include the heat

(901.2 kJ) on the product side:

$4\ NH_3(g) + 5\ O_2(g) \rightleftharpoons 4\ NO(g) + 6\ H_2O(g)\ \Delta H° = +\ 901.2\ kJ$

The stress of added heat when the temperature is increased will be relieved by net reaction from products to reactants, which absorbs the added heat. The equilibrium will therefore shift to the reactant side will decrease) with an increase in temperature. Consequently, the equilibrium mixture will contain less NO at higher temperatures.

13. A platinum catalyst is used in automobile catalytic converters to hasten the oxidation of carbon monoxide:

$2\ CO(g) + O_2(g) \rightleftharpoons 2\ CO_2(g)\ \Delta\ H° = -566\ kJ$

Suppose that you have a reaction vessel containing an equilibrium mixture of $CO(g)$, $O_2(g)$ and $CO_2(g)$. Under the following conditions, will the amount of CO increase, decrease, or remain the same?

(a) A platinum catalyst is added. (**No change in the amount of either $CO(g)$, $O_2(g)$ or $CO_2(g)$**

(b) The temperature is increased.**(the amount of $CO(g)$, $O_2(g)$ increase while $CO_2(g)$ decrease)**

(c) The pressure is increased by decreasing the volume.(**the amount of $CO(g)$, $O_2(g)$ decreases while $CO_2(g)$ increases)**

(d) The pressure is increased by adding argon gas.**(neither of the $CO(g)$, $O_2(g)$ and $CO_2(g)$ is increased or decreased)**

(e) Adding O_2 gas.**($CO_2(g)$ increases while $CO(g)$ decreases.)**

16.9. Extended activities

1. The hydrogen used in the Haber process is made in the reaction shown below, which is an equilibrium.

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3\ H_2(g)\ \ \Delta H = +206\ kJ/mol$

a) i) If the temperature of this equilibrium was increased, what would happen to the yield of hydrogen?

ii) Explain your reasoning.

b) i) If the pressure of this equilibrium was increased, what would happen to the yield of hydrogen?

ii) Explain your reasoning.

c) i) If more steam was added to this system, what would happen to the yield of hydrogen?

ii) Explain your reasoning.

1) a) i) increase yield of H_2

ii) Equilibrium moves right in endothermic direction

b) i) decrease yield of H_2

ii) Equilibrium moves left to side with less gas molecules

c) i) increase yield of H_2

ii) Equilibrium moves to remove steam, so moves right to convert it to hydrogen

2. Complete the table to show what would happen to the position of the following gas phase equilibria if the following changes were made. Tick the correct column in each case.

Equilibrium	ΔH	Increase temperature			Increase pressure			Remove some of B		
		Moves left	No move	Move right	Moves left	No move	Move right	Moves left	No move	Move right
$2A(g)+B(g) \rightleftharpoons X(g)+Z(g)$	Exo-thermic									
$A(g)+B(g) \rightleftharpoons X(g)+Z(g)$	endo-thermic									
$B(g) \rightleftharpoons X(g) +Z(g) +Y(g)$	Exo-thermic									
$X(g) +Y(g) \rightleftharpoons 2B(g)$	Exo-thermic									
$2X(g) \rightleftharpoons 2A(g) +B(g)$	endo-thermic									

Equilibrium	ΔH	Increase temperature			Increase pressure			Remove some of B		
		Moves left	No move	Move right	Moves left	No move	Move right	Moves left	No move	Move right
$2A(g)+B(g) \rightleftharpoons X(g)+Z(g)$	Exo-thermic	×					×	×		
$A(g)+B(g) \rightleftharpoons X(g)+Z(g)$	endo-thermic			×		×		×		
$B(g) \rightleftharpoons X(g) +Z(g) +Y(g)$	Exo-thermic	×			×			×		
$X(g) +Y(g) \rightleftharpoons 2B(g)$	Exo-thermic	×				×				×
$2X(g) \rightleftharpoons 2A(g) +B(g)$	endo-thermic			×	×					×

3. When bismuth chloride is added to water, a reaction occurs and a white precipitate forms. The following equilibrium is set up

$$BiCl_3(aq) + H_2O(l) \rightleftharpoons BiOCl(s) + 2\ HCl(aq)$$

What would be the effect on the amount of precipitate if sodium hydroxide solution is added to the mixture (explain your answer)?

3) NaOH reacts with HCl and removes it; equilibrium shifts right to replace lost HCl; therefore more BiOCl white precipitate formed.

4. A simple form of colorimetric analysis may be used to study the equilibrium represented by the following equation.

$$Br_2(aq) + 2OH^-(aq) \rightleftharpoons OBr^-(aq) + Br^-(aq) + H_2O(l)\ \Delta H = +15\ kJ\ mol^{-1}$$

As molecular bromine, Br_2, is the only coloured species in this reaction, its red-brown colour may be used to monitor various changes made to this equilibrium.

A student performed an experiment where 10 ml samples of reaction mixture were poured into identical test tubes. The four changes listed below were then made to different samples of the equilibrium mixture. The colours before and after the changes were compared.

Change 1: A small amount of solid potassium bromide was added and the mixture stirred to dissolve it.

Change 2: A small amount of solid sodium chloride was added and the mixture stirred to dissolve it.

Change 3: The solution was warmed from room temperature to 50 °C.

For each of these three changes:

(a) State whether you would expect the solution to darken, lighten or stay the same 3 marks

(b)Use Le Châtelier's principle to explain your answer in (a).

Answer

Change 1: the solution turns red-brown

Change 2: no observable change

Change 3: the red-brown colour fades

6. The following equilibrium takes place in a rigid container.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)\ \Delta H = +56\ kJ$$

In which direction does the equilibrium shift as a result of each change?

(a) Adding phosphorus pentachloride gas

(b) Removing chlorine gas

(c) Decreasing the temperature

(d) Increasing the pressure by adding helium gas

(e) Using a catalyst

(a) [PCl_5] increases. Therefore, the equilibrium must shift to minimize [PCl_5]. The reaction shifts to the right.

(b) [Cl_2] is reduced. Therefore, the equilibrium must shift to increase [Cl_2]. The reaction shifts to the right.

(c) The temperature decreases. Therefore, the equilibrium must shift in the direction in which the reaction is exothermic. From left to right, the reaction is endothermic. Thus, the reaction must be exothermic from right to left. The reaction shifts to the left if the temperature is decreased.

(d) Helium does not react with any of the gases in the mixture so it does not change the position of equilibrium.

(e) A catalyst has no effect on the

UNIT 17

QUANTITATIVE CHEMICAL EQUILIBRIUM

17.1. Key unit competence

Calculate the values of equilibrium constant, interpret the values of K_c in relation to the yield of the products in reversible reactions.

17.2. Prerequisite knowledge and skills

Students will learn better quantitative chemical equilibrium if they have understanding on: The factors that affect chemical equilibrium; reversible reactions; Chatelier's principle; effects of changing temperature, pressure, concentration and pressure on a system in equilibrium; endothermic and exothermic reactions (covered in year 2 unit 16)

17.3. Cross-cutting issues to be addressed

- **Environment and Sustainability**

Chemical equilibrium deals with reversible reactions which are mainly processes of production in industries. An example is like ammonia gas production which sometimes pollute environment. Ammonia is a common naturally occurring substance. It is also manufactured by man. At normal environmental conditions, pure ammonia is a colourless, pungent-smelling, caustic (corrosive) gas. The main local problem of ammonia released into air is the unpleasant odour, which is detectable even at low concentrations. At particularly high concentrations it can also harm vegetation. The harm caused by ammonia in water bodies is more serious, because it is very toxic to aquatic organisms. Low concentrations of ammonia in soil are natural and actually essential for plant nutrition. Over-fertilization can however lead to excessive concentrations which result in leaching to water bodies. On a wider scale, ammonia plays a role in the transportation and enhanced deposition of acidic pollutants - resulting in acidification of ground and water bodies, which can harm plant and animal life. Not only ammonia but there others like production of sulphuric acid. The teacher must emphasize on the problems that can be caused by those substances and how to prevent and handle them. Therefore measures should always be taken and even during production.

- **Gender**

The teacher has always to mind about the gender balance in assignment of roles during learning activities. He/she must make sure that both genders are represented and avoid using examples that minimize/praise any of them (boys or girls).

17.4. Guidance on the introductory activity:

- Put your students in groups of 3-4(or even 5 depending on the size of your class)
- Provide them with books or worksheets with the introductory activity, unit 17 from student's book year 2
- Give them time between 15 and 20 minutes to read, analyze, interpret and discuss about the activity. Here they have to analyze, answer the questions asked in this activity. Let them use books or search from internet if possible, in order to discover what they don't discover directly.
- Call one or two groups to present their findings. You may note some key points at this stage.
- Ask other members (randomly) to give their input. Don't worry if some of them fail to reach the exact results. They get to understand as the unit progresses.

Address your views about their presentations. But it is not necessary to conclude. Just motivate them to create curiosity in them

Answers to introductory activity:

1. a) The two chemical reactions are different A cannot complete, it reaches equilibrium, the second can occur and complete. For the first it is shown by ⇄ while in the second it is shown by →

   b) A is reversible reaction and B is irreversible reaction

2. a) The equilibrium will shift from left to right, we know that increasing temperature, go hand in hand with endothermic reaction and the reverse reaction is the one which is favoured.

   b) It does not affect the equilibrium; it can only reduce the time to reach equilibrium.

   c) It will shift equilibrium from left to right to reduce the change in oxygen

   d) It will shift equilibrium from right to left to reduce the increase in concentration of SO_3

If a system at equilibrium is disturbed by a change in temperature, pressure, or the concentration of one of the components, the system will shift its equilibrium position so as to counteract the effect of the disturbance''.

3. The forward reaction will be favoured which means that equilibrium shift from left to right.

4. a) The equilibrium will shift form right to left to favour the endothermic reaction as we know that increase in temperature favours the endothermic reaction.

   b) The production of ammonia will reduce because the reaction which is favoured is from right to left.

5. The equilibrium shift from left to right to favour the production of ammonia with fewer number of moles.

17.5. List of lessons

	Lesson title	**Learning objectives**	**Number of periods**
1	Definition of equilibrium constant Kc • Deriving equilibrium constant Kc (from thermodynamic approach and kinetic approach).	Explain how the temperature affects the magnitude of equilibrium constant K_c Derive equilibrium constant K_c	1
2	Mass action law and equilibrium constant expression.	• Appreciate the values of K_c in relation to the completion of different reactions	1
3	• Definition of equilibrium constant in terms of partial pressures Kp	Derive the equilibrium constant K_p	1
4	• Derivation of the relationship between Kc and Kp • Calculations on Kc and Kp.	• Derive the relationship between K_c and K_p • Write expression for K_c and K_p • Performing calculations involving equilibrium constants in terms of concentration K_c and partial pressure K_p	1
5	End unit assessment		1

Lesson 1: Definition and characteristics of equilibrium constant Kc and Deriving equilibrium constant Kc

a) Prerequisites

Students will learn better characteristics of equilibrium constant if they have knowledge on reversible reactions and on factors that affect chemical equilibrium (covered in year 1)

They will also learn better the methods of deriving the equilibrium constant if he has got the knowledge of factors that affect chemical equilibrium that has been covered in year 1.

b) Teaching resources

You can use worksheets/books, projectors /chalkboard, etc.

c) Learning activities

- Before teaching this topic, be aware that students know something about factors that affect the chemical equilibrium.
- As a facilitator, you are expected to guide learners to learn by doing ***activity 17.1***, as described below.
- Give the activity to students. This activity has to be done in pairs and it takes at most 10 min.
- Choose randomly three representatives of all groups to present their findings.
- Allow some other students to comment about the findings presented by their colleagues.
- Give your feedback highlighting characteristics of equilibrium constant.
- Through different small verbal questions, help the students to make the conclusion themselves.
- To check their understanding, give them the ***Application activity17.1*** in the Student's Book as an individual homework. The feedback will be given in the next session after the correction.
- You may refer to the proposed answers of the ***Activity 17.1 and 17.1.3*** and the ***Application activities 17.1***

Answers to activity 17.1

1. a) Decrease in pressure shifts equilibrium from left to right (the forward reaction), which favours the reaction that produces the products with increase in volume.

   b) There will be no change on equilibrium because there is same number of moles on both sides.

   c) The equilibrium will shift from left to right to favour the production of CO and H_2.

