NATIONAL OPEN UNIVERSITY OF NIGERIA
AND
NATIONAL TEACHERS' INSTITUTE

BACHELOR'S DEGREE PROGRAMME

MANUAL

SCHOOL OF SCIENCE

CHM 122 GENERAL CHEMISTRY II

SED 214 HISTORY & PHILOSOPHYOF INTEGRATED SCIENCE EDUCATION

SED 225 NIGERIAN INTEGRATED SCIENCE CURRICULUM

(TESSA Integrated Manual)

Foreword

The National Teachers' Institute, Kaduna, was established in 1976 to provide in-service education for teachers through the open and distance learning system (DLS). As stipulated in Decree No. 7 (now Act No. 7) of the then Federal Military Government of Nigeria (1978), the Institute is **"charged with the duty of providing courses of instruction leading to the development, upgrading, and certification of teachers as specified in the relevant syllabus, using Distance Education techniques"**.

After several years of running the Nigeria Certificate in Education (NCE) programmes, the Institute deems it appropriate to upgrade the academic and professional qualifications of teachers to the degree level, in order to greatly raise the quality of teaching and learning in schools. Consequently, the Institute has embarked on offering degree programmes, in affiliation with the National Open University of Nigeria (NOUN), initially in the following areas:

(i) B.A. Ed. (English)
(ii) B.A. Ed. (Social Studies)
(iii) B.A. Ed. (Primary)
(iv) B.Sc. Ed. (Mathematics)
(v) B.Sc. Ed. (Integrated Science)
(vi) B.Sc. Ed. (Physical & Health Education)

In order to ensure the highest quality degree, existing course materials initially developed by NOUN in four (4) programmes of English, Mathematics, Integrated Science, and Primary Education were critically and expertly reviewed, updated, and upgraded by a team of seasoned academics from various universities across the country and the NTI. For programmes not available in NOUN, fresh course materials were expertly designed, developed, and produced by a core of experts in the areas of Social Studies and Physical and Health Education (PHE) ab initio. Furthermore, in order to ensure quality delivery of the degree programmes, course facilitators with the highest academic qualifications (Ph.D, M.Ed.) in the degree course programmes have been screened and employed to deliver the programmes to mature students along open and distance education lines, using best practice methods and techniques (learner-centred, participatory, and interactive approaches). The innovative techniques involve various media, which include ICT, audio-video, CD ROMs, and the net.

In order to further enhance quality, various facilities, such as science and PHE labs/workshops, library, etc are provided at the study centres.

For you to gain maximum benefits from the course materials, you are expected to study them very carefully/critically as well as acquaint yourself with their accompanying Study Guides. Furthermore, you are expected to work through the assignments in every unit/module in order to ensure full mastery of the contents and concepts presented in the course materials. This will help you in assessing your learning achievement as you progress towards your degree. I wish you the best.

Dr. Aminu Ladan Sharehu, OON, NPON, FNIM, FICEN
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Module 2: Difficult Topics/Units in Nigerian Integrated Science Curriculum II

COURSE GUIDE

Introduction

Chemistry is an experimental science. Indeed, experiments have played a vital role in the development of Chemistry. On one hand, experiments have provided pieces of evidence for testing theories; on the other hand, their results have thrown up new questions and puzzles, which required new insights, giving rise to new theories.

The Course

CHM 122: General Chemistry II (2 Units)

The course is divided into two modules of five units each. The first unit of module one discusses the historical development and importance of organic chemistry and the unit covered nomenclature and classes of organic compounds. The remaining units cover homologous series (Unit 3); functional groups (Unit 4); qualitative and quantitative organic chemistry (Unit 5). The five units of Module two are stereo-chemistry (Unit 1); electronic theory in organic chemistry (Unit 2); saturated hydrocarbons (Unit 3); unsaturated hydrocarbons and their reactions (Unit 4) and the chemistry of elected metals and non-metals (Unit 5).

The guiding theme in the development of these materials is a brief description of the historical development of organic chemistry, the underlying principles of naming organic compounds, physical and chemical properties of some organic and inorganic compounds.

Course Aims

The aim of this course is to give you a general introduction to organic and inorganic chemistry, giving explanations to observed physical and chemical properties of compounds of both.

Course Objectives

After studying this course, you should be able to:

Describe the general features of a covalent bond.

Working through this Course

This course is very important for any student intending to study Chemistry at any level, as it provides the basic ideas about the guiding principles for the preparation, classification of organic compounds. You are, therefore, expected to put some effort in understanding this course, as some of the knowledge available in this course might not be so easy to pick up later in your study of Chemistry.

The Course Material

You will be provided with the following materials:

Study Units

The following study units are contained in this course:

Module 1

Unit 1: The historical development and importance of organic chemistry.
Unit 2: Nomenclature and classes of organic compounds.
Unit 3: Homologous series;
Unit 4: Functional groups.
Unit 5: Qualitative and quantitative organic chemistry.

Module 2

The units of Module two are;
Unit 1: stereo-chemistry.
Unit 2: spectroscopy and structure Determination of organic compounds.
Unit 3: Electronic theory in organic chemistry.
Unit 4: Saturated hydrocarbons unsaturated hydrocarbons and their reactions
Unit 5: The chemistry of selected metals and non-metals.

Assessment

There are two components of assessment for this course. The Continuous (CA) Test and the end of course examination

Tutor-Marked Assignment

The TMA is the continuous assessment component of your course. It accounts for 30% of the total score. You will be given 4 TMAs to answer. Three of these must be answered before you are allowed to sit for the end of course examination. The TMAs would be given to you by your facilitator and returned after they have been graded.

Final Examination and Grading

This examination concludes the assessment for the course. It constitutes 70% of the whole course. You will be informed of the time for the examination. It may or may not coincide with the university semester examination.

Summary

This course is intended to give you an introduction to the study of organic and inorganic chemistry on topics ranging from nomenclature to physical and chemical properties of inorganic and organic compounds. At the end of this course, you will be able to answer questions from all areas covered.

We wish you success.

MODULE 1

UNIT 1: HISTORICAL DEVELOPMENT AND IMPORTANCE OF ORGANIC CHEMISTRY

CONTENTS

1.0 INTRODUCTION

Organic chemistry is the area of chemistry that involves the study of carbon and its compounds. Carbon is now known to form a seemingly unlimited number of compounds. The uses of organic compounds impact our lives daily in medicine, agriculture, and general life.

Organic chemistry may have its beginnings with the big bang when the components of ammonia, nitrogen, carbon dioxide and methane combined to form amino acids, an experiment that has been verified in the laboratory. Organic chemicals were used in ancient times by Romans and Egyptians as dyes, medicines and poisons from natural sources, but the chemical composition of the substances was unknown. In the 16th century organic compounds were isolated from nature in the pure state and analytical methods were developed for determination of elemental composition. Scientists believed that organic chemicals found in nature contained a special "vital force" that directed their natural synthesis, and therefore, it would be impossible to accomplish a laboratory synthesis of the chemicals. Fortunately, later in the century Frederich Wöhler (1828) discovered that urea, a natural component in urine, could be synthesized in the laboratory by heating ammonium cyanate. His discovery meant that the natural "vital force" was not required to synthesis organic compounds, and paved the way for many chemists to synthesize organic compounds. By the middle of the nineteenth century many advances had been made into the discovery, analysis and synthesis of many new organic compounds. Understanding about the structures of organic chemistry began with a theory of bonding called valence theory.

Organic chemistry developed into a productive and exciting science in the nineteenth century. Many new synthetic methods, reaction mechanisms, analytical techniques and structural theories have been developed. Toward the end of the century much of the knowledge of organic chemistry has been expanded to the study of biological systems such as proteins and DNA. Volumes of information are published monthly in journals, books and electronic media about organic and biological chemistry.

The vast information available today means that for new students of organic chemistry a great deal of study is required. Students must learn about organic reactions, mechanism, synthesis, analysis, and biological function. The study of organic chemistry, although complex, is very interesting, and begins here with an introduction of the theory of chemical bonding.

2.0 OBJECTIVES

After studying this unit, you should be able to:

1. Understand the history of organic compounds.
2. Explain why we study organic chemistry.
3. Explain the importance of organic chemistry.

3.0 HOW TO STUDY THIS UNIT

1. Read through the whole unit.
2. Reflect on the issues raised throughout the unit.
3. Read the unit again step by step to get deeper understanding of the unit.
4. Carry out all the activities.

4.0 MAIN CONTENT

Carbon and silicon are two of Group 4A elements that form the basis of most natural substance. Silicon has great affinity for oxygen, forms chains and rings containing Si – O Si bridges to produce the silica and silicates that form the basis for must rocks, sands and soils. Carbon on the other hand has the usual ability of bonding strongly to itself to form long chains or rings of carbon atoms. In addition, carbon forms atoms bonds to other non-metals such as hydrogen, nitrogen, oxygen, silver and the halogens,. Because of these bonding properties, they are myriad of carbon compounds, many are known and many others are yet to be discovered. Among these many compounds are the bio-molecules that are reasonable for maintain and reproducing life.

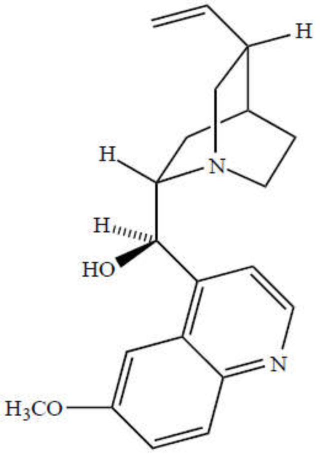
In the early days, the distinction between in organic and organic substance was based on whether a compound was produced by living systems. Until early nineteenth century it was believed that organic compounds had some sort of ''life force'' and could be synthesised only by living organism. This view was disputed in 1828 when the German chemist Friedrich Wöhler (1800 – 1882) prepared urea from the in organic salt ammonium cyantate by simple heating:

Urea is a component of urine, so it is clearly on organic material, yet there was clear evidence that it could be produced in the laboratory as well as by living things.

Organic chemistry plays a vital role in our quest to understand living systems. In addition, the synthetic fibres, plastics, artificial sweeteners, and dings that are such in accepted part of our life are protons of industrial organic chemistry. The energy on which we rely so heavily to power our civilization in based mostly on the organic materials found in coal and petroleum.

4.1 HISTORY AND IMPORTANCE OF ORGANIC CHEMISTRY

Plants provided ancient humans with many organic chemicals or mixtures of chemicals that were useful for purposes other than medicine. Humans have been using practical applications of chemistry for thousands of years. The discovery and use of folk medicines, the development of metallurigal techniques, and the use of natural dyes are simple examples. For most of human history, humans were able to use chemicals without actually understanding the science behind them. Organic chemistry became a defined science (the chemistry of carbon compounds) in the 19th century, but organic compounds have been known and used for millennia. Plants have been "milked," cut, boiled, and eaten for thousands of years as folk medicine remedies, particularly in Africa, China, India, and South America.



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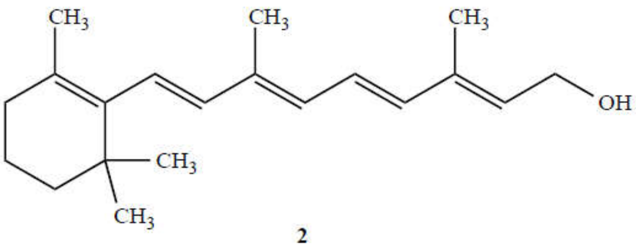

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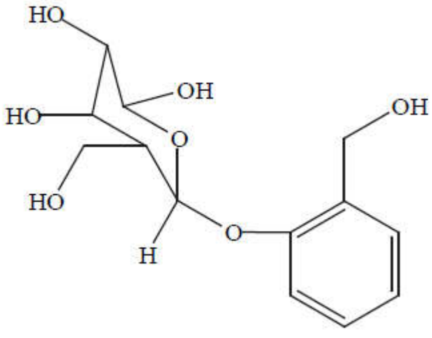
Modern science has determined that many of these plants contain organic chemicals with effective medical uses, and indeed many of our modern medicines are simply purified components of these plants or derivatives of them made by chemists. In one example, the bark of Cinchona trees was chewed for years to treat symptoms of malaria, and it was later discovered that this bark contains quinine (**1**), which is a modern medicine Ancient Egyptians ate roasted ox liver in the belief that it improved night vision. Later it was discovered that ox liver is rich in Vitamin A (**2**), a chemical important for maintaining healthy eyesight.



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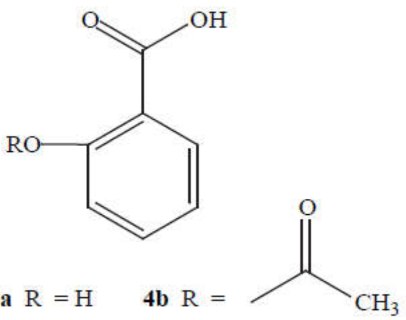


4a R = H **4b** R =

.

An ancient antipyretic treatment (this means that it lowers a fever) involved chewing willow bark and it was later discovered that this bark contained the glycoside salicin (**3**), a derivative of salicylic acid (**4a**). Eventually, we learned how to make new organic molecules rather than simply isolating and using those that were found. In the mid-19th Century a new compound was synthesized (chemically prepared from other chemicals) called acetylsalicylic acid (**4b**), better known as aspirin, and it was found to be well tolerated by patients as an effective analgesic (this means that it reduces some types of pain). These few examples are meant to represent the thousands of folk medicine remedies that have led to important medical discoveries. All of these involve organic compounds. The symbols used (**1-4**) to represent the chemicals require some explanation. Each "line" is a chemical bond. Therefore, C—C is a carbon-carbon bond and — is used as a shorthand notation to represent that bond. Each "intersection of bonds" such as [] is a carbon atom. Various groups can be attached to these carbon atoms (OH, NH_2, CH_3, etc.). The symbol C—N is a carbon-nitrogen bond, C—O is a carbon oxygen bond, and O—H is an oxygen-hydrogen bond.

4.2 SOME IMPORTANCE OF ORGANIC CHEMISTRY

Organic chemistry touches our daily lives. We are made of and surrounded by organic compounds. Almost all the reactions in living matter involve organic compound, and it is impossible to understand life, at least from the physical point of view, without knowing some organic chemistry.

1. Medicines are another important factor in the health and well-being of man. Specific examples of medicine are common antibiotics like penicillin ($C_{16}H_{17}N_2O_4SNa$) and streptomycin ($C_{12}H_{39}N_7O_{12}$). These are widely used in the treatment of communicable diseases like tuberculosis, pneumonia, venereal diseases and other infections.

2. Organic chemicals have been responsible for the rapid increase in food production to meet the demands of an expanding world population. The two famous substances that generally greatly helped in these developments were the insecticide DDT ($C_{14}H_9C_{l5}$, dichloro-diphenyl-trichloroethane) and the herbicides 2,4-D ($C_8H_6Cl_2O_3$). But DDT have been discovered to have an adverse ecological effects. Therefore, it is now important to discover insecticides which would surpass the effectiveness of DDT and be reasonably biodegradable (organic matter degraded or decomposed by aerobic bacteria in conjunction with other aerobic organisms) so that they do not accumulate and poison the ecosystem.

3. Organic chemistry is important in the petroleum industry. From the drilling of the crude oil to the separation of the various organic substances and the petrochemical materials. Products gotten from the various organic molecules include gasoline, oil, tires for our cars, the clothing we wear.

SELF ASSESSMENT EXERCISE 1

Is all carbon containing compounds organic?

5.0 CONCLUSION

Organic chemistry is more than just a branch of science for the professional chemist or for the student preparing to become a physician, dentist, veterinarian, pharmacist, nurse, or agriculturist. It is part of our technological culture.

6.0 SUMMARY

Organic chemistry has been in existence since 1828 when Frederich Wöhler discovered urea. It remains the most important part of chemistry that deals with both living and non living compound in the universe. Organic chemistry deals with our daily activities since we are surrounded by organic.

TUTOR-MARKED ASSIGNMENT

1. Trace the historical development of organic chemistry.
2. Discuss the importance of organic chemistry to life.

7.0 REFERENCES/FURTHER READINGS

Ababio, O. Y. (2011). *New School Chemistry* (6th Ed.), Africana First Publishers PLC, Nigeria.

Hart, H., Craine, L. E. & Hart, J. D. (2003). *Organic Chemistry: A short course* (11th Ed). Boston: Houghton Mifflin Company.

Morrison, R. T. & Boyd, R. N. (2011). *Organic chemistry* (7th Ed.), India: Prentice-Hall Pvt Ltd.

UNIT 2: NOMENCLATURE OF ORGANIC COMPOUNDS

CONTENTS

1.0 INTRODUCTION

Organic chemistry is so broad in scope; it includes not only carbon compounds from nature but also synthetic carbon compounds. There are thousands of organic compounds today which are grouped into different families or series called homologous series, based on their functional groups- the groups which determines the chemical properties of each compound. Each homologous series has its general name in all the members belonging to this series must obey it. The varieties of organic compounds are also grouped according to their molecular structures.

In this unit, we shall study how we will name different classes of organic compounds with different functional groups. And we shall also study the classes of organic compounds in which hydrocarbons i.e. alkanes, alkenes and alkynes will be given more emphasis.

2.0 OBJECTIVES

After studying this unit, you should be able to:

1. Identify the rules followed in the IUPAC system of naming organic compounds.
2. Draw and name the member of a series using IUPAC rules.
3. Describe the aliphatic and aromatic organic compounds.
4. Give detail explanation of hydrocarbons and the cracking process of larger molecular mass hydrocarbons.

3.0 HOW TO STUDY THIS UNIT

5. Read through the whole unit.
6. Reflect on the issues raised throughout the unit.
7. Read the unit again step by step to get deeper understanding of the unit.
8. Carry out all the activities.

4.0 MAIN CONTENT

4.1 Nomenclature of Organic Compounds

In the early days of organic chemistry, every new compound was given a name that is usually based on its source or use. Examples include limonene (from lemons), α-pinene (from pine trees) and penicillin (from the mold that produces its, penicillioum notatum). Even today, this method of naming can be used to give a short, simple name to a molecule with a complex structure. For example, cubane was named after its shape. The earliest nomenclature systems followed almost no systematic rules. Substances were named based on their smell, or their natural source, etc. Many of those names are still in use today and are collectively known as common names. As organic chemistry developed and structures became more complex, a systematic method for naming organic compounds became necessary. The *International Union of Pure and Applied Chemistry* (IUPAC) is the organism that sets the rules for nomenclature of organic compounds today. Names that follow IUPAC rules are known as systematic names, or IUPAC names. It became clear many years ago, however, that one could not rely on common or trivial names and that a systematic method for naming compounds was needed. Ideally, the rules of the system should result in a unique name for each compound. Knowing the rules and seeing a structure, one should be able to write the systematic name. Seeing the systematic name, one should also be able to write the correct structure.

Eventually, internationally recognized systems of nomenclature were devised by a Commission of the International Union of Pure and Applied Chemistry (IUPAC) known as IUPAC systems of nomenclature. However, in some cases, the common name is so widely used that it is important to learn it. For example, formaldehyde (common) is used in preference to methanol (systematic), and cubane is much easier to remember than its systematic name, pentacyclo [$4.2.0.0^{2,5}0^{3,8},0^{4,7}$] octane.

4.2. The IUPAC Nomenclature for Aliphatic Compounds

The international union of pure and applied chemistry (IUPAC) has put forward a system of nomenclature which relates the name of the compound to its molecular structure. In this system, every name consists of a root, a suffix and as many prefixes as necessary.

Root

The root is generally the longest chain of carbon atoms in an aliphatic hydrocarbon. The root of a hydrocarbon is the straight chain of linked carbon atoms either in a straight chain or cyclic hydrocarbon.

Roman numbers are used as a prefix to indicate the number of carbon atoms in a root of hydrocarbon. Table 1.0 below shows the roman number from 1–10.

Table 1.0: roman numbers used for atoms with 1–10 carbon atoms

Roman name	Number of carbon atoms	Example
Meth–	1	Methane (CH_4)
Eth–	2	Ethane (C_2H_6)
Prop–	3	Propane (C_3H_8)
But–	4	Butane (C_4H_{10})
Pent–	5	pentane (C_5H_{12})
hex–	6	Hexane (C_6H_{14})
Hep–	7	Heptane (C_7H_{16})
Oct–	8	Octane (C_8H_{18})
Non–	9	Nonane (C_9H_{20})
Dec–	10	Decane ($C_{10}H_{22}$)

All aliphatic compounds are regarded as being derived from the root hydrocarbon by:

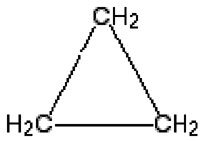
- The replacement of hydrogen atoms by alkyl or functional groups;
- The introduction of multiple bonds (i.e. double and triple covalent bonds)

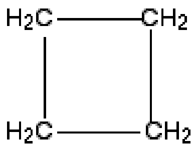
The systematic name of a compound is formed from the root hydrocarbon by adding a suffix and prefixes to denote the substitution of the hydrogen atoms.

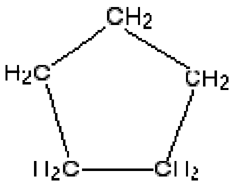
Suffixes

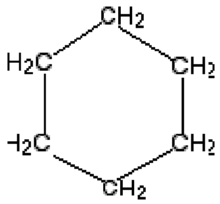
A suffix is added to the root to indicate the presence of the principal substituent, which is usually also the principal functional group in the molecule. Compounds having the same functional groups, such as those belonging to the same homologous series, would carry a common suffix at the end of their names. The following are some examples:

Alkanes: Alkanes are the simplest family of hydrocarbons - compounds containing carbon and hydrogen only. They only contain carbon-hydrogen bonds and carbon-carbon single bonds. The names of alkanes end with –ane; the first six are: methane CH_4, ethane $C_2H_{6,}$ propane C_3H_8, butane $C_4H_{10,}$ pentane C_5H_{12}, hexane C_6H_{14}. The general formula for alkanes is C_nH_{2n+2}. Cycloalkanes again only contain carbon-hydrogen bonds and carbon-carbon single bonds, but this time the carbon atoms are joined up in a ring. The smallest cycloalkane is cyclopropane.


cyclopropane


cyclobutane


cyclopentane


cyclohexane

Alkenes: The members of the alkenes are named after the corresponding alkanes by changing the –ane ending to –ene, e.g. C_2H_4 is ethane, C_3H_6 is propene and C_4H_8 is butane. This is because the members of the alkene series are formed from the alkenes by the removal of two hydrogen atoms and the introduction of a double bond in the carbon chain. The general formula for alkenes is C_nH_{2n}.

Alkynes: Each member of this series is formed by the removal of four hydrogen atoms and the introduction of a triple bond in the appropriate alkane molecule. They are named by replacing the –ane ending by –yne, e.g. C_2H_2, ethyne and C_3H_4 propyne. The general formula for alkynes is C_nH_{2n-2}.

Alkanols: The members of this series are named after the corresponding alkanes by replacing the –e ending with –ol, e.g. CH_3OH, methanol and C_3H_7OH propanol.

Alkanoic acids: Also known as carboxylic and organic acids. The members of this series are named by replacing the –e ending in the corresponding alnes by –oic acid e.g. CH_3COOH is ethanoic acid, C_2H_5COOH is propanoic acid and C_3H_7COOH is butanoic acid.

Esters: These are form when a carboxylic acid reacts with an alkanol. They have a general molecular formula of $RCOOR^1$, where RCO – is the group derived from the acid and $–OR^1$ is the group derived from the alkanol. In naming an ester, the alkyl group, R, is named first, followed by the name of the acid group with a –oate ending as suffix. For example $HCOOCH_3$ is methyl methanoate, CH_3COOCH_3 is methyl ethanoate and $CH_3(CH_2)_2COOC_2H_5$ is ethyl butanoate.

Amides: Members of this series have an –amide ending in their names, instead of the –e in the corresponding alkanes. For example, CH_3CONH_2 is ethanamide, and $CH_2H_5CH_2CONH_2$ is butanamide.

Alkanals or Aldehydes: The members of this series are named by replacing the –e ending in the corresponding alkanes by –al. For example, HCHO is methanol, CH_3CHO is ethanol and C_4H_9CHO is pentanal.

Alkanones or Ketones: The members of this series have an –one ending in their names, instead of the –e in the corresponding alkanes, e.g. CH_3COCH_3 is propan -2-one and $CH_3COC_2H_5$ is butan -2-one.

Amines: The members of this series are named by adding the –amine ending to the alkyl group, e.g. CH_3NH_2 is methylamine and $C_2H_2NH_2$ is ethylamine.

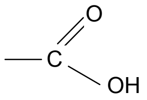
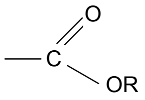
Prefixes

Cyclic compounds can be indicated by adding the prefix cyclo- to the names of the corresponding aliphatic compound, e.g. cyclohexane and cyclopentene. Prefixes are also added to indicate the presence of substituted akyl or functional groups other than the principal group, as well as the positions of these substituents in the carbon chain.

