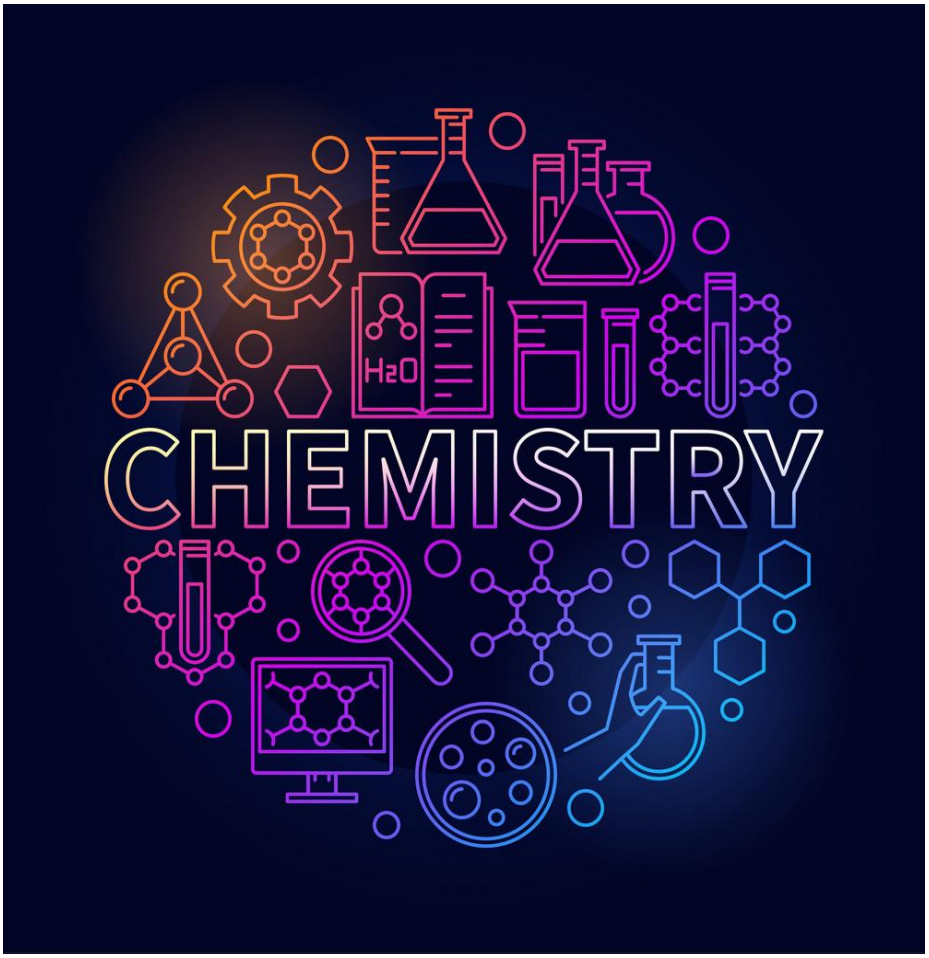


Thomas A. Edison
''I believe that the science of chemistry alone almost proves the existence of an intelligent creator."-

CHEMISTRY SS 1

Third term

Compiled by Prosper Nwonu (2022)

Scheme of work

WEEK	TOPIC	CONTENTS
1.	WATER	- Water as an oxide of hydrogen - Sources - Properties (physical and chemical) - Test for water - Water pollution, pollutants and control
2	CARBON & ITS COMPOUNDS	- Properties, allotropes, structures and properties of allotropes. - Coal; types, destructive distillation, uses of products.
3.	CARBON & ITS COMPOUNDS	- Coke; gasification of coke, synthetic gases; manufacturing and uses, fuel gases.
4.	CARBON & ITS COMPOUNDS	- Oxides of carbon, trioxocarbonate (IV) acid; preparation, properties and uses. - Hydrogen trioxocarbonates (IV): Trioxocarbonates (IV) salt; preparation, properties and uses.
5.	HYDROCARBONS	- Classification of hydrocarbons, tetravalency of carbon - Reasons why carbon form many compounds, properties of organic compounds, homologous series;

		isomerism, saturated and unsaturated, organic compounds
6.	HYDROCARBONS	- Alkanes: naming, properties, isomerism, preparation, uses
7.	HYDROCARBONS	- Alkenes: naming, isomerism; structural and geometric isomerism, physical and chemical properties: additional and polymerization reactions, test for unsaturation; bromine water etc.
8.	HYDROCARBONS	- Alkynes: Naming, ethyne; preparation, properties, uses - Benzene; structure, properties, derivatives, uses.
9.	PETROLEUM	- Occurrence, origin and composition. - Nigeria and world crude oil reserves, location of refineries in Nigeria - Fractional distillation of crude oil and major products. - Cracking and reforming, quality of petrol and octane number
10.	PETROLEUM	- Petrochemicals as starting materials for organic synthesis, - Natural gas: packing as LNG. Economic importance of petroleum & natural gas. - Environmental impact of petroleum

11.	PETROLEUM	- Alternative sources of energy; - Hydrogen as a potential fuel for use in future, reacting with oxygen to generate electricity - In fuel cells: advantages and disadvantages - Explain how photosynthesis can provide renewable energy source
12.	REVISION	- Revision
13.	EXAMINATION	- Examination

WEEK 1: WATER

Water is one of the most common substances known. It is a good solvent for many substances and rarely occurs in its pure form in nature.