2. The equilibrium will shift from left to right to favour the forward reaction which is endothermic reaction.

Answers to activity 17.1.3

a) $$K_c = \frac{\left[Fe^{2+}\right]^2\left[Sn^{4+}\right]}{\left[Fe^{3+}\right]\left[Sn^{2+}\right]}$$

b) $$K_c = \frac{\left[Fe^{3+}\right]}{\left[Fe^{3+}\right]\left[Ag^{+}\right]}$$

c) $$K_c = \frac{\left[Cr^{2+}\right]\left[Fe^{2+}\right]}{\left[Cr^{3+}\right]^2}$$

2. $$K_c = \frac{[C]^2}{[A][B]} = \frac{(0.50)^2}{(0.25)\times(0.4)} = \frac{0.25}{0.1} = 2.5$$

d) Application activity

Answers to application activity 17.1

1 a) Decrease in pressure favours the reverse reaction that produces SO_2 and O_2

b) The time to reach equilibrium will multiply by two, because the equilibrium does not change equilibrium but it affects the time to reach at it.

2. High pressure favours the production of ammonia because ammonia is on the side with few moles. And it is known that the increase in pressure favours reaction that reduces the volume.

3. a) K_c = , unit is $mol^{-1}dm^3$

   b) K_c = , unit = $mol^{-1}dm^3$

4. a) K_c = , unit = mol^{-1} dm^3

   b) The concentration of SO_3 = dm^{-3}

   The concentration of SO_2 = dm^{-3}

   The concentration of O_2 = dm^{-3}

   K_c = $mol^{-1}dm^3$

Lesson 2: Mass action law and equilibrium constant expression

a) Prerequisites/Revision/Introduction:

Refer to lesson 1

b) Teaching resources

You can use worksheets/books, projectors /chalkboard, etc.

c) Learning activities

- As a facilitator, you are expected to guide learners to learn by doing ***activity 17.2***, as described below.
- Give the activity to students. This activity has to be done in group of 4 and it takes at most 10 min.
- Choose randomly some students in different groups to present their findings.
- Allow some other students to comment about the findings presented by their colleagues.
- Give your feedback making clear it is needed.
- Through different small verbal questions, help the students to make the conclusion themselves.
- To check their understanding, give them the ***Application activity 17.2*** in the Student's Book as a homework that must be submitted individually. The feedback will be given in the next session after the correction.
- You may refer to the proposed answers of the ***Activity 17.2*** and the ***Application activity17.2***

Answer to activity 17.2

1. Law of Mass Action or Equilibrium law states that "*The ratio of a equilibrium concentrations of products and reactants each raised to the power of their coefficients in the balanced stoichiometric equations is a constant, Kc, at a constant temperature.*

2. According to law of mass action: the total mass of A and B involved in the collision must be equal to the total mass of new formed compounds

Rate of **forward reaction** $\propto \mathbf{[A]^a[B]^b} = K_f\,[A]^a[B]^b$

Rate of **backward reaction** $\propto \mathbf{[C]^c[D]^d} = K_b\,[C]^c[D]^d$

The concentration is expressed in unit moles per unit volume.

d) Application activity

Answers to application activity 17.2

$$K_c = \frac{[R]^2}{[Q][P]^2}$$

$$K_c = \frac{[Fe^{3+}]}{[Fe^{3+}][Ag^{+}]}$$

$$K_c = \frac{[H_2][CO_2]}{[CO][H_2O]}$$

$$K_c = \frac{[SO_3]^2}{[O_2][SO_2]^2}$$

$$K_c = \frac{[Cr^{2+}][Fe^{2+}]}{[Cr^{3+}]^2}$$

About the units refer to the mathematical ratio of the respective concentrations in a given expression

Lesson 3: Definition of equilibrium constant in terms of partial pressures ''Kp''

a) Prerequisites/Revision/Introduction:

Learners will learn better the equilibrium constant in terms of partial pressures ''K_p'' if they have knowledge on ideal gas law and partial pressures

b) Teaching resources

You can use worksheets/books, projectors /chalkboard, etc.

c) Learning activities

- As a facilitator, you are expected to guide learners to learn by doing ***activity 17.3***, as described below.
- Give the activity to students. This activity has to be done in group of 4 and it takes at most 10 min.
- Choose randomly some students in different groups to present their findings.
- Allow some other students to comment about the findings presented by their colleagues.
- To check their understanding, give them the ***Application activity 17.3*** in the Student's Book as an individual homework. The feedback will be given in the next session after the correction.
- You may refer to the proposed answers of the ***Activity 17.3*** and the ***Application activity 17.3***

Answers to activity 17.3

1. PV = nRT
2. P = pressure, V= volume, n = number of moles, R = gas constant, T = temperature.

   Partial pressure is the hypothetical pressure of the gas if it, alone, occupied the entire volume of the original mixture at the same temperature. The total pressure of an ideal gas mixture is the sum of the partial pressures of the gases in the mixture.

d)Application activity

Answers to application activity 17.3

Answers to activity 17.3

1. a) $$\mathrm{K_p}=\frac{P_{SO_3}}{\left[p_{SO_2}\right]\left[p_{O_2}\right]^{\frac{1}{2}}}=\frac{1\ atm}{[0.05][0.025]^{\frac{1}{2}}}=\frac{1}{0.05\times 0.158}=\frac{1}{0.0079}=126.58\ atm^{-1/2}$$

b) $$\mathrm{K_p}=\frac{\left(P_{SO_3}\right)^2}{\left(p_{O_2}\right)\left(p_{SO_2}\right)^2}=\frac{(1\ atm)^2}{[0.025][0.05]^2}=16,000\ atm^{-1}$$

2. $$\mathrm{K_p}=\frac{P_{H_2}P_{CO_2}}{p_{H_2O}p_{CO}}$$

b) No effect on hydrogen gas. The pressure does not affect the equilibrium for that reaction because on both sides of chemical equation there is same number of moles. Right hand side, there are two moles which is the same for the left hand side.

3. $$\mathrm{K_p}=\frac{\left(P_{SO_3}\right)^2}{\left(p_{O_2}\right)\left(p_{SO_2}\right)^2}$$

$$P_{SO_3}=1.04-p_{SO_2}-p_{O_2}=1.04-0.025-0.64=0.15\ atm$$

$$K_p=\frac{\left(P_{SO_3}\right)^2}{\left(p_{O_2}\right)\left(p_{SO_2}\right)^2}=\frac{(0.15)^2}{(0.64)(0.25)^2}=0.5625\ atm^{-1}$$

Lesson 4: Derivation of the relationship between Kc and Kp, Calculations on K_c and K_p

a) Prerequisites/Revision/Introduction:

Students will learn better the method of relating Kc to Kp when they have the knowledge on Kc and Kp that have been learnt in previous lessons

b) Teaching resources

You can use worksheets/books, projectors /chalkboard, etc.

c) Learning activities

- As a facilitator, you are expected to guide learners to learn by doing ***activity 17.4***, as described below.
- Give the activity to students. This activity has to be done in pairs and it takes 10 min.
- Choose randomly some students in different groups to present their findings.
- Allow some other students to comment about the findings presented by their colleagues.
- Give your feedback making clear where it is necessary.
- Through different small verbal questions, help the students to make the conclusion themselves.
- To check their understanding, give them the ***Application activity 17.4*** in the Student's Book as a work in pairs. The feedback will be given in the next session after the correction.
- You may refer to the proposed answers of the ***Activity 17.4*** and the ***Application activity 17.4***

Answers to activity 17.4

1. The equilibrium constant, Kc, is the ratio of the equilibrium concentrations of products over the equilibrium concentrations of reactants each raised to the power of their stoichiometric coefficients while when the pressure is proportional to the concentration for gases in a closed system, the equilibrium constant can be written in terms of the pressures of the different components rather than their molecular concentrations and Kp expression is used.

2. $Kc = \dfrac{[C]^3}{[A]^2[B]}$

$K_p = \dfrac{P_C^3}{P_C^2 P_B}$

3. $N2 + 3H2 \rightleftharpoons 2NH3$

a) 1 mole of NH_3 was produced by 46 kJ/mol

2 moles of NH_3 were produced by 46 x 2 kJ

Then:

If 34 g of NH_3 were produced by 92 kJ

1 x 109 g NH_3 produces = $\dfrac{92\times1.02\times10^9}{34}$ = 2.76 x 109kJmol^{-1} each day.

b) i) $N_2 + 3H_2 \rightleftharpoons 2NH_3$

At equilibrium 0.6 2.0 ??

Total moles on the left hand side = 0.6 + 2.0 = 2.6

4 moles of N_2 and H_2 produced 2 moles of NH_3

2.6 moles of N_2 and H_2 produced $\dfrac{2\times2.6}{4}$ = 1.3 moles

$[N_2] = \dfrac{0.6\ mol}{2\ dm^3} = 0.3$ M

$[H_2] = \dfrac{0.6\ mol}{2\ dm^3} = 1$ M

$[NH_3] = \dfrac{1.3\ mol}{2\ dm^3} = 0.65$ M

ii) $Kc = \dfrac{[NH_3]^2}{[N_2][H_2]^3} = \dfrac{0.65^2}{0.3\times1^3}$ = 1.4 mol^{-2} dm^{-6}

d) Application activity

Answers to application activity 17.4

1. a) $K_p = K_c(RT)^{\Delta n}$, $\Delta n = 2-(2+1) = -1$

   $K_p = K_c\,(RT)^{-1}$

   $$K_p = \frac{K_c}{RT}$$

b) $K_p = \frac{K_c}{RT}$, R = 0.082atm $mol^{-1}K^{-1}$, T = 45000C+273 = 4773 K $K_c = 0.2\ atm^{-1}$

$$K_p = \frac{0.2}{0.082 \times 4773} = \frac{0.2}{391.386} = 5.11\text{x}10^{-4}atm^{-2}mol$$

c) i) $2SO_2 + O_2 \rightleftharpoons 2SO_3$

ii) Vanadium pentoxide (V_2O_5)

iii) $Kp = \frac{P_{SO_2}^2}{P_{SO_2}^2 \times P_{O_2}}$

iv) $2SO_2 \quad + O_2 \rightleftharpoons 2SO_3$

Initial amount 2000 1000 2x

At equilibrium 2000-2x 1000-x

Amount of SO2 remains = 2000 – 2x = 1333

- 2x = 1333 – 2000

- 2x = -667

x = 333.5

Amount of SO_2 at equilibrium = 1333 cm^3

Amount of O_2 at equilibrium = 1000 cm^3 – 333.5 cm^3 = 666.5 cm^3

Amount of SO_3 at equilibrium = 2 x 333.5 = 667 cm^3

Total volume = 1333 + 666.5 + 667 = 2666.5 cm^3

Partial pressure = molar fraction x total pressure

$$P_{SO_2} = \frac{1333 \times 10}{2666.5} = 5\ \text{atm}$$

$$P_{O_2} = \frac{667 \times 10}{2666.5} = 2.5\ \text{atm}$$

$$P_{SO_3} = \frac{667 \times 10}{2666.5} = 2.5\ \text{atm}$$

v) $Kp = \frac{2.5^2}{5^2 \times 2.5} = 0.1\ atm^{-1}$

17.6. Summary of the unit

In most of the chemical reactions, the reactants are not completely converted into products. The reaction proceeds to a certain extent and reaches a state at which the concentrations of both reactants and products remain constant with time. The equilibrium constant, Kc, is the ratio of the equilibrium concentrations of products over the equilibrium concentrations of reactants each raised to the power of their stoichiometric coefficients.