Rules for naming more than one prefix: when more than one of the same substituents group is present, the multiplying prefixs, such as di- for two, tri-for three and tetra-for four are used. If more than one prefix is needed, they are placed in alphabetical order. Multiplying prefixes do not affect this order. For example, $ClCH_2CHBr_2$ is 1,1-dibromo -2-chloro ethane.

Table 1.1 gives the common functional groups which usually replace the hydrogen atoms in the root of a hydrocarbon, together with their names when they are used as suffixes or prefixes and some examples.

Table: 1.1: some functional groups with their names as suffix and as prefix, with examples

Functional Groups	Name as Suffix	Name as Prefix	Examples
–COOH 	-carboxylic acid -oic acid	Carboxy-	C_2H_5COOH propanoic acid
–COOR 	-carboxylate -oate	Alkoxy carbonyl	$CH_3CH_2COOCH_2CH_3$ Ethyl butyrate
$–CONH_2$	-amide	-	CH_3CONH_2 Acetamide
–CHO	-al	Oxo-	
–C=O	-one	Oxo-	CH_3COCH_3 acetone
–CN	-carbonitrile	Cyano-	$CH_3CH_2CH_2CH_2CN$ cyanobutane
–OH	-ol	Hydroxyl-	CH_3OH methanol
$–NH_2$	-amine	Amino-	CH_3NH_2 Methalamin
Cl–	-	Chloro-	CH_3Cl Chloromethane
Br–	-	Bromo	CH_3CH_2Br Bromoethane
I–	-	Iodo-	$CH_3CH_2CH_2I$ Iodopropane

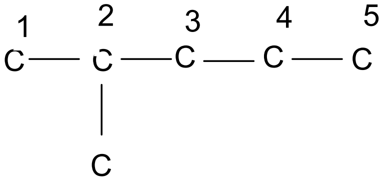
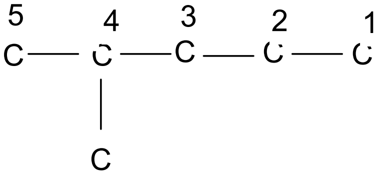
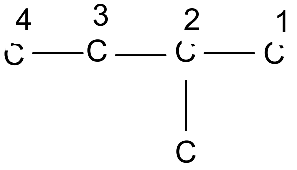
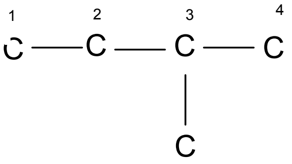
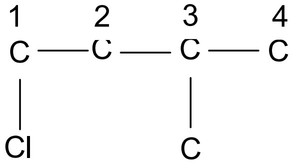
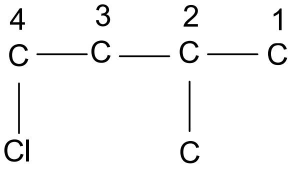
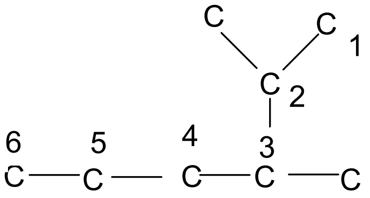
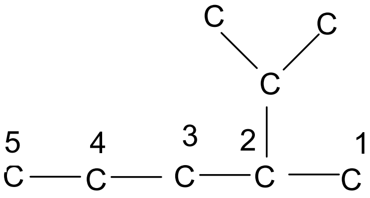
4.2.1 Numbering of the Carbon atoms

The positions of the substituent groups and the multiple bonds in the carbon chain of a compound are indicated by the number of carbon atom or atoms to which they are attached. The IUPAC convention is to number all the carbon atoms in the longest chain starting from the end which is the closest to the branch chain or other modifications of the simple alkane structure. This is done as to give

- The lowest possible number to the group cited by the suffix and then
- The lowest possible individual numbers to the groups cited as prefixes
- Substiuents are arranged in alphabetical order

For example

Table: 1.2: correct and incorrect way of numbering carbon atoms in an organic compound

Correct Numbering	**Incorrect Numbering**
 2-methylpentane	 4-methylpentane
 2-methylbutane	 3-methylbutane
 1-chloro-3-methylbutane	 4-chloro-2-methylbutane
 2,3-dimethylhexane	 2-Isopropylpentane

Numbers (especially 1) are often omitted when the structure can be deduced without them, e.g. bromoethane can only be CH_3CH_2Br.

4.2.2 Basic rules for naming aliphatic compounds

Aliphatic organic compounds can be named by following these basic rules:

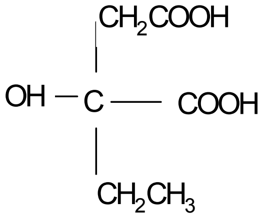
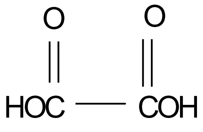
(a) Take the longest continuous carbon chain as the root hydro carbon and name it according to the number of carbon atoms it contains, adding the appropriate suffix(such as Meth-, eth-, prop-, and so on) to indicate the principal substituent group.

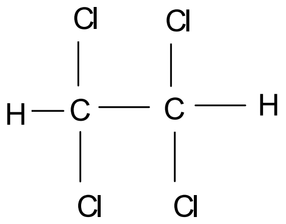
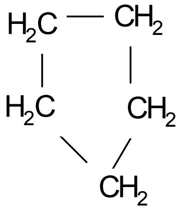
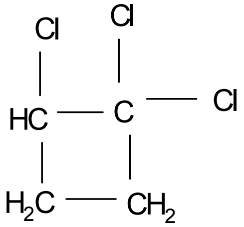
(b) Number the carbon atoms in the root hydro carbon from the end which will give the lowest number to the suffix, and then the prefix(es).

(c) Indicate the other substituent by prefixes preceded by numbers to show their positions on the carbon chain.

(d) When two different alkyl groups are substituted to one organic compound, they should be named based on the one that came first alphabetically.

Table 1.3: Naming Compounds according to the IUPAC system of Nomenclature

Structural Formula	IUPAC Name
$CH_3CH_2CH(CH_3)CH=CH_2$	3-methylpent-1-ene
$CNCH_2CCH_3$	4-cyanobut-2-yne
CH3CH(OH)CHO	2-hydroxypropanal
 $OH-\overset{CH_2COOH}{\overset{\vert}{\underset{CH_2CH_3}{\underset{\vert}{C}}}}-COOH$	3-carboxyl-3-hydroxy pentanoic acid
$HCOOC_8H_{17}$	Octyl methanoate
$CH_2=CHCH=CH_2$	Buta-1, 3-diene
$CH_3CH_2COCH_2NH_2$	2-oxobutalamine
$CH_3C=OC(NH_2)HCH_3$	3-aminobutan-2-one
 $\overset{O}{\overset{\Vert}{HOC}}-\overset{O}{\overset{\Vert}{COH}}$	Ethan dioic acid
$CH_3COO(CH_2)_3C(Cl)HCH_3$	2-chloropentyl ethanoate
$CH_3(CH_2)_3C(C_3H_7)HC_2H_5$	4-ethyl octane

	1,1,2,2-Tetrachloro ethane
	Cyclopentane
	1,1,2-trichoro cyclobutane

4.3 Classification of Organic Compounds

Organic compounds are classified into two main classes; Hydrocarbon and non hydrocarbons. The hydrocarbons are organic compounds that contain carbon and hydrogen only. The hydrocarbon can be classified also into aliphatic and aromatic compounds according to their molecular structures, i.e. the arrangement of atoms in the molecular.

4.3.1 Aliphatic compounds

Compounds whose molecules are composed of chains of carbon atoms are known as aliphatic compounds. There is no limit to the number of carbon atoms in a given chain. Often, a given carbon chain may even have one or more branches. Some examples of aliphatic compounds are:

CH_3-CH_2-CH_2-CH_2-CH_3

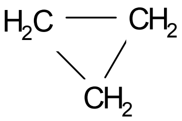
Pentane (a straight chain compounds)

CH_3-CH_2-CH_1-CH_3

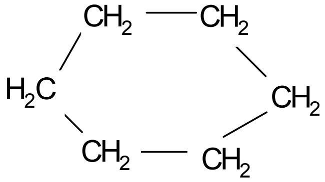
2-methylbutane (a branched chain compounds)

Such straight and branched chain aliphatic compounds are called acyclic compounds. In the actual molecular structures, the carbon chains are not truly straight lines as is conveniently represented on paper. Instead, the chains are zigzag lines because of the tetrahedral nature of the carbon bonds.

Sometimes, the end carbon atoms of an open aliphatic chain can also join together to form a closed system or ring as in cyclopropane and cyclohexane. Such compounds are called cyclic compounds.



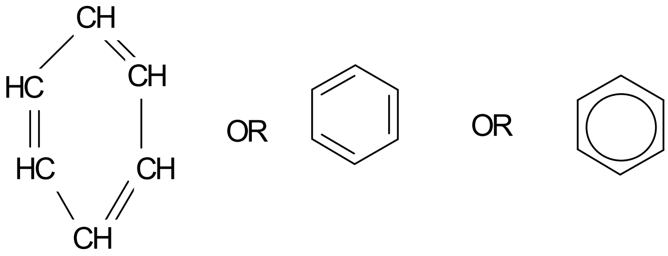
Cyclopropane



cyclohexene

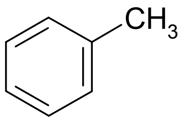
4.3.2 Aromatic compounds

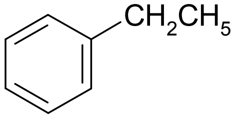
Aromatic compounds are a special class of compounds whose structures are based on the structure of benzene, C_6H_6, a 6-carbon ring compound.



benzene

Aromatic compounds include the compounds derived from benzene or benzene like compounds, e.g.





Methyl benzene ethyl benzene

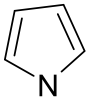
Others are not derivatives of benzene in but related to benzene in satisfying the conditions for aromaticity namely;

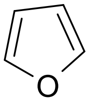
(i) Must be cyclic (ring form)

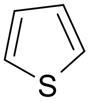
(ii) Must be planer

(iii) Must have a system of $(2n + 4)$ π-electrons

Example of such compounds are:

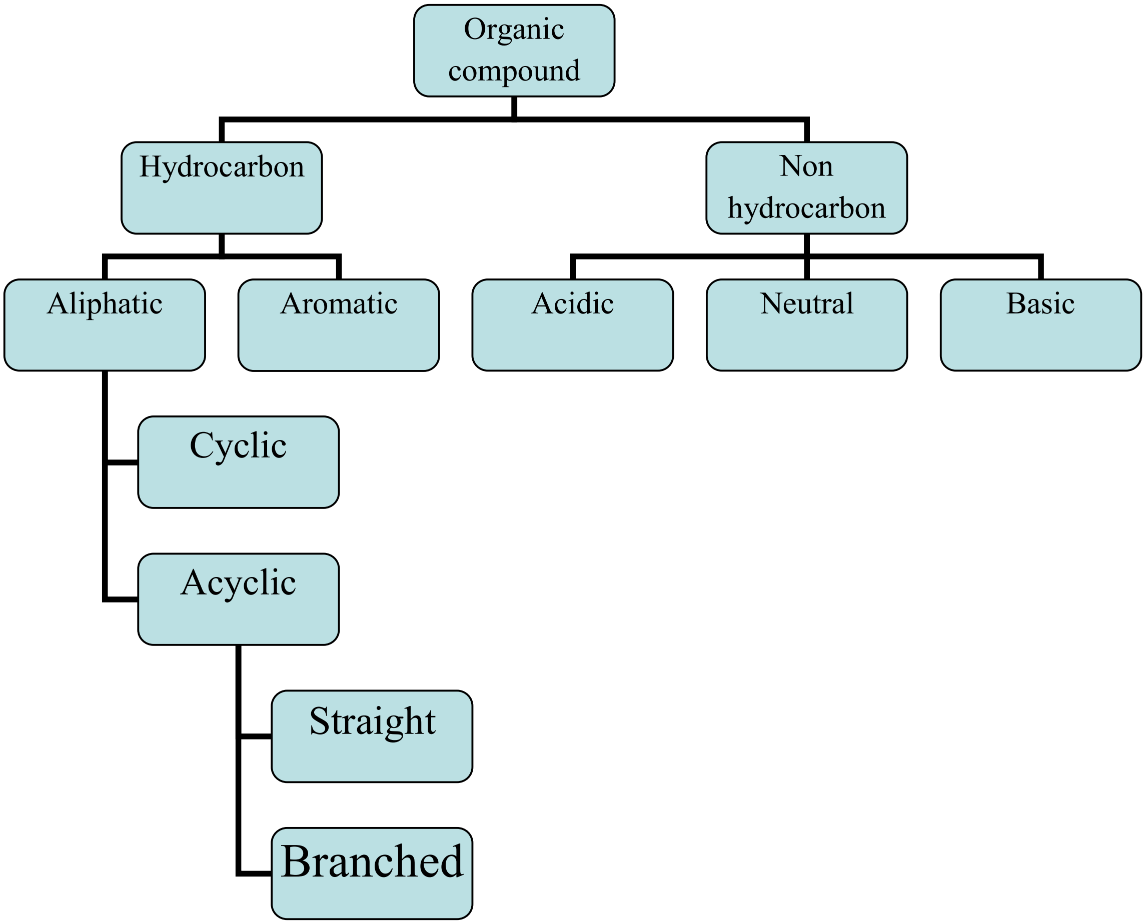

Pyrrole


Furan


Thiophene

The non-hydrocarbons organic compounds are the compounds that are composed of carbon, hydrogen and atoms of other elements. All other hydrocarbons that have other elements apart from carbon and hydrogen belong to this class of organic compounds. The non-hydrocarbons organic compounds may be acidic, basic or neutral.

The summary of the classification of organic compounds is shown in figure1 below;



4.4 Hydrocarbon

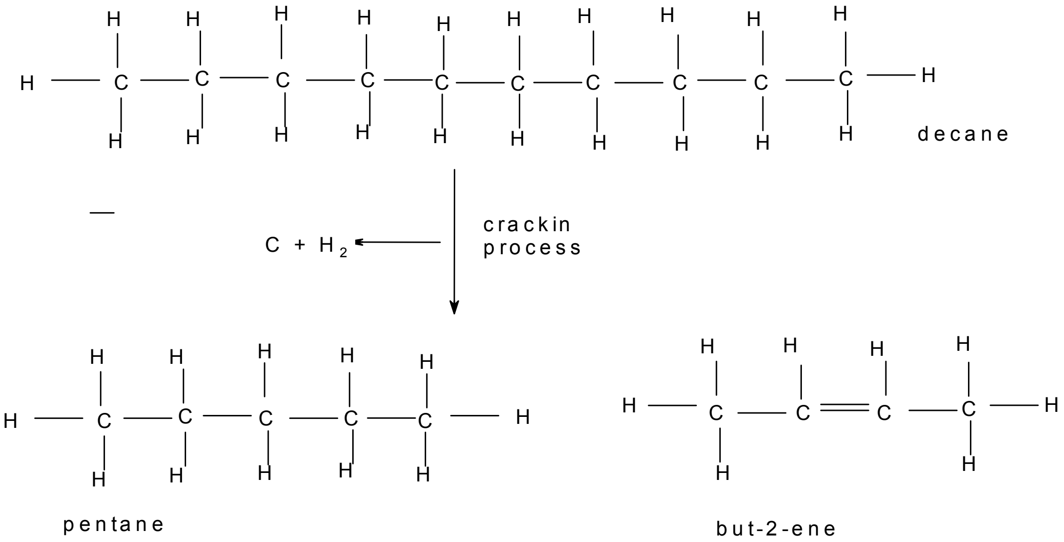
Hydrocarbons are the simplest organic compounds because they are composed only of two elements, namely carbon and hydrogen. All hydrocarbons have the molecular formula of C_xH_y, where x and y are positive integers. Some examples are methane, CH_4, propane C_3H_8, and benzene C_6H_6.

Hydrocarbons are classified into two main groups – the aliphatic hydrocarbons and the aromatic hydrocarbons, according to their structure.

Sources of hydrocarbon

The natural sources of hydrocarbons are coal, natural gas and petroleum. Coal is a solid fuel, petroleum is a dark viscous liquid fuel and natural gas is a gaseous fuel. These fuels are often known as fossil fuels because they are the remains of plants and animals that died millions of years ago, and they are used mainly as fuels, that are burnt to release heat or other forms of energy.

Crude oil or petroleum is the most important source of fuel nowadays. Petroleum is first fractionally distilled. Then the less volatile fractions are subjected to further treatment called cracking. Cracking means breaking down or decomposition of a compound by the action of heat. This process involves splitting larger molecules into smaller molecules by subjecting them to high temperatures and pressures, usually in the presence of a catalyst. In cracking process, a heavier hydrocarbon molecule is splitted into two or lighter hydrocarbon molecule. Depending on the reaction on the reaction conditions, cracking can take place at any point along the main carbon skeleton of the alkane to give shorter chains alkanes or alkenes. The cracking of decane is shown below:



Note: The products given are only some of the many possible products formed during the cracking of decane.

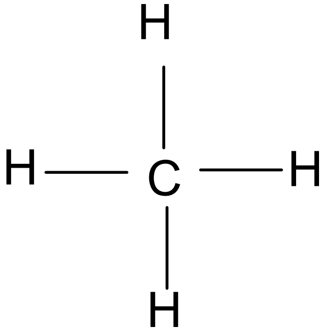
The thermal cracking is not particularly efficient because there is poor control over the cracking pattern to yield alkanes of desirable chain length. This is due to the fact that the carbon – carbon bonds of the alkanes in the heavy oil fractions are about the same strength.

Nowadays, catalytic cracking is the method used for the cracking of petroleum in the presence of a catalyst. Catalytic cracking is better because the process is more controllable, i.e. the conditions can be adjusted so those desirable products of certain chain lengths are obtained. These processes thus, yield a source of alkenes which serve as a raw material for great variety of organic chemicals. Another reason is that, the process not only yield petrol but also gives petrol of high quality.

Catalytic reforming is another important conversion process aimed at improving the quality of petrol, by increasing the proportion of branched – chain hydrocarbons which yield high octane petrol. This involves making of structural changes to a hydrocarbon to improve its anti-knock activities.

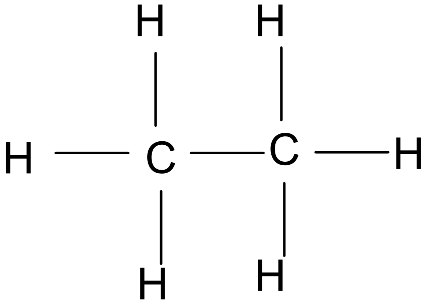
4.5 Alkanes

The alkanes are aliphatic hydrocarbons. They form a homologous series of saturated hydrocarbons, with a general formula of C_nH_{2n+2}. In each alkane member, all the carbon atoms are tetrahedrally bonded to the hydrogen and other carbon atoms. The structural formulas of the first five members are given below:



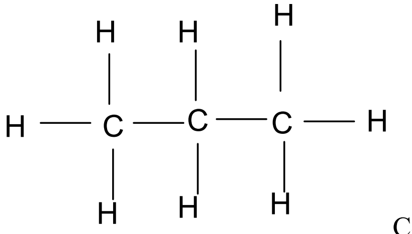
$$\begin{array}{ccc} & H & \\ & | & \\ H - & C & - H \\ & | & \\ & H & \end{array}$$

CH_4 methane



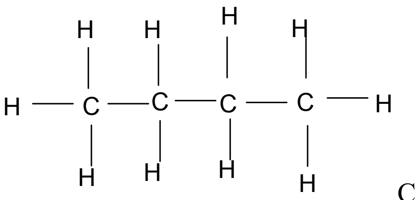
$$\begin{array}{cccc} & H & H & \\ & | & | & \\ H - & C - & C & - H \\ & | & | & \\ & H & H & \end{array}$$

$C_2H_{6,}$ ethane



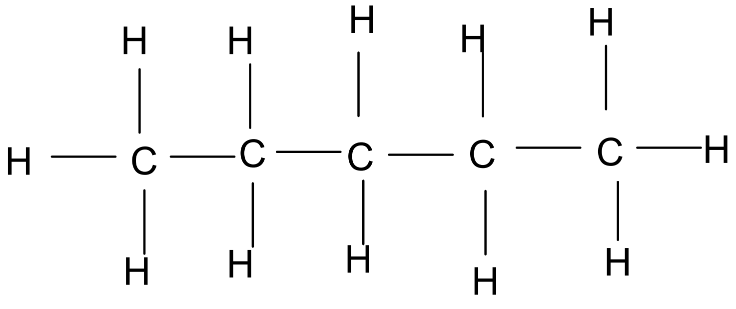
$$\begin{array}{ccccc} & H & H & H & \\ & | & | & | & \\ H - & C - & C - & C & - H \\ & | & | & | & \\ & H & H & H & \end{array}$$

C_3H_8 propane



$$\begin{array}{cccccc} & H & H & H & H & \\ & | & | & | & | & \\ H - & C - & C - & C - & C & - H \\ & | & | & | & | & \\ & H & H & H & H & \end{array}$$

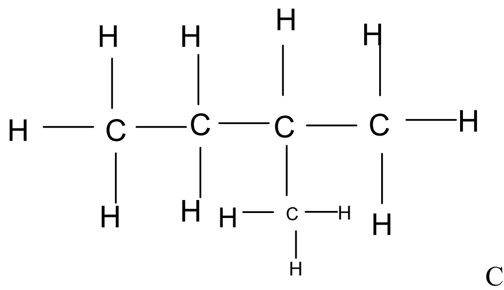
C_4H_{10} butane



$$\begin{array}{ccccccc} & H & H & H & H & H & \\ & | & | & | & | & | & \\ H - & C - & C - & C - & C - & C & - H \\ & | & | & | & | & | & \\ & H & H & H & H & H & \end{array}$$

C_5H_{12} pentane

The general formula, C_nH_{2n+2}, remains unchanged for branched alkanes. For example, pentane, a straight – chained 5-carbon alkane, and 2-methyl butane, a branched 5-carbon alkane, have the same molecular formula, C_5H_{12}.



C_5H_{12}, 2–methylbutane

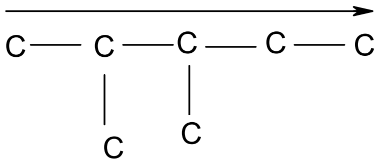
Since all the four valence electrons of each carbon atoms in an alkane molecule are used up, the alkanes are very stable compounds

4.5.1 IUPAC rules for naming alkanes

(a) The general name for saturated hydrocarbons is alkane. The –ane ending is used for all saturated hydrocarbons.

(b) Alkanes without branches are named according to the number of carbon atoms. These names, up to ten are given in Table 3.

(c) For alkanes with branches, the root name is that of the longest continuous chain of carbon atoms. For example



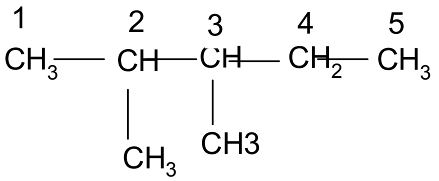
The longest continuous chain (arrow) has five carbon atoms. The compound is therefore named as a substituted pentane, even though there are seven carbon atoms altogether.

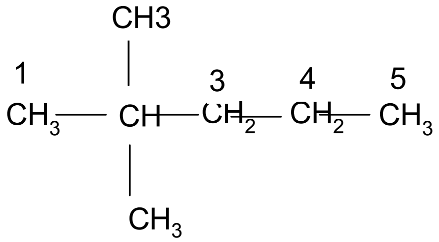
(d) Groups attached to the main chain are called substituent. Saturated substituent that contains carbon and hydrogen only are the alkyl group (see unit 2, section 3.4).

(e) The main chain is numbered in such a way that the first substituent encountered along the chain receives the lowest possible number.

(f) Each substituent is then located by its name and by the number of the carbon atom to which it is attached.

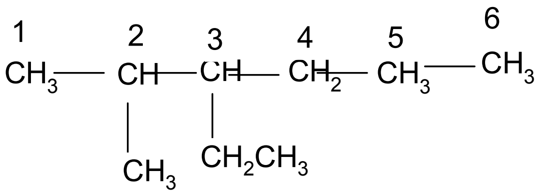
(g) When two or more identical groups are attached to the main chain, prefixes such as di-, tri-, and tetra- are used. Every substituent must be named and numbered, even if two identical substituent are attached to the same carbon of the main chain, e.g. the compounds.





are correctly named; 2,3-dimethyl pentane for 1 and 2,2-dimethyl pentane for 2.

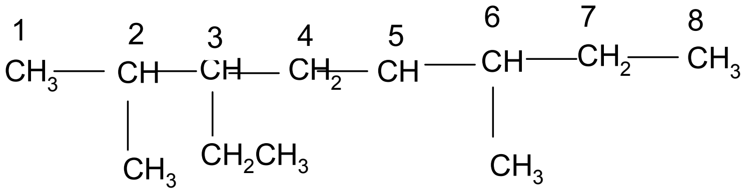
(i) If two or different types of substituents are present, they are listed in alphabetical order, except that prefixes such as di-, tri- and tetra- are not considered when alphabetizing, e.g.



3-ethyl-2-methylhexane

(j) Function is very important when writing IUPAC names. IUPAC names for hydrocarbons are written as one word. Numbers are separated from each other by commas and are separated from letters by hyphens. There is no space between the last named substituents and the name of the parent alkane that follows it.