Water an Oxide of Hydrogen

When dry hydrogen is ignited, it burns with a pale blue flame to give steam.

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$$

Sources of water

1. Rain
2. Streams and rivers
3. Spring and underground
4. Seas and Oceans

Physical properties of water

1. Pure wate is clear, colourless, tasteless and odourless
2. Has a boiling point of 100^{o}C
3. A freezing point of 0^{o}C
4. Maximum density of 1 g/cm^{3} at 4 ^{o}C
5. It is neutral to litmus

Chemical properties of water

1. water react with metals in a number of ways. Degree of reactivity depends on the position of the metal in the activity series
   i. Na, K and Ca react with water to liberate hydrogen gas

   $2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$

   ii. Mg and Zn

   $\mathbf{Mg_{(s)}} + H_2O_{(g)} \rightarrow MgO_{(s)} + H_{2(g)}$

   iii. Fe reacts only with excess steam at red heat.

   $3Fe(s) + 4H_2O(g) \leftrightharpoons Fe_3O_4(s) + 4H_2(g)$

   iv. Cu, Au, Ag and Hg do not react with water in any form

2. Non-metals like Chlorine also react with water

   $Cl_2 + H_2O \rightarrow HOCl + HCl$
3. Oxides of alkaline metals readily form strong alkalis or hydroxides with water. E.g slaking of lime

   $CaO + H_2O \rightarrow Ca(OH)_2$
4. Certain oxides of non-metals like carbon, sulphur and nitrogen form acid with water (acid anhydrides)

   $CO_2 + H_2O \leftrightharpoons H_2CO_3$
5. Water reacts with organic and inorganic compounds. Such reactions are generally referred to as Hydrolysis

Test for Water

When a few drops of water are added to

1. White anhydrous copper (II) sulphate, it turns blue

$CuSO_4(s)$ (white) + $5H_2O(l)$ → $CuSO_4.5H_2O(s)$(blue)

2. blue cobalt (II) chloride, it turns pink

$CoCl_2(s)$(blue) + $6H_2O(l)$ → $CoCl_2.6H2O(s)$ (Pink)

Water pollution

this is the contamination of water bodies as a result of human activities. The main cause of water pollution is the indiscriminate dumping of solid and liquid wastes into water bodies. It threatens aquatic life and changes water bodies in to foul smelling and unsightly scenes

Pollutants

1. Refuse and sewage
2. Industrial and agricultural wastes
3. Crude oil spills

Control of water pollution

1. Refuse should be buried or burnt in an incinerator or recycled
2. Sewages should be processed to fertilizers
3. Chemical wastes should be made biodegradable before disposal
4. Safety measures should be implemented to prevent crude oil spills
5. Strict laws must be passed to control water pollution by individuals and companies

WEEK 2-4: CARBON AND ITS COMPOUNDS

Carbon is a chemical element with the symbol C and atomic number 6. It is non-metallic and tetravalent—making four electrons available to form covalent chemical bonds. It belongs to group 14 of the periodic table. Carbon makes up only about 0.025 percent of Earth's crust.