For a given chemical equation of a reaction: $a\,A + b\,B \rightleftarrows c\,C + d\,D$

The equilibrium constant is K = $\frac{[C]^c [D]^d}{[A]^a [B]^b}$

Law of Mass Action states that *"The rate of a chemical reaction is directly proportional to the product of the molar concentrations of the reactants at a constant temperature at any given time".* Consider the reaction, $H_2(g) + I_2(g) \rightleftarrows 2HI(g)$, where gaseous compounds are involved in the reaction, the equilibrium constant can be written as; $K_p = \frac{(P_{HI})}{P_{H_2} \times P_{I_2}}$

Where pHI, pH_2 and pI_2 are the partial pressures of the different compounds. If no other gases are present.

Relationship between K_c and K_p

$$K_p = \frac{[C]^c [D]^d (RT)^{c+d}}{[A]^a [B]^b (RT)^{a+b}} = KC(RT)^{(c+d)-(a+b)}$$

$K_p = K_c(RT)^{\Delta n}$

Where R (ideal gas constant) = 0.0821 L.atm/K. mol^{-1}; T = temperature in Kelvin

Δn = moles of gaseous products - moles of gaseous reactants

For a reaction of known Kc value

17.7. Additional information

a. Comparison between reaction quotient Qc and equilibrium constant Kc

The **reaction quotient, Q,** is the resulting value when we substitute reactant and the product concentrations into the equilibrium expression. A reaction quotient (Q_r or Q) is a function of the activities or concentrations of the chemical species involved in a chemical reaction.

The difference is that Q can be calculated at any conditions (not only on equilibrium conditions) while the equilibrium constant is determined when there is a reversible reaction.

Example:

Consider for the following general equation:

$aA + bB \rightleftarrows cC + dD$

The reaction quotient $Q = \frac{[C]^r [D]^s}{[A]^p [B]^q}$

The reaction quotient Q is obtained at any time of the reaction but Kc is only applicable for the 'equilibrium' concentrations of reactants and products.

Q is dependent on both concentration and temperature. It tells us whether the reaction will move forward or backward and it is not a constant value. If any reactant is added and reaction move forward, it means that Q is affected but not the equilibrium constant Kc.

17.7.1. Using equilibrium constant to predict the direction of net reaction

For a reaction of known Kc value, the direction of the net reaction can be predicted by calculating the reaction quotient, Q. Consider the reaction:

$pA + qB \rightleftharpoons rC + sD$

$Q = \frac{[C]^r [D]^s}{[A]^p [B]^q}$

- If Q = Kc:

  The reaction is at equilibrium and the concentrations will not change since the rates of forward and backward reactions are equal.

- If Q < Kc:

  The ratio of products over the reactants is too small and the reaction is not at equilibrium; the reaction will move toward the equilibrium by forming more products.

- If Q > Kc: The ratio of products over the reactants is too large and the reaction is not at equilibrium; the reaction will move toward the equilibrium by forming more reactants.

17.7.2. Worked example to predict the direction of the reaction

For the reactions:

1. $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$, the equilibrium constant, K_c is 1.0×10^{-5} at 1500 K.

Predict the direction of the reaction if the reactants and products have the following concentrations:

$[N_2] = 0.05M$ $[O_2] = 0.02M$ $[NO] = 0.30M$

Solution

The reaction quotient Q is equal to:

$$Q = \frac{[NO]^2}{[A]^p[O_2]} = \frac{(0.30)}{(0.05)\times(0.02)} = 90$$

Compare Q to K: Q (90) > K (1.0×10^{-5})

Prediction of the direction of reaction: Q > K

- The reverse reaction is favoured.
- The reaction moves from right to left until the equilibrium is established.

2. $H_{2(g)} + I_{2(g)} \leftrightarrow 2HI_{(g)}$

$K_c = 57.0$ at 700K. At time t, the molar concentration of $H_2 = 0.10M$, $I_2 = 0.20M$ and $HI = 0.40M$.

The reaction quotient is: Q = (0.40)2 / (0.10) (0.20)

Q = 8.0

At the time t, Q is less than Kc and Q has to upgrade itself to reach Kc. In order to increase the value of Q for the reaction to produce more products, the reaction will be shifted in forward direction.

If at a certain time t_2 you find Q greater than K_c, then Q has to lower itself by increasing the concentration of reactants, the reaction is shifted in backward direction.

For the reversible reactions, they have a tendency to reach the equilibrium state by favouring either the backward or forward direction.

Guidance to skills lab 17

The tutor provides all the chemicals and laboratory apparatus

The learners will themselves perform the experiments, discuss and exchange opinions about the facts.

The teacher will monitor the work of learners to help them develop self confidence in manipulating chemicals.

Information to teacher about the experiment

The cobalt chloride equilibrium.

The element cobalt can form compounds in two different oxidation

states, +2 and +3. The +2 state is more common. The ion Co^{2+} (aq) is pink. Other compounds of

cobalt(II), which include both anhydrous Co and complex ions, are commonly blue.

If an aqueous solution contains both cobalt(II) and chloride ions, the blue ion $CoCl_4$

2- forms, in equilibrium with the pink Co^{2+} (aq) ion.

$CoCl_4^{2-}$(aq) <===========> Co^{2+} (aq) + 4Cl1-(aq)

Blue **Pink**

At relatively low concentrations of chloride, the equilibrium lies far to the right, and the solution is pink. If there is a large concentration of excess chloride, the equilibrium tends to the left, and the solution tends to be blue.

The equilibrium is sensitive to temperature as well as to concentration of solutes. At lower

temperatures, the equilibrium tends to lie to the right, that is, to be more pink; at higher

temperatures, it lies to the left and appears more blue.

Cobalt complexes

Name Formula Colour

cobalt(II) chloride CoCl2 (s) light blue

cobalt(II) chloride hexahydrate CoCl2·6H2O (s) red

cobalt(II) ion Co^{+2} (aq) red

cobalt(II) chloride ion $CoCl_4^{2}$- (aq) dark blue

Chemical equilibrium in cobalt complexes

Some ionic compounds exist as hydrates. They form weak bonds to water molecules. The attachment of these water molecules can affect the electronic structure of the compound and affect its colour.

Example is cobalt (II) chloride. Without the attached water molecules cobalt (II) chloride is a blue solid.

When exposed to humid air, however, the salt forms a hydrate and turns a dark red. The compound is called cobalt(II) chloride hexahydrate and its formula is: $CoCl_2 \cdot 6H_2O$. This process can be represented by equation 1:

Equation 1: $\underset{\text{blue}}{CoCl_2(s)} + \underset{\text{from air}}{6H_2O(g)} \longrightarrow \underset{\text{dark red}}{CoCl_2.6H_2O}$

By heating the hydrate water can be driven off:

Equation 2 $\underset{\text{dark red}}{CoCl_2.6H_2O} \underset{\text{cool}}{\overset{\text{heat}}{\rightleftharpoons}} \underset{\text{blue}}{CoCl_2(s) + 6H_2O}$

When dissolved in water the cobalt(II) chloride salt decomposes, resulting in the formation of the

$Co(H_2O)_6^{2+}$

2+ ion and a deep red solution. This process is represented by equation 3:

Equation 3 $\underset{\text{dark red}}{CoCl_2.6H_2O} \xrightarrow[H_2O]{} Co(H_2O)_6^{2+} + 2Cl^-(aq)$

Alternatively, solutions high in chloride concentration can form the dark blue aqueous $CoCl_4^{2-}(aq)$

Equation 4 $\underset{\text{red}}{Co(H_2O)_6^{2+} + 4Cl^-(aq)} \rightleftharpoons \underset{\text{blue}}{CoCl_4^{2-}(aq) + 6H_2O}$

End of unit assessment

Answers to end of unit assessment

1.a) $Kc = \dfrac{[N_2]\times[H_2O]^2}{[NO]^2\times[H_2]^2}$

b)

	[NO](M)	$[H_2]$(M)	$[N_2]$(M)	$[H_2O]$(M)
Initial	0.10	0.050	0.00	0.10
Change	-0.038	-0.038	+0.019	+0.038
Equilibrium	0.062	0.012	0.019	0.138

$[H_2] = 0.012$, $[N_2] = 0.019M$, $[H_2O] = 0.138$ M

$Kc = \dfrac{(0.019)\times(0.138)^2}{(0.062)\times(0.012)^2} = 653.681 \text{ mol}^{-1}\text{L}$

c)Relationship between Kc and Kp

Kp = $Kc\left(RT\right)^{\Delta n_g}$

d) Kp = (653.681 mol^{-1}L) (0.0821 atm K^{-1} mol^{-1}x298K)$^{(3-4)}$ = 26.728L atm^{-1}

2 a) A dynamic equilibrium is a chemical equilibrium between a forward reaction and the reverse reaction where the rates of reactions are equal in closed system.

b) (i) Kp = $\frac{\left(P_{NH_3}\right)^2}{P_{N_2}\left(P_{H_2}\right)^3}$

(ii) the units of Kp → $\frac{atm^2}{atm \times atm^3}$ = atm^{-2}

c. i) Increasing the pressure favours the forward reaction which produces fewer molecules of gas.

ii) Increasing the temperature favours reverse reaction which is endothermic reaction.

d) The catalyst used in the Haber process is iron.

e) The catalysts increase equally the rates of both forward and backward reactions in equilibrium. So they enable equilibrium to be achieved much more rapidly but they do not alter the concentrations of reacting substances at equilibrium.

3. a)Kc = $\frac{[NO_2]^2}{[N_2O_4]}$

b) Increase in pressure favours side with less number of moles therefore if the pressure is doubled, the backwards reaction will be favoured. NO_2 will decompose into N_2O_4.

4. a) i) Kp = $\frac{P^4_{H_2}}{P^4_{H_2O}}$

ii) Kp = $\frac{P_{COCl_2}}{P_{CO} \times P_{Cl_2}}$

b) Reaction I: Increase in pressure will shift to the right where is few number of moles.

Reaction II: Increase in pressure has no effect on the equilibrium position since the number of moles of gases on the left hand side is equal to the number of moles on the left hand side.

5. a) Kc = $\frac{[NH_3]^2}{[N_2]H_2]^3}$

b.i) $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

Initial conc. 0.20 0.20 0

At eqm 0.20-x 0.20-3x 2x

2x = 0.060

x = 0.030 mol

At equilibrium $[N_2]$: 0.20-0.03 = 0.17mol

At equilibrium $[H_2]$: 0.20-3x0.03 = 0.11mol

ii) $$Kc=\frac{(0.06)^2}{(0.17)(0.11)^3} = 15.9$$

$$Kc = \frac{\left(moldm^{-3}\right)^2}{\left(moldm^{-3}\right)\left(moldm^{-3}\right)^3} = mol^{-2}dm^{-6}$$

c) An increase in pressure favours the forward reaction, thus the yield of ammonia (NH_3) increases. Because high pressure favours the direction where the number of moles decreases (Le Chatelier's principle)

d) A low temperature would give a higher yield but the rate would be too slow, hence not economical. A higher temperature of 500^0C increases the rate. A high pressure increases the yield but if it is higher than 200 atm, it becomes very expensive because of the higher cost of repairing broken parts.

e) Manufacture of fertilizers

Manufacture of nitric acid.