(k) When more than one carbon chains of equal length are available, the principal or parent chain should be the one that has the greatest number of substituents, e.g.



3-ethyl-2,5,6-trimethyl octatane

4.6 Alkenes and Alkynes

The alkenes are the homologous series of hydrocarbons with a general molecular formula of C_nH_{2n}, where n is a positive whole number which is equal to or greater than 2 (CH_2 does not exist). They contain two hydrogen atoms less than the alkanes. This is because unlike the alkanes which are saturated compounds, the alkenes are unsaturated compounds which contain a carbon – carbon double bond in their molecular structures. The structural formula and the names of the first five alkenes members are given in table 1.4 below.

Table 1.4: The Formula and the IUPAC Names of some Alkenes

Molecular and Structural Formulae	IUPAC Name
C_2H_4 $CH_2 = CH_2$	Ethene
C_3H_6 $CH_2 = CH – CH_3$	Propene
C_4H_8 $CH_2 = CHCH_2CH_3$	But-1-ene
C_4H_8 CH_3 - $CH= CHCH_3$	But-2-ene
C_5H_{10} $CH_2 = CH(CH_2)_2$ CH_3	Pent-1-ene

The alkynes, like alkanes and alkenes are the homologous series of hydrocarbons with a general molecular formula of C_nH_{2n-2}, where n is a positive whole number which is equal to or greater than 2 like alkenes. Alkynes contain two hydrogen atoms less than alkenes and four hydrogen atoms less than alkanes. This is because alkynes are unsaturated hydrocarbons with carbon-carbon triple bonds in their molecules. The alkynes are more unsaturated than alkenes, thus, they are more reactive than alkenes. The structural formula and the names of some alkynes are given in table 1.5 below.

Table 1.5: The Formula and the IUPAC Names of some Alkynes

Molecular and Structural Formulae	IUPAC Name
C_2H_2 $HC \equiv CH$	Ethyne
C_3H_4 $CH \equiv CCH_3$	Propyne
C_4H_6 $CH \equiv CCH_2CH_3$	But-1-yne
C_4H_6 $CH_3C \equiv CCH_3$	But-2-yne
C_5H_8 $CH \equiv C(CH_2)_2CH_3$	Pent-1-yne

4.6.1 IUPAC rules for naming alkenes and alkynes

The IUPAC rules for naming alkenes and alkynes are similar to those for alkane, but a few rules must be added for naming and locating the multiple bonds.

1. The ending –ene is used to designate a carbon carbon double bond. When more than one double bond is present, the ending is –diene, -triene, and so on. The ending –yne is used for triple bond (-diyne for two triple bonds and so on). Compounds with a double and triple bonds are –enynes.

2. Select the longest chain that includes both carbons of the double or triple bond.
3. Number the chain from the end nearest the multiple bonds, so that the carbon atoms in that bond have the lowest possible numbers.

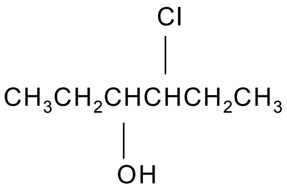
   If the multiple bonds are equidistance from both ends of the chain, number from the end nearest the first branch point.
4. Indicate the position of the multiple bond using the lower numbered carbon atom of that bond.
5. If more than one multiple bond is present, number from the end nearest the first multiple bond
6. If a double and a triple bond are equidistant from the end of the chain, the double bond receives the lowest numbers.

   In the case of the cyclic hydrocarbon, we start numbering the ring with the carbons of the multiple bonds.

SELF ASSESSMENT EXERCISE 2

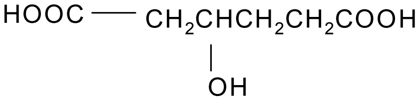
(1) Name the following compounds according to the IUPAC system of nomenclature

(a)



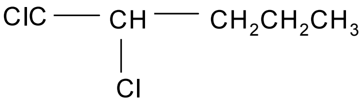
$CH_3CH_2\underset{OH}{CH}\overset{Cl}{CH}CH_2CH_3$

(b)



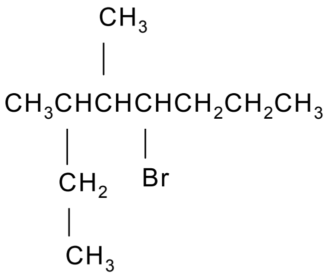
$HOOC-CH_2\underset{OH}{CH}CH_2CH_2COOH$

(c)



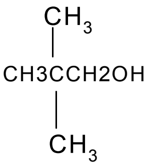
$ClC-\underset{Cl}{CH}-CH_2CH_2CH_3$

(d)



$CH_3\underset{CH_2CH_3}{CH}\overset{CH_3}{CH}\underset{Br}{CH}CH_2CH_2CH_3$

(e)



$CH3\overset{CH_3}{\underset{CH_3}{C}}CH2OH$

5.0 CONCLUSION

We have studied the general rules for naming aliphatic compounds. We have also briefly discussed the main classes of organic compounds which include the aliphatic hydrocarbons: Alkanes, alkenes, and alkynes; and the aromatic hydrocarbons which are benzene and benzene like compounds.

6.0 SUMMARY

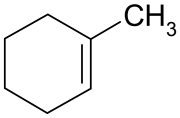
You have learnt about how the names of organic compounds originate from the plant or animals that produces it. You have also studied the modern way for naming organic compounds of various classes:

TUTOR-MARKED ASSIGNMENT

1. Name the following compounds according to the IUPAC system of nomenclature

(a) ClCH=CHCl

(b) $CH_2=C(CH_3)CH=CH_2$

(c) 

(d) $CH_3(CH_2)_3C\equiv CH$

(e) $CH_2=C(OH)CH_3$

2. Write structural formulae for the following:

(a) 2,4–dimethylpentene

(b) 3–hexyne

(c) 2–bromo–4–nitrotoluene

(d) 3–methyl–2–buten–1–ol

(e) 5–hexyn–2–one

7.0 REFERENCES/FURTHER READING

Ababio, O. Y. (2011). *New School Chemistry* (6th Ed.), Africana First Publishers PLC, Nigeria.

Hart, H., Craine, L. E. & Hart, J. D. (2003). *Organic Chemistry: A short course* (11th Ed). Boston: Houghton Mifflin Company.

Morrison, R. T. & Boyd, R. N. (2011). *Organic Chemistry* (7th Ed.), India: Prentice-Hall, Ltd.

UNIT 3: HOMOLOGOUS SERIES

1.0 INTRODUCTION

Organic chemistry is the chemistry of carbon compounds, which include carbon compounds that occur in nature and the ones that are synthesized in the laboratory. Because of this, there are vast compounds in organic chemistry, which ranges from compound that contain one carbon atom in its molecule to those that contain many carbon atoms in their molecule. The study of the individual molecule/compound will be very difficult, therefore chemist grouped these numerous organic compound into a comparatively small number of series called homologous series based on the bond they formed and the heteroatom they contained which are also known as the functional groups

In this unit, we shall begin our study with the key things that are unique to carbon which has resulted in giving it chemistry to its own among other elements in the periodic table. We shall also study the homologous series with its characteristics and then, the functional groups.

2.0 OBJECTIVES

After studying this unit, you should be able to:

- Explain the unique nature of carbon
- State the characteristics of organic compounds
- Define homologous series
- Name the different homologous series

3.0 HOW TO STUDY THIS UNIT

1. Read through the whole unit.
2. Reflect on the issues raised throughout the unit.
3. Read the unit again step by step to get deeper understanding of the unit.
4. Carry out all the activities.

4.0 MAIN CONTENT

4.1 Meaning of Organic Chemistry

The term organic suggest that this branch of chemistry has something to do with organisms, or living things. Originally, organic chemistry did deal only with substances obtained from living matter. Years ago, chemist spent much of their time extracting, purifying, and analyzing substances from animals and plants. They were motivated by natural curiosity about living and also by the desire to obtain from nature ingredients for medicine, dyes, and other useful products.

It gradually became clear that most compounds in plants and animals differ in several respects from those that occur in non living matter, such as minerals. In particular, most compounds in living matter are made up of the same few elements: carbon, hydrogen, oxygen, nitrogen and sometimes sulfur, phosphorus, and a few others. Carbon is virtually always present. This fact lead to our present definition: Organic chemistry is the chemistry of carbon compounds. This definition broadens the scope of the subject to include not only compounds from nature but also synthetic compounds (compounds invented by organic chemists and prepared in their laboratories).

Today, there are over 3,000 organic compounds as more compounds are added to the list either by syntheses in the laboratory or by discovery in nature. The uses of organic compounds are innumerable. Some are eaten as food, others are worn as clothing; they include the wonder drugs, the most deadly poisons and the most effective fertilizations. The ultimate source of organic compounds is the sun. Carbon combines with chlorophyll in green leaves in the presence of sun's energy to produce the basic hydro carbon. These are then acted upon by heat and pressure to produce the more complex organic compounds.

4.2 The Apparent Unique Nature of Carbon

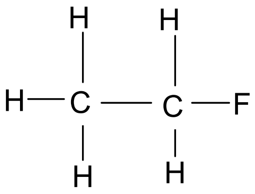
It is easy to explain the unique nature of carbon which has resulted in giving it chemistry all to its own among the 100 odd elements in the periodic table. These unique natures include:

(a) The valency of carbon. Carbon has the following configuration:

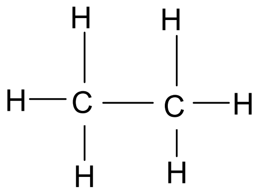
$$1S^2\ 2S^1\ 2PX^1\ 2PY^1\ 2P2^1.$$

It forms mainly covalent bonds and after covalency, it has neither vacant orbital nor lone pair. Thus, many carbon compounds are chemically stable compared with analogues compounds of other elements.

(b) The bond between carbon and hydrogen is almost non-polar. Thus hydrogen atoms attached to carbon do not weaken carbon-carbon bonds. For example, if you compare the two compounds below:



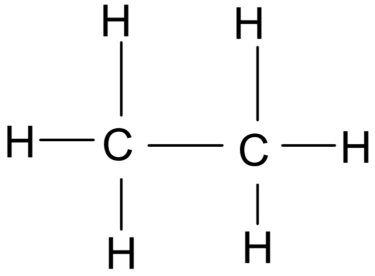
floroethane



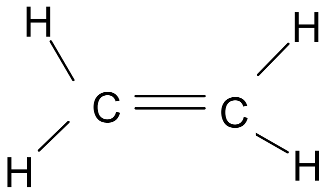
ethane

The electronegativity of C is 2.5, hydrogen is 2.1 and fluorine is 4.0. So the fluorine will weaken the carbon-carbon bond in flouroethane

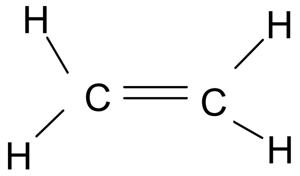
(c) The types of orbital hybridization available to carbon. There are three types of hybridization open to carbon namely Sp^3, Sp^2 and Sp hybridization. These give rise to a variety of compounds having single, double and triple bonds.



ethane

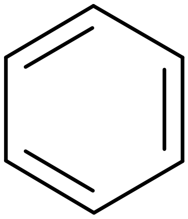


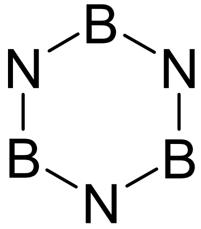
ethene



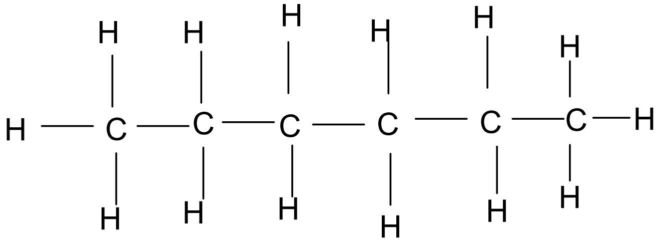
ethene

(d) Delocalization or continuous x-bonding. This occurs in carbon compounds than in any compounds of other elements. This phenomenon assures that six membered ring carbon compounds with delocalized orbitals are particularly stable compared to benzene and borazine which is chemically less stable than aromatic carbon compounds.

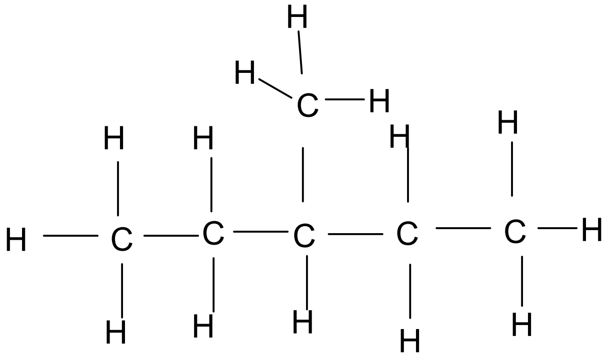




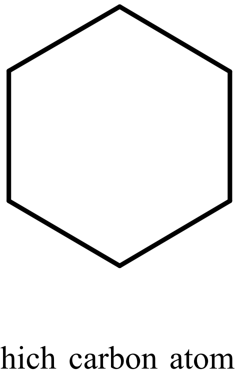
(e) The exceptional ability of carbon to catenate, that is, to combine with one another to form straight chains, branched chains or ring compound containing many carbon atoms.



Straight chain (hexane)



branched chain (2,3 dimethylbutane)



Ring compound (cyclohexene)

(f) The ease with which carbon atom combines with other elements like hydrogen, oxygen, nitrogen, sulfur, halogens, fluorine, chlorine, bromine and iodine, and metals like sodium and potassium.

As a result of those unique nature of carbon, many and different compounds of carbon are formed which are group into different families called homologous series.

4.3 Characteristics Feature of Organic Compounds

Covalent nature: carbon atoms form stable covalent bonds with one another. A carbon – carbon single covalent bond has energy of 346kj mol^{-1}. This high energy indicates a strong bond. Most organic compounds are stable because of the strong carbon-carbon bonds. Since they have a covalent nature, they do not ionize in solution and are non-conductors of electricity.

Polarity and solubility of non-polar compounds: carbon-hydrogen bonds are, non-polar, like the carbon-carbon bonds. This is because of the almost equal electronegativities of the two elements. Most organic compounds are non-polar unless the compounds consist of very electronegative elements like chlorine or group like the hydroxyl group.

Since most organic compounds are non-polar, they cannot form bonds with water molecules. So must organic compounds are insoluble in water. For example, petrol, kerosene, and paraffin oil do not dissolve in water. If an organic contains polar groups, hydrogen bonds can form between the polar groups in the molecules of the organic and the water molecules. This enables the compounds to dissolve in water. For example, an ethanol molecule contains a hydroxyl group which is polar, so it is soluble in water.

Low melting and boiling points: Organic compounds generally have lower melting and boiling points than inorganic compounds. This is because these compounds posses' relatively weak intermolecular bonds which can be easily broken by heat energy. Many of them (mainly those with low relative molecular masks) tend to be volatile and boil at temperatures below 300^oC.

Thermal Instability: Many organic compounds are thermally unstable, decomposing into simpler molecules when heated to temperatures above 500^oC. However, this property is sometimes of commercial importance as in the cracking of petroleum.

Flammability: Most organic compounds are flammable and burn exothermically in a plentiful supply of air to yield carbon (iv) oxide and water. Thus, most fuels such as wood, coal, oil, petrol and natural gas are organic and their combustion provides our main sources of heat energy.

Reactivity: Reactions involving organic compounds tend to be much slower than ionic reactions commonly encountered in inorganic chemistry. They usually require heating, thorough mixing and catalyst to speed up the reactions.

4.4 Homologous Series

The numerous organic compounds can be grouped into a comparatively small number of series or families of compounds known as homologous series. A homologous series is a family of organic compounds which follows a regular structural pattern, in which each successive member differs in its molecular formula by a $-CH_2-$ group.

Different homologous series exist in organic chemistry. Alkanes being the simplest of series of compounds, table 2.0 shows some examples of alkanes with their properties.

Table 2.0: Properties of the first ten members of the Alkane series

Name of Alkene	**Molecule formula (C_nH_{2n+2})**	**Relative molecular mass**	**Physical State**	**Boiling point (^oC)**	**Melting point (^oC)**
Methane	CH_4	16	Gases	-162	-183
Ethane	C_2H_6	30		-89	-172
Propane	C_3H_8	44		-42	-187
Butane	C_4H_{10}	58		-1	-138
Pentane	C_5H_{12}	72	Liquids	36	-130
Hexane	C_6H_{14}	86		69	-94
Heptane	C_7H_{16}	100		98	-91
Octane	C_8H_{18}	114		125	-57
Nonane	C_9H_{20}	128		151	-54
Decane	$C_{10}H_{22}$	142		174	-30

The alkanes are a series of hydrocarbons with a general molecular formular **(C_nH_{2n+2})** where n is a whole number with a value of one or more. From table 2.0, we see that each individual member of the alkane series differs from the preceding or the successive member by one carbon atom and two hydrogen atoms, i.e. $–CH_2$ – group. Such a family of compounds is known as a homologous series and each individual member is referred to as a homologue.

Other homologous series include the alkanes, alkynes, alkanols, carboxylic acid, alkanone, alkanals, ether, esters, amins, amides, nitriles. Homologous series have the following common characteristics:

General molecular formula – All members share a general molecular formula, i.e. **(C_nH_{2n+2})** for the alkanes, C_nH_{2n} for the alkenes and so on.

Difference between successive homologues: Each successive member in such a series differs in its molecular formula by the addition of a $–CH_2$- group, and in its relative molecula mass by an increase of 14.

Physical properties: The physical properties of the members change gradually as the number of carbon atoms per molecules increases. For example, the boiling point of the alkanes increase down the series, so that the first four member are gases at room temperature and standard pressure, member with five to seventeen carbon atoms per molecule are volatile liquids, while the higher the members are wax-like solids. Similarly, the melting points and densities of the alkanes also increase, while their solubility in water decreases down the series.

Chemical properties: The members show similar chemical properties. For example, the alkanes are fairly nonreactive under ordinary conditions. They burn in air forming carbon (iv) oxide and water, undergo substitution reactions with other substances such as halogens.

General method of preparation: All members of a homologous series can usually be prepared by using the same general methods, e.g. alkanes can be prepared by the action of hot soda lime on the appropriate sodium salt of an acid.

4.5 Alkyl Group

Many homologous series can be regarded as being derived from the alkanes by the substitution of one or more of the hydrogen atoms by other elements or groups. The univalent group which is formed from an alkane by the loss of a hydrogen atom is known as the alkyl group. Thus, the compound that is formed by substitution can be considered as being made up of the alkyl group and the substituent group. For example, chloromethane, CH_3Cl, is composed of the methyl groups, CH_3-, (obtained from methane, CH_4, by the loss of a hydrogen atom) linked to the substituent chlorine atom, -Cl.

Alkyl groups have a general formula of C_nH_{2n+1}. They are named after the parent alkanes by replacing the ending –ane by –yl. Alkyl groups are given the general symbol, R. Sometimes, R may stand for more complex groups than just simple alkyl groups. Different alkyl groups can be present in one compound. If that is the case, the alkyl groups can be differentiated from one another in this manner: R, $R^{'}$, $R^{''}$, and so on. Examples of the alkyl groups derived from alkane series are given in table 2.1 below:

Table 2.1: The Alkyl Groups derived from the first ten members of the parent alkane series.

Parent Alkane	Alkyl Group	Formula
Methane	Methyl	CH_3-
Ethane	Ethyl	C_2H_5-
Propane	Propyl	C_3H_7-
Butane	Butyl	C_4H_9-
Pentane	Pentyl	C_5H_{11}-
Hexane	Hexyl	C_6H_{13}-

Heptane	Heptyl	C_7H_{15}-
Octane	Octyl	C_8H_{17}-
Nonane	Nonyl	C_9H_{19}-
Decane	Decyl	$C_{10}H_{21}$-

SELF ASSESSMENT EXERCISE 3

Give three properties that make carbon so unique from other elements.

5.0 CONCLUSION

We have studied some properties of carbon which resulted in the numerous compounds of carbon. We have also studied the characteristics and the names of the homologous series.

6.0 SUMMARY

In this unit, we have studied the unique nature of carbon which includes its valency, absence of d-orbital, and the types of hybridization available to it and so on. We have also seen the characteristics features of organic compounds which include covalent nature, solubility, thermal instability, flammability and reactivity.

TUTOR-MARKED ASSIGNMENT

Name the homologous series to which the following organic compounds belong to
(a) $CH_3CH_2COOCH_3$
(b) $CH_3CH_2CH_2CH_2OH$
(c) C_3H_7CHO
(d) CH_3COOH
(e) C_5H_{10}
(f) $CH_3COC_2H_5$
(g) $C_6H_{13}NH_2$

7.0.REFERENCES/FURTHER READINGS

Ababio, O. Y. (2011). *New School Chemistry* (6th Ed.), Africana First Publishers PLC, Nigeria.

Hart, H., Craine, L. E. & Hart, J. D. (2003). *Organic Chemistry: A short course* (11th Ed). Boston: Houghton Mifflin Company.

Morrison, R. T. & Boyd, R. N. (2011). *Organic Chemistry* (7th Ed.), India: Prentice-Hall, Ltd.

UNIT 4: FUNCTIONAL GROUP

CONTENT

1.0 INTRODUCTION

The study of the individual molecule/compound will be very difficult, therefore chemist grouped these numerous organic compound into a comparatively small number of series called homologous series based on the bond they formed and the heteroatom they contained which are also known as the functional groups

In the previous unit we studied the homologous series with its characteristics and then in this unit we shall study the functional groups.

2.0 OBJECTIVES

After studying this unit, you should be able to:

- Define functional groups
- Name the different classes of functional groups.

3.0 HOW TO STUDY THIS UNIT

1. Read through the whole unit.
2. Reflect on the issues raised throughout the unit.
3. Read the unit again step by step to get deeper understanding of the unit.
4. Carry out all the activities.

4.0 MAIN CONTENT

4.1 Functional Groups

The alkyl group of a compound is fairly inert chemically because of the stability of the carbon hydrogen bonds. The chemical reactivity of an alkyl compound is determined mainly by the substituent group. These groups are referred to as the functional group. A functional group can be heteroatoms (atoms other than carbon hydrogen in organic compounds) or double and triple covalently bonded carbon atoms. Therefore, a functional group is defined as an atom, group of atoms or a covalent bond common to a homologous series, and which determines the main chemical properties of the series.

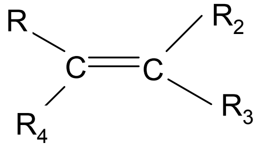
Each functional group has its own characteristic properties. The knowledge of homologous series allows us to focus attention on the chemistry of the various functional groups. We can study classes of compounds instead of having to learn the chemistry of each individual compound. When two or more functional groups occur in one molecule, the properties of one are often modified or influenced by the presence of the others.

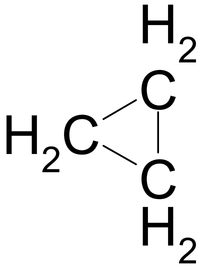
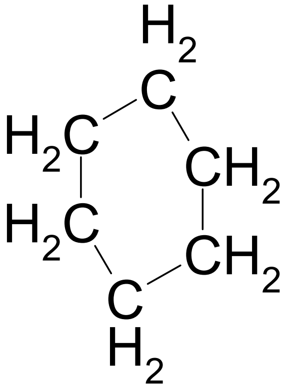
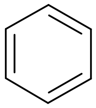
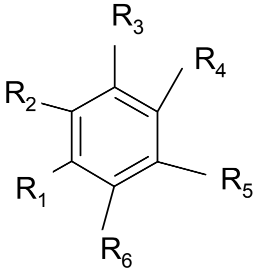
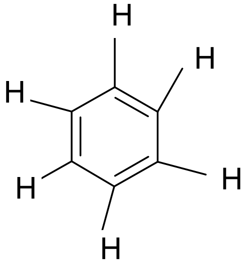
4.2 Classes of Functional Groups

Thus, the presence of the functional group or groups determines the chemical properties of a homologous series. Table 3.0 below shows the number of important functional groups in organic chemistry.