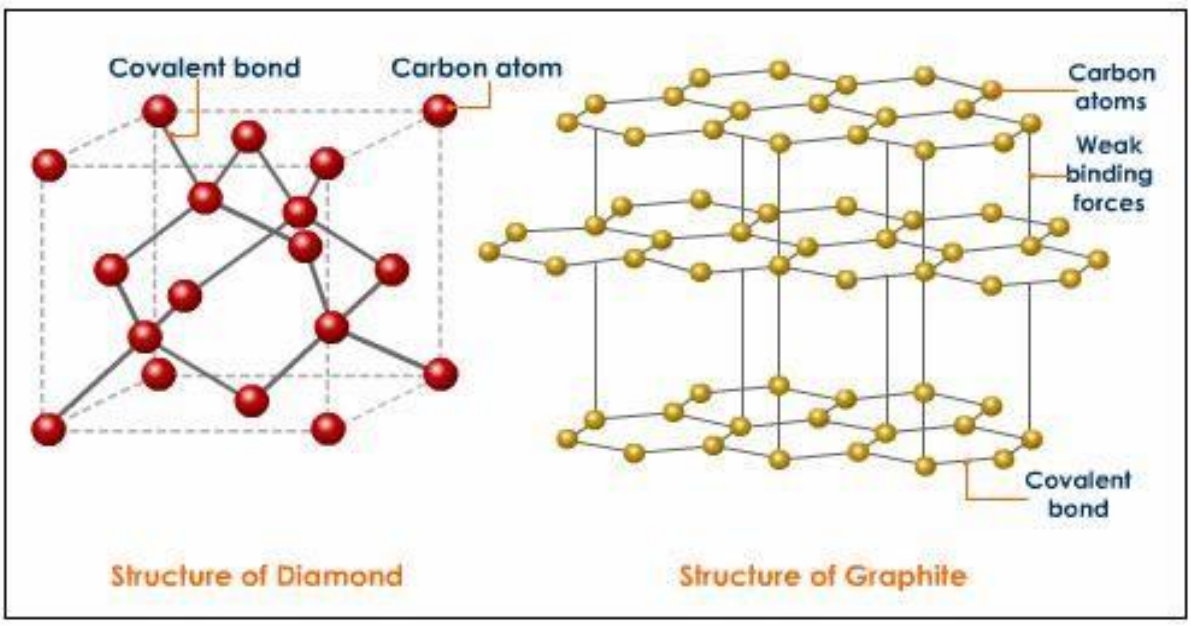
Allotropy

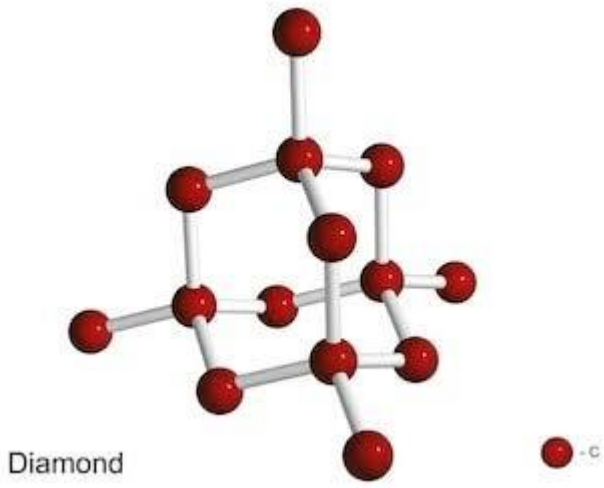
This is the ability of an element to exist in various forms in the same physical state. Elements that exhibit allotropy include carbon, sulphur, tin, oxygen, phosphorus etc

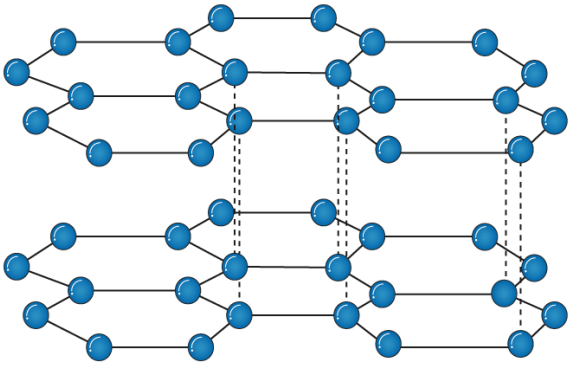
Allotropes of Carbon

1. Crystalline allotropes: diamond and graphite
2. Amorphous allotropes: coal, coke, charcoal, soot etc

Structure of diamond and graphite




Diamond
- C



Properties and uses of diamond

1. Diamond is the hardest substance known in nature. They are dense, hard and resistant to high temperatures and chemical attacks;
   i. They are used industrially in drills for mining,
   ii. as abrasives to sharpen very hard tools and for cutting glass and metals.
2. it is a non-conductor of electricity due to the absence of free mobile electrons
3. they are transparent with high refractive index and dispersion power giving it a sparkling brilliance when it is cut and polished;
   i. making it valuable as jewellery.
4. It occurs as octahedral crystals

Properties and uses of Graphite

1. **Gra**phite is soft and flakes easily because of its layered crystalline structure held together by van der waals forces. This allows one layer to slide over one another easily;
   i. making it useful as a dry lubricant,
   ii. it is mixed with clay to make lead in pencils,
   iii. it is usually used on bicycle chains and for the bearings of some motor cars.
2. Graphite is a good conductor of electricity due to the presence of free mobile electrons
   i. it is often used as electrodes in electroplating and in dry cells
3. It can with stand high temperatures
   i. it is used to line crucibles used for making high grade steel and other alloys.
   ii. It is used as a neutron moderator in atomic piles
4. It is black and opaque
   i. graphite is used as black pigment in paint.
5. It occurs as hexagonal crystals

Coal

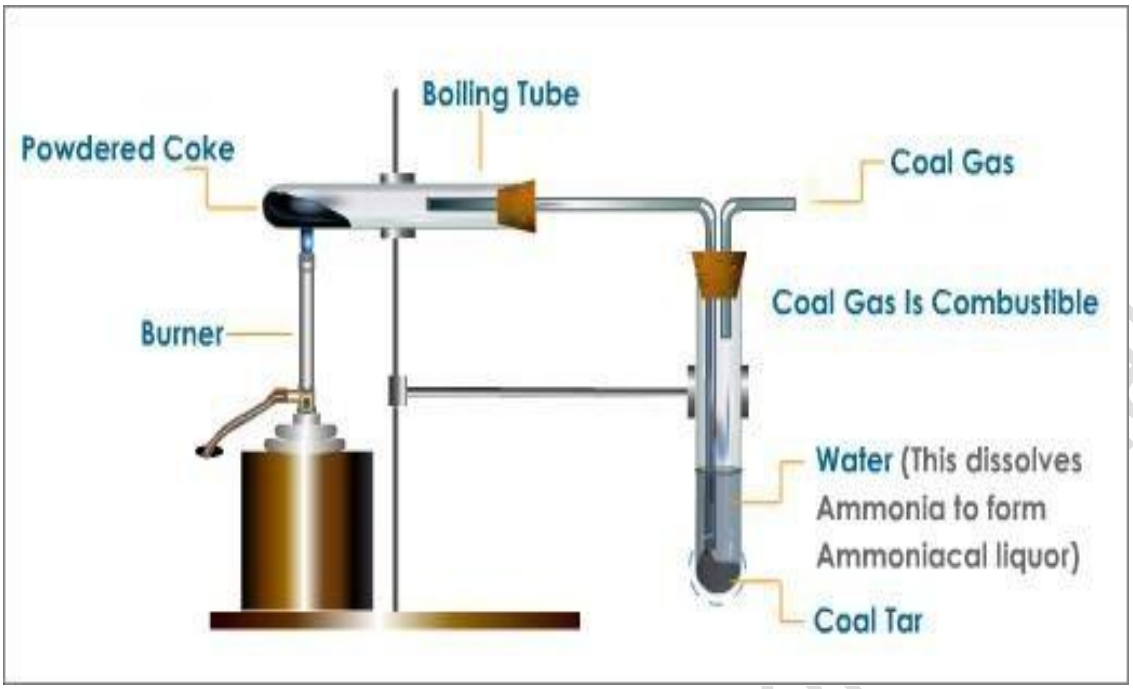
Coal is a combustible black or brownish-black sedimentary rock, formed as rock strata called **coal** seams. **Coal** is mostly carbon with variable amounts of other elements; chiefly hydrogen, sulphur, oxygen, and nitrogen