6. a) There is increase in moles of gas (volume) in the forward reaction. Increase in pressure favours the backward reaction or shifts equilibrium position to the left where there are a few moles of gas.

b) $Kc = \frac{[H_2]^3[CO_2]}{[CH_4][H_2O]}$;units of Kc are mol^2dm^{-6}

17.8 Additional activities

17.8.1 Remedial activities

1) 1.0 mole of sulphur dioxide was introduced into a $1dm^3$ vessel. The vessel was heated to 1000K until equilibrium was attained. At equilibrium, 0.35 mole of sulphur trioxide was present:

a) a.Write;

i) Equation for decomposition of sulphur trioxide

ii) an expression for the equilibrium constant K_c and calculate the K_c value

b) b. 0.2 mole of sulphur dioxide, 0.1 mole of oxygen and 0.7 mole of sulphur trioxide were introduced into the vessel in a) at 1000 K.

i) Calculate the new K_c value for the reaction

ii) Using your answers in b) and c)i), state how the position of equilibrium has been affected.

2) Consider the reaction between sulphur dioxide and oxygen to produce sulphur trioxide at 700°C:

$$2SO_2\,(g) + O_2(g) \rightleftharpoons 2SO_3(g)d \quad \Delta H = \text{negative}$$

a) a .Write the expression for the equilibrium constant , K_c, for the above reaction and give its units

b) What happens to the sulphur trioxide in the equilibrium mixture if:

i) the temperature is raised from 700°C to 800°C?

ii) More oxygen is added?

iii) Nitrogen is added?

iv) The volume of reaction vessel is increased?

The equilibrium mixture of the above reaction at 700°C contains 0.4 mole of sulphur dioxide, 0.03 mole of oxygen and 1.00 mole of sulphur trioxide in a 2.0 dm^3 container. Calculate the value of K_c.

Answers

ii) The concentration of sulphur trioxide in the equilibrium mixture would increase as the equilibrium shifts to the right.

iii) Nitrogen is an inert gas and it reduces the partial pressure of the gases in the equilibrium mixture. Reduction in pressure is opposed by the equilibrium shifting in a direction, which leads to an increase in volume, which in this case, is the backward direction. Consequently, the concentration of sulphur trioxide would decrease as the equilibrium shift to the left.

iv) The concentration of sulphur trioxide would decrease as the equilibrium shifts to the left.

c) [ ] signifies concentration in mol dm^{-3}

Therefore, concentration of SO_3 = $\frac{1.00}{2} = 0.5\ \text{moldm}^{-3}$

Concentration of SO_2 = $\frac{0.4}{2} = 0.2\ \text{moldm}^{-3}$

Concentration of oxygen = $\frac{0.03}{2} = 0.015\ \text{moldm}^{-3}$

$$K_c = \frac{(0.5)^2}{(0.2)^2(0.0150)} = 416.7\ \text{mol}^{-1}\text{dm}^3$$

17.8.2. Consolidation activities

1. The exothermic reaction between nitrogen and hydrogen takes place according to the equation:

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$, ΔH =negative

a) a. Write the expression for the equilibrium constant, K_c for the forward reaction.

b) b. At 500°C, the equilibrium concentration of hydrogen is 0.25 moldm^{-3} and that of nitrogen is 0.27 mol dm^{-3}. Calculate the equilibrium concentration of ammonia at the same temperature, given that the equilibrium constant $K_c = 6.0 \times 10^{-2}\ \text{mol}^{-2}\ \text{dm}^6$ at 500°C.

c) c. What would happen to the ammonia in the equilibrium mixture if:

i) helium was added at 500°C?

ii) the temperature was increased

2. a) The degree of dissociation of 3.4 moles of hydrogen iodide at 468°C was found to be 20 percent. Calculate:

i) The number of moles of hydrogen iodide, hydrogen and iodine formed at equilibrium

ii) The equilibrium constant for the dissociation reaction

2. a) The degree of dissociation of 3.4 moles of hydrogen iodide at 468°C was found to be 20 percent. Calculate:

i) The number of moles of hydrogen iodide, hydrogen and iodine formed at equilibrium

ii) The equilibrium constant for the dissociation reaction

2. a) The degree of dissociation of 3.4 moles of hydrogen iodide at 468°C was

found to be 20 percent. Calculate:

i) The number of moles of hydrogen iodide, hydrogen and iodine formed at equilibrium

ii) The equilibrium constant for the dissociation reaction

b) A mixture containing 28 moles of hydrogen and 22 moles of iodine was heated in a sealed tube at 463°C until equilibrium was reached, when 36 moles of hydrogen of hydrogen iodide was obtained. Calculate the degree of dissociation of hydrogen iodide at 463°C

Answers

1.a) $K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$

b) $[N_2] = 0.27$; $[H_2] = 0.25$; $[NH_3]^2 = K_c [N_2][H_2]^3$

$$[NH_3] = \sqrt{K_c[N_2][H_2]^3} = \sqrt{6.0\times10^{-2}\times0.27\times(0.27)^3} = 1.59\text{x}10^{-2}\text{moldm}^{-3}$$

c) i) The concentration of ammonia would decrease if the pressure is not maintained constant since the noble will result in increase of volume. Therefore if the pressure is constant there will be no effect since the volume will remain constant

ii) the concentration of ammonia would decrease since the forward reaction is exothermic.

2. a) Hydrogen iodide dissociates according to the following equation:

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

Initially, there were 3.4 moles of HI. The degree of dissociation, α is 20% (0.20)

At equilibrium;

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

$$3.4(1-\alpha) \qquad \frac{3.4}{2}\alpha \quad \frac{3.4}{2}\alpha$$

i) The number of moles of HI at equilibrium = $3.4(1-\alpha) = 3.4\,(1-0.20) = 2.72$

Number of moles of H_2 at equilibrium = $\frac{3.4}{2}\alpha = \frac{3.4}{2}(0.20) = 0.34$

The equilibrium constant for the dissociation for the dissociation reaction can be obtained by making an assumption that the volume of the reaction vessel is V litres. For n moles of HI dissociating, initial molar concentrations is $\frac{n}{v}$

Therefore, equilibrium molar concentrations are

[HI] = $\frac{2n(1-\alpha)}{v}$; [H_2] = $\frac{n\alpha}{v}$ [I_2] = $\frac{n\alpha}{v}$

ii) The equilibrium constant, K_c = $\frac{[H_2][I_2]}{[HI]^2}$

Therefore, K_c = $\frac{\frac{n\alpha}{v}\frac{n\alpha}{v}}{\left(\frac{2n(1-\alpha)}{v}\right)^2} = \frac{\alpha^2}{4(1-\alpha)^2} = \frac{(0.20)^2}{4(1-0.20)^2} = 0.01562$ or $1.562\text{x}10^{-2}$

b)The equation for the formation of hydrogen iodide is: $H_2(g)+I_2(g) \rightleftharpoons 2HI(g)$

Let the initial number of moles be as follows:

Moles of H_2 = a ; Moles of I_2 = b; Moles of HI = 0

Let the number of moles of at equilibrium be:

Moles of H_2 = (a-x); moles of HI = 2x; moles of I_2 = (b-x)

In this case, 2x = 36 and x = 18

a = 28 and b = 22

a-x = 10 and b-x = 4

Therefore, equilibrium constant,

K_c = $\frac{(2x)^2}{(a-x)(b-x)} = \frac{(36)^2}{10\times4} = 32.4$

Equation for the dissociation of hydrogen iodide is:

$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$

For n moles of HI dissociating, the initial molar concentrations is $\frac{n}{v}$

(Assuming the volume of the reaction vessel is V litres)

Therefore, the equilibrium molar concentrations are

[HI] = $\frac{2n(1-\alpha)}{v}$ [H_2] = $\frac{n\alpha}{v}$ [I_2] = $\frac{n\alpha}{v}$

Where α is the degree of dissociation. The equilibrium constant for the dissociation is

$$\frac{\frac{n\alpha}{v}\frac{n\alpha}{v}}{\left(\frac{2n(1-\alpha)}{v}\right)^2} = \frac{\alpha^2}{4(1-\alpha)^2} \quad 4 \; 1 \quad 0.20$$

But this equilibrium constant for dissociation of HI is equal to $\frac{1}{K_c}$ for the formation of HI above: the Kc in .....(i) is 32.4

Therefore, $\frac{\alpha^2}{4(1-\alpha)^2} = \frac{1}{32.4}$ (1)

By taking square root of each side in .....(ii)

$\frac{\alpha}{4(1-\alpha)} = \frac{1}{5.69} \Rightarrow 5.69\ \alpha = 2 - 2\alpha$

Therefore, the degree of dissociation at 4.63° c = 0.26 (or 26%)

17.9. Extended activities

1. a) At 122°C, silver carbonate decomposes to silver oxide and carbon dioxide according to the equation:

$$Ag_2CO_3(s) \rightleftharpoons Ag_2O(s) + CO_2(g)$$

i) The equilibrium constant, K_p, for the reaction at 122°C is 9.5×10^{-3} atmospheres. Calculate the partial pressure of carbon dioxide. State any assumptions made

ii) At 122°C and 1 atmosphere pressure, air contains 1% of carbon dioxide. Calculate the partial pressure of carbon dioxide in the air.

b) State whether there would be any change in the mass of silver carbonate at equilibrium when the percentage of carbon dioxide was increased to 4%. Give reasons for your answer.

2. Hydrogen Iodide decomposes when heated, according to the equation:

$2HI\ (g) \rightleftharpoons H_2(g) + I_2(g)\quad \Delta H = +11.3\ KJmol^{-1}$

a) Write an expression for the equilibrium constant, K_c, for the reaction

b) 1.54g of hydrogen iodide was heated in a 600 cm^3 bulb at 530°C. When equilibrium was attained, the bulb was rapidly cooled to room temperature and broken under potassium iodide solution. The iodine formed from the decomposition required 67.0cm^3 0f 0.1M sodium thiosulphate solution for complete reaction. Calculate:

i) The number of moles of hydrogen iodide in 1.54g (H=1, I = 127)

ii) The number of moles of iodine formed when hydrogen iodide was decomposed.

iii) The value of K_c at 530°

c) State the effect on the value of K_c if

i) the temperature was raised from 530° to 800°C

ii) The volume of the bulb was increased to $1200 cm^3$

Answers

1. a) i) Assuming that the decomposition occurs in a closed system, the equilibrium constant, K_p, for decomposition is equal to the partial pressure of carbon dioxide. The concentration of solid silver carbonate and silver oxide remain constant during the reaction, and therefore do not take part in the equilibrium as they are in solid state. The carbon dioxide is assumed to behave ideally. The pressure of the carbon dioxide is therefore constant at any temperature.

$pCO_2 = K_p = 9.5 \times 10^{-3}$ atmospheres

ii) Partial pressure of $CO_2 = \frac{1}{100} \times 1 = 0.01$ atmospheres

b) Since the equilibrium position for this reaction is attained because the system is closed, there will be no change in the mass of silver carbonate. The system does not gain or lose matter to the surroundings, and the amount of carbon dioxide at that temperature will be constant, and so the quantity of silver carbonate and silver oxide will not change.