Table 3.0: Functional Groups

(a) Containing C and H only

Class	**Functional**	**General formula**	**Example**
Alkane	None	R-H	CH_4, methane
Alkene	C=C		$H_2C=CH_2$ Ethane
Alkyne	C≡C	$R-C≡C-R_1$	H-C≡C-H, ethyne
Alkyne	R	R	CH_3-, methyl

Cyclo alkane	None		 Hexane
Aromatic compounds			 Benzene

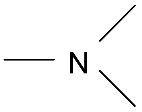
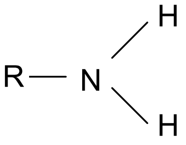
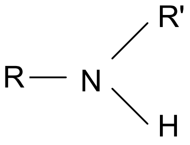
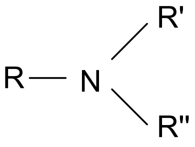
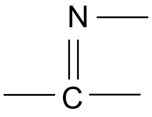
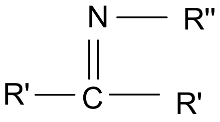
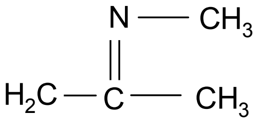
(b) containing C, H and O

Alkanol	-OH	R-OH	C_2H_5OH, ethanol
Ethers	-O-	R-O-R'	CH_3-O-CH_3 methoxymethane

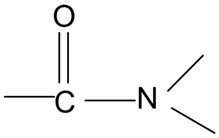
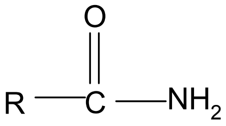
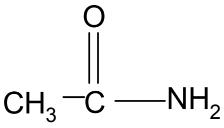
C) Containing carbonyl compounds

alkanals	-CHO	**RCHO**	**CH_3CHO, ethanol**
alkanones	-CO-	**RCOR**	**CH_3COCH_3, propanoic acid**
Alkanoic acid	-COOH	**RCOOH**	**CH3COOH, ethanoic acid**
alkanoate	-COO-	**RCOOR**	**CH_3COOCH_3, methylethanoate**
Acid anhydride	-COOCO-	**RCOOCOR'**	**$CH_3COOCOCH_3$**

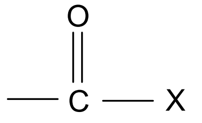
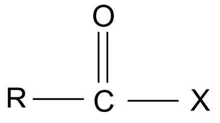
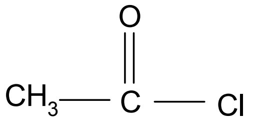
(d) containing C, H and N

Amine		 (primary amine)  (secondary amine)  (tertiary amine)	CH_3NH_2, methylamine H_3CNHCH_3, dimethylamine $CH_3N(CH_3)CH_3$ Trimethylamine
Nitrile	-C≡N	RC≡N	CH3C≡N, methyl nitrile
Imine			 N-ethyldene-methylamine

(e) Containing C, H, N and O

Nitro compounds	$-NO_2$	$R-NO_2$	CH_3-NO_2 Nitromethane
Amides			 Ethanamide

(f) Containing C, H and other elements

Alkylhalide	$-X$	$R-X$	CH_3-Cl Methylchloride
Acylhalide	 $-\overset{O}{\overset{\|}{C}}-X$	 $R-\overset{O}{\overset{\|}{C}}-X$	 $CH_3-\overset{O}{\overset{\|}{C}}-Cl$
Thiol	$-SH$	$R-SH$	CH_3-SH Methanethiol
Sulphonic Acid	$-SO_2-OH$	$R- \quad -OH$	CH_3-SO_2-OH Methane, sulphonic acid

***Here, R** stands for the alkyl group and X stands for Halogen (F, Cl, Br and I)*

The compounds in table 4.1 are categorized according to the atoms that constitute compounds. The ones listed in the first category are hydrocarbons. The hydrocarbons can be classified as aliphatic, alicyclic or aromatic. In the aliphatic hydrocarbons, the carbon atoms are linked to each other to form chains (straight or branched). The aliphatic hydrocarbons can be further divided into saturated hydrocarbons, which contain carbon-carbon single bond called alkanes and unsaturated hydrocarbons, which composed of carbon-carbon double bond ($C = C$) and carbon-carbon triple bond ($C \equiv C$) called alkenes and alkynes respectively and these serves as their functional groups.

In the alicyclic hydrocarbons, the carbon atoms are arranged in rings to yield cyclic structures. These compounds are also known as cycloalkanes.

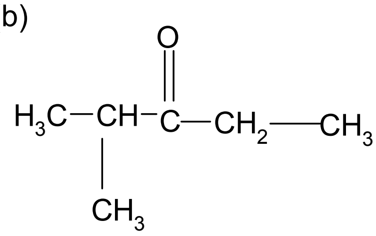
The aromatic hydrocarbons include benzene and those compounds which resemble benzene in their properties. Hydro carbons provide a root to which various functional groups may be attached to yield an enormous variety of organic compounds.

SELF ASSESSMENT EXERCISE 4

(1) Encircle and name the functional groups present in the following compounds:

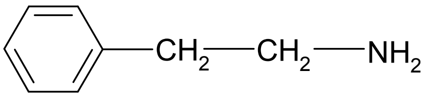
(a) $CH_3 - CH_2 - CH = CH - CHO$

(b)



$H_3C-CH(CH_3)-C(=O)-CH_2-CH_3$

(c)



(d) $C_7H_{15}COOH$

(e) $CH_3(CH_2)C\equiv C-CH_2I$

5.0 CONCLUSION

We have studied the meaning of functional groups and variety of functional groups in organic chemistry.

6.0 SUMMARY

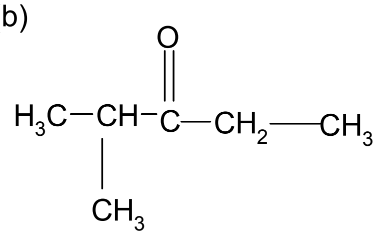
In this unit, we have studied the names and the structure of the different functional groups and because of these the organic compounds are grouped into a series or class called homologous series in order to study their behavior in group.

TUTOR-MARKED ASSIGNMENT

Encircle and name the functional groups present in the following compounds:

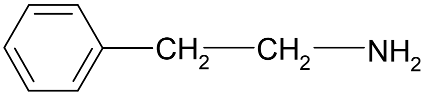
(b) $CH_3-CH_2-CH=CH-CHO$

(b)



$H_3C-CH(CH_3)-C(=O)-CH_2-CH_3$

(c)



(d) $C_7H_{15}COOH$

(e) $CH_3(CH_2)C\equiv C-CH_2I$

7.0 REFERENCES/FURTHER READINGS

Ababio, O. Y. (2011). *New School Chemistry* (6th Ed.), Africana First Publishers PLC, Nigeria.

Hart, H., Craine, L. E. & Hart, J. D. (2003). *Organic Chemistry: A short course* (11th Ed). Boston: Houghton Mifflin Company.

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UNIT 5: QUANTITATIVE AND QUALITATIVE ANALYSIS

CONTENTS

1.0 INTRODUCTION

The general expression Qualitative Analysis refers to analyses in which substances are identified or classified on the basis of their chemical or physical properties, such as chemical reactivity, solubility, molecular weight, melting point, radioactive properties (emission, absorption), mass spectra, nuclear half-life, etc. Quantitative Analysis refers to analyses in which the amount or concentration of an analyte may be determined (estimated) and expressed as a numerical value in appropriate units. Qualitative Analysis may take place with Quantitative Analysis, but Quantitative Analysis requires the identification (qualification) of the analyte for which numerical estimates are given.

The term "quantitative analysis" is often used in comparison (or contrast) with "qualitative analysis", which seeks information about the identity or form of substance present. For instance, a chemist might be given an unknown solid sample. He or she will use "qualitative" techniques (perhaps NMR or IR spectroscopy) to identify the compounds present, and then quantitative techniques to determine the amount of each compound in the sample. Careful procedures for recognizing the presence of different metal ions have been developed, although they have largely been replaced by modern instruments; these are collectively known as qualitative inorganic analysis. Similar tests for identifying organic compounds (by testing for different functional groups) are also known. Many techniques can be used for either qualitative or quantitative measurements. For instance, suppose an indicator solution changes color in the presence of a metal ion. It could be used as a qualitative test: does the indicator solution change color when a drop of sample is added? It could also be used as a quantitative test; by studying the color of the indicator solution with different concentrations of the metal ion (This would probably be done using ultraviolet-visible spectroscopy).

2.0 OBJECTIVES

After studying this unit, you should be able to:

1. Define quantitative and qualitative organic analysis
2. Explain properties of qualitative

3.0 HOW TO STUDY THIS UNIT

1. Read through the whole unit.
2. Reflect on the issues raised throughout the unit.
3. Read the unit again step by step to get deeper understanding of the unit.
4. Carry out all the activities.

4.0 MAIN CONTENT

4.1 Quantitative Analysis

Once the presence of certain substance(s) in a sample is known, the study of their absolute or relative abundance can help in determining specific properties. Knowing the composition of a sample is very important and several ways have been developed to make it possible, like gravimetric and volumetric analysis. Gravimetric analysis yields more accurate data about the composition of a sample than volumetric analysis does, but the first one takes more time to perform in the laboratory. Volumetric analysis, on the other side, doesn't take that much time and the results that we obtain are in the most cases satisfactory. Volumetric analysis can be simply a titration based in a neutralization reaction but it can also be a precipitation or a complex forming reaction as well as a titration based in a redox reaction. However, each method in quantitative analysis has a general specification, in neutralization reactions, for example, the reaction that occurs is between an acid and a base, which yields a salt and water, hence the name neutralization. In the precipitation reactions the standard solution is in the most cases silver nitrate which is used as a reagent to react with the ions present in the sample and to form a high insoluble precipitate. Precipitation methods are often called simply as argentometry. In the two other methods the situation is the same. Complex forming titration is a reaction that occurs between metal ions and a standard solution that is in the most cases EDTA (ethylene diamine tetra acetic acid). In the redox titration that reaction is carried out between an oxidizing agent and a reduction agent.

4.2 Titration

Titration, also known as titrimetry, is a common laboratory method of quantitative chemical analysis that is used to determine the unknown concentration of an identified analyte. Since volume measurements play a key role in titration, it is also known as volumetric analysis. A reagent, called the titrant or titrator is prepared as a standard solution. A known concentration and volume of titrant reacts with a solution of analyte or titrand to determine concentration. The volume of titrant reacted is called titre.

4.3 Qualitative Analysis

The general expression Qualitative Analysis refers to analyses in which substances are identified or classified on the basis of their chemical or physical properties, such as chemical reactivity, solubility, molecular weight, melting point, radiative properties (emission, absorption), mass spectra, nuclear half-life. Identification and characterization of the structures of unknown substances are an important part of organic chemistry. It is often, of necessity, a micro process, for example, in drug analyses. It is sometimes possible to establish the structure of a compound on the basis of spectra alone (IR, UV, and NMR), but these spectra must usually be supplemented with other information about the unknown: physical state, elementary analysis, solubility, and confirmatory tests for functional groups. Conversion of the unknown to a solid derivative of known melting point will often provide final confirmation of structure.

However, before spectra are run, other information about the sample must be obtained. Is it homogeneous (test by thin-layer, gas, or liquid chromatography)? What are its physical properties (melting point, boiling point, color, solubility in various solvents)? Is it soluble in a common NMR solvent? It might also be necessary to determine which elements are present in the sample and its percentage elemental composition (mass spectroscopy).

Nevertheless, an organic chemist can often identify a sample in a very short time by performing solubility tests and some simple tests for functional groups, coupled with spectra that have not been compared to a database. Conversion of the unknown to a solid derivative of known melting point will often provide final confirmation of structure. This chapter provides the information needed to carry out this type of qualitative analysis of an organic compound.

4.4 Some Properties of Organic Compound for Qualitative Organic Analysis

1) solubility

Solubility is the property of a solid, liquid, or gaseous chemical substance called solute to dissolve in a solid, liquid, or gaseous solvent to form a homogeneous solution of the solute in the solvent. The solubility of a substance fundamentally depends on the physical and chemical properties of the solute and solvent as well as on temperature, pressure and the pH of the solution. The extent of the solubility of a substance in a specific solvent is measured as the saturation concentration, where adding more solute does not increase the concentration of the solution and begin to precipitate the excess amount of solute.

2) Reactivity

The chemical reactivity of a substance can refer to the variety of circumstances (conditions that include temperature, pressure, and presence of catalysts) in which it reacts, in combination with the:

- Variety of substances with which it reacts
- Equilibrium point of the reaction (i.e., the extent to which all of it reacts)
- Rate of the reaction

3) Melting point

The melting point (or, rarely, liquefaction point) of a solid is the temperature at which it changes state from solid to liquid at atmospheric pressure. At the melting point the solid and liquid phases exist in equilibrium. The melting point of a substance depends (usually slightly) on pressure and is usually specified at standard pressure. When considered as the temperature of the reverse change from liquid to solid, it is referred to as the freezing point or crystallization point. Because of the ability of some substances to supercool, the freezing point is not considered as a characteristic property of a substance. When the "characteristic freezing point" of a substance is determined, in fact the actual methodology is almost always "the principle of observing the disappearance rather than the formation of ice", that is, the melting point.

4) Molecular weight

Molecular mass or molecular weight refers to the mass of a molecule. It is calculated as the sum of the mass of each constituent atom multiplied by the number of atoms of that element in the molecular formula. The molecular mass of small to medium size molecules, measured by mass spectrometry, determines stoichiometry. For large molecules such as proteins, methods based on viscosity and light-scattering can be used to determine molecular mass when crystallographic data are not available.

5) Radioactive property

Conduction and convection are heat transfer processes that require the presence of a medium. Radiation heat transfer is characteristically different from the other two in which it does not require a medium and, in fact it reaches maximum efficiency in a vacuum. Electromagnetic radiation has some proper characteristics depending on the frequency and wavelengths of the radiation. The phenomenon of radiation is not yet fully understood. Two theories have been used to explain radiation; however neither of them is perfectly satisfactory.

Qualitative Methods for Some Organic Compounds

(a) Metal Salts of Carboxylic Acids

The free acid can be liberated by addition of acid and extraction into an appropriate solvent, after which the carboxylic acid can be characterized by mp or bp before proceeding to prepare a derivative.

(b) Ammonium Salts

Ammonium salts on treatment with alkali liberate ammonia, which can be detected by its odor and the fact that it will turn red litmus to blue. A more sensitive test utilizes the copper (II) io`n, which is blue in the presence of ammonia. Ammonium salts will not give a positive hydroxamic acid test (Ih) as given by amides.

(c) Amino Acids

Add 2 mg of the suspected amino acid to 1 mL of ninhydrin reagent, boil for 20 sec, and note the color. A blue color is a positive test. *Reagent:* Dissolve 0.2 g of ninhydrin in 50 mL of water.

5.0 Conclusion

In this unit we study quantitative and qualitative analysis. Quantitative analysis involves finding the concentration of a substance in a solution of known volume. Qualitative analysis deals with identification on bases of their physical and chemical properties.

6.0 Summary

Quantitative analysis involves finding the concentration of a substance using titration. Titration is a method or experiment use to find the concentration or volme of a substance using another substance of known concentration and volume. Qualitative analysis deal with identification on bases of their physical and chemical properties, such as chemical reactivity, solubility, molecular weight, melting point, radiative properties (emission, absorption), mass spectra, nuclear half-life.

SELF ASSESSMENT EXERCISE 5

Give some properties of organic substance.

TUTOR-MARKED ASSIGNMENT

Enumerate the methods in carrying out titration.

References/Further Reading

Ababio, O. Y. (2011). *New School Chemistry* (6th Ed.), Africana First Publishers PLC, Nigeria.

Hart, H., Craine, L. E. & Hart, J. D. (2003). *Organic Chemistry: A short course* (11th Ed). Boston: Houghton Mifflin Company.

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MODULE 2

UNIT 1: STEREOCHEMISTRY

CONTENTS

1.0 INTRODUCTION

Stereochemistry is the study of structure in three dimensions. From our previous knowledge, we will recall that it is possible to arrange the atoms in the molecule in more than one way. This means that, it is possible to have two or more different structural arrangement for the same molecular formular. For example, the four carbon atoms and the ten hydrogen atoms in butane molecule can be linked in two different ways which will satisfy the valencies of carbon and hydrogen. Such a phenomenon is known as isomerism.

Isomerism is very common feature in organic chemistry. Isomers with the same molecular formula and belonging to the same homologous series tend to have similar chemical properties but slightly different physical properties as a result of their structural difference. However, it is also possible to have isomers with the same molecular formular but belonging to different homologous series. For example, both ethanol and methoxymethane have the same molecular formula of C_2H_6O, belongs to the alkanol and ether series respectively.

In this unit, we shall study the other aspect of isomerism, that is, the geometric and optical isomerism. Stereo isomers have the same order of attachment of the atoms, but different arrangements of the atoms in space.

2.0 OBJECTIVES

After studying this unit, you should be able to:

- Draw the starggered and eclipsed conformation of alkanes.
- Described the geometric isomerism in alkenes
- Draw the enantiomers of a certain organic compounds.
- Name compounds using **R-S** and **E-Z** convections.

3.0 HOW TO STUDY THIS UNIT

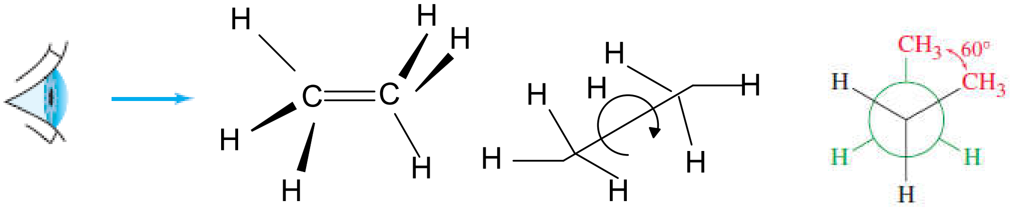
1. Read through the whole unit.
2. Reflect on the issues raised throughout the unit.
3. Read the unit again step by step to get deeper understanding of the unit.
4. Carry out all the activities.

4.0 MAIN CONTENT

4.1 Conformation of Alkane

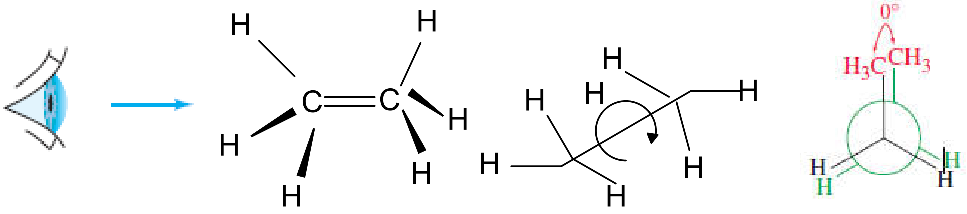
The shapes of molecules often affect their properties. A sample molecule like ethane, for example, can have an infinite number of shape as a consequence of rotating one carbon atom (and its attached hydrogen) with respect to the other carbon atom. These arrangements are called conformation or conformers. Conformers are stereo isomer, isomers in which the atoms are connected in the same order but are arrange differently in space. Two possible conformers for ethane are shown below:

Staggered;



A dash wedge sawhorse

Eclipse;

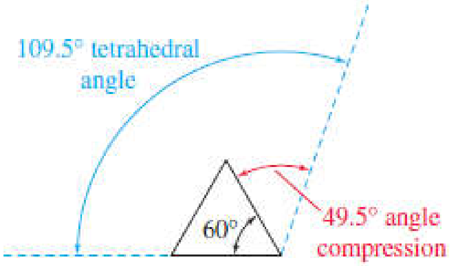


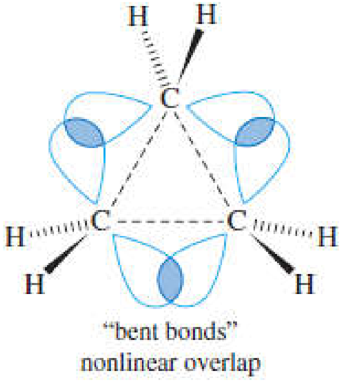
In the staggered conformation of ethane, each C-H bond on one carbon bisects on H-C-H angle on the other carbon. In the eclipsed conformation, C-**H bond** on the front and back carbons are aligned by rotating one carbon 60° with respect to the other, we can interconvert staggered and eclipsed conformations. Between these two extremes are infinite numbers of intermediate conformation of ethane.

In the staggered and eclipsed conformation of ethane interconversion is easy via 60° rotation about the **C-C** bond as shown by the curved arrows. The structures at the left are "dash-wedge" structure, which if viewed as shown by the eyes, converts to the “saw horse” drawing, or the Newman project at the right, an end-on viewed down the **C-C** axis. In the Newton, the circle represents two connected carbon atoms. Bonds on the “rear” carbon go only to the edge of the circle.

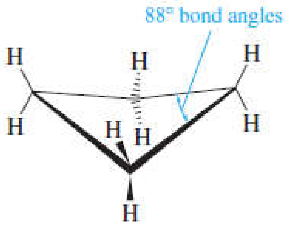
The staggered and eclipsed conformations of ethane can be regarded as rotamers because each is convertible to the other by rotation about the carbon-carbon bond. Such rotation about a single bond occurs easily because the amount of overlap of the sp^3 orbitals on the two carbon atoms is unaffected by rotation about the signs bond. And there is sufficient thermal energy for this rotation at room temperature it is usually not possible to separate conformers from one another.

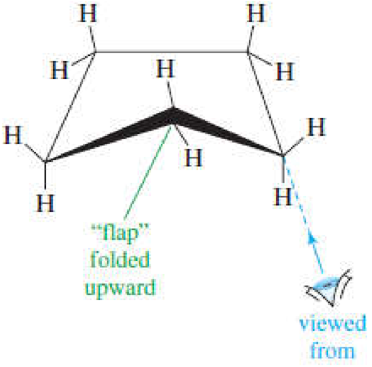
In the case cycloalkane, cyclopropane with only three carbon atoms is necessary planer (because three points determine the plane). The C-**C-C angle** is 60^o (the carbons form an equilateral triangle), much less than the usual tetrahedral angle of 109.5^o. The hydrogen lie above and below the carbon plane, and hydrogens on adjacent carbon are eclipsed.





Cycloalkanes with more than three carbon atoms are non planer and have “parkered” conformations. In cyclobutane and cyclopentane, puckering allows the molecule to adopt the most stable conformation. Puckering introduces strain by making the C-**C-C** angle a planar; however, less eclipsing of the adjacent hydrogens compensates for this.





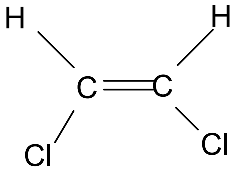
Cyclobutane 88^o cyclopetane 108^o

SELF ASSESSMENT EXERCISE 6

Draw the Newman projections for the staggered and eclipsed conformations of propane.

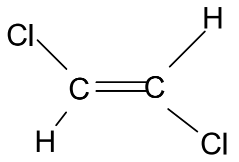
4.2 GEOMETRIC (CIS-TRANS) ISOMERISM IN ALKANES

Because rotation at carbon-carbon double bonds is restricted, geometric (cis-trans) isomerism is possible in appropriately substituted alkenes. For example, 1,2-dichloroethene exist in two different forms:



cis-**1,2-dichloroethene**

bp 60°, MP **-80°**



trans-**1,2-dichloroethene**

bp 47°, MP **-50°**

These stereoisomers are not readily interconverted by rotation around the double bond at room temperature. cis-trans isomers of ethane are configurational stereoisomers and can be separated from one another by distillation, taking the advantage of the difference in their boiling points.

Cis-trans isomerism plays a key role in the process of vision. The rod cells in the retina of the eye contain a red, light sensitive pigment called rhodopsin. This pigment consists of the protein opsin combined at its active site with 1-cis-retinal. When visible light with theappropriate energy is absorbed by rhodopsin, the complexed cis-retinal is isomerized to the transisomer. This process is fantastically fast, occurring in only picoseconds (10^{-12} seconds).

The trans-retinal complex with opsin (called metarhopsin-11) is less stable than cis-retinal complex, and it dissociates into opsin and trans-retinal complex. This change in geometry triggers a response in the rod nerve cells that is transmitted to the brain and perceived as vision.

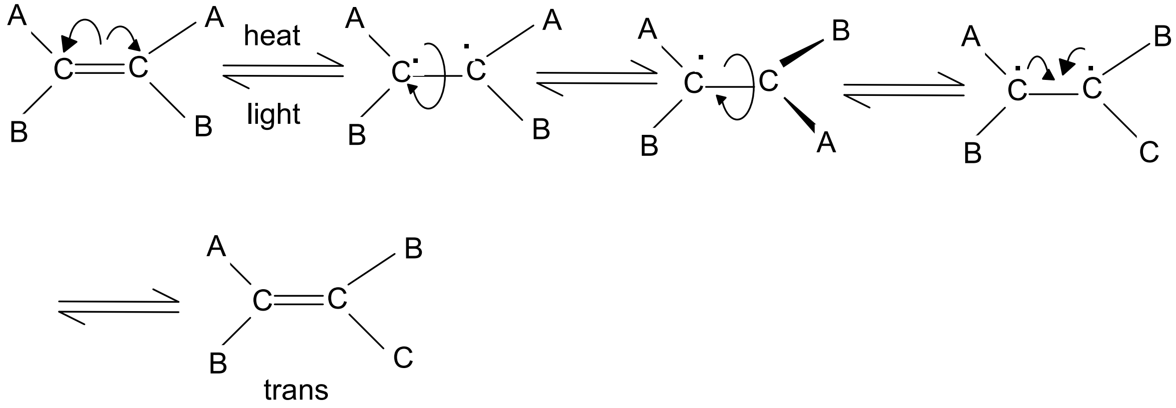
For cis-trans isomer to occur in alkanes, each carbon of the double bond must have two different atoms or groups to it.

SELF ASSESSMENT EXERCISE 7

Are cis and transisomers possible for 1-butene and 2-butene?