Types of coal

1. Peat
2. Lignite or brown coal
3. Bituminous coal or soft coal
4. Anthracite coal which is about 95% pure carbon

Destructive distillation of coal

This is a chemical process in which coal is heated to a high temperature in the absence of air.



Products and uses

Coal → coke + coal tar + ammoniacal liquor + coal gas

Coke (solid)

- This is a fuel and a reducing agent

Coal tar(liquid)

- A mixture of different carbon compounds.
- It is used to make soap, fats, dyes, plastics, explosives and more

Ammoniacal liquor(liquid)

- Used to make fertilizers

Coal gas(gas)

- Also called **town gas** is a mixture of hydrogen, methane and carbon monoxide and is used as a fuel

Coke

Coke is a fuel with few impurities and high carbon content. It is formed through destructive distillation of good quality bituminous coal.

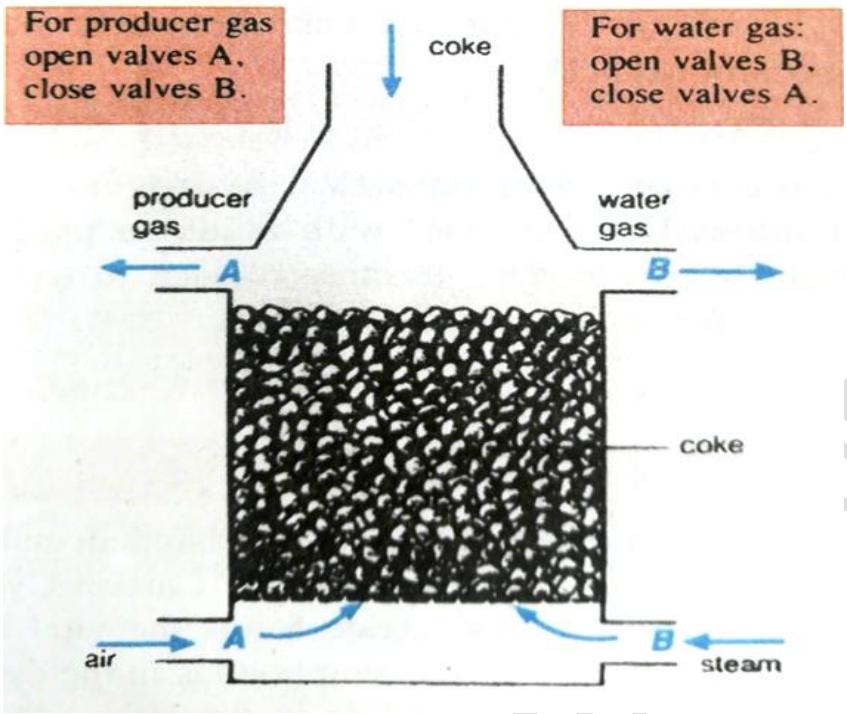
Gasification of coke

This is a process that converts organic or fossil fuel based carboniferous materials into carbon monoxide, hydrogen and carbon dioxide.

Fuel gases

1. Producer gas
2. Water gas

Industrially, producer and water gas are made in the same plant known as the **producer** by passing air and steam alternatively through heated coke. The heat generated when producer gas is formed is sufficient for water gas formation.



- **Producer gas:** this is a mixture of nitrogen and carbon (II) oxide prepared by passing a stream of air through red hot coke in the producer

  $O_{2(g)} + N_{2(g)} + 2C_{(s)} \rightarrow 2CO_{(g)} + N_{2(g)} + heat$

- **Water gas:** this is a mixture containing equal volumes of hydrogen and carbon (II) oxide prepared by passing steam over white-hot coke at 1000 ^{o}C

  $C_{(s)} + H_2O_{(g)} \rightarrow CO_{(g)} + H_{2(g)}$

Critical thinking

Why does water gas make a better fuel than producer gas?

What is the implication of using water gas as a domestic fuel?

Oxides of Carbon

Carbon forms two kinds of oxides, carbon (IV) oxide, CO_2, and carbon (II) oxide, CO. Both oxides are obtainable as the products of combustion of carbon.