2. a) $K_c = \frac{[H_2][I_2]}{[HI]^2}$

b) i) The number of moles of hydrogen iodide in 1.54g

$= \frac{1.54}{128} = 0.012$

ii) $2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$

Number of moles of $S_2O_3^{2-}$, which reacted $= \frac{67.0 \times 0.1}{1000} = 0.0067$

Therefore, number of moles of I_2 which reacted = 0.0067x1/2 = 0.00335

Number of moles of I_2 formed when HI was decomposed = 0.00335 moles

iii) Total number of moles of HI before reaction = 0.012. Since 2 moles of HI forms 1 mole of hydrogen or 1 mole of iodine, then moles of HI reacted = 0.00335 x2 = 0.0067. The moles of HI which remained unreacted at equilibrium = (0.012-0.0067) = 0.0053. At equilibrium, moles of hydrogen formed is equal to moles of iodine formed = 0.00335.

$K_c = \frac{(0.00335)^2}{(0.0053)^2} = 0.40$

a) i) The value of K_c would increase, since the forward reaction is endothermic.

ii) The value of K_c would not change.

UNIT 18

ACIDS AND BASES

18.1. Key unit competence

Explain the acid-base theory according to Arrhenius, Bronsted-Lowry and Lewis.

18.2. Prerequisite knowledge and skills

Distinguish between acidic and basic substances encountered in everyday life from the point of view taste, feel, their effect on litmus paper and reading on a pH scale.

18.3. Cross-cutting issues to be addressed

Environment sustainability

During the lesson you should emphasize that acids and bases cover a wide range of uses in everyday life. However, they have harmful effects on both living organisms and inert organisms. A great attention should be paid when carrying out laboratory experiments. The used chemicals should be disposed accordingly so as to preserve and protect our environment.

18.4. Guidance on Introductory activity

Have the learners attempt introductory activity. This activity intends to identify the prerequisite learners have on acids and bases and relate them to everyday life circumstances.

18.5. List of lessons

Unit No	Lesson title	Learning objectives	No of periods
1	Acid-base theory (Arrhenius theory of acid and base, Bronsted-Lowry theory of acid and base and Lewis'theory of acid and base).	- Define Arrhenius acid and Arrhenius base. - Explain the behaviour of Arrhenius acid and base in aqueous solution. - Define Bronsted-Lowry acid and Arrhenius base. - Explain the behaviour of Arrhenius acid and base - Identify the acid-base conjugate complex in a reaction involving Bronsted-Lowry acid and Arrhenius base. - Define Lewis acid and Arrhenius base. - Identify Lewis lewis acid and base for a given reaction involving Lewis acid and base.	2
2	End unit assessment		1

Lesson 1: Acid-base theories.

This is an introduction to acid-base equilibrium. You are advised to recall the prior knowledge of learners about acids and bases through the introductory activities suggested in the student book. This is intended to raise the curiosity of learners and relate the lesson to real/daily life.

a) Prerequisites/Revision/Introduction

For students to learn better the acid-base theories, they should have some knowledge on the existence of acids and bases and bases among the wide range of products daily met. They should know how to distinguish between acids and bases from point of view taste, feel and effect on litmus paper.

b) Teaching resources:

- Illustrations in the students' book for lesson unit 18 or draw them on a manila paper.
- Teaching videos downloaded videos from you tube.
- Chemistry text books if available in the library.

c) Learning activities

Guidance

Before introducing the lesson, you will have to introduce the whole unit by allowing learners to do introductory activity and then proceed to activities 18.1.

- Form groups of 4-5 depending on the size of the class.
- Distribute the introductory activity and estimate the time for it.
- Have the learners do activities 18.1of lesson.
- Allow the learners to work together in groups.
- Invite group leaders to present their findings.
- In this step you can guide the learners to evaluate the findings by confirming the correct answers, eliminating the wrong ones or completing some statements.
- You summarise the learned knowledge and give examples which illustrate the learned content. Here you can also give other necessary examples that could have not indicated in step 2.
- Integrate crosscutting and real life experiences by linking them with the lesson learned.

Answers to Introductory activity

The pictures A, B, C, D and E represent some of the products used in everyday life.

1. You are advised to guide learners answering the questions given in the activity and correct the wrong answers.
2. a. A is called Milk of magnesia which is a solution of Magnesium hydroxide.

   b. The substance B is cheese. It is essentially of lactic acid (2-ydroxypropanoic acid).

   c. The image in C is a lemon fruit. It is essentially citric acid.

   d. The substance D is soap. It is mainly made of fatty acid such as lauric acid, myristic acid, palmitic acid i.e salt from strong base and weak acid.

   e. The image E shows pepper. It is mainly butyric acid.

Substance	**Main use**
Magnesium hydroxide	Magnesium hydroxide is a common component of antacids, such as milk of magnesia, as well as laxatives
Lactic acid	Lactic acid is used as a food preservative, curing agent, and flavoring agent.

Citric acid.	It is a natural preservative and is also used to add an acidic (sour) taste to foods and soft drinks.
Lauric acid	lauric acid has multiple uses in cosmetics. It's also used as a base for cleansing agents.
Butyric acid	The acid is of considerable commercial importance as a raw material in the manufacture of esters of lower alcohols for use as flavouring agents.

3. i.

Magnesium hydroxide	A	Milk of magnesia
Lactic acid	B	Butter
Citric acid.	C	Lemon
Lauric acid	D	Soap
Butyric acid	F	Pepper

ii. The substances could be classified in two groups.

iii. The mentioned in 2(i) groups are acids and bases.

Answers to activity 18.1

Table 16.1. Results of acid-base testing

Reagent	**Red Litmus**	**Blue Litmus**	**Acid, base or neutral?**
Hydrochloric acid (HCl)	Red	Red	Acid
Sodium hydroxide (NaOH)	Blue	Blue	Base
Sodium chloride (NaCl)	Purple	Purple	Neutral
Distilled water (H_2O)	Purple	Purple	Neutral
Glucose ($C_6H_{12}O_6$)	Purple	Purple	Neutral
Sulphuric acid (H_2SO_4)	Red	Red	Acid
Ammonia (NH_3)	Blue	Blue	Base
Ethanoic acid (CH_3COOH)	Blue	Blue	Base

The acidic chemicals are Hydrochloric acid (HCl) and Sulphuric acid (H_2SO_4).

1. The basic chemicals are Sodium hydroxide (NaOH) and Ammonia (NH_3).
2. The neutral chemicals are Sodium chloride (NaCl), Distilled water (H_2O) and Glucose ($C_6H_{12}O_6$).

c) Application activities

Answers to application activity 18.1(a)

1. The filled table

Substance	**Acid/Base**	**Positive ions in water**	**Negative ions in water**
HCl	Acid	H^+	Cl^-
HBr	Acid	H^+	Br^-
HNO_3	Acid	H^+	NO_3^-
KOH	Base	K^+	OH^-
$Ca(OH)_2$	Base	Ca^{2+}	OH^-
NH_4OH	Base	NH_4^+	OH^-
HCOOH	Acid	H^+	$HCOO^-$

2. The information in the given table revealed the following.

a) Two strongest acidic substances are battery acid (pH=0.3) and stomach acid ($1 \leqq pH \leqq 2$)

b) Two weakest acidic substances are beer (pH=5) and milk or urine which have both pH=6.

c) Two weakest alkaline substances Human blood ($7.3 \leqq pH \leqq 7.3$) and sea water (pH=8).

d) Two strongest alkaline substances are sodium hydroxide (pH=14.0)and bleach (pH=12.6)

e) The neutral substance is pure H_2O.

Answers to Study questions:

a. i)Both pH values for HCl and CH_3COOH are less than 7.

The pH of HCl is lower than that of CH_3COOH.

ii)Both pH values for NaOH and NH_4OH are higher than 7.

The pH of NaOH is higher than that of NH_4OH.

b. The results show

i)that HCl is stronger than CH_3COOH and

ii) NaOH is stronger than NH_4OH.

Answers to application activity 18.1(b)

1. Labelling of the acid (A), base (B), conjugate acid (CA) and conjugate base (CB) in given chemical equations.

a. $HCl(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + Cl^-(aq)$

A B CA CB

b. $H_2PO_4^-(aq) + NH_3(aq) \rightleftharpoons NH_4^+(aq) + HPO_4^{2-}(aq)$

A B CA CB

c. $NH_4^+(aq) + CN^-(aq) \rightleftharpoons HCN(aq) + NH_3(aq)$

A B CA CB

d. $H_2SO_4(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HSO_4^-(aq)$

A B CA CB

2. The conjugate base for the given Brønsted-Lowry acid.

	Molecule/ Ion	**Conjugate base**
a	HI	I-
b	NH_4^+	NH_3
c	H_2CO_3	HCO_3^-
d	HNO_3	NO_3^-

2. The conjugate acid for each of the following Brønsted-Lowry bases.

a) CN^- : HCN
b) O^{2-} : OH-
c) CH_3COO^-: CH_3COOH
d) NH_3: NH_4^+

Answers to Application activity 18.1 (c)

5. a. $Fe^{3+}(aq) + 6H_2O(l) \rightleftharpoons [Fe(H_2O)_6]^{3+}(aq)$

   b. $Cu^{2+}(aq) + 4\,NH_3 \rightleftharpoons [Cu(NH_3)_4]^{2+}(aq)$

   c. $Cu^{2+}(aq) + 6H_2O(l) \rightleftharpoons [Cu(H_2O)_6]^{2+}(aq)$

6. c

7. b

18.6 Summary of the unit

- According to Arrhenius, the pioneer of the acid-base theory an acid is any chemical species that produces hydrogen ions (H^+) in aqueous solution while a base is any chemical species that produces hydroxide ions (OH^-) in aqueous solution. The strength of an acid or base is determined by the extent to which it liberates H^+ or OH^- ions.
- Brønsted-Lowry's theory of acids and bases helped to overcome the drawbacks of the Arrhenius theory. He defines an acid as proton donor and a base as a proton receptor.
- Lewis's theory defines an acid as any chemical species that is electron deficient and a base as an electron rich species.

GUIDANCE TO SKILLS LAB 18

By the end of the lesson the learners are expected to carry out acid-base test on their own. The teacher will guide learners to prepare the acid-base indicator from local material. The teacher gives the procedure and make the follow up to check whether the learners are using it to prepare the indicator from coloured plants .The learners use known acid and base to serve as control sample. Then the learners may use any solution of their choice to test its acidic/basic character the after they draw conclusion from their observations. Below are some ways of preparing natural indicators

How to make an indicator using hibiscus petals

1. Cut approximately 10 mature hibiscus flowers.
2. Remove the stigma, and detach the leaves, so as to have only the red petals remaining.
3. Put them in a container, and pour approximately 6ml of ethanol or surgical spirit; the latter works best.
4. Crush the petals using an appropriate implement, such as a mortar and pestle. Crush until all of the liquid has been extracted from the petals.
5. Filter the solution, and you have the reddish indicator ready.
6. View results in sunlight if possible.

If an indicator is prepared from hibiscus petals, the following colours should be observed:

- Initial/Neutral colour: **Pink**
- Colour when exposed to strong acid:**red**
- Colour when exposed to strong base: **green**/**blue**

How to prepare a natural indictor:

Select a suitable coloured plant material, such as purple cabbage.

Extract the colour from the plant material by either:

Boiling it in water.

Crushing it with water or alcohol using a mortar and pestle.

Decant the solution from the solid.