4.3 GEOMETRIC ISOMERISM IN ALKANE

Geometric isomers of alkenes can be interconnected if sufficient energy is supplied to break the Pi bond and allow rotation about the remaining, somewhat stronger, sigma bonds. The required energy may take the form of light or heat.



This conversion does not occur under normal laboratory conditions.

4.4 CHIRALITY AND ENANTIOMERS

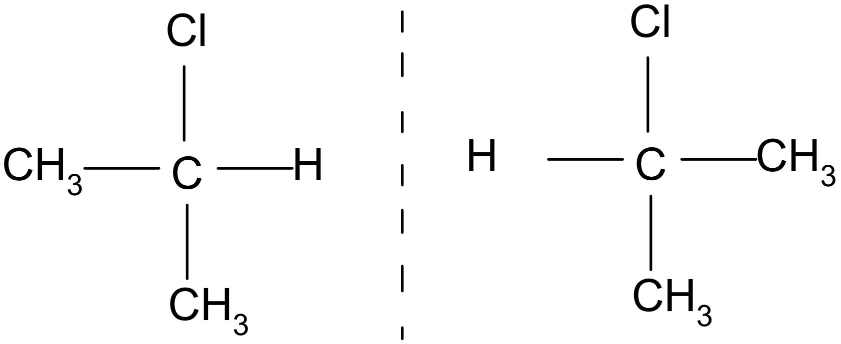
We have already seen that stereoisomers can be characterized according to the ease with which they can be interconverted. That is, they may be conformers, which can be interconverted by rotation about a single bond, or they may be configurational isomers, which can be interconverted only by breaking and remaking covalent bonds here we will consider other useful ways to categorise streoisomers, ways that are particularly helpful in describing their properties.

Consider the difference between a pair of gloves and a pair of socks. A sock, like its partner, can be worn on either the left or right foot. But a left-hand glove, unlike its partner, cannot be worn on the right hand. Like a pair of gloves, certain molecules possess this property of “handedness”, which affect their chemical behavior.

A molecule is either chiral or achiral. A chiral molecule is one that exhibits the property of handedness. An achiral molecule does not have this property.

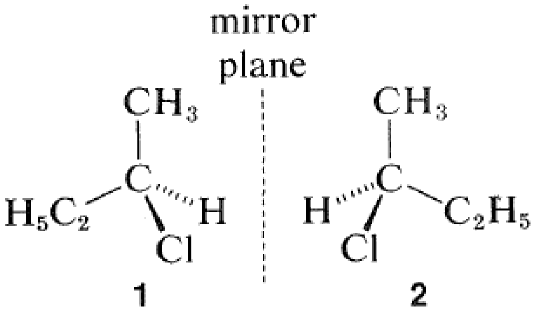
The test we can apply to tell whether a molecule is chiral or achiral is by examining the molecule and its mirror image. The mirror image of achiral molecule cannot be superimposed on the molecule itself.

Now let us look at two-molecules, 2-chloropropane and 2-chlorobutane, and their mirror images in figure below:



2-chloropropane

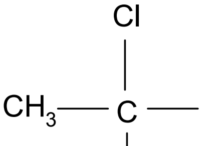
The figure shows that 2-chloropropane is chiral. Its mirror image is superimpossible on the molecule itself. Therefore 2-chloropropane has only one possible structure.



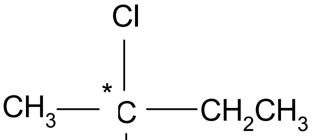
2-chloro-butane

On the other hand, the figure above shows, 2-cholorobutane has two possible structures, related to one another as nonsuperimposable are called enantiomers.

Stereogenic centre:



2-choloropropane



2-cholorobutane

What is about their structure that leads to chirality in 2-cholorobutane but not in 2-choloropropane? Notice that in 2-cholorobutane, carbon atom 2, and the one marked with asterisk has four different groups attached to it (Cl, H, CH_3 and CH_2CH_3). A carbon atom with four different groups attached to it is called stereogenic carbon atom. This type of carbon is also called a stereogenic centre because it gives rise to the streoisomers.

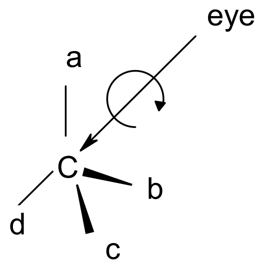
SELF ASSESSMENT EXERCISE 8

1. *Locate the stereogenetic centre in 3-methylhexane*
2. *Draw the two enantiomers of 3-methylhexane*

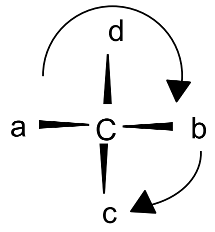
4.5 CONFIGURATION AND THE R-S CONVENTION

Enantiomers differ in the arrangement of the groups attached to the stereogenic centre. This arrangement of groups is called the configuration of the stereogenic centre. Enantiomers are another type of configurations.

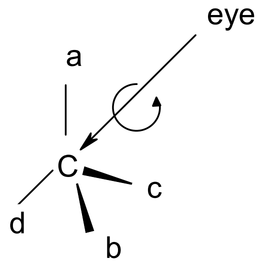
When referring to particular enantiomers, we would like to be able to specify which configuration we mean without having to draw the structure. A convention for doing this is known as the R-S or Cahn-Ingold-prelog (CIP) system. Here is how it works

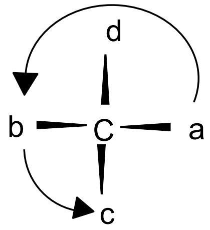


a→b→c clockwise (R)



a→b→c clockwise (R)





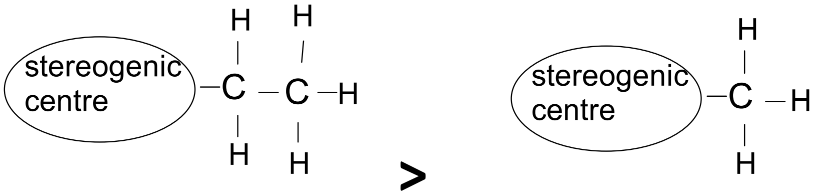
a→b→c counterclockwise (S)

The four groups attached to the stereogenic centre are place in a priority order a→b→c→d. the stereogenic centre is then observed from the side opposite the lowest priority group, d. If the remaining three groups (a→b→c) from a clockwise array, the configuration is designated R (from the Latin rectus, right). If they form a counter clockwise array the configuration is designated as S (from the Latin rectus, left).

The prior order of the four groups is set in the following ways;

Rule 1: The atoms directly attached to the stereogenic centre are ranked according to atomic number, the higher the atomic number, the higher the priority. If one of the four groups is H, it always has the lowest priority, and views the stereogenic centre looking down the C-H bond from C to H.

Rule 2: if a decision cannot be reached with rule 1, workout ward from the stereogenic centre until a decision is reached. For example, the ethyl group has a higher priority than the methyl group, because at the first point of difference, working out ward from the stereogenic centre, we come to a carbon (higher priority) in the ethyl group and a hydrogen (lower priority) in the methyl group.



ethyl

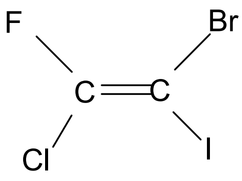
Rule 3: a third, somewhat more complicated, rule is required to handle double or triple bonds and aromatic rings. Multiple bonds are treated as if they were an equal number of single bonds. For example the vinyl group, -$CH=CH_2$ is counted as:

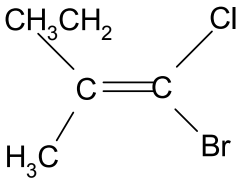
SELF ASSESSMENT EXERCISE 9

(a) Which group has the highest priority, isopropyl or vinyl?

4.6 THE E-Z CONVECNTION FOR CIS-TRANS ISOMERS

The system of we have just discussed for stereogenic centre has been extended to double-bond isomers. We use exactly the same priority rules. The two groups attached to each carbon of the double-bond are assigned priorities. If the two higher priorities are on opposite sides of the two bond, the prefix E (from the German entgegen, opposite) is used. If the two higher priority groups are on the same side of the double bond, the prefix is Z (from the german, Zusammen, together). For example, the correct names for the following structures are given below;



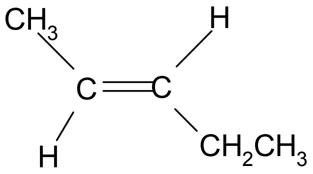


(z) -1-bromo-2-chloro-2-fluro-1-iodoethene *(E)-1-bromo-1-chloro-2-methyl-1-butane*

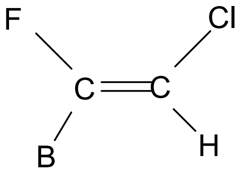
SELF ASSESSMENT EXERCISE 10

Name each compound by the E-Z system.

(a)



(b)



5.0 CONCLUSION

We have learnt the general features of stereochemistry/stereoisomerism and define conformational and configurational isomers, chiral compound, enantiomers and stereogenetic centre. Copounds have been named using the R-S configuration and the E-Z convention.

6.0 SUMMARY

In this unit, we have studied about the different kind of streoisomers which include conformational isomers, in which are the isomers that can be interconverted by rotation about a single bond. And the isomers that can be interconverted only by breaking and remarking covalent bonds, we have also seen that a chiral molecule is the one that exhibits the property of handedness and the mirror images of the chiral molecule cannot be superimposed on the molecule itself, such molecule that are related as nonsuperimposable mirror images are known as enantiomers. In thi unit we have also learnt how to name configurational isomers such as enantiomers, using R-S and E-Z conventions.

TUTOR-MARKED ASSIGNMENT

1. *Locate the stereogenetic centre in 3-methylhexane*
2. *Draw the two enantiomers of 3-methylhexane*

7.0 REFERENCES/FURTHER READINGS

Ababio, O. Y. (2011). *New School Chemistry* (6th Ed.), Africana First Publishers PLC, Nigeria.

Hart, H., Craine, L. E. & Hart, J. D. (2003). *Organic Chemistry: A short course* (11th Ed). Boston: Houghton Mifflin Company.

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UNIT 2: SPECTROSCOPY AND STRUCTURE DETERMINATION

1.0 INTRODUCTION

As aspiring young chemist thinks he has just synthesized 2 phenylethanol, but how does he know for sure? In the early years of organic chemistry, determining the structure of a new compound was often a formidable task. The first step, of course, was an elemental analysis. Knowing the percentage of each element present allowed the empirical formula to be calculated; the molecular formular was the either the same as or a multiple of that formula. Elemental analysis is still an important criterion of the purity of a compound.

But how are the atoms arranged? What functional groups are present? And what about the carbon skeleton? Is it a acyclic or cyclic, are there branches and where are they located, are benzene rings present? All of these questions and more to be answered by chemical means.

To identify a functional group, various chemical tests could be applied (such as the bromine or permanganate tests for unsaturation, or the tollens' silver mirror test for an aldehyde group).

Once the functionality was known, reactions whose chemistry was well understood could be used to convert the unknown compound to a compound whose structure was already known for Example, if the compound was an aldehyde suspected to have the same R group as a known acid, It could be oxidize. If the physical properties (bp, mp,specific rotation if chiral, and so on) and the chemical properties of the acid obtained from the aldehyde agree with those of the known acid, it could safely be concluded that the two R groups were the same, and the structure of the aldehyde also became known. If they didn't agree, one had to do some rethinking about the suspected structure. Ultimate structure proof came through synthesis of the unknown by reactions whose outcome was unambiguous.

These methods which often require week, months, even year are still used in appropriate situations. But since the 1940's, various types of spectroscopy have simplified and speeded up the process of structure determination greatly. Automated instruments have been developed that permit us to determine and record spectroscopic properties often with little more effort than pushing a button. And these spectra, if properly interpreted, yield a great deal of structural information.

In this unit, we will describe some of the more important spectroscopic technique used today and how they can be applied to structural problems. But let us examine some general principle that forms the basis of most of these techniques.

2.0 OBJECTIVES

After studying the unit, you should be able to:

- Explain the general principles of spectroscopy
- Describe the NMR spectroscopy.
- Draw the infrared spectra of conjugated compounds using visible ultraviolet
- Draw and explain the spectra of conjugated compounds using visible ultraviolet.
- Discuss briefly the mass spectrometry method.
- Discuss the usefulness of the different type's spectroscopy.

3.0 HOW TO STUDY THE UNIT

1.0 Read through the whole unit.

2.0 Reflect on the issues raised throughout the unit.

3.0 Read the unit again step by step to get deeper understanding of the unit.

4.0 Carry out all the activities.

4.0 SPECTROSCOPY AND STRUCTURE DETERMINATION

4.1 PRINCIPLES OF SPECTROSCOPY.

Equation describes the relationship between the energy of light (or any other form of radiation), E, and its frequency, V (greek nu, pronounced "new").

$$E = hv$$

The equation says that there is a direct relationship between the frequency of light and its energy: the higher the frequency the higher the energy. The proportionality constant between the two is known as planks constant, h*. Because the frequency of light and its wavelength are inversely proportional, the equation can be written as

$$E = hc/\lambda ,$$

because $V=c/\lambda$

Where λ(Greek lambda) is the wavelength of light and c is the speed of light. In this form, the equation tells us that the shorter the wavelength of light, the higher its energy.

Molecules can exist at various energy levels. For example, the bonds in a given molecule may be stretch, bend, or rotated, electrons may move from one orbital to another; and so on. These processes are quantized; that is, bonds may stretch, bend or rotate only with certain frequencies (or energies; the two are proportional), and electrons may only jump between orbital with well defined energy differences. It is this energy (or frequency) difference that we measure by various types of spectra.

The idea behind most forms of spectroscopy is very simple and is expressed schematically in figure 1.0. a molecule at some energy level, E1, is exposed to radiation. The radiation passes through the molecule to a detector. As long as the molecule does not absorbed the radiation, the amount of radiation detected will be equal to the amount of radiation emitted by the source (top part of figure 1.0) at frequency that corresponds to some molecular energy transition, from E1 to E2, the radiation will be absorbed by the molecule and will not appear at the detector (bottom part of figure 1.0).

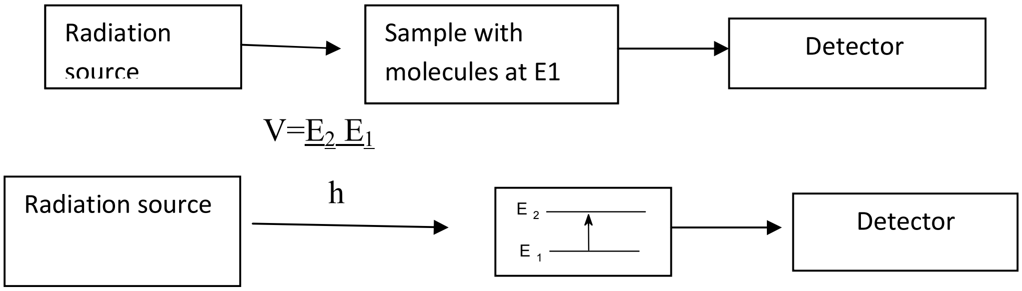


Figure 1.0

The spectrum, then, consist of a record or plot of the amount of energy (radiation) received by the detector as the input energy (radition) received by the detector as the input energy is gradually varied.

Some transitions required more energy than others, so we must use radiation of the appropriate frequency to determine them. In this chapter, we will discuss three types of spectroscopy that depend on such transitions. They are nuclear magnetic resonance (NMR), infrared (IR), and ultraviolet visible (UV-Vis) spectroscopy.

4.2 NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY (NMR)

The kind of spectroscopy that has had by far the greatest impact on the determination of organic structure is nuclear magnetic resonance (NMR) spectroscopy. Commercially instruments became available tool for the organic chemist. Let us look briefly at the theory and then see what practical information we can obtain from a NMR spectrum.

Certain nuclei behave as though they are spinning. Because nuclei a charged and a spinning charge create a magnetic field, these spinning nuclei behave like tiny magnets. The most important nuclei for organic structure determination are ‘H (ordinary Hydrogen) and ^{13}C, a stable nonradioactive isotope of ordinary carbon.

Although ^{12}C and ^{16}O are present in most organic compounds, they do not possess a spin and do not give NMR spectra. When nuclei with spin are place between the poles of a powerful magnet, they align their magnetic fields with or against the field of the magnet. Nuclei aligned with the applied field have a slightly lower energy than those aligned against the field (figure5.2). By applying energy in the radiofrequency range, it is possible to excite nuclei in the lower energy spin state to the higher energy spin state (we sometimes say that the spins “flip”).

The energy gap between the two spin state depend on the strength of the applied magnetic field; the stronger the field, the larger the energy gap. Instruments currently in use have magnetic field that range from about 1.4 to 14 tests (T) (by comparison, the earth’s magnetic field is only about 0.0007T). At these field strengths, the energy gap corresponds to which chemists are more accustomed, the energy gap is exceedingly small, modern technology permits its detection with great accuracy.

4.2.1 Measuring an NMR spectrum.

A ‘H NMR’ spectrum is usually obtained in the following way. A sample of the compound being studied which is tetramethylsilane (TMS) is dissolve in some inert solvents that does not contain ‘H nucei. Examples of such solvents are CCl_4, or solvent with the hydrogens replaced by deuterium, such as $CDCl_3$ (deuteriochloroform) and CD_3COCD3 (hexadeuterioacetone). A small amount of a reference compound is also added. The solution, in a thin glass tube, is placed in the center of radiofreqency (Rf) coil, between the poles faces of a powerful magnet. The nuclei align themselves with or against the field. Continuously increasing amounts of energy can then be applied to the nuclei by the rf coil. When this energy corresponds exactly to the energy gap between the lower and higher energy spin state, it is absorbed by the nuclei. At this point, the nuclei are said to be in resonance with the applied frequency, hence the term nuclear magnetic resonance. A plot of the energy absorbed by the sample against the applied frequency of the rf coil gives an NMR spectrum.

In practice, there are two ways by which the resonance frequencies of ‘H nuclei can be determined. Because of the magnetic field strength and the size of the energy gap between nuclear spin states are directly related, either the magnetic field strength or the rf can be varied. In the earlier analysis, NMR spectrometers a constant radiofrequency was varied, and different ‘H nuclei resonated at different magnetic field strengths.

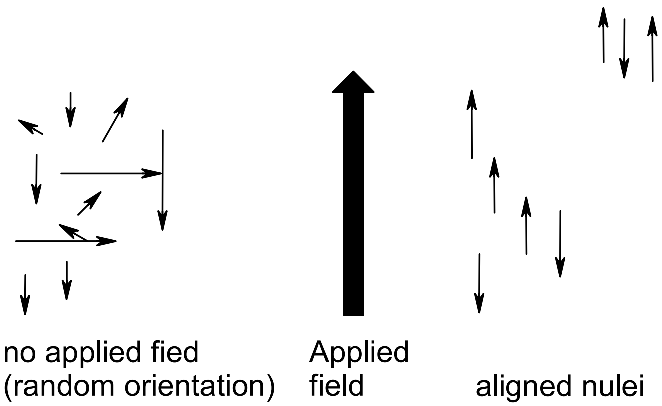


Figure 1.1; orientation of nuclei in an applied field, and exercitation of nuclei from the lower to the higher energy spin state.

In modern fourrier transform (FT–NMR) spectrometers, the applied magnetic field is held constant and a short pulse of rf energy causes all the ‘H nuclei to resonate simultaneously at their resonance rfs. The instrument computer uses a mathematical rfs of the different ‘H nuclei. This variable increases from left to right in the recorded spectra.

Most organic compounds have peaks down field (at lower field) from TMS, the positions of the peaks are measure in δ (delta) units and are given positive δ values. A δ value of 1.00 means that a peak appear 1 parts per million (ppm) down field from the TMS peak. If the spectrum is measured at 60MHz (60×10^6Hz), then 1ppm is 60Hz (one million of 60MHz) down field from TMS and so on. The chemical shift of a particular kind of ‘H signal is its δ value with respect to TMS. It is called a chemical shift because it depends on the chemical environment of the instrument on which it is measured.

$$\text{Chemical shift} = \delta = \frac{\text{distance of peak from TMS, in } H_2}{\text{spectrometer frequency in } MH_2}$$

4.2.2 ^{13}C NMR Spectroscopy

Whereas ‘H NMR spectroscopy gives information about the arrangement of hydrogen in a molecule, ^{13}C NMR spectroscopy gives information about the carbon skeleton. The ordinary isotope of carbon–12, does not have a nuclear spin, but carbon–13 does. Carbon–13 constitutes only 1.1% of naturally occurring carbon atoms.

Also, the energy gap between the higher and lower spin state of ^{13}C is very small. For these two reasons, ^{13}C NMR spectrometers must be exceedingly sensitive, and ^{13}C NMR spectroscopy has become routine.

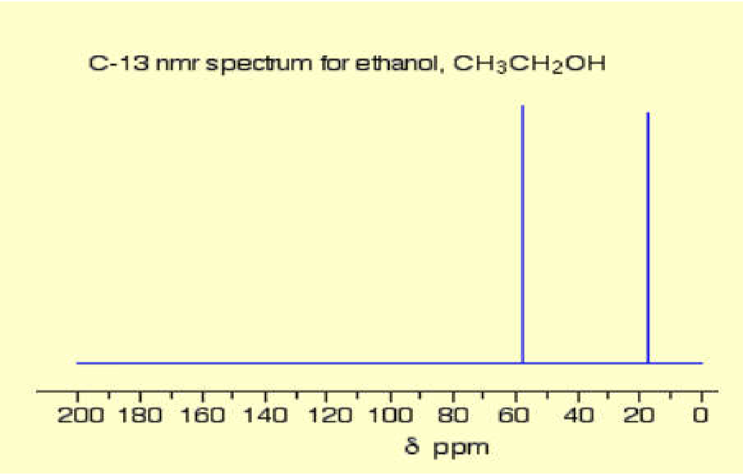
Carbon–13 spectra differ from ‘H spectra in several ways carbon–13 chemical shifts occur over a wider range than those of ‘H nuclei. They are measured against the same reference compound, TMS, whose methyl carbons are all equivalent and give a sharp signal. Chemical shifts for ^{13}C are reported in δ unit, but the usual range is about 0 to

200ppm down field from TMS (instead of the smaller range of 0 to 10ppm observed for ‘H) this wide range of chemical shifts tends to simplify ^{13}C spectra relative to ‘H spectra.

Because of the low natural abundance of 13C, the chance of finding two adjacent ^{13}C atoms in the same molecule is small. Hence ^{13}C–^{13}C–spin splitting is ordinarily not seen. This feature simplifies ^{13}C spectra. However, ^{13}C–‘H spin–spin splitting can occur.

SELF ASSESSMENT EXERCISE 11

Describe the ^{13}C spectrum of CH_3CH_2OH



4.3 INFRARED SPECTROSCOPY

Even though NMR spectroscopy is a powerful tool for deducing structures, it is usually supplemented by other spectroscopy methods that provide additional structural information. The more important of these is infrared spectroscopy.

Infrared frequency is usually expressed in units of wave number, define as the number of waves per centimeter. Ordinarily instruments scan the range of about 700 of muscle tissue, for example adenosine triphosphate (ATP), phosphocreatine, and inorganic phosphate. By comparing concentration changes of these components in normal people with those in patients with muscle disorder, the nature of the disorder and treatment can be advised.

In topical NMR, the NMR magnet is brought to the object being studied, instead of vice versa. A magnet prove of some sort placed on the surface induces resonances in molecule close to the surface, and useful ‘H, ^{13}C or ^{31}P spectra of molecules within living bodies can be obtained in this way. The method has been used, for example to monitor effects of various drugs on metabolic processes.

Magnetic resonance imaging (MRI) is a technique that has been used clinically in hospitals since the mid 1980’s. The method allows one to obtain internal images of the whole body parts and has several advantages over x-rays. For one, it is far less hazardous, since it does not cause radiation damage. For another, it gives good images of soft tissue, which are more difficult to obtain with x-rays.

The NMR was discovered by physicists and developed by chemists and is now being applied by biologist and others. The benefits to humanity could not have been foreseen in the beginning another example of the wisdom of investing fundamental research without immediate regard for practical applications.