Carbon (IV) Oxide

Preparation:

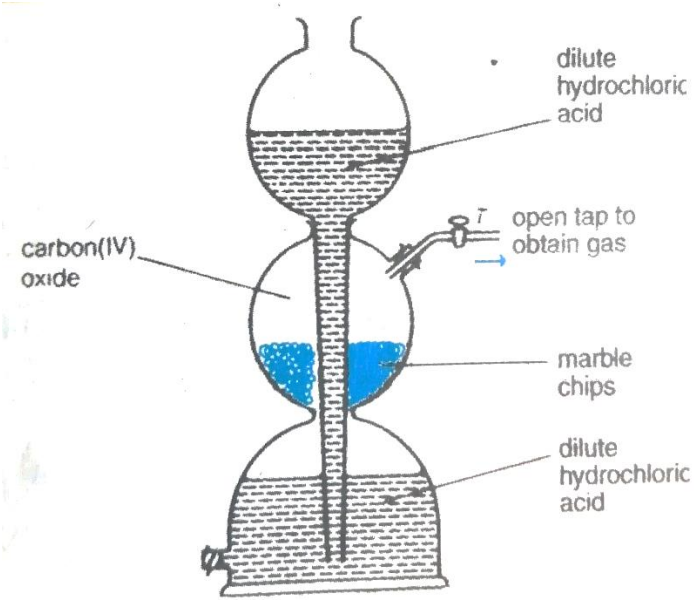
1. Carbon (IV) oxide is made in the laboratory through the action of dilute hydrochloric acid or trioxonitrate (V) acid on metallic trioxocarbonate (IV) or hydrogen trioxocarbonate.

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

$$CaCO_3 + 2HNO_3 \rightarrow Ca(NO_3) + H_2O + CO_2$$

$$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$$

A Kipp's apparatus is used to provide intermittent supply of the gas when ever it is needed in the laboratory



2. Action of heat on metallic trioxocarbonate (IV) apart from those of sodium and potassium or the hydrogen trioxocarbonates (IV) of sodium and potassium

$$CaCO_3 \rightarrow CaO + CO_2$$

$$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + 2CO_2$$

Carbon (IV) oxide is acquired industrially as by-product in the fermentation process and manufacture of quicklime (CaO) from limestone ($CaCO_3$).

Physical properties:

- CO_2 is a colourless, odourless and tasteless gas.
- It is around 1.5 times denser than air.
- This is moderately soluble in water.
- It turns damp blue litmus paper red as CO_2 dissolves in water to form an acidic oxide, trioxocarbonate (IV) acid.
- This can readily be liquefied and solidified (- 78°C). Solid CO_2 is termed as cardice or dry-ice.

Chemical properties:

1. CO_2 doesn't burn nor does it support the combustion. Though burning magnesium decomposes CO_2 leaving a black carbon deposit and magnesium (II) oxide ash.

$$CO_2 + 2Mg \rightarrow 2MgO + C$$

2. CO dissolves in the water to form trioxocarbonate (IV) acid (that is, soda water). This is a weak acid.

$$CO_2 + H_2O \leftrightharpoons H_2CO_3$$

3. CO_2 reacts directly by alkalis example: NaOH, to form trioxocarbonates (IV).

$$NaOH + CO_2 + H_2O \rightarrow 2NaHCO_3$$

Test for CO_2

Whenever CO_2 is passed via the alkali, calcium hydroxide (that is, limewater), the lime water turns milky due to the precipitation of insoluble calcium trioxocarbonate (IV). This reaction is employed to test for CO_2.

$$\underset{\text{Limewater}}{Ca(OH)_2} + CO_2 \rightarrow \underset{\text{Insoluble}}{CaCO_3} + H_2O$$

Though, whenever excess gas is bubbled, the milkiness disappears leaving a clear solution as the Soluble trioxocarbonate (IV) is transformed to soluble hydrogen trioxocarbonate (IV). (This is used as a test for carbon dioxide)

$$CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$$

Uses

1. Most of the fire extinguishers make use of carbon (IV) oxide to put out fires as the gas doesn't support combustion.
2. Carbon (IV) oxide is employed in the manufacture of trioxocarbonates.
3. Yeast and baking powder are employed in baking to produce carbon (IV) oxide that causes the dough to rise, making dough light.
4. Solid carbon (IV) oxide that is, dry ice is employed as a refrigerant for perishable goods, and as a coolant in the nuclear reactors.
5. Carbon (IV) oxide is employed to give carbonated (or aerated) drinks a pleasant and refreshing taste.
6. Green plants make use of CO_2 throughout photosynthesis.

Carbon (II) Oxide:

CO is made by the incomplete combustion of carbon compounds, like octane, C_8H_{18}, found in petrol.

$$2C_8H_{18}\ (l) + 17O_2\ (g) \rightarrow 16\ CO\ (g) + 18\ H_2O\ (l)$$

Preparation:

1. Carbon (II) oxide is made by passing carbon (IV) oxide over red-hot carbon

$$CO_2 + C \rightarrow 2CO$$

2. This can as well be made by dehydrating methanoic acid, HCOOH, or ethanedioic acid, $C_2H_2O_4$, by utilizing concentrated tetraoxosulphate (VI) acid, that act as the dehydrating agent.

$$HCOOH \xrightarrow[-H_2O]{\text{Conc. } H_2SO_4} CO$$

$$C_2H_2O_4 \xrightarrow[-H_2O]{\text{Conc. } H_2SO_4} CO_2 + CO$$

The preparation of CO should be done in the fume cupboard as the gas is poisonous. In the later reaction, the CO_2 is eliminated by passing gaseous products via concentrated sodium hydroxide.

Physical Properties:

- Carbon (II) oxide is a colourless, tasteless and odourless gas.
- It is insoluble in water, however dissolves in a solution of ammoniacal copper (I) chloride.
- It is to some extent less dense than air.
- It consists of no effect on litmus

Chemical Properties:

1. Act as a reducing agent:

$$PbO\ (s) + CO\ (g) \rightarrow Pb(s) + CO_2(g)$$
$$H_2O(g) + CO(g) \rightarrow H_2(g) + CO_2(g)$$

2. It burns in air having a blue flame to provide carbon (IV) oxide

$$2C0 + O_2 \rightarrow 2CO_2$$

3. The poisoning nature of Carbon (II) oxide is as a result of its reaction having haemoglobin in the red blood cells and therefore prevents the haemoglobin from transporting oxygen in our body. Death resultant from CO poisoning take place whenever the supply of oxygen to the body becomes not enough as the carrier haemoglobin is not available for this function.