To test a natural indicator:

If an indicator is prepared from purple cabbage, the following colours should be observed:

- Initial/Neutral colour: **Purple**
- Colour when exposed to strong acid: **Pink, then Red**
- Colour when exposed to strong base: **Blue-Green, then Yellow**

18.7 Additional information for tutors

Overview of the Acid-Base Properties of Salt

Key Points

- Basic salts result from the neutralization of a strong base with a weak acid.
- Acid salts result from the neutralization of a strong acid with a weak base.
- For salts in which both cation and anion are capable of hydrolysis, compare K_a and K_b values to determine the solution's resulting pH.

Terms

- neutralization reaction is a reaction between an acid and a base in which water and a salt are formed
- hydrolysis is a reaction with water in which chemical bonds break
- salt in acid-base chemistry, one of the products in a neutralization reaction

Summary of Acidic and Basic Salts

Salts can form acidic or basic solutions if their cations and/or anions are hydrolysable (able to react in water). Basic salts form the neutralization of a strong base and a weak acid; for instance, the reaction of sodium hydroxide (a strong base) with acetic acid (a weak acid) will yield water and sodium acetate. Sodium acetate is a basic salt; the acetate ion is capable of deprotonating water, thereby raising the solution's pH.

Acid salts are the converse of basic salts; they are formed in the neutralization reaction between a strong acid and a weak base. The conjugate acid of the weak base makes the salt acidic. For instance, in the reaction of hydrochloric acid (a strong acid) with ammonia (a weak base), water is formed, along with ammonium chloride. The ammonium ion contains a hydrolysable proton, which makes it an acid salt.

Answers to End unit assessment

1. Equation for the dissociation of the given acids in water.

   a. $HClO_4$: $HClO_4(aq) \rightarrow H^+(aq) + ClO_4^-(aq)$
   b. $H_2SO_4(aq)$: $H_2SO_4 \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$
   c. $CH_3COOH(aq) \rightleftharpoons H^+(aq) + CH_3COO^-(aq)$
   d. $H_2S(aq) \rightarrow 2H^+(aq) + S^{2-}(aq)$
   e. $HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$

2. The balanced reaction for the dissociation of nitric acid when put in water

   $HNO_3(aq) + H_2O(l) \rightarrow NO_3^-(aq) + H_3O^+(aq)$

3. The balanced reaction for the dissociation of acetic acid when put in water

   $CH_3COOH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH_3COO^-(aq)$

4. Equation for the dissociation of barium hydroxide is put in water.

   $Ba(OH)_2 \rightarrow Ba^{2+} + 2OH^-$

5. The conjugate base of HSO_4^- is SO_4^{2-}.

6. The formula **and** name of the conjugate acid corresponding to the following bases:

	Molecule/ Ion	Conjugate acid	Name of conjugate acid
a	NH_3	NH_3	Ammonium ion
b	PO_4^{3-}	HPO_4^{2-}	Monohydrogen phosphate ion
c	CN^-	HCN	Hydrogen cyanide
d	HCO_3^-	H_2CO_3	Hydrogen carbonate

7. The balanced equation for the Bronsted-Lowry acid HPO_4^{2-} in water.

   $HPO_4^{2-} + H_2O(l) \rightleftharpoons H_3O^+(aq) + PO_4^{3-}(aq)$

8. The reaction for the dissolution of ammonia in water.

   $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

9. The increasing order of alkalinity strength: **D<C<B<A**

   Reason: The stronger the acid the weaker its conjugate base and vice versa.

10. A>B>C>D

    A depicts the strongest acid and strongest electrolyte.

    B depicts the weakest acid and weakest electrolyte.

Reason:

- In A, all four molecules (100%) of the acid are dissociated.
- In B, three out of four molecules (75%) of the acid are dissociated.
- In C, two out of four molecules (50%) of the acid are dissociated.
- In D, no molecule of the acid (0%) is dissociated.

18.8. Additional Activities

18.8.1. Remedial Activity

1. Which of the following gases is a contributor to the formation of acid rain?

   A. H_2

   B. O_3

   C. SO_2

   D. NH_3

2. Consider the following:

I	PO_4^{3-}
II	HPO_4^{2-}
III	$H_2PO_4^-$
IV	H_3PO_4

The term amphiprotic can be used to describe

A. I only.
B. II and III only.
C. I, II and III only.
D. II, III and IV only.

3. An Arrhenius acid is defined as a chemical species that

   A. is a proton donor.
   B. is a proton acceptor.
   C. produces hydrogen ions in solution.
   D. produces hydroxide ions in solution.

4. Which statement about Arrhenius acids is FALSE?

   A. Their water solutions are called aqueous acids.
   B. They are molecular compounds with ionisable hydrogen atoms.
   C. Their pure aqueous solutions are electrolytes.
   D. They increase the concentration of hydroxide ions in aqueous solution.

5. Strong bases are

A. Strong electrolytes.

B. Non-electrolytes.

C. Weak electrolytes.

D. Also strong acids

6. Whose definition of acids and bases emphasizes the role of protons?

A. Arrhenius

B. Brønsted and Lowry

C. Lewis

D. Faraday

7. An electron pair acceptor is a

A. Lewis acid.

B. Brønsted Lowry base.

C. Traditional acid.

D. Lewis base.

Expected answers to Remedial activity

1.C 2.B 3.C 4.D 5.A 6.B 7.A

18.8.2. Consolidation Activity

1. For each each of the following, identify the acids and bases in both the forward and reverse reactions.

A. $HClO_2 + H_2O \rightleftharpoons ClO_2^- + H_3O^+$

B. $OCl^- + H_2O \rightleftharpoons HOCl + OH^-$

C. $NH_3 + H_2PO_4^- \rightleftharpoons NH_4^+ + HPO_4^{2-}$

D. $HCl + H_2PO_4^- \rightleftharpoons Cl^- + H_3PO_4$

2. The dihydrogen phosphate ion, $H_2PO_4^-$, is amphiprotic. In which of the following reactions is it serving as a base?

i. $H_3O^+(aq) + H_2PO_4^-(aq) \rightleftharpoons H_3PO_4(aq) + H_2O(l)$

ii. $H_3O^+(aq) + HPO_4^{2-}(aq) \rightleftharpoons H_2PO_4^-(aq) + H_2O(l)$

iii. $H_3PO_4(aq) + HPO_4^{2-}(aq) \rightleftharpoons 2\ H_2PO_4^-(aq)$

A. i only

B. i and ii

C. i and iii

D. ii and iii

E. i, ii and iii.

3. The probe of the pH meter shown here is sitting on a beaker that contains a clear liquid. You are told that the liquid is

   A. Pure water

   B. A solution of HCl

   C. A solution of KOH

   D. A weak base.

4. Consider the following Brönsted-Lowry equilibrium system:

   $HSO_3^- + H_2PO_4^- \rightleftharpoons SO_3^{2-} + H_3PO_4$

   What are the two Brönsted-Lowry bases in the equilibrium above?

   A. HSO_3 and SO_3^{2-}

   B. $H_2PO_4^-$ and SO_3^{2-}

   C. HSO_3^- and H_3PO_4

   D. $H_2PO_4^-$ and H_3PO_4

5. Consider the acid-base equilibrium system

   $HC_2O_4^- + H_2BO_3^- \rightleftharpoons H_3BO_3 + C_2O_4^{2-}$

Identify the Brønsted-Lowry acids in this equilibrium.

A. $HC_2O_4^-$ and $C_2O_4^{2-}$

B. $HC_2O_4^-$ and H_3BO_3

C. $H_2BO_3^-$ and H_3BO_3

D. H_2BO_3 and $C_2O_4^{2-}$

Answers

1. The acids and bases involved in the given equations are given in the following table.

	Acid 1	**Base 1**	**Acid 2**	**Base 2**
a	$HClO_2$	ClO_2^-	H_3O^+	H_2O
b	$HOCl$	OCl^-	H_2O	OH^-
c	NH_4^+	NH_3	$H_2PO_4^-$	HPO_4^{2-}
d	HCl	Cl^-	H_3PO_4	$H_2PO_4^-$

2. E
3. C
4. B
5. B

18.9 Extended activity

Model 1: A Definition of Acids and Bases

(i) $HCl(g)+H_2O(l) \rightleftharpoons H_3O^+(aq)+$-
$Cl^-(aq)$

(ii) $NH_3(aq)+H_2O(l) \rightleftharpoons$
$NH_4^+(aq)+OH^-(aq)$

1. (a) What chemical species are the Brønsted-Lowry acids in the forward reactions in the table above?

   (b) What chemical species are the Brønsted-Lowry bases in the forward reactions in the table above?
2. Is it possible for a substance to act as both an acid and a base? Explain your reasoning.
3. (a) What species results from the loss of a proton from the Brønsted-Lowry acid in the forward reaction?

   (b) Does this species act as an acid or a base when the reverse of reaction (i) occurs?

   (c) What species results from the gain of a proton from the Brønsted-

Lowry base in the forward reaction (i).

(d) Does this species act as an acid or a base when the reverse of reaction (i) occurs?

4. Repeat questions (a) – (d) for reaction (ii).

Model 2: Conjugate Pairs

As you discovered in Model 1, certain pairs of molecules are related through their acid and base properties. These pairs are described as **conjugate acid-base pairs**. They differ by *a single proton*. A base has *one less proton* than its conjugate acid. An acid has *one more proton* than its conjugate base.

Acid	**Base**
H_2CO_3	HCO_3^-
HCO_3^-	CO_3^{2-}
H_3O^+	H_2O
H_2S	HS^-

Critical thinking questions

1. There are two conjugate pairs in the following reaction. Identify *both* pairs.

$$H2O(l) + H2O(l) \rightleftharpoons H3O^+(aq) + OH^-(aq)$$

2. Amino acids have both an acidic (-COOH) and a basic (-NH2) functional group. The simplest amino acid is glycine, H2N-CH2-COOH. Give the structure of the conjugate acid and the conjugate base of glycine.

Answers to extended activity

1. (A) (i) HCl (ii) H_2O

(b) (i) H_2O (ii) NH_3

2. Yes, a substance can act as an acid when it interacts with bases or a base when it interacts with. Such a substance is known as amphoteric substance or amphiprotic substance.

3. (a) In the forward reaction (i) Cl^- is the result from the loss of a proton from the Brønsted-Lowry acid.

(b) This species act as a base when the reverse of reaction (i) occurs.

(c) In the forward reaction (i) the result from the gain of a proton by the Brønsted-Lowry base is the conjugate acid (H_3O^+).

(d) This species act as an acid when the reverse of reaction (i) occurs.

4. (a) In the forward reaction (ii) OH^- is the result from the loss of a proton from the Brønsted-Lowry acid.

   (b) This species act as a base when the reverse of reaction (iii) occurs.

   (c) In the forward reaction (iii) the result from the gain of a proton by the Brønsted-Lowry base is the conjugate acid (NH_4^+).

   (d) This species act as an acid when the reverse of reaction (i) occurs.

5. The two acid-base conjugate pairs are $H_2O(l)$/ $OH^-(aq)$ and $H_3O^+(aq)$/ $H_2O(l)$.

6. The conjugate acid is $H_3N^+\text{-}CH_2\text{-}COOH$ and the conjugate base is $H_2N\text{-}CH_2\text{-}COO^-$

UNIT 19

ENERGY CHANGES AND ENERGY PROFILE DIAGRAMS

19.1. Key unit competence

Explain the concept of energy changes and energy profile diagrams for the exothermic and endothermic processes.