Figure 1.2: *stretch and bending motions of a CH_2 group that require energies in the infrared region.*

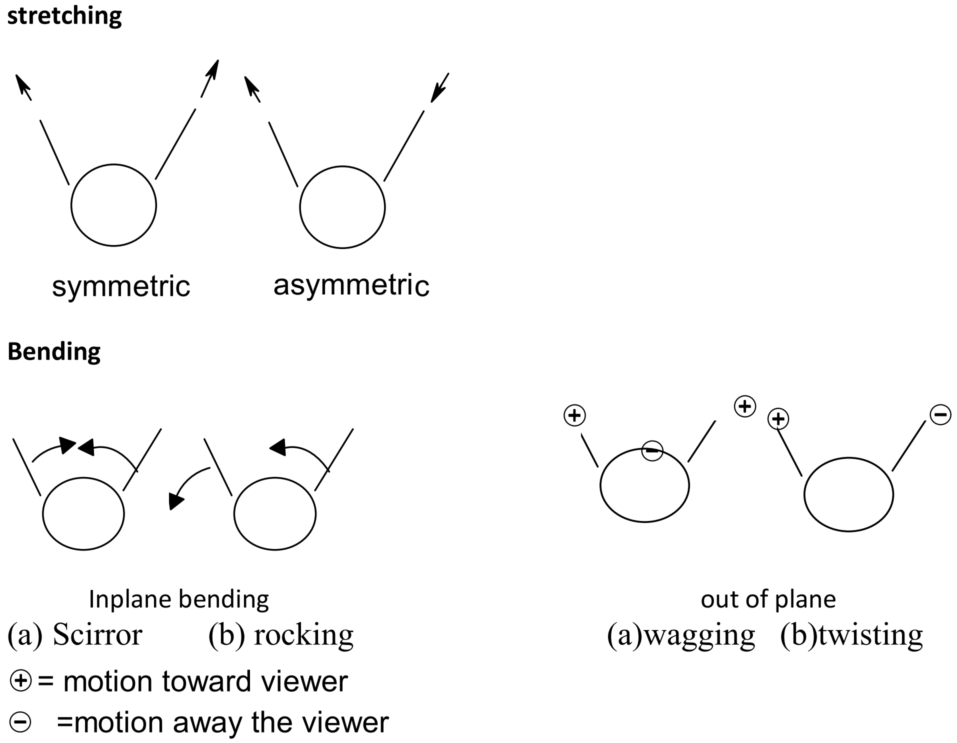
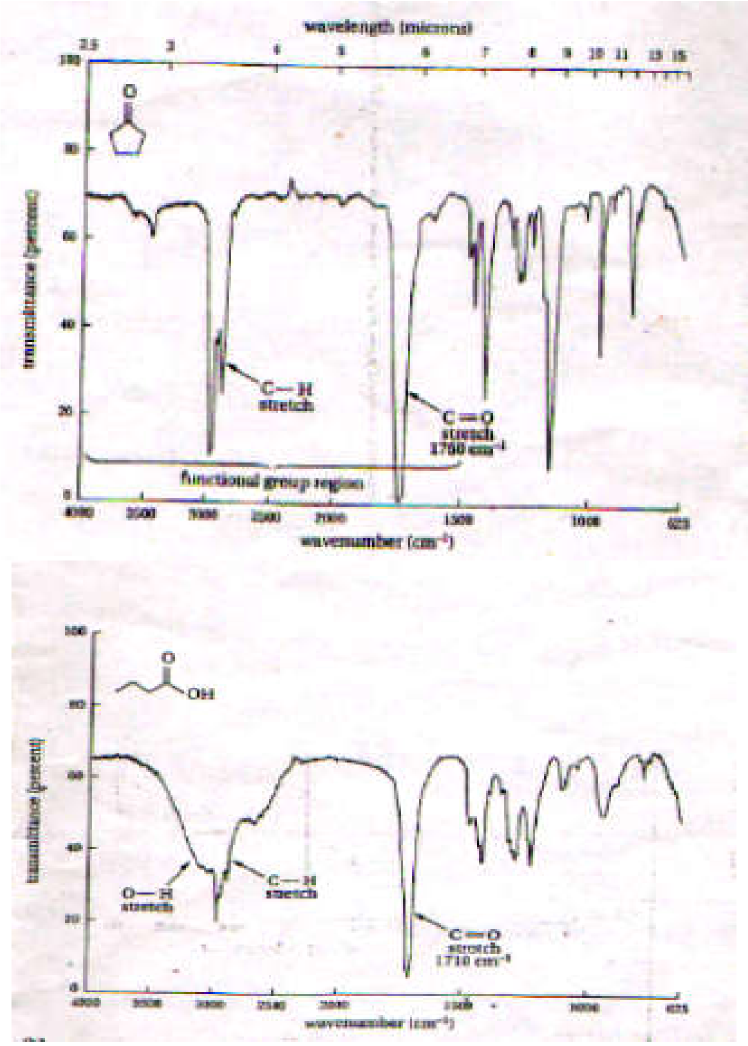
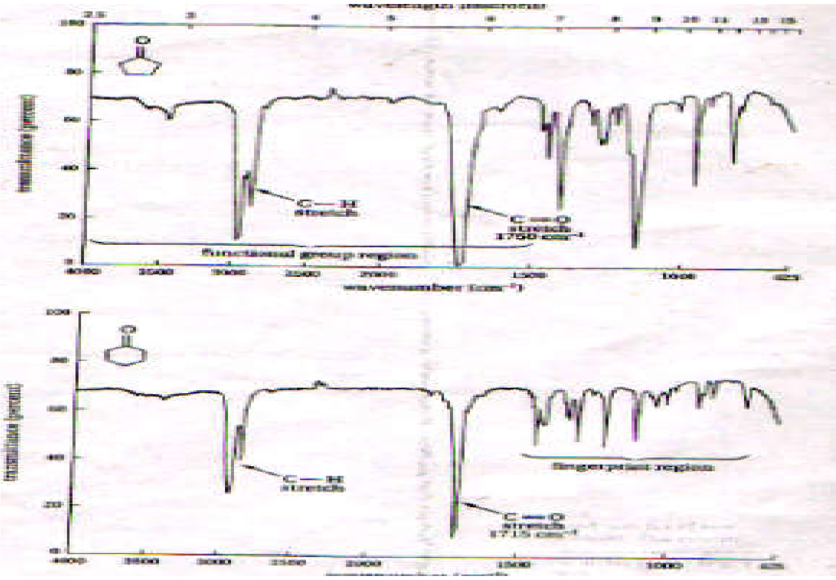


Figure 1.3: *infrared spectra of two similar ketones. The spectra have similar functional group bands but differ in the finger print region*



Spectral of 1 butanal, butanoic acid, and 1 butanamine illustrate typical functional group bands for alcohol, carboxylic acids, and amines in figure below:



4.4 Visible and ultraviolet spectroscopy

The visible region of the spectrum (visible to the human eye, Ultraviolet–visible spectroscopy or ultraviolet-visible spectrophotometry (UV-Vis or UV/Vis) refers to absorption spectroscopy or reflectance spectroscopy in the ultraviolet-visible spectral region. This means it uses light in the visible and adjacent (near-UV and near-infrared [NIR]) ranges. The absorption or reflectance in the visible range directly affects the perceived color of the chemicals involved. In this region of the electromagnetic spectrum, molecules undergo electronic transitions.

This technique is complementary to fluorescence spectroscopy, in that fluorescence deals with transitions from the excited state to the ground state, while absorption measures transitions from the ground state to the excited state. UV/Vis spectroscopy is routinely used in analytical chemistry for the quantitative determination of different analytes, such as transition metal ions, highly conjugated organic compounds, and biological macromolecules. Spectroscopic analysis is commonly carried out in solutions but solids and gases may also be studied.

- Solutions of transition metal ions can be colored (i.e., absorb visible light) because the electrons within the metal atoms can be excited from one electronic state to another. The colour of metal ion solutions is strongly affected by the presence of other species, such as certain anions or ligands. For instance, the colour of a dilute solution of copper sulfate is a very light blue; adding ammonia intensifies the colour and changes the wavelength of maximum absorption (λ_{max}).
- Organic compounds, especially those with a high degree of conjugation, also absorb light in the UV or visible regions of the electromagnetic spectrum. The solvents for these determinations are often water for water-soluble compounds, or ethanol for organic-soluble compounds. (Organic solvents may have significant UV absorption); not all solvents are suitable for use in UV spectroscopy. Ethanol absorbs very weakly at most wavelengths.) Solvent

polarity and pH can affect the absorption spectrum of an organic compound. Tyrosine, for example, increases in absorption maxima and molar extinction coefficient when pH increases from 6 to 13 or when solvent polarity decreases.
- While charge transfer complexes also give rise to colours, the colours are often too intense to be used for quantitative measurement.

The Beer-Lambert law states that the absorbance of a solution is directly proportional to the concentration of the absorbing species in the solution and the path length.

A= ECl (beer's law)

Were E is the molar absorptivity (extinction coefficient)
C is the concentration of the solution
L is the length in centimeterfor the sample

Thus, for a fixed path length, UV/Vis spectroscopy can be used to determine the concentration of the absorber in a solution. It is necessary to know how quickly the absorbance changes with concentration. This can be taken from references (tables of molar extinction coefficients), or more accurately, determined from a calibration curve.

A UV/Vis spectrophotometer may be used as a detector for HPLC. The presence of an analyst gives a response assumed to be proportional to the concentration. For accurate results, the instrument's response to the analyte in the unknown should be compared with the response to a standard; this is very similar to the use of calibration curves.

The response (e.g., peak height) for a particular concentration is known as the response factor.

5.0 CONCLUSION

Automated instruments have been developed that permit us to determine and record spectroscopic properties often with little more effort than pushing a button. And these spectra, if properly interpreted, yield a great deal of structural information.

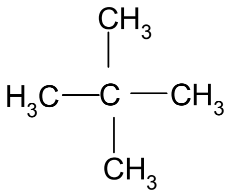
6.0 SUMMARY

In this unit, we have described the importance of spectroscopic techniques used today and how they can be applied to structural problems. We have also examined some general principles that formed the basis of most of these techniques.

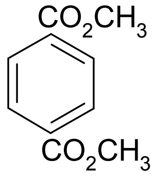
TUTOR-MARKED ASSIGNMENT

1. *How many pears do you expect to see in the 'H NMR spectrum of each of the following compounds? If you expect several peaks, what will their relative areas be?*

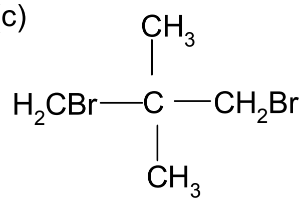
(a)



(b)



(c)



2. What is the effect of doubling the concentration of a particular absorbing sample on A and E in beer's law?

7.0 REFERENCES/FURTHER READING

Ababio, O. Y. (2011). *New School Chemistry* (6th Ed.), Africana First Publishers PLC, Nigeria.

Hart, H., Craine, L. E. & Hart, J. D. (2003). *Organic Chemistry: A short course* (11th Ed). Boston: Houghton Mifflin Company.

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UNIT 3: ELECTRONIC THEORY IN ORGANIC CHEMISTRY

CONTENTS

1.0 INTRODUCTION

The electronic theory is the basis upon which millions of facts about hundreds of thousands of individual compounds have been brought together and arranged in a systematic. It is the basis upon which these facts can best be accounted for and understood.

The electronic theory is the framework of ideas about how atoms are put together to make molecules. The theory has to do with the order in which atoms are attached to each other, and with the electrons that hold them together. It has to do with the shape and sizes of the molecules that these atoms form, and with the way that electrons are distributed over them. In this unit, we shall study how electrons are arranged in an atom and the way in which atoms react to form molecule and compounds. You are already familiar with the fact that compounds are divided into ionic and covalent compounds. Since, we are dealing with the chemistry of carbon compounds (organic chemistry), therefore, the covalent bond in carbon which includes the single bond and the multiple bonds will be studied. Finally, we will study the valence of carbons and other simple elements.

2.0 OBJECTIVES

After studying the unit, you should be able to:

- Identify the element that can form ionic and covalent bond based on the arrangement of electrons in their atoms.
- Write equation for the formation of a molecule
- Estimate the bond length of some simple molecule
- Use valences to write the structure of a compound

3.0 HOW TO STUDY THE UNIT

1. Read through the whole unit.
2. Reflect on the issues raised throughout the unit.
3. Read the unit again step by step to get deeper understanding of the unit.
4. Carry out all the activities.

4.0 HOW ELECTRONS ARE ARRANGED IN ATOMS

Atoms contain a small, dense nucleus surrounded by electrons. The nucleus is positively charged and contains most of the mass of the atom. The nucleus consists of protons, which are positively charged, and neutrons, which are neutral (the only exception is hydrogen whose nucleus consists of only a single proton). In a neutral atom, the positive charge of the nucleus is exactly balanced by the negative charge of the electrons that surround it. The atomic number of an element is equal to the number of protons in the nucleus (and to the number of electrons around the nucleus in a neutral atom. The atomic weight is approximately equal to the sum of the number of protons and the number of neutrons in the nucleus; the electrons are not counted because they are very light by comparison.

We are concerned here mainly with the atom's electrons because their number and arrangement provide the key to how a particular atom reacts with other atoms to form molecules. Also, we will deal with the electron arrangements in the lighter elements because these elements are the most important in organic molecules.

Electrons are concentrated in certain regions of space around the nucleus called orbitals. Each orbital can contain a maximum of two electrons. The orbitals, which differ in shape, are designated by the letters S, P and D. In addition, orbitals are grouped in shells designataed by the numbers 1, 2, 3 and so on. Each shell contains different types and numbers of orbitals, corresponding to the shell number. For example, shell 1 contains only one type orbital, designated the 1s orbital. Shell 2 contains two types of orbitals, 2s and 2p, and shell 3 contains three types of 3s, 3p and 3d. Within a particular shell, the number of s, p and d orbitals is 1, 3 and 5 respectively. These rules permit us to count how many electrons each shell will contain when it is filled. Table 4.0 below shows how the electrons of the first 18 elements are arranged:

Table 4.0: Electron arrangements of the first 18 elements

ATOMIC NUMBER	**ELEMENT**	**NUMBER OF ELECTRONS IN EACH ORBITAL**				
		1s	**2s**	**2p**	**3s**	**3p**
1	H	1				
2	He	2				
3	Li	2	1			
4	Be	2	2			
5	B	2	2	1		
6	C	2	2	2		
7	N	2	2	3		
8	O	2	2	4		
9	F	2	2	5		
10	Ne	2	2	6		
11	Na	2	2	6	1	
12	Mg	2	2	6	2	
13	Al	2	2	6	2	1
14	Si	2	2	6	2	2
15	P	2	2	6	2	3
16	S	2	2	6	2	4
17	Cl	2	2	6	2	5
18	Ar	2	2	6	2	6

The first shell is filled for helium (He) and all elements beyond, and the second shell is filled for neon (Ne) and all elements beyond. Filled shells play almost no role in chemical bonding. Rather, the outermost electrons, or valence electrons, are mainly involved in chemical bonding and we will focus our attention on them.

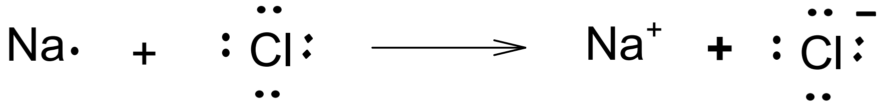
Armed with this information about atomic structure, we are now ready to tackle the problem of how element combine to form chemical bonds.

4.2 Ionic and Covalent Bonding

An early, but still useful, theory of chemical bonding was proposed in 1916 by Gilbert Newton Lewis, then a Professor at the University of California in Barkeley. Lewis noticed that the inert gas helium had only two electrons surrounding its nucleus and that the next inert gas neon had ten such electrons (2 + 8, see table 2.0). He concluded that atoms of these gases must have very stable electron arrangements because these elements do not combine with other atoms. He further suggested that other atoms might react in such a way as to achieve these stable arrangements. This stability could be achieved in one of two ways: by complete transfer of electrons from one atom to another or by sharing of electrons between atoms.

3.2.1 Ionic compounds

Ionic bonds are formed by the transfer of one or more valence electrons from one atom to another. Because electrons are negatively charged, the atom that gives up the electron(s) becomes positively charge (cation). The atom that receives the electron(s) becomes negatively charged (anion). The reation between sodium and chlorine atom to form sodium chloride (ordinary table salt) is a typical electron transfer reaction.



The sodium atom has only one valence electron (it is in the third shell; see Table 2.0). By giving up the electron, it achieves the electron arrangement of neon. At the same time it becomes positively charged, a sodium cation. The chlorine atom has seven valence electrons. By accepting an additional electron it achieves the electron arrangement of argon and becomes negatively charged, a chloride anion. Atoms, such as sodium, that tend to give up electrons are said to be electropositive. Often such atoms are metals. Atoms such as chlorine, that tend to accept electrons are said to be electronegative. Often such atoms are non-metals.

The product of the above equation is sodium chloride, an ionic compound made up of equal numbers of sodium and chloride ions. In general, ionic compounds form when strongly electropositive atoms and strongly electronegative atoms interact. The ions in a crystal of an ionic substance are held together by the attractive force between their opposite charges.

In a sense, the ionic bond is not really a bond at all. Being oppositely charged, the ions attract one another like the opposite poles of a magnet. In the crystal, the ions are packed in a definite arrangement, but we cannot say that any particular ion is bonded or connected to any other, particular ion. And, of course, when the substance is dissolved, the ions separate and are able to move about in solution relatively freely.

4.2.2 Covalent compound

Elements that are neither strongly electronegative nor strongly electropositive, or that have similar electronegativities, tend to form bonds by sharing electron pairs instead of completely transferring electrons. A covalent bond involves the mutual sharing of one or more electron pairs between atoms. Two (or more) atoms joined by covalent bonds constitute a molecule. When the two atoms are identical or have equal electronegativities, the electron pairs are shared equally. The hydrogen molecule is an example.

$$\mathrm{H}\cdot \quad + \quad \mathrm{H}\cdot \quad \longrightarrow \quad \mathrm{H} : \mathrm{H} \ + \ \text{heat}$$

Each hydrogen atom can be considered to have filled its first electron shell by the sharing process. That is, each atom is considered to "own" all the electrons it shares with the other atom, as shown by the loops in these structures.

The H – H bond is a very strong bond. The main reason for this is that the shared electron pair is attracted to both hydrogen nuclei, whereas in a hydrogen atom, the valence electron is associated with only one nucleus. But other forces in the hydrogen molecule tend to counter balance the attraction between the electron pair and the nuclei. These forces are the repulsion between the two like charged electrons. A balance is struck between an attractive and the repulsive forces. The hydrogen atoms neither fly apart nor fused together. Instead they remain connected, or bonded, and vibrate about some equilibrium distance, which we call the bond length. For a hydrogen molecule, the bond length (that is, the average distance between the two hydrogen nuclei) is 0.74A or 74pm.

Remember: Å = angstronm unit

1Å= 100pm

The length of a covalent bond depends on the atoms that are bonded and the number of electron pairs shared between the atoms. Bond lengths for some typical covalent bonds are given in Table 4.1:

Table 4.1: Bond lengths for some typical covalent bond

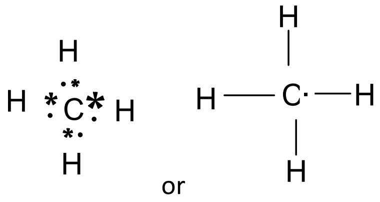
Bond	**Bond Length (pm)**	**Bond**	**Bond Length (pm)**
H – H	74	C – F	142
C – H	112	C – Cl	177
C – C	154	C – Br	191
C = C	134	C – I	213

C ≡ C	120	C – O	143
F – F	144	C = O	120
Cl – Cl	198	N – H	103
Br – Br	228	N – N	147
I – I	266	N = N	130
C – C in C_6H_6	139	C = N	130
O - H	97	C ≡ N	110

4.3 Carbon and the Covalent Bond

Now let us look at carbon and its bonding. We represent atomic carbon by the symbol $\cdot\overset{\bullet}{\underset{\cdot}{C}}\cdot$ where the letter C stands for the nucleus plus the two 1s electrons and the dots represent the valence electrons.

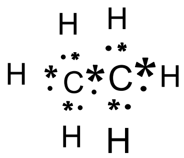
With four valence electrons, the valence shell of carbon is half filled (or half empty). Carbon atoms have neither a strong tendency to lose all their electrons (and become C^{4+}) nor a strong tendency to gain four electrons (and become C^{4-}), being in the middle of the periodic table. Instead, it usually forms covalent bonds with other atoms by sharing electrons. For example, carbon combines with four hydrogen atoms, each of which supplies one valence electron by sharing four electron pairs. The substance formed is known as methane.



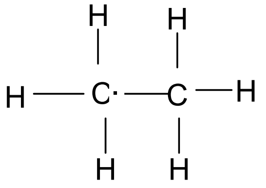
The shared electron pair is called a covalent bond because it bonds or links atoms by its attraction to both nuclei.

Carbon-Carbon Single Bonds

The unique property of carbon atoms – that is, the property that makes it possible for millions of organic compounds to exist- is their ability to share electrons not only with different elements but also with other carbon atoms. For example, two carbon atoms may be bonded to one another, and each of these carbon atoms may be linked to other atoms. In ethane and bexachloro ethane, each carbon is connected to the other carbon and to three hydrogen atoms or three chlorine atoms.



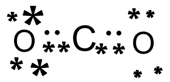
or



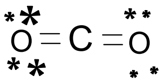
The carbon-carbon bond in ethane, like the hydrogen – hydrogen bond in a hydrogen molecule, is purely covalent bond, with the electrons shared equally between the two identical carbon atoms. As with the hydrogen molecule, heat is required to break the carbon – carbon bond of ethane to give two CH_3 fragments called methyl radicals. A radical is a molecular fragment with an odd number of unshared electrons.

4.5 Multiple Covalent Bond

To complete their valence shells, atoms may sometimes share more than one electron pair. Carbondioxide, CO_2 is an example. The carbon atom has four valence electrons, and each oxygen has six valence electrons. A structure that allows each atom to complete its valence shell with eight electrons is



or

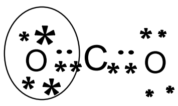


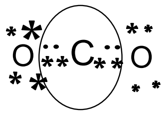
or

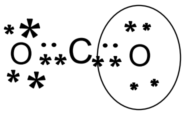
$O=C=O$

A B C

In structure A, the dots represent the electrons from carbon, and the x's are the electrons from the oxygen. Structure B shows the bonds and oxygen's unshared electrons, and structure C shows only the covalent bonds. Two electrons pairs are shared between carbon and oxygen. Consequently, the bond is called a double bond. Each oxygen atom also has two pairs of non bonding electrons, or unshared pairs of electron. The loops in the following structures show that each atom in carbon dioxide has a complete valence shell of eight electrons.

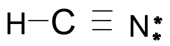






Hydrogen Cyanide, HCN, is an example of a simple compound with a triple bond, a bond in which three electron pairs are shared

or

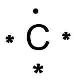
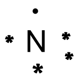
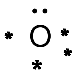
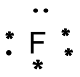
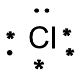


Hydrogen cyanide

4.6 Valence

The valence of an element is simply the number of bonds that an atom of the element can form. The number is usually equal to the number of electrons needed to fill the valence shell. Table 2.2 gives the common valences of several elements. Notice the different between the number of valence electrons and the valence. Oxygen for example, has six valence electrons but valence of only 2. The sum of the two numbers is equal to the number of electrons in the filled shell.

Table 4.2: Valences of Common Elements

Element						
Valence	1	4	3	2	1	1

The valences in Table 4.2 apply whether the bonds are single, double, or triple. For example, carbon has four bonds in each of the structures we have written so far: methane, ethane, carbon dioxide, and so on. These common valences are worth remembering, because they will help you to write correct structures.

SELF ASSESSMENT EXERCISE 12

(a) Write an equation for the reaction of lithium atoms (Li) with bromine atoms (Br).

(b) Using Table 4.0, determine what charge the ion will carry when each of the following elements reacts to form an ionic compound: Al, Li, S, H.

(c) Judging from its position in Table 4.0, do you expect carbon to be electropositive or electronegative?

5.0 CONCLUSION

We have studied the arrangement of electrons in atoms and the general features of ionic and covalent bond. The bond length for different molecules were also studied and the structure of compounds using the valences of their constituents atoms.

6.0 SUMMARY

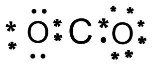
In this unit, you have studied the arrangement of electrons in carbon and other atoms. You have also studied the general features of covalent bond which is the bond occurring in all the compounds of carbon and is responsible for the formation of organic compounds. Structure of simple covalent compounds using valences were also seen

TUTOR-MARKED ASSIGNMENT

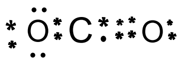
1. Write an equation for the formation of a fluorine molecule from two fluorine atoms.
2. Using the structure of ethane as a guide, draw the structure for propane, C_3H_8.
3. what is wrong with each of the following electron arrangements for carbon dioxide

(i)

(ii)



(iii)



4. Does C_2H_5 represent a stable molecule?

7.0 REFERENCES/FURTHER READINGS

Ababio, O. Y. (2011). *New School Chemistry* (6th Ed.), Africana First Publishers PLC, Nigeria.

Hart, H., Craine, L. E. & Hart, J. D. (2003). *Organic Chemistry: A short course* (11th Ed). Boston: Houghton Mifflin Company.

Morrison, R. T. & Boyd, R. N. (2011). *Organic Chemistry* (7th Ed.), India: Prentice-Hall, Ltd.

UNIT 4: SATURATED AND UNSATURATED HYDROCARBONS AND THEIR REACTIONS

TABLE OF CONTENTS

1.0 INTRODUCTION

2.0 OBJECTIVES

After studying the unit, you should be able to:

- Identify saturated hydrocarbon.
- Write equation of alkanes, alkene and alkynes.
- Know the physical and chemical properties of saturated and unsaturated hydrocarbon.