Uses:

1. CO is utilized as a reducing agent in the extraction of metals example: iron from its ores.
2. CO is the significant constituent of gaseous fuels such as producer gas (CO + N_2) and water gas (CO + H_2).

Trioxocarbonate (IV) and Hydrogen Trioxocarbonate (IV)

Trioxocarbonates (IV) and hydrogen trioxocarbonates (IV) are the inorganic compounds of carbon. Trioxocarbonates (IV) acid reacts with some free metals, metallic oxides and alkalis to form trioxocarbonate (IV) salts.

$$Zn + H_2CO_3 \rightarrow ZnCO_3 + H_2$$

$$CaO + H_2CO_3 \rightarrow CaCO_3 + H_2O$$

$$2NaOH + H_2CO_3 \rightarrow Na_2CO_3 + 2H_2O$$

Trioxocarbonate (IV) salts are of two kinds:

- Normal trioxocarbonate (IV) MCO_3 and
- Acidic hydrogen trioxocarbonate (IV) $MHCO_3$

Preparation of soluble trioxocarbonate (IV) salt:

The water soluble trioxocarbonate (IV) salts are sodium, potassium and ammonium trioxocarbonate (IV). They are generally made by passing carbon (IV) oxide via a solution of corresponding alkali.

$$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

Preparation of insoluble trioxocarbonate (IV) salts:

Most of the metallic trioxocarbonate (IV) are insoluble in water. The common methods for preparing them are:

1. Reaction of a base, metals or metallic oxide with trioxocarbonate (IV) acid

$$Ca(OH)_2 + H_2CO_3 \rightarrow CaCO_3 + 2H_2O$$

$$Zn + H_2CO_3 \rightarrow ZnCO_3 + H_2$$

$$MgO + H_2CO_3 \rightarrow MgCO_3 + H_2O$$

2. By adding a solution of sodium trioxocarbonate (IV) to a solution of the corresponding metal salt.

$$Na_2CO_3 + CaCl_2 \rightarrow CaCO_3 + 2NaCl$$

$$Na_2CO_3 + 2AgNO_3 \rightarrow 2NaNO_3 + Ag_2CO_3$$

Hydrogen Trioxocarbonate (IV) salts:

These are the acid salts of trioxocarbonate (IV) acid made whenever a metal or ammonium radical substitutes one of the two hydrogen atoms in the molecule. They are soluble in water.

Hydrogen trioxocarbonates (IV) might be prepared through passing CO_2 via a solution of the corresponding hydroxides or trioxocarbonates (IV).

$$NaOH + CO_2 \rightarrow NaHCO_3$$

$$Na_2CO_3 + CO_2 + H_2O \rightarrow 2NaHCO_3$$

Properties of trioxocarbonates (IV) salts:

1. All trioxocarbonate (IV) salts apart from those of sodium, potassium and barium, decompose on heating to release carbon (IV) oxide.

$$ZnCO_3 \rightarrow ZnO + CO_2$$

$$(NH_4)_2CO_3 \rightarrow 2NH_3 + CO_2 + H_2O$$

The entire hydrogen trioxocarbonates (IV) as well decompose on heating the solid or solution to provide carbon (IV) oxide, water and the corresponding trioxocarbonates (IV).

$$2KHCO_3 \rightarrow K_2CO_3 + H_2O + CO_2$$

2. All the trioxocarbonate (IV) and hydrogen trioxocarbonate (IV) salts react by dilute acids to form carbon (IV) oxide water and a salt.

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

$$Ca(HCO_3)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O + 2CO_2$$

3. All trioxocarbonate are **insoluble** except that of sodium, potassium and ammonium. While all hydrogen trioxocarbonates are soluble

Uses of some significant trioxocarbonate (IV) salts:

i) Na_2CO_3 is utilized in the manufacture of glass, soap and detergents, and also in the production of paper and pulp.

ii) $NaHCO_3$ is employed in baking powder to discharge CO_2 gas that helps the dough to rise throughout baking. It is as well employed as medicine to relieve indigestion example: in Andrews liver salts. This is utilized in dry-powder fire extinguishers.

iii) $CaCO_3$ is utilized in the production of cement, chalk and significant industrial chemicals example: CaO and NH_3.