19.2. Prerequisite knowledge and skills

- Interpret the experimental results about energy changes occurring during chemical reactions.
- Carefully deal with reactions that produce a lot of energy.
- Respect the experimental protocol during chemistry practicals.

19.3. Cross-cutting issues to be addressed

a) Inclusive education

This unit involves number of structures that require experiment. It is therefore imperative to note that learners with visual impairment are helped by team working.

b) Standardisation culture

During the lesson of standard enthalpy changes, the word standard must be emphasised to remind the learners about the importance of standardization culture in daily life especially when purchasing and selling items on the market to always check their expiry dates. It is important to mention that expired items are very likely to exert negative side effects on the health of the consumers. This would stain the reputation of the traders.

19.4. Guidance on Introductory activity

Organise the learners in groups of 4 or 5 depending on the size of the class. Have the learners carry out the laboratory experiment.This activity intends to identify the prerequisite learners have energy and types of reactions according to the absorption or release of heat.

Before introducing the lesson, you will have to introduce the whole unit by allowing learners to do introductory activity i form of experimental activity 19.1

- Form groups of 4-5 depending on the size of the class.
- Distribute the introductory activity and estimate the time for it.
- Assign working groups with tasks.
- Have the learners do activities 19.1 of lesson.
- Allows the learners to work together in groups.
- Collect the recorded information by different working groups.
- Invite group leaders to present their findings.
- In this step you can guide the learners to evaluate the findings by confirming the correct answers, eliminating the wrong ones or completing some statements.
- You summarise the learned knowledge and gives examples which illustrate the learned content. Here you can also give other necessary examples that could have not indicated in step 2.
- Integrate crosscutting and real life experiences by linking them with the lesson learned.

Explanation to Introductory

1. The chemicals (reactants and products) represent the part of universe under the study. They represent the system. Everything outside the system is called surroundings. In our context the surroundings are represented by the container of the reactants and products.

Confirm the right findings from the recorded observations made by learners and correct the wrong ones.

2. Some reactions produce heat that is manifested by the increase in the temperature of the surroundings or heating up of the beaker in our case. They are called exothermic reactions. The reaction between calcium oxide and water and that between Zinc and hydrochloric acid are examples of such reactions.

3. Others absorb energy from the surroundings which results in the decrease in temperature of the surroundings, beaker in our case. They are called endothermic reactions. The reaction of Ammonium chloride and water and that of sodium thiosulphate and water are some examples of such reactions.

19.5. List of lessons

	Lesson title	Learning objectives	No of periods
1	Concept of systems	Explain the concept of system and distinguish between the types of systems.	1
2	The internal Energy of a system, heat energy and temperature	Distinguish between Temperature and heat.	1
3	The fist law of thermodynamics and some forms of standard enthalpy changes	Explain the concept of Exothermic and endothermic reactions and represent them using energy profile diagrams.	1
4	Energy profile diagrams for Exothermic and Endothermic reactions.	• Relate the type of reaction to its energy profile diagram. • Interprete the experimental results about energy changes occurring during chemical reactions. • Explain the energy change as a function of the breaking and formation of chemical bonds.	1
5	End unit assessment		1

Lesson 1: Concept of Systems

Guidance to Activity 19.1

- Form groups of 4-5 depending on the dimensions of the Laboratory.
- Give the printed experimental protocol one copy per group.
- Give clear instructions related to the procedure for the safety of learners.
- Have learners work to work in groups.
- Collect the recorded observations by different working groups.
- Invite group leaders to present their findings.
- In this step you can guide the learners to evaluate the findings by confirming the correct answers, eliminating the wrong ones or completing some statements.

- You summarise the learned knowledge and gives examples which illustrate the learned content. Here you can also give other necessary examples.
- Integrate crosscutting issues and real life experiences by linking them with the learning activity.

Answers to Activity 19.1

1. In beaker 1.a) the learners will feel hot wall: sulphuric acid dissolves by releasing energy to the surrounding.(exothermic reaction)

1.b) the learners will fill coldness by touching the wall of the beaker: ammonium dissolves by absorbing the energy from the surrounding(endothermic reaction)

2.both systems are open system because they exchange either heat energy and matter with the surrounding

Expected answers to Application activity 19 .1

1. Ocean: open, aquarium: closed, a greenhouse: closed.
2. The final mass will be 2g. Remember, a closed system does not allow for mass exchange.
3. The final temperature will be 30°C. Remember, an isolated system does not allow energy transfer.

Lesson 2: The internal energy of a system, heat energy and temperature

Guidance to Activity 19.2

- Organise learners in groups of 4-5 depending on the dimensions of the class
- Give them the activity 19.2
- Invite group leaders to present their findings.
- In this step you can guide the learners to evaluate the findings by confirming the correct answers, eliminating the wrong ones or completing some statements.
- You summarise the learned knowledge and gives examples which illustrate the learned content. Here you can also give other necessary examples.
- Integrate crosscutting issues and real life experiences by linking them with the learning activity.

Answers to Activity 19.2

1.a)KE= $\frac{1}{2}$ mv^2= $\frac{1}{2}(80kg)\times(8ms^{-1})^2$ =2,560J.

b) PE= mgh

= 0.154kg×9.81ms^{-2}×1.5=2.27J

c)ME=KE+PE

Therefore,

KE=ME-PE

=50,725J-34,300J =16,425J

2. a) Warmed water feels hotter. It has more heat than the hands. Heat is flowing from water to hands.

b) Water collected from tap is colder. It has less heat than the hands. Heat is flowing from hands to water.

c) After mixing warm and cold water the same temperature is reached. The two types of water have the same amount of heat.

3. A stationary pencil has potential energy and a falling pencil has kinetic energy.

Answers to application activity19.2

1. a. S

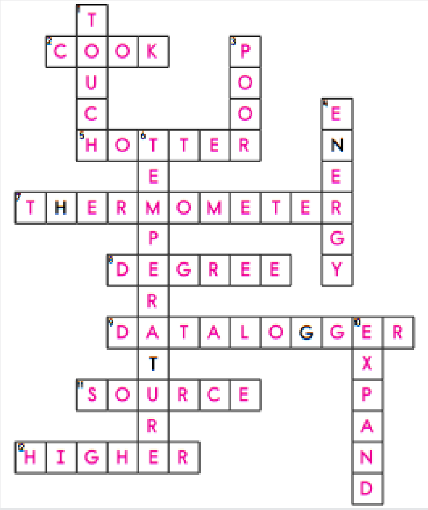
b. P

2. A

3. B

4. Hotter, colder

5.



Lesson 3: Standard enthalpy changes

Guidance on Activity 18.3

In order to acquire a good understanding of the different forms of standard enthalpy changes, the learners need to remember the meaning of concept Standard. This part highlights some of the forms of standard enthalpy changes. The term is used to describe things which are usual and normal.

Answers to activity 19.3

1. The standard conditions of temperature and pressure refer to 0°C (273 K) and 1atmosphere (1atm=101,325Pa).
2. The term that describes the sum of kinetic energy and Potential energy?

Answers to application activity 19.3

1.$\Delta U = q + w$

w is positive because the surroundings are working on the system, 462J.

q is negative because the system is transferring heat to the surroundings, -128J.

$\Delta U = (-128J) + (462J)$

$\Delta U = 334J$

2. All bonds in the compound are broken in atomization (exothermic) and none are formed so enthalpies of atom are always positive.

Lesson4: Energy profile diagrams for Exothermic and Endothermic reactions.

Guidance on activity 19.4

You are advised to have learners understand new terms especially the term *profile*. The term profile means the representation of something in outline.

Answers to Activity 19.4

1. The term energy of an object means the ability of that object to do work.

   In points A, B and C the moving car has kinetic,

2. In the diagram of ***activity 19.4*** the car starts with maximum kinetic energy in point A. As it moves uphill, its kinetic energy decreases while its potential energy increases and becomes maximum at point B. As the car moves downhill, its potential energy decreases while its kinetic energy increases and becomes maximum at point C.

3. The points corresponding to maximum stability are A and C because they are the ones corresponding to minimum potential energy.

Answers to application activity 19.4

i) The compound AX and the element M are in gaseous and solid states, respectively.

ii) What effect would grinding M into a fine powder have o the above graph?

iii) The activation energy of a reaction is the minimum energy required to start that reaction.

iv) E (Reactants)=52 kJ

v) E (Products)=16 kJ

vi) Ea (Forward)= (80-52) kJ=+28 kJ

vii) Ea (Reverse)= (52-16) kJ=+64 kJ

viii) ΔH (Forward)= (16-52) kJ= -36 kJ

ix) ΔH (Reverse)= (52-16) kJ= +36 kJ

x) a.The forward reaction is exothermic

xi) b.The reverse reaction is endothermic

xii) Activated complex is AXM

xiii) The stronger chemical bond is MX.

a. Reason: It has lower energy (more stable). It takes more energy (+64 J) to break M-X bond than to break A-X bond (+28 kJ).

xiv) The chemical species whose particles move the fastest are A+MX.

a. Reason: Since these species have minimum potential energy, they have maximum kinetic energy and therefore the highest speed.

xv) The chemical species whose particles move the slowest are AX+M.

Reason: Since these species have maximum potential energy, they have minimum kinetic energy and therefore the lowest speed.

19.6. Summary of the unit

- Thermodynamics is the study of energy changes that accompany chemical reactions or physical transformations. The part of universe under the study using laws of Thermodynamics is called System. Everything outside the system is known as surroundings.
- Internal energy represents the sum of energy of particles. According to the first law of Thermodynamics energy can neither be created nor destroyed. This holds well for isolated systems. The heat of an object is the total energy of all the molecular motion inside that object. The temperature is refers to the flow of thermal energy from a hotter object to a colder one. The standard conditions referring to thermochemical measurements are:
- The standard temperature corresponds to 25^0C (298 K), the standard pressure is equivalent to 1 atmosphere (1atm=101, 325 Pa.) while the concentration of solutions is 1.0 mol.dm^{-3} or 1.0 mol L^{-1}. The standard enthalpy changes are heat changes accompanying chemical reactions or physical transformations under standard conditions.
- Finally energy profile diagrams are representations of the energy change occurring as the chemical reactions progresses. They represent both exothermic and endothermic reactions

GUIDANCE TO SKILLS LAB 19

The teacher will explain first the purpose of the skills lab ,the role of the calorimeter ,is functioning and how the results from the experiment are used. Then he/she give the learners the task of improvising the calorimeter and to use it in finding the standard enthalpy of combustion of ethanol.

Expected answers to guide the teacher

The heat produced by burning the mass “m” of fuel is given by:

$Q=mCp\Delta t$ Where m:mass of water

Cp: specific heat capacity of water=4.18J/g.^{o}c

Δt:Change in temperature of water during burnig

The heat produced by the mass of burnt fuel and therefore extend to the molar mass of the fuel to find the standard enthalpy change .

This obtained value is the different to the accurate standard value because of the reasons below:

- The operating conditions are not standard
- The heat capacity of the container that makes the calorimeter is not considered
- The errors can arise from the inaccuracy of measurements.....

Answers to End unit Assessment 19

a.**The overall reaction is endothermic**

b.130-50=80kj

c.130-100=30kj

d.Hp-Hr=100-50=50kj

e. the reverse reaction is exothermic

f.activated complex is X_2Y_2

h. X_2Y_2

i. $X_2 + Y_2$

j.XY

k.50-130= -80kj

l. the reverse reaction

m. their PE goes down while their KE goes up

n. The activated complex is the intermedicate species, where former chemical bonds are being

broken, whereas new chemical bonds are being formed. In term of energy, it corresponds to the activation energy.

o. Species with maximum stability are $X_2 + Y_2$,because of the minimum potential energy

p. The addition of a catalyst reduces the activation energy. The curve with a catalyst will be under the curve without a catalyst

19.7. Additional activities

19.7.1. Remedial Activity

1. Which statement about enthalpy is true?

a. Heat is given off to the surroundings in endothermic reactions.

b. Some substances have a negative specific heat capacity.

c. Specific heat capacity is the same for all liquids.

d. The sign of ΔH is always negative in exothermic reactions.