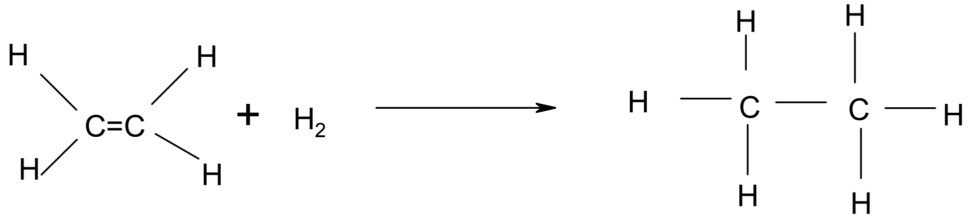
3.0 HOW TO STUDY THE UNIT

1. Read through the whole unit.
2. Reflect on the issues raised throughout the unit.
3. Read the unit again step by step to get deeper understanding of the unit.
4. Carry out all the activities.

4.0 MAIN CONTENT

4.1 Saturated Hydrocarbon and their reactions

Hydrocarbons are compounds composed of carbon and hydrogen. Those compounds whose carbon – carbon bonds are all single bonds are said to be saturated, because each carbon is bond to four atoms, the maximum number. Hydrocarbon containing carbon – carbon multiple bonds are described as being unsaturated, since the carbon atoms involved in a multiple bonds can react with additional atoms, as shown by the addition of hydrogen to ethylene:



Unsaturated saturated

In the above chemical equation each carbon in ethylene is bonded to three atoms (one carbon and two hydrogen) but that each can bond one additional atom of one bond of the carbon – carbon double bondies broken.

The singlast – member of the saturated hydrocarbon, which are also called alkanes, is methane (CH4). Methane has a tetrahedral structure and can be describe in terms of carbon atom using SP3 hybrid set of orbitals to bond to the four hydrogen atoms (See figure 4.1)

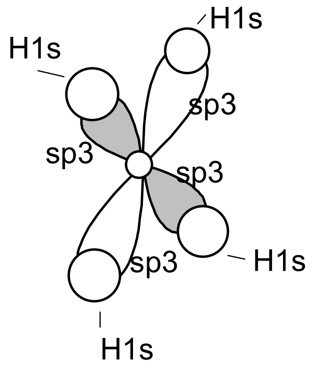
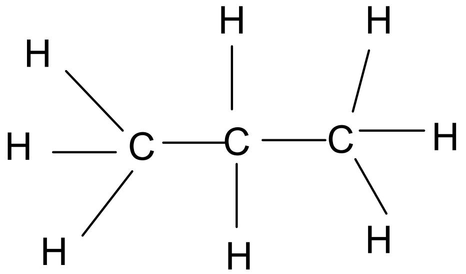


Figure 4.1: *the C H bond in methane*

Alkanes on which the carbon atoms form long “string” or chains are called normal, straight – chain, or unbounded hydrocarbon.



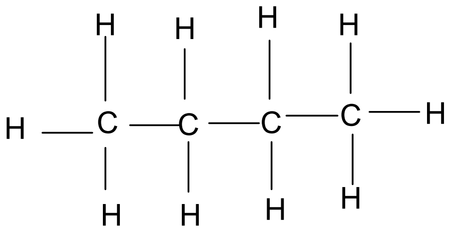
Alkanes are represented by the general formula Cn H_{2n+2}, Where n is an integer.. The first ten normal alkanes and some of their proportion are listed in table 1. Note that the melting and boiling points increase as the molar mass increases.

Table 5.0: *Properties of the First Ten Normal Alkanes*

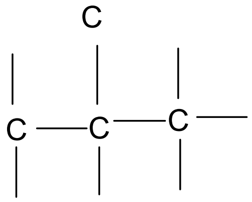
NAME	FORMULA	MOLAR MASS	MELTING POINT (^{O}C)	BOILING POINT (^{O}C)	NUMBER OF THE STRUCTUE ISOMERS
Methane	CH_4	16	- 182	- 162	1
Ethane	$C_2 H_6$	30	- 183	- 89	1
Propane	$C_3 H_8$	44	- 187	- 42	1
Butane	$C_4 H_{10}$	58	- 138	0	2
Pentane	$C_5 H_{12}$	72	- 130	36	3
Hearne	$C_6 H_{14}$	86	- 97	68	5
Heptane	$C_7 H_{16}$	100	- 91	98	9
Octane	$C_8 H_{18}$	114	- 57	126	18
Nonane	$C_9 H_{20}$	128	- 54	151	35
Deane	$C_{10} H_{22}$	142	- 30	174	78

4.2 Isomerism in Alkanes

Butane and all succeeding member of the alkanes exhibit structural isomerism. Structural isomerism occurs when two molecules have the same atoms but differ in butane, for example, butane can exit as a straight chain molecules (normal butane or n-butane) or with a branched – chain structure (called iso butane);



n–butane

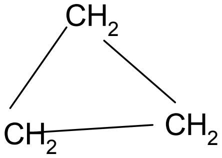


Isobutane

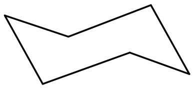
Because of their different structures, these molecules have different properties. The bp of n-butane is $-0.5^{\circ}C$, whereas that of iso butane is $12^{\circ}C$.

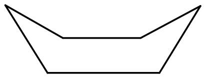
4.3 Cyclic Alkanes

Besides forming in chain, carbon atoms form rings. The simplest of the cyclic alkanes (general formular CnH2n) is cyclo propane



The carbon atoms in cyclopropane forms an equilateral triangle with 60^{o} bond angles, the sp^3 Hybrid orbital do not develop head – on as in normal alkanes. This result in usually weak, or strained, C–C bonds; thus the cyclo propane molecule is much more straight – chained propane. Among the cyclo alkanes, cyclo haxone can exist in two forms, the "chair" and the "boat" forms as follows:


chair form


boat form

4.4 Reactions of Alkanes

Because they are saturated compounds and because the C–C and C–H bonds are relatively strong, alkanes are fairly unreactive. For example at $25^{o}C$ they do not react on the acids, bases or strong oxidizing agents, this chemical inertness makes them valuable as lubricating materials and as the backbone for structural materials such as plastics.

At a sufficiently high temperature alkanes do react ingloriously and exothermically with oxygen, and these combustion reactions are the basis for their wide spread use as fuel. For example, the reaction of butane with oxygen is

$$\mathbf{2C_4H_{10}(g) + 13O_2(g) \longrightarrow 8CO_2(g) + 10H_2O(g)}$$

Alkenes can undergo substitution reactions, primarily where halogen atoms replace hydrogen atoms. For example, methane can be successively chlorinated as follows:

$$\mathbf{CH_4 + Cl_2 \xrightarrow{hv} \underset{\text{chloromethane}}{CH_3Cl} + HCl}$$

$$\mathbf{CH_3Cl + Cl_2 \xrightarrow{hv} \underset{\text{Dichloromethane}}{CH_2Cl_2} + HCl}$$

$$\mathbf{CH_2Cl_2 + Cl_2 \longrightarrow CHCl_3 + HCl}$$

Trichloromethane

$$\mathbf{CHCl_3 + Cl_2 \longrightarrow CCl_4 + HCl}$$

Tetrachloromethane

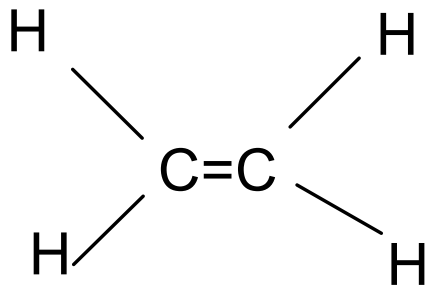
Alkenes can also undergo de hydrogenation reaction in which the hydrogen atoms are removed and the product is an unsaturated hydrocarbon. For example, in the presence of chromium (III) oxide at high temperature, ethane can be de hydrogenated yielding ethylene.

$$CH_3CH_3 \xrightarrow[500^{\circ}]{Cr_2O_3} CH_2{=}CH_2 + H_2$$

Ethane ethylene

4.5 Unsaturated Hydrocarbon Alkenes

Multiple carbon – carbon bonds result when hydrogen atoms are removed from alkanes. Hydrocarbon that contain at least one carbon – carbon double bond are called alkenes and have the general formula C_2 H_4), commonly known as ethylene, has the lewis structure



Each carbon atom in ethylene can be descended as SP^2 orbitals, and X bond is formed by sharing a pair of electrons P orbitals.

4.6 Alkynes

Alkynes are unsaturated hydrocarbon containing at least one triple carbon bond. The systematic name ethyne. The triple bond in ethyne can be described as one O bond betoken SP two SP hybrid orbitals on the two carbon atoms and π bonds involving two 2p orbitals on each carbon atom.

$$H - C \equiv C - H$$

Ethyne

4.7 Reactions of Alkenes and Alkynes

Because alkenes and alkynes are unsaturated, their most important reactions. In these reaction π bonds, which are weaker than the $C-C$ 6 bonds, are broken, and new 6 bonds are formed to the atoms being added for example,. Hydrogenation reactions involve the addition of hydrogen atoms:

$$CH_2{=}CHCH_3 + H_2 \xrightarrow{\text{catalyts}} CH_3CH_2CH_3$$

1 propane propane

For this reaction to proceed rapidly at normal temperatures, a catalyst of platimuny Palladrim, or nickel is used. The catalyst serves to help break the relatively strong H – H bond. Hydrogenation of alkenes is an important industrial process, particularly in the manufacture of solid shortening where unsaturated fats (fats containing double bonds), which are generally liquid, are converted to solid saturated fats.

Halogeration of unsaturated hydrocarbons involves addition of halogen atoms for example:

$$CH_2{=}CHCH_2CH_2CH_3 + Br_2 \longrightarrow CH_2BrCHBrCH_2CH_2CH_3$$

Polymerization is another reaction involving unsaturated hydrocarbons. It is a process in which many small molecules are joined together to form a large molecule.

SELF ASSESSMENT EXCERSICE 13

Give 2 reactions of alkane, alkene and alkyne.

5.0 CONCLUSION

In this unit we studied saturated and unsaturated hydrocarbons, their reactions, and also we studied some of their physical and chemical properties such as melting point, boiling point and so on. We also studied isomerism in hydrocarbons.

6.0 SUMMARY

Unsaturated hydrocarbon are compound that has one or more double or triple bond include alkene (example ethane, pentene, decene and so on) and alkyne (examples ethyne, propyne, hexyne and so on) while saturated hydrocarbons are those that posses one or more single bonds include all alkane (example methane, butane, heptane and so on). The melting point and the boiling point of alkane increases as the number of carbon atom increase. And also the number of possible isomers increases as the number of carbon atom increases. Alkanes react with nonmetals and also with metal to form a compound. Alkene and alkyne are sp2 and sp hybridise compound, react with hydrogen to form alkanes, also react with Halogens forming haloalkanes.

TUTOR-MARKED ASSIGNMENT

Enumerate the reactions of alkane

7.0 REFERENCES AND FURTHER READING

Ababio, O. Y. (2011). *New School Chemistry* (6th Ed.), Africana First Publishers PLC, Nigeria.

Hart, H., Craine, L. E. & Hart, J. D. (2003). *Organic Chemistry: A short course* (11th Ed). Boston: Houghton Mifflin Company.

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UNIT 5: THE CHEMISTRY OF SELECTED METALS AND NON-METALS

1.0 INTRODUCTION

On the basis of their general physical and chemical properties, every element in the periodic table can be termed either a metal or a nonmetal. (A few elements with intermediate properties are referred to as metalloids). Metals are one of the most important elements in the periodic table because of some of their properties which make them to be used for various purposes. Metals are solid of group 1 (alkali metals) and 2 (alkaline earth metals) of the periodic table, they include sodium, lithium, potassium

2.0 OBJECTIVES

After studying the unit, you should be able to:

- Identify metals and non metals
- Know the importance of metals and non metals
- Know the physical and chemical properties of metals and non metals

4.0 HOW TO STUDY THE UNIT

1. Read through the whole unit.
2. Reflect on the issues raised throughout the unit.
3. Read the unit again step by step to get deeper understanding of the unit.
4. Carry out all the activities.

5.0 Main content:

5.1 Metals: General properties of metals

Physical properties of metals

Metals show following general physical properties.

1) Physical state - Metals are solids at room temperature e.g. sodium, aluminum, potassium, magnesium. Mercury and gallium are metals but they are in liquid state at room temperature.

2) Luster – Metals have a shining surface called luster when freshly prepared. They have a quality of reflecting light from their surface and they can be polished e.g. metals like gold, silver, copper show this property.

3) Malleability - Metals can be beaten into thin sheets. This property is called malleability. Due to this property, metals can be rolled into sheets e.g. aluminum, copper, zinc can be beaten into sheets.

4) Ductility - Metals can be drawn into thin wires. This property is called ductility. For example, 100 grams of silver can be drawn into a thin wire about 200 meters long.

5) Hardness – Metals are generally hard e.g. iron, cobalt, nickel. There are few exceptions to this. Sodium and potassium are soft and they can be cut with a knife.

6) Conduction – Generally, metals are good conductors of heat and electricity because they have free electrons. Silver and copper are the two best conductors. Relatively, lead and bismuth are poor conductors of heat and electricity.

7) Density - Metals generally have high density and they are heavy. Iridium and osmium have the highest densities while lithium has the lowest density.

8) Melting and boiling point – Metals usually have high melting point and boiling point.
For example, iron, cobalt and nickel have high melting and boiling point. Tungsten has the highest melting point. There are some exceptions to this. For example, most of the alkali metals have low melting and boiling point.

9) Tensile strength – Most of the metals possess high tensile strength i.e. tenacity. For example, iron, titanium, some alloys have high tensile strength. However, elements like sodium, potassium and mercury do not possess tenacity.

Chemical properties of metals

Metals show following general chemical properties.

1) Electron configuration – Metals usually have 1 to 3 electrons in the outermost shell of their atom. For example, sodium, magnesium and aluminium have 1, 2 and 3 electrons respectively in the outermost shell of their atom.

2) Valency- Metal atoms can lose 1 to 3 electrons in their outermost shell and show valencies1 to 3.

3) Electrochemical nature - Metal atoms have tendency to lose electrons and form cations. This tendency is called the electropositive nature. Metals generally have moderate to high electropositive nature. For example, Na, Mg and Al have high electropositive character while Zn, Cd, Sn and Pb have moderate electropositive nature.

4) Electronegativity - Metals generally have low electronegativity i.e. tendency to attract electrons in the state of molecule. For example, metals like Ca, Mg, Al, Zn have low electronegativity.

5) Formation of oxides – Metals form oxides which are generally ionic and basic in nature. If this basic oxide dissolves in water, it forms an alkali. For example, oxides of Na, K and Ca viz. Na2O, K2O and CaO are highly basic in nature and when dissolved in water, they form alkalis NaOH, KOH and Ca(OH)2. The oxides react with acids to form salts. Oxides of metals like Pb, Zn, Al and Sn viz. PbO2, ZnO, Al2O3 and SnO2 are moderately basic and they react with acids as well as alkalis to form salt. So such oxides are called amphoteric oxides. The oxides Sb2O3 and Cr2O3 are exceptions and they are acidic in nature.

6) Reducing agent - All metals act as reducing agents. Strongly electropositive metals like Mg, Al and Cr act as strong reducing agents while moderately electropositive elements like Zn, Cd and Sn act as moderate reducing agents.

7) Reaction with water - Strongly electropositive metals like Na and K react even with cold water to produce their hydroxides and they evolve hydrogen gas. The heat evolved is not sufficient for the hydrogen to catch fire. Metals like Mg do not react with cold water. They react only with hot water to form hydroxide evolving hydrogen. The elements less electropositive than Na, K and Mg like Al, Fe and Zn do not react with cold or hot water. These hot metals react only with steam to form their oxides and hydrogen .However, metals like Cu, Ag and Au which are below hydrogen in the activity series do not react with water at all.

8) Reaction with acids - Highly reactive metals like Na, Mg and K react with dilute mineral acids like HCl or H2SO4 to form salt and hydrogen gas. These reactions are displacement reactions. If nitric acid is used, the hydrogen evolved gets oxidized to water and hence no hydrogen gas is evolved. Metals like Cu, Ag and Au which are below hydrogen in the reactivity series do not react with dilute mineral acids and do not evolve H_2.

9) Reaction with non-metals - Metals like Mg, Ca, Al etc. react with non-metals like H, S, Cl, Br and I under different conditions of temperature to form their respective salts. However, all metals are not equally reactive so they require different conditions to react with non-metals.

4.2 Alkali Metals

The alkali metals belong to Group 1A in the periodic table of elements with ns1 valence – election configurations. They are all very active metals except (they lose their valance election very readily), except for hydrogen, which behaves as a non-metal. The source and methods of preparation of fuse alkali metals in given in Table 4.1. The ionization energies, standard reduction potentials, ionic radii, and melting points form are listed in Table 5.1 below:

Table 5.1: Sources and Methods of Preparation of the pose Alkali Metals

Element	**Source**	**Method of Preparation**
Lithium	Silicate minerals such as spodumene $LiA(Si_2O_6)$	Electrolysis of molten LiCl
Sodium	NaCl	Electrolysis of molten NaCl
Potassium	KCl	Electrolysis of molten KCl
Rubidium	Impurity in lepidolite $Li_2(F,OH)_2Al_2(SiO_3)_3$	Reduction of RbOH with Mg and H_2
Caesium	($C_{s4}A1_4Si_9$. H_2O) and an impurity in lepidolite.	Reduction of CsOH with Mg and H_2

All alkali metals react vigorously with water to replace hydrogen gas:

Based on the ionization energies, we might accept lithium to be the weakest of the alkali metals as a reducing agent in water. However, the standard reduction potential indicates that it is the strongest. This reversal result mainly from the very large energy of hydration of the both small Lit ion Because of its relatively high charge density, the Lit ion very effectively attracts water molecules. A large quantity of energy is released in the process, forming the formation of the Lit ion and melting lithium a strong reducing agent in aqueous solution.

Table 5.2 Selected Physical Properties of the alkali Metals

. . Element	Ionization Energy (KJ/mol)	Standard Reaction Potential (V) For $M^+ + \acute{e} \rightarrow M$	Radius 2 M^+ (pm)	Melting Point (℃)
Lithium	520	- 3.05	60	180
Sodium	495	- 2.71	95	98
Potassium	419	- 2.92	133	63
Rubidium	409	- 2.99	148	39
Caesium	382	- 3.02	169	29

Lithium reacts more strongly with water than does sodium or potassium do, because as a solid it has a higher melting point than either of them. It does not become molten from the heat of reaction with water as sodium and potassium do, and thus it has a smaller area of contact with the water. The relative ease with which the alkali metals lose elements to from M^+ cation means that they react with non-metals to forms ionic compounds. Although it might be expected that the alkali metals will react with oxygen to form regular oxides of the general formula M_2 O, lithium is the only one that does so in the presence of excess oxygen gas:

Sodium forms solid N_2O if the oxygen supply is limited, in excess oxygen it from Sodium Peroxide:

Sodium peroxide contains the basic O_2^{2}- anion and reacts with water to form hydrogen peroxide and hydroxide ions:

Hydrogen peroxide is a strong axidizing agent often used as bleach for hair and as a disinfectant Potassium, rubidium and lesium react with oxygen to produce super oxides of the general formula MO_2 which contains the O_2^{2}- anion. For example, potassium reacts with oxygen as follows:

The super oxides release oxygen gas in reaction with water or carbon dioxide.

This chemistry makes supper oxides very useful in the self – contained breathing apparentness used by fire-fighters. The types of compounds formed by alkali metals with oxygen are summarized in Table 5.3:

Table 5.3 Types of Compounds Formed by the Alkali Metal with Oxygen

General Formula	Name	Example
M_2O	Oxide	Li_2O, Na_2O
M_2O_2	Peroxide	$Na_2 O_2$
MO_2	Superoxide	KO_2, RbO_2 $Cs O_2$

Other reactions of alkali metals include.

$2 M + S \rightarrow M_2 S$ (M = K, Rb or $C_{s)}$
2 Li + N2 → 2 Liz N

4.3 Importance of Alkali Metals

The alkali metal ions are very important for the proper functioning of biologic systems, such as nervous and muscle, and Na + and K+ ions are present in all body cells and fluids. In human blood plasma the concentration is:

$[Na^+] = 0.05M$ and $[K^+] = 0.005$ M

For the fluids inside the cells the concentrations are reversed:
$[Na^+] = 0.005M$ and $[K^+] = 0.16$ M.

Since the concentrations are so different inside and outside the cells, an elaborate mechanism is needed to transport Na^+ and K^+ ions through the cell members.

SELF ASSESSMENT EXERCISE 14

Predict the products formed by the following reactions:
(a) Li_3 N(s) and H_2O(1)
(b) K_2O(s) and H_2O (1)

4.4 NON METALS: General properties

Physical properties of non-metals

Non- metals are elements of groups 5, 6, 7 and the noble gases in the periodic table show properties opposite to that of metals. Non-metals show following general physical properties.

1) Physical state – Non-metals can exist in solid or liquid or gaseous state at room temperature. For example, carbon, sulphur, phosphorus, iodine are in solid state, bromine is in liquid state while oxygen, nitrogen, chlorine are in gaseous state at room temperature.

2) Luster – Non-metals do not have luster. They do not reflect light from their surface. (exception – diamond and iodine) Non-metals have dull appearance. For example, sulphur, phosphorus and carbon show this property.

3) Malleability - Non-metals are non-malleable. If solids, they are brittle i.e. they break or shatter on hammering. For example, coal, sulphur, phosphorus are brittle.

4) Ductility – Non-metals cannot be drawn into thin wires. So they are not ductile.

5) Hardness – Non-metals are usually not hard. They are soft. For example, coal, sulphur and phosphorus are soft. Diamond is exception to this. It is the hardest substance known.

6) Conduction - Non- metals are usually poor conductors of heat and electricity. However, carbon in the form of gas carbon and graphite is exception to this. These forms of carbon are good conductors of electricity.

7) Density – Non- metals which are gases have low density. Solid non-metals have low to moderate density. They are medium light. For example, sulphur, phosphorus and boron have densities 1.82, 2.07 and 2.34 respectively. . However, diamond has high density which is about 3.5.

8) Melting and boiling point – Non-metals usually have low melting and boiling points. For example, phosphorus, sulphur, and iodine have melting points 440, 1150 and 1140 C respectively and boiling points 2800, 4450 and 1840C respectively. . However, carbon, silicon and boron possess very high melting and boiling points.

9) Tensile strength – Non-metals have low tensile strength i.e. they have no tenacity.

Chemical properties of non - metals

Non – metals show following general chemical properties

1) **Electron configuration** – Non -metals usually have 4 to 8 electrons in their outermost shell. For example, C, N, O, F and Ne have 4, 5, 6, 7 and 8 electrons in their outer most shell respectively.

2) **Valency** - Non - metals can gain or share 1 to 4 electrons in their outermost shell and show valencies 1 to 4. Sometimes, they show valency 5 to 7. For example, P shows valency 5 in P_2O_5, S shows valency 6 in SO_3 and Cl shows valency 7 in $HClO_4$.

3) **Electrochemical nature** - Non – metal atoms have tendency to gain electrons and form anions or share electrons with other non-metals to form covalent bonds. Non - metals generally have moderate to high electronegative nature. For example, Cl, O and N have high electronegative nature while Si, P, S and I have moderate electronegative nature.

4) **Electronegativity** - Non - metals generally have high electronegativity i.e. tendency to attract electrons in the state of molecule. For example, non - metals like F, Cl, O and N have high electronegativity.

5) **Formation of oxides** – Non- metals form oxides which are generally covalent and acidic in nature. If this acidic oxide dissolves in water, it forms an oxyacid. For example, oxides of Cl, P and S viz. $C_{l2}O_7$, P_2O_5 and SO_3 are highly acidic in nature and when dissolved in water, they form acids like $HClO_4$, H_3PO_4 and H_2SO_4. These oxides react with alkalies to form salts. Oxides of non- metals like C, H and N i.e. CO, H_2O and NO are neutral.

6) Oxidizing agent - All non - metals (except carbon) act as oxidizing agents. Strongly electronegative elements such as F, Cl and O act as strong oxidizing agents while moderately electronegative elements like sulphur, bromine and iodine act as moderate oxidizing agents. Carbon sometimes acts as a reducing agent.

7) Reaction with water - Non-metals do not react with water. Whether the water is in the form of cold water, hot water or steam, all non-metals remain unresponsive to water. The reason for this is that non-metals are electronegative and are unable to break the bond between H and O in water.

8) Reaction with acids: Most non-metals do not react with non-oxidizing acids. They are not capable of replacing hydrogen from the acids and forming a salt. For example, C, S or P do not react with dilute and concentrated HCl or dilute H2SO4 to give off hydrogen. Concentrated nitric acid, dilute nitric acid and concentrated sulphuric acid act as oxidizing agents and react with non – metals to form their oxides or acids. Nonmetals like N, O, Si, halogens and noble gases are exception to this and they do not react with these acids. Usually solid non-metals react with these oxidizing acids.