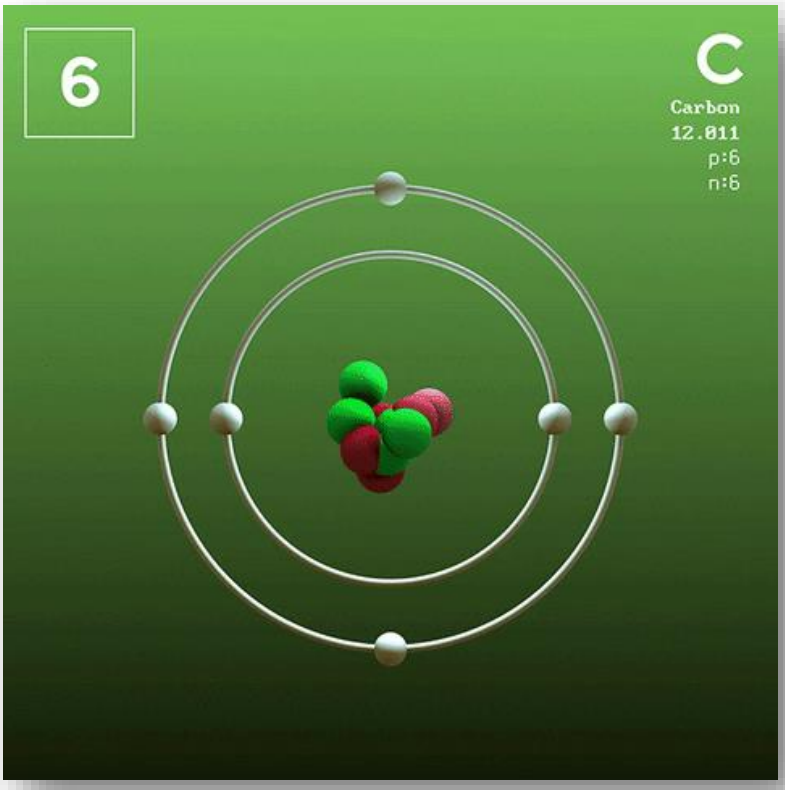
WEEK 5-8: HYDROCARBONS

Hydrocarbons are organic compounds composed of only two elements- carbon and hydrogen

Hydrocarbons can be classified as
1. Aliphatic – (cyclic or acyclic)
2. Aromatic

Tetravalency of carbon

A carbon atom completes its octet only by sharing its valence electrons with other atoms. As a result, a carbon atom forms four covalent bonds by sharing valence electrons with other atoms. This is known as tetravalency of carbon ("tetra" means four).



Why Does Carbon Form a Large Number of Compounds?

1. its ability to catenate. **Catenation** is the ability of carbon to combine with one

another to form straight chains, branch chains and ring compounds containing many carbon atoms

2. The ease with which it bonds with other elements
3. Its Ability to Form Single, Double and Triple Covalent Bonds
4. The stability of the carbon-carbon single, double and triple bonds

Characteristic features of organic compounds

1. Organic compounds are generally covalent and hence they do not dissolve in water (polar solvents) but dissolve in organic solvents (non-polar solvents) such as ether, alcohol, benzene etc.

2. Due to maximum catenation and tetravalency of carbon, they have tendency to form long open and closed chain compounds.

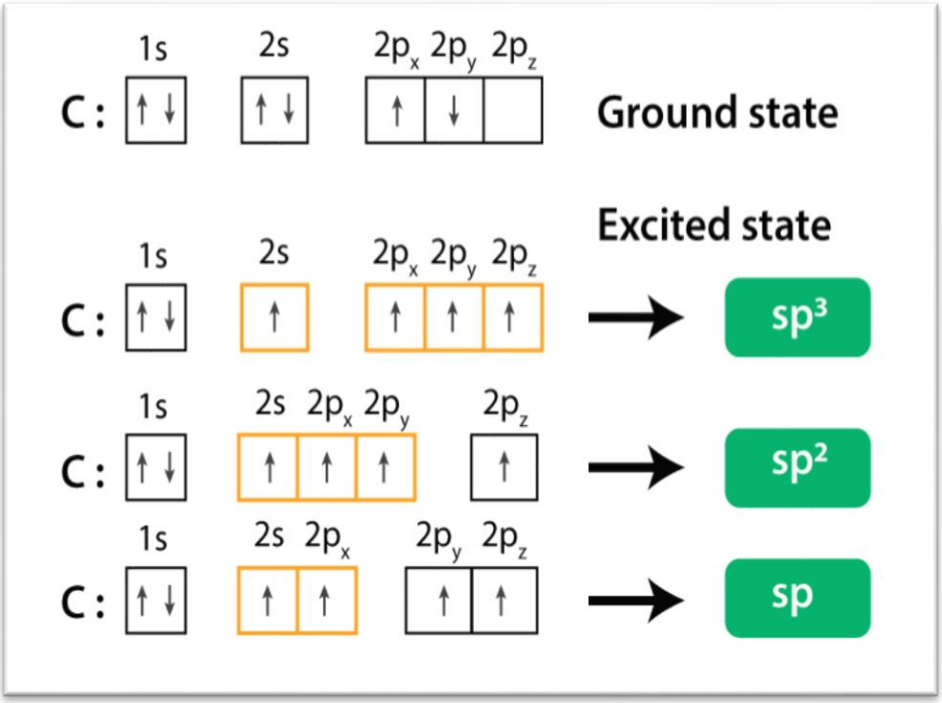
3. They are volatile, inflammable and possess low boiling points and melting points.

4. Some organic compounds exhibit the phenomenon of polymerization. For example, ethylene polymerizes to poly ethylene.

5. They are non-conductors of electricity.

What is hybridization?

This is the joining together of two or more orbital of the same principal quantum number to form a new set of orbitals that are degenerate or equivalent



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 $–CH_2$ or a molecular mass of 14

Characteristics

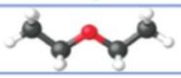
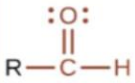
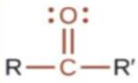
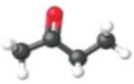
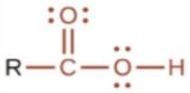
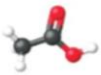
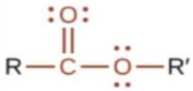
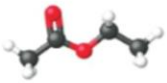
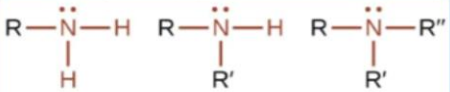
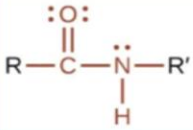
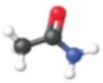
1. Similar method of preparation
2. Differ in their molecular formula by CH_2 or a molecular mass of 14
3. Similar chemical properties and a graduation in their physical property
4. The same functional group and the same general formula

Assignment

With the aid of examples differentiate between molecular formula, empirical formula and structural formular

What is a functional group?

A functional group is a group of atoms or bonds common to the series of organic compounds and determines the chemical properties of the series

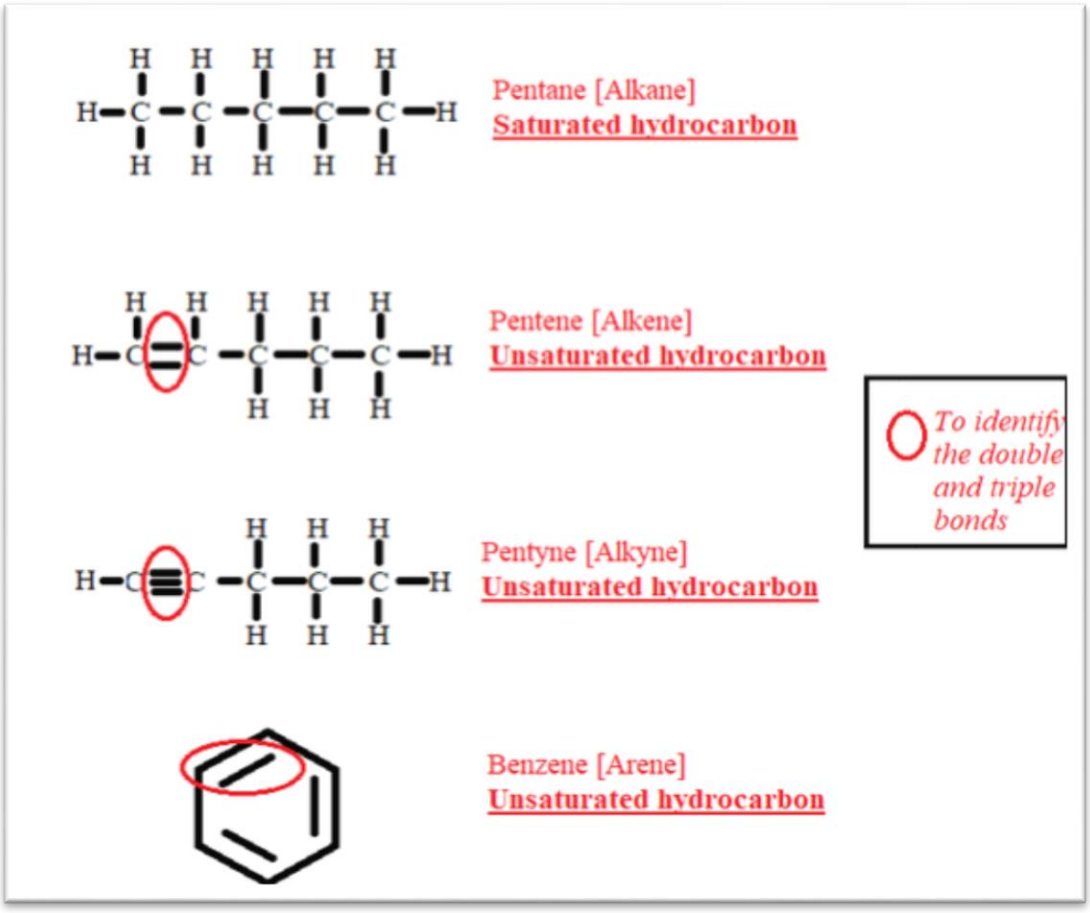
Compound Name	Structure of Compound and Functional Group (red)	Example	
		Formula	Name
alkene	C═C	C_2H_4 	ethene
alkyne	C≡C	C_2H_2 	ethyne
alcohol	R—Ö—H	CH_3CH_2OH 	ethanol
ether	R—Ö—R′	$(C_2H_5)_2O$ 	diethyl ether
aldehyde		CH_3CHO 	ethanal
ketone		$CH_3COCH_2CH_3$ 	methyl ethyl ketone
carboxylic acid		CH_3COOH 	acetic acid
ester		$CH_3CO_2CH_2CH_3$ 	ethyl acetate
amine		$C_2H_5NH_2$ 	ethylamine
amide		CH_3CONH_2 	acetamide

Alkyl groups

The general term alkyl group includes all groups derived from the alkanes by the loss of a hydrogen. Examples CH_3-methyl, CH3CH2-ethyl, $CH_3CH_2CH_2$ -propyl

Saturated and unsaturated compounds

- If an organic compound contains atoms joined only by single bonds, the compound is said to be saturated.
- If it contains carbon atoms joined by double or triple covalent bonds, it is said to be unsaturated



Naming Hydrocarbons

In general, an IUPAC name will have three essential features:

- A root or base indicating a major chain or ring of carbon atoms found in the molecular structure.
- A suffix or other element(s) designating functional groups that may be present in the compound.

• Names of substituent groups, other than hydrogen, that complete the molecular structure.

(practice on naming of organic compounds)

Isomerism