2. What happens to the value of ΔH for a thermochemical reaction if the reaction is reversed?

a. ΔH has the same numerical value, and the sign changes.

b. ΔH has the same numerical value, and the sign remains the same.

c. ΔH is the reciprocal of the original value, and the sign changes.

d. ΔH is the reciprocal of the original value, and the sign remains the same.

3. Which is an exothermic process?

a. Ice melting

b. Water boiling

c. Water evaporating

d. Water vapour condensing

4. Which statement is true for the combustion of ethanol?

$C_2H_5OH (l) + 3O_2(g) \rightarrow 2CO_2 (g) + 3H_2O(l)$ $\Delta H = -1370$ kJ

a. The enthalpy change would be the same is gaseous water were produced.

b. The potential energy of the products is less than the potential energy of the reactants.

c. The products of the reaction occupy a larger volume than the reactants.

d. The reaction is endothermic.

5. Which statement correctly describes an endothermic chemical reaction?

a. The products have higher potential energy than the reactants, and the ΔH is negative.

b. The products have higher potential energy than the reactants, and the ΔH is positive.

c. The products have lower potential energy than the reactants, and the ΔH is negative.

d. The products have lower potential energy than the reactants, and the ΔH

is positive.

6. What is the ΔH value for an exothermic energy change?

a. Always negative

b. Always positive

c. Could be positive or negative

d. Depends on the potential energy of the reactants

7. Which of the following statements is true?

a. In an endothermic process heat is transferred from the surroundings to the system.

b. In an exothermic process heat is transferred from the surroundings to the system.

c. The surroundings will feel cooler in an exothermic process.

d. The surroundings will feel warmer in an endothermic process.

8. Which of the following processes is exothermic?

a. Ether evaporating

b. Ice melting

c. Steam condensing

d. Water decomposing

9. As energy is added to a substance, the temperature remains constant. How may the substance be changing?

a. From a gas to a solid

b. From a liquid to a gas

c. From a liquid to a solid

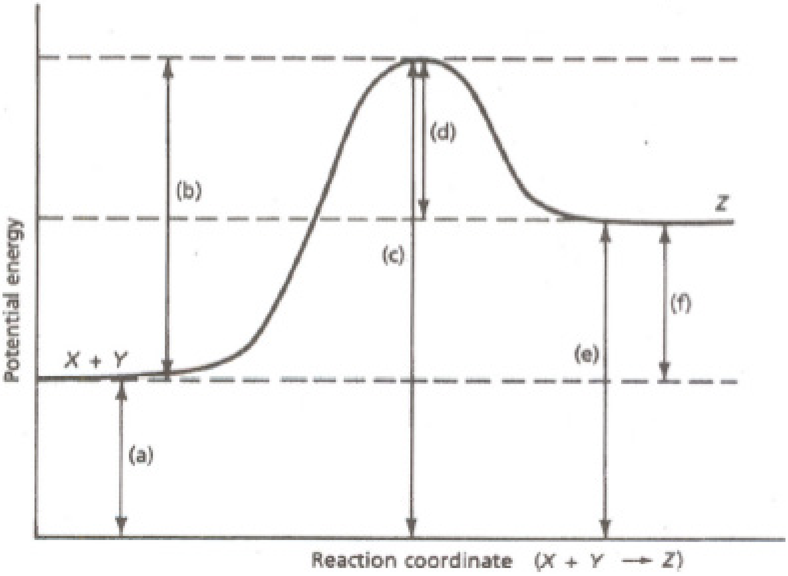
d. In the amount of kinetic energy

Answers to remedial activity

1. d 2.a 3.d 4.b 5.b 6.a 7.d 8.c 9.a

19.7.2. Consolidation Activity

Answer the questions by referring to the diagram of the potential energy of a reaction below.



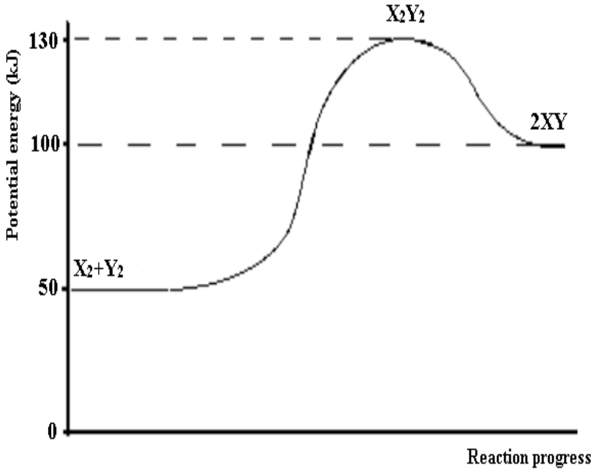
1. Which of the letters (a)-(f) in the diagram represents the potential energy of the products?
2. Which letter indicates the potential energy of the activated complex?
3. Which letter indicates the potential energy of the reactants?
4. Which letter indicates the activation energy?
5. Which letter indicates the heat of reaction?
6. Is the reaction exothermic or endothermic?
7. Which letter indicates the activation energy of the reverse reaction?
8. Which letter indicates the heat of reaction of the reverse reaction?
9. Is the reverse reaction exothermic or endothermic?
10. If a catalyst were added, which lettered quantities, if any, would change?
11. Would the activation energy increase, decrease, or remain unchanged?
12. Would the heat of reaction increase, decrease, or remain unchanged?

Answers to Consolidation Activity

1.e 2.c 3.a 4.b 5.f 6.endo 7.d 8.f 9.exo 10.b,c,d 11.decrease 12.unchanged

19.7.3. Extended Activity

Study the following Potential energy diagram and answer the questions related to it.



1. Is the overall reaction as shown exothermic or endothermic?
2. What is the activation energy for the forward reaction?
3. What is the activation energy for the reverse reaction?
4. What is the enthalpy change of reaction (ΔH) for the forward reaction?
5. What is the enthalpy change of reaction (ΔH) for the reverse reaction?
6. Is the reverse reaction exothermic or endothermic?
7. Which species forms the activated complex?
8. Which species or set of species has the strongest bonds?
9. Which species or set of species has the weakest bonds?
10. What is the enthalpy change of reaction for the reaction $X_2Y_2 \rightarrow 2XY$?

Answers to Extended Activity

1. The overall reaction is endothermic because ΔH (products) > ΔH (Reactants).
2. Ea (Forward)=(130-50) kJ=+80 kJ
3. Ea(Reverse)=(130-100) kJ=+30 kJ
4. ΔH (Forward)= (130-50) kJ= +50 kJ
5. ΔH (Reverse)= (50-100) kJ= -50 kJ

6. The reverse reaction is exothermic

7. The activated complex is X_2Y_2

8. The reactants X_2+Y_2 have the strongest bond because they have the lowest energy and therefore are in a maximum stability state. It requires high energy to break bonds in $X_2+Y_{2.}$

9. The products 2XY have the weakest bond because they have the highest energy and therefore are in a minimum stability state. It requires low energy to break bonds in 2XY.

10. ΔH for the reaction $X_2Y_{2\rightarrow}2XY$ =-30 kJ.

REFERENCES

1. Arnaud, P. (1991). *Chimie Organique, Exercices resolus, 3e edition.* Paris: DUNOD.
2. BAHL, G.D. Tuli et Arun BAHL (2000), *Essential of Physical chemistry*: S.Chand Campany Ltd, New Delhi. 8.
3. Chang, R. (2005). *Chemistry, Eighth Edition.* New York: McGraw-Hill.
4. Clark, J. (2018, March 20). *ALIPHATIC AMINES MENU*. Retrieved from chemguide Helping you to understand Chemistry: http://chemguide.co.uk/organicprops/aminemenu.html#top
5. Dakin, H., & West, R. (1928). A GENERAL REACTION OF AMINO ACIDS. II. *Journal of Biological Chemistry*, 745-756. Retrieved Mars 25, 2018, from http://www.jbc.org/content/78/3/745.citation
6. Daniel R.Bloch(2012), ORGANIC CHEMISTRY DeMYSTiFieD, SECOND EDITION, McGrawHill.
7. De Levie, , (1999) *R.Aqueous Acid-base Equilibria and Titrations.* Oxford University Press.
8. Dhoot, A.S; Naha, A; Priya, J.; Xalxo, N.2018. Phase diagrams for three component mixtures in pharmaceuticals and its applications. J Young Pharm, 2018; 10(2): 132-137
9. E.N.Ramsden (2000), A-Level CHEMISTRY, FOURTH EDITION, Nelson Thornes
10. GRAHAM HILL, J. H. (2000). *Chemistry in context,fifth edition.* Nerson Thornes.
11. Hanson, B. (2018, March 18). *Acid-Base Properties of Amino Acids I, II & III*. Retrieved from Organic Chemistry Practice Problems at Michigan State University: https://www2.chemistry.msu.edu/faculty/reusch/VirtTxtJml/Questions/problems.htm
12. Harris, D.C(2010). *Quantitative chemical Analysis*.8th edn, W.H.Freeman.
13. Hill, G., & Holman, J. (1995). *Chemistry in Context, Fourth Edition.* Thomas Nelson and Sons Ltd.

14. Holman, G. H. (1995). *Chemistry in context.* UK: Thomas Nelson and sons Ltd.
15. https: //www.chemguid.co.uk
16. Kasangandjo, Lwish; (2013) *Advanced level Chemistry Students' Book for* S_5. Pearson.
17. Kazemi, F., Kiasat, A.R. andMombaini, B. (2007). Simple preparation of symmetrical carboxylic acid anhydrides by means of Na2CO3/SOCl2. An International Journal for Rapid Communication of Synthetic Organic Chemistry, 37(18): 3219-3223
18. Lim You Sie, Yip Kim Hong; (2008) *Physical Chemistry. Pearson*.
19. Llc, B. Titration:Ph , (2010)*Indicator, Thermometric Titration, Non aqueous Titration, Equivalent Point, Acid-Base Titration, Amperometric Titration*. General Books LLc.
20. Obot, Keith; (2003) *Advanced Level Practical Chemistry.*
21. Obot, Keith; (2008).*A complete Revision Notes in Advanced Level Physical Chemistry*, Fifth impression.
22. Olinga, Simon Peter; (2004) *Simplified Approach for A-level Chemistry Practicals.*
23. Peter Cann, P. H. (2002). *Chemistry for advanced level.* JOHN MURRAY.
24. Peter.W. Atkins, (2007) *Physical chemistry*, ninth edition; oxford.
25. Petr Cann, P. H. (2002). *Chemistry for advanced level.* London: John Murray Ltd.
26. Rwanda Education Board. (2015). *Advanced level chemistry syllabus.* Kigali: PRINTEX.
27. Schmitz, A. (2018, March 25). *Introduction to Chemistry: General, Organic, and Biological (v. 1.0)*. Retrieved from 18.1 Properties of Amino Acids: https://2012books.lardbucket.org/books/introduction-to-chemistry-general-organic-and-biological/s21-01-properties-of-amino-acids.html
28. Woser, J. (1967) *Acid-base Titration and Distribution curves*. J.Chem. Educ.44, 274, doi: 10.1021/ed044P$_{274}$.