4.5 CHEMISTRY OF OXYGEN

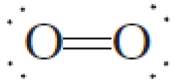
It is hard to overstate the importance of oxygen. Oxygen is the most abundant element on this planet. The earth's crust is 46.6% oxygen by mass, the oceans are 86% oxygen by mass, and the atmosphere is 21% oxygen by volume. Oxygen was first discovered by scheede in 1772 and priestly in 1774 rediscover it two years after by heating the oxide of mercury. The name *oxygen* comes from the Greek stems *oxys,* "acid," and *gennan,* "to form or generate." Thus, oxygen literally means the "acid former." The name was introduced by Lavoisier, who noticed that compounds rich in oxygen, such as SO_2 and P_4O_{10}, dissolve in water to give acids

$$SO_2(g) + H_2O(aq) \longrightarrow H_2SO_3(aq)$$
$$P_4O_{10}(s) + 6\,H_2O(aq) \longrightarrow 4\,H_3PO_4(aq)$$

The electron configuration of an oxygen atom

$1s^22s^22p^2$
or
$[He]\ 2s^2\ 2p^4$

Suggests that O atoms can achieve an octet of valence electrons by sharing two pairs of electrons to form an OO double bond, as shown in the Figure below:



Lewis structure of oxygen (O_2)

The most common elemental form (allotrope) of Oxygen (O_2) constitutes 21% of the volume of the earth's atmosphere. Liquid oxygen is a pale blue liquid that freezes at –219^oC and boils at –183^oC. According to the Lewis structure, all of the electrons in the O2 molecule are paired. The compound should therefore be **diamagnetic**—it should be *repelled* by a magnetic field. Experimentally, O_2 is found to be **paramagnetic**—it is *attracted* to a magnetic field. This can be explained using molecular orbital theory, which predicts that there are two unpaired electrons in the π^* antibonding molecular orbitals of the O_2 molecule. Also the paramagnetism of the O_2 molecule can be demonstrated by pouring liquid oxygen between the poles of a strong magnet, where it "sticks" as it boils away. Its paramagnetism can also be accounted for by the molecular orbital model which also explains its bond strength.

LABORATORY PREPARATION OF OXYGEN

Oxygen can be prepared in the laboratory in two ways

1. Thermal decomposition of potassium trioxochlorate (v).
   This can be done by heating potassium trioxochlorate (v) using manganese (iv) oxide as catalyst.

   $$KClO_3 \xrightarrow[MnO_2]{heat} 2KCl + 3O_2$$

2. From hydrogen peroxide (H_2O_2)
   This method requires no heat that makes it the most convenient method. 20cm^3 of hydrogen peroxide (H_2O_2) solution is added through the dropping funnel drop by drop to manganese (iv) oxide which catalyses the decomposition of the peroxide and oxygen is librated.

   $$2H_2O_2 \xrightarrow{MnO_2} 2H_2O + O_2(g)$$

INDUSTRIAL PREPARATION OF OXYGEN

Oxygen is obtained from liquid air; air in the gaseous form is passed through caustic soda to remove carbon dioxide. The purified air is forced under pressure 200atm, through the cooled tube at right side. The cooled air is passed into the cooled tube at the left where it is further cooled. The cooled air suddenly expands as it comes out from the jet. This sudden expansion of the air into a region of lower pressure causes it to cool even further. The cooled air will cool even further. The cooled air will cooled the incoming stream of air thus the air circulates again and again through the whole apparatus becoming cooler and cooler until it begins to liquefy at -200^oC.

The liquid air is then passed into a fractionating column. Nitrogen which is more volatile boils out first at a temperature of -196^oC, and is collected as liquid nitrogen. Oxygen boils out at -186^oC and is collected as liquid oxygen.

Oxygen is sold as a gas compressed in strong steel cylinder not as a liquid.

PHYSICAL PROPERTIES OF OXYGEN

1. Oxygen is slightly soluble in water; three volumes dissolve in a hundred volumes at 20°C and normal pressure.
2. Pure oxygen is colorless, odorless, and tasteless.
3. It is neutral to litmus paper.
4. Gaseous oxygen is approximately 1-1 times denser than air.
5. Gaseous oxygen liquefies at -183°C and solidifies at -225°C.

CHEMICAL PROPERTIES OF OXYGEN

Oxygen is an Oxidizing Agent. It combines with many metals and non metals producing basic (alkaline) and acidic oxide examples

Basic $4Na + O_2 \longrightarrow 2Na_2O$

$2Ca + O2 \longrightarrow 2CaO$

$2Mg + O_2 \longrightarrow 2MgO$

Acidic $C + O_2(g) \longrightarrow CO_2(g) + H_2O \longrightarrow H_2CO_3$ Trioxocarbonate (iv) acid

$P_4(s) + 5O_2(g) \longrightarrow P_4O_{10}(s)$

USES OF OXYGEN

1. Oxygen from air is breathed in by animals. In hospital, pure oxygen is given to patients suffering from respiratory complaints. It is also used by divers and people at high altitudes.
2. Oxygen is also used in the manufacture of important chemical compounds like tetraoxosulphate (iv) acid, trioxonitrate (v) acid and ethanoic acid.
3. Oxygen is used in the making steel for the removal of carbon, sulphur and phosphorous impurities from pig iron. A great and increase oxygen tonnage is now used in this way.
4. Liquid oxygen and fuels are used as propellent for space rockets.
5. Oxygen is used in the industry in the following ways; **Oxy-ethyne flame**: oxygen is used in the oxyethyne flame which has a temperature of about 3000°. the flame is used to cut through metals like steel.

   oxygen-hydrogen blow pipe: when oxygen is mixed with hydrogen, it gives oxygen-hydrogen gas which burns at a high temperature of about 2000°C. This is used for cutting and welding steel.

   When oxygen is liquefied and mixed with charcoal, it is used as industrial explosive.

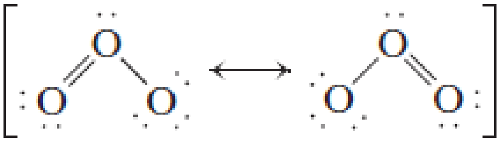
CHEMISTRY OF OZONE

Ozone (O_3) is an unstable triatomic molecule of oxygen. It was first discovered by Schohnbein in 1839. In 1866 another scientist, J. Soret was able to demonstrate that ozone was an allotrope of oxygen, this is another form of oxygen (allotrope of oxygen) that is much more powerful oxidizing agent than oxygen, because of its oxidizing ability, ozone is being considered as a replacement for chlorine in municipal water purification. In the presence of lightning or another source of a spark, O_2 molecules dissociate to form oxygen atoms. But ozone is too reactive to remain for long in the atmosphere but it exists in a layer at a height of about 20km above earth were it is believe to protect the earth' surface from receiving too much ultra violate radiation.

O_3

ozone molecule

The ozone molecule can be represented by the resonance structures



The bond angle in the O_3 molecule is 117 degrees; in a reasonable agreement with the prediction of VSEPR model (three effective pairs require a trigonal planar arrangement). That the bond is slightly less than 120^o can be explained by concluding that more space is require for the lone pair than for the bonding pairs.

The most famous characteristic of ozone is its ability to absorb high energy radiation in the ultraviolet portion of the spectrum ($\lambda \leq 300$ nm), thereby providing a filter that protects us from exposure to high energy ultraviolet radiation emitted by the sun. We can understand the importance of this filter if we think about what happens when radiation from the sun is absorbed by our skin.

PREPARATION OF OZONE

Ozone can be prepared by passing an electric discharge through pure oxygen gas. The electrical energy disrupts the bond in some O_2 molecules to give oxygen atoms, which react with other O_2 molecule to form ozone.

$$O_2(g) \xrightarrow{spark} 2O(g)$$

The O atoms can react with O2 molecules to form ozone, O3.

$$O_2(g) + O(g) \xrightarrow{spark} O_3(g)$$

PHYSICAL PROPERTIES OF OZONE

1. Ozone is slightly soluble in water but readily dissolve in turpentine.
2. Ozone is gas at room at ordinary temperature and pressure.
3. Pure ozone can be obtained by liquefaction as a dark blue explosive liquid.

4. It is a poisonous at concentration above 100 parts per million.

CHEMICAL PROPERTIES OF OZONE

1. Ozone is a vigorous oxidizer. It oxidizes lead (ii) sulphide to lead (ii) tetraoxosulphate (vi).
   $PbS(s) + 4O3 \longrightarrow PbSO_4(s) + 4O_2(g)$
2. It oxizes hydrogen sulphide to tetraoxosulphate (vi) acid.
   $H_2S\ (g) + 4O_3(g) \longrightarrow H_2SO_4\ (aq) + 4O_2$
3. It also librates iodine from potassium iodide in acidic solution.
   $2KI\ (aq) + H_2SO_4 + O_3 \longrightarrow I_2(aq) + O_2(g) + K_2SO_4 + H_2O(l)$

USES OF OZONE

1. It is a good bleaching agent
2. It is used as a disinfectant in water and sewage purification and in air conditioning plant.
3. It is used for ventilating areas which get very little fresh air such as underground railway premises.

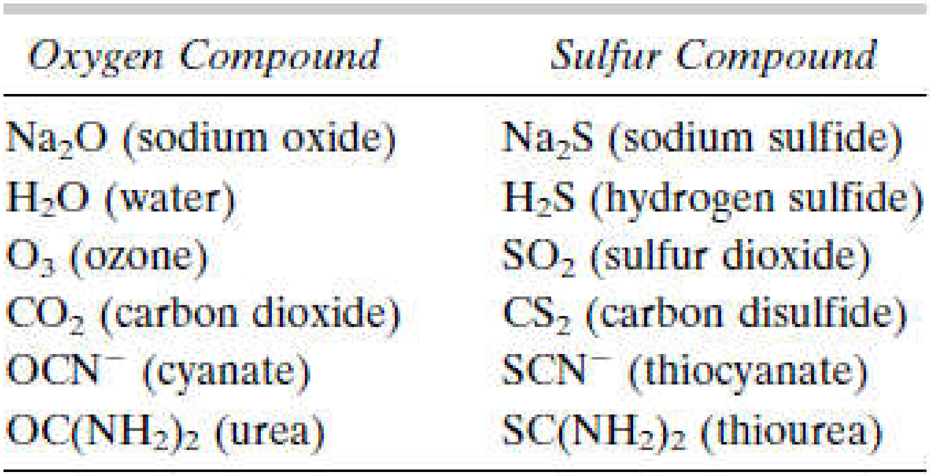
4.6 CHEMISTRY OF SULFUR

This is a yellow, nonmetallic, naturally occurring element, found mainly in the upper surface of the earth in sicily and deep in the earth. Because sulfur is directly below oxygen in the periodic table, these elements have similar electron configurations.

O [He] 2*s*2 2*p*4
S [Ne] 3*s*2 3*p*4

As result of this electronic configuration sulfur forms many compounds that are analogs of oxygen compounds, as shown in Table below. The last two examples in Table below show how the prefix *thio*- can be used to describe compounds in which sulfur replaces an oxygen atom.

Table 5.4: Common Oxidation Numbers for Nitrogen



Oxygen Compound	*Sulfur Compound*
Na_2O (sodium oxide)	Na_2S (sodium sulfide)
H_2O (water)	H_2S (hydrogen sulfide)
O_3 (ozone)	SO_2 (sulfur dioxide)
CO_2 (carbon dioxide)	CS_2 (carbon disulfide)
OCN^- (cyanate)	SCN^- (thiocyanate)
$OC(NH_2)_2$ (urea)	$SC(NH_2)_2$ (thiourea)

There are four principal differences between the chemistry of sulfur and oxygen.

- O=O double bonds are much stronger than S=S double bonds.
- S—S single bonds are almost twice as strong as O—O single bonds.
- Sulfur is much less electronegative than oxygen.
- Sulfur can expand its valence shell to hold more than eight electrons; oxygen cannot.

These seemingly minor differences have important consequences for the chemistry of these elements.

EXTRACTION OF SULPHUR

Over 90% of the world sulphur is obtained from underground deposits in the USA. These deposits are between 150 and 500 metres, below the ground and are covered by the layers of sand which make normal mining method impossible.

Sulphur is extracted by the Frasch process. A hole about 30cm in diameter is bored down through the clay, sand and limestone to the sulphur bed. This boring is lined with an iron pipe and inside the pipe is sunk a device called the sulphur pump. It consists of three concentric tubes which terminate in a reservoir of large diameter. Water is super heated under pressure to a temperature of 180 to 200^{o}C and is pumped down to the beds to melt the sulphur. Hot compressed air is then forced down the inside tube and this pushes the sulphur. Hot compressed air is then forced down the inside tube and this pushes the molten sulphur is run into large tanks, where it solidifies and can be separated from the water. The sulphur obtained is 99.5% pure.

PHYSICAL PROPERTIES OF SULPHUR

1. Sulphur has a melting point of 115^{o}C and a boiling point of 444^{o}C.
2. Sulphur is soluble in organic solvents such as benzene and toluene. It is also soluble in carbon (IV) Sulphide but is insoluble in water.
3. Sulphur is a bad conductor of heat and electricity.
4. It is brittle.

CHEMICAL PROPERTIES OF SULPHUR

Sulfur burns with a blue flame concomitant with formation of sulfur dioxide, notable for its peculiar suffocating odour. Sulfur is insoluble in water but soluble in carbon disulfide and, to a lesser extent, in other non polar organic solvents, such as benzene and toluene. The first and the second ionization energies of sulfur are 999.6 and 2252kJ·mol−1, respectively. Despite such figures, the +2 oxidation state is rare, with +4 and +6 being more common. The fourth and sixth ionization energies are 4556 and 8495.8 kJ·mol−1, the magnitude of the figures caused by electron transfer between orbitals; these states are only stable with strong oxidants as fluorine, oxygen, and chlorine.

Allotropes of sulfur

Sulphur can exist in four allotropic states. These include

1. Rhombic sulphur (α sulphur): this is the most stable allotrope at a temperature below 96^oC. they are octahedral in shape.
2. Monoclinic or prismatic sulphur (β sulphur): this is the stable form of sulphur above 96^oC and produced if sulphur crystallizes above 96^oC. They are Needle shape crystals.
3. Amophous sulphur (δ sulphur): a sulphur in a white powdered form deposited when dilute HCl acid act on a thiosulphate VI solution.
4. Plastic sulphur: this is a long elastic light yellow ribbons of plastic sulphur which are soluble in carbon dioxide. After few days plastic sulphur revert to rhombic sulphur.

USES OF SULPHUR

1. Sulphur is used in the manufacture of tetraoxosulphate (VI) acid.
2. It is used in the manufacture of Drugs.
3. In the production of important chemicals such as carbon (IV) sulphide, CS_2 and calcium hydrogen trioxosulphate (IV), $Ca(HSO_3)_2$.
4. It is used for vulcanization of rubber; a process which convert the soft pliable rubber into the hard, tough substance from which motor tire and similar product are made.

SULFURIC ACID

Elemental sulfur is mainly used as a precursor to other chemicals. Approximately 85% (1989) is converted to sulfuric acid (H2SO4):

$$2\ S + 3\ O_2 + 2\ H_2O \rightarrow 2\ H_2SO_4$$

With sulfuric acid being of central importance to the world's economies, its production and consumption is an indicator of a nation's industrial development. For example with 32.5 million tonnes in 2010, the United States produces more sulfuric acid every year than any other inorganic industrial chemical. The principal use for the acid is the extraction of phosphate ores for the production of fertilizer manufacturing. Other applications of sulfuric acid include oil refining, wastewater processing, and mineral extraction.

Other important compounds of sulphur include hydrogen sulphide gas H_2S, sulphur (IV) oxide, trioxosulphate (IV) acid and tetraoxosulphate (VI) acid.

SELF ASSESMENT EXERCISE 14

1. *Mention any five physical properties of metals*
2. *Which of these elements are not metals, Mg, Na, K, Al, Ca, Ar, H, He, Si, and C.*
3. *Describe the process of extraction of sulphur.*

5.0 CONCLUTION

In this unit we study the general properties of both metals (alkali earth metals) and non metals (oxygen and sulphur). The special properties of metals make them a very important class of element.

6.0 SUMMARY

Metals have physical property such as luster, solid at room temperature with exception of mercury, malleable, ductility, high density, good conductors of heat and electricity, high tensile strength and so on. Metals react with nonmetals to form salts under different conditions. Alkali metals are elements of group 1 of the period table. They are called alkali metal because they react with water to form alkali (base). Nonmetals are mostly liquid and gases at room temperature (they may be solids). They include the elements of group 4,5,6,7 and the noble gases. They have the properties such as low density, low tensile strength, and poor conductor of both heat and electricity and so on. Oxygen is one of the most abundant elements in the atmosphere constituting about 21%. Oxygen can be prepared in laboratory by action of water on $KClO_3$. Oxygen is used for breathing and many other industrial purposes and it is obtain in industry from liquid air. Ozone is an example of important compounds of oxygen. Sulphur is one of the abundant elements in underground deposit mostly in USA. It is used in the manufacture of drugs and some industrially important compounds.

TUTOR-MARKED ASSIGNMENT

1. Describe the method of extraction of sulphur.

7.0REFERENCES/FURTHER READINGS

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APPENDIX 1: Answers

UNIT 1: History and Importance of Organic Molecule

Answer to Self Assessment Exercise 1

No. Not all carbon containing compound are organic. Carbon dioxide, carbon monoxide, cyanide, carbonates, bicarbonates are examples. Note that these exceptions do not contain hydrogen to the carbon atom, the basic requirement for the classification of organic compounds.

UNIT 2: Nomenclature of Organic Compounds

Answer to Self Assessment Exercise 2

(1) a. 4-chloro-3-hexanol

b. 3-hydroxyhexanedioic acid

c. 2-chloropentonoyl chloride

d. 4-bromo-6-ethyl-5-methylheptane

e. 2,2-dimethyl propanol

UNIT 3: Homologous Series

Answer to Self Assessment Exercise 3

(i) Carbon can have single, double, or triple covalent bonds, because of the three types of hybridization available to it.

(ii) Carbon has the ability to form bonds with its self and other elements.

(iii) Carbon has valency of four, it forms mainly covalent bond, and nor vacant orbital and lone pair. Thus many carbon compounds are chemically stable compare to compounds of other elements.

UNIT 4: Functional Group

Answer to Self Assessment Exercise 4

(a) CHO, Esters or alkanoate

(b) $RCOR_{2,}$ Alkanol

(c) NH_2, Primary amine

(d) COOH, Alkanoic acid or carboxylic acid

(e) I, halogens

UNIT 5: Quantitative and Qualitative Analysis

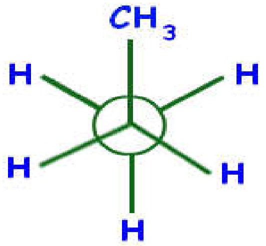
Answer to Self Assessment Exercise 5

1) Solubility
2) Reactivity
3) Melting point
4) Molecular weight
5) Radiative property

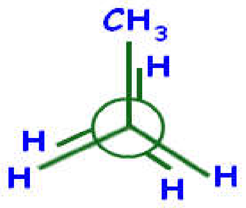
Module 2

Unit 1: Stereochemistry

Answer to Self Assessment Exercise 6



Staggered propane

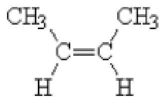


Eclipsed propane

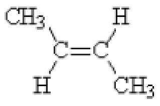
Self Assessment Exercise 7

For *1-butene* cis and trans isomer are not possible because there is no substituent. But cis and trans isomers are possible for *2-butene:*

cis-2-Butene

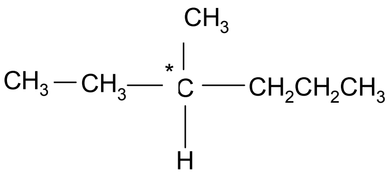


trans-2-Butene



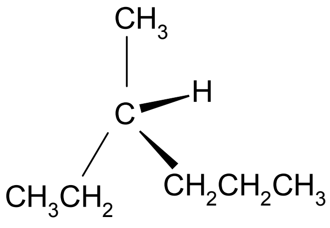
Self Assessment Exercise 8

i)



$$CH_3-CH_3-\overset{CH_3}{\underset{H}{\overset{*}{C}}}-CH_2CH_2CH_3$$

ii)

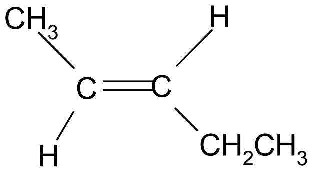


Self Assessment Exercise 9

a) vinyl

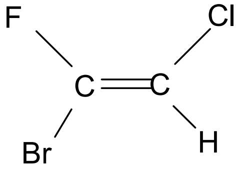
Self Assessment Exercise 10

(a)



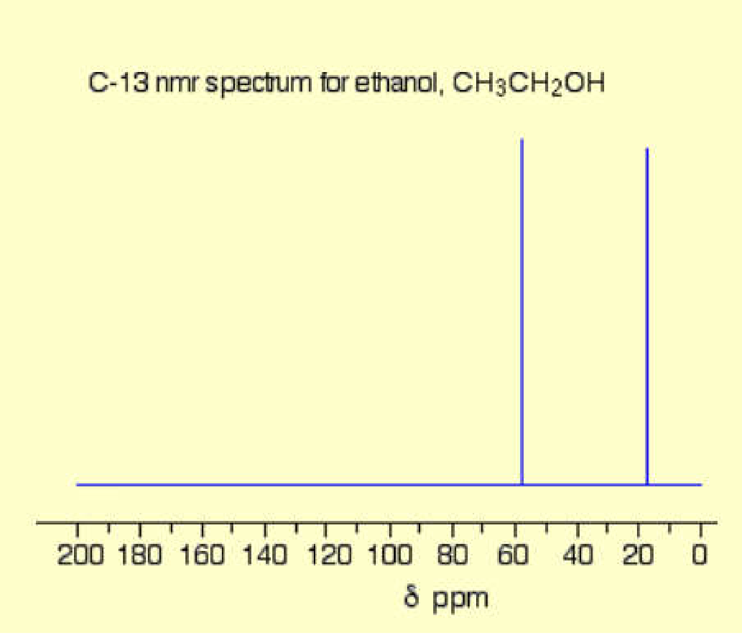
(Z)-pentene

(b)



(E)-1-flouro-1-bromo-2-chloroethene

Self Assessment Exercise 11



There are two peaks because there are two different environments for carbons. The carbon in the CH_3 group is attached to 3 hydrogens and a carbon, while the carbon in the CH_2 group is attached to 2 hydrogens, a carbon and oxygen. The two lines are in different places in the NMR spectrum because they need different external magnetic fields to bring the in to resonance at a particular radio frequency.

UNIT 3 Electronic Theories in Organic Chemistry

Self Assessment Exercise 12

(a)

$$2\,Li + Br_2 \longrightarrow 2LiBr$$

(b) Al = +3

Li = +1

S = -2, -1, +1, +2, +3, +4, +5, +6

H = +1

(c) Electronegative

UNIT 4: Saturated and Unsaturated Hydrocarbons and Their Reactions

Self Assessment Exercise 13

Reactions of Alkane

$$\mathbf{2C_4H_{10}(\mathit{g}) + 13O_2(\mathit{g}) \longrightarrow 8CO_2(\mathit{g}) + 10H_2O(\mathit{g})}$$

$$\mathbf{CH_4 + Cl_2 \xrightarrow{hv} CH_3Cl + HCl}$$

chloromethane

$$\mathbf{CH_3Cl + Cl_2 \xrightarrow{hv} CH_2Cl_2 + HCl}$$

Dichloromethane

$$\mathbf{CH_2Cl_2 + Cl_2 \longrightarrow CHCl_3 + HCl}$$

Trichloromethane

$$\mathbf{CHCl_3 + Cl_2 \longrightarrow CCl_4 + HCl}$$

Tetrachloromethane

Reactions of Alkene and Alkyne

$$CH_2{=}CHCH_3 + H_2 \xrightarrow{catalyts} CH_3CH_2CH_3$$

$$CH_2{=}CHCH_2CH_2CH_3 + Br_2 \longrightarrow CH_2BrCHBrCH_2CH_2CH_3$$

UNIT 5: The Chemistry of Selected Metals and Non-Metals

Answer to Self Assessment Exercise 14

$Li_3N(s) + 3H_2O(l) \longrightarrow 3Li^+ (aq) + OH^- (aq) + NH_3(g)$

$2KO_2 (s) + 3H_2O (l) \longrightarrow 2K^+ (aq) + 2OH^- (aq) + O_2(g) + H_2O_2$

Answer to Self Assessment Exercise 15

1) a) Physical state(solid)

   b) Luster

   c) Malleability

   d) Ductility

   e) Hard

   f) Good conductor and so on

2) *Ar, H, He, Si, and C.*

3) Sulphur is extracted by the Frasch process. A hole about 30cm in diameter is bored down through the clay, sand and limestone to the sulphur bed. This boring is lined with an iron pipe and inside the pipe is sunk a device called the sulphur pump. It consists of three concentric tubes which terminate in a reservoir of large diameter. Water is super heated under pressure to a temperature of 180 to 200°C and is pumped down to the beds to melt the sulphur. Hot compressed air is then forced down the inside tube and this pushes the sulphur. Hot compressed air is then forced down the inside tube and this pushes the molten sulphur is run into large tanks, where it solidifies and can be separated from the water. The sulphur obtained is 99.5% pure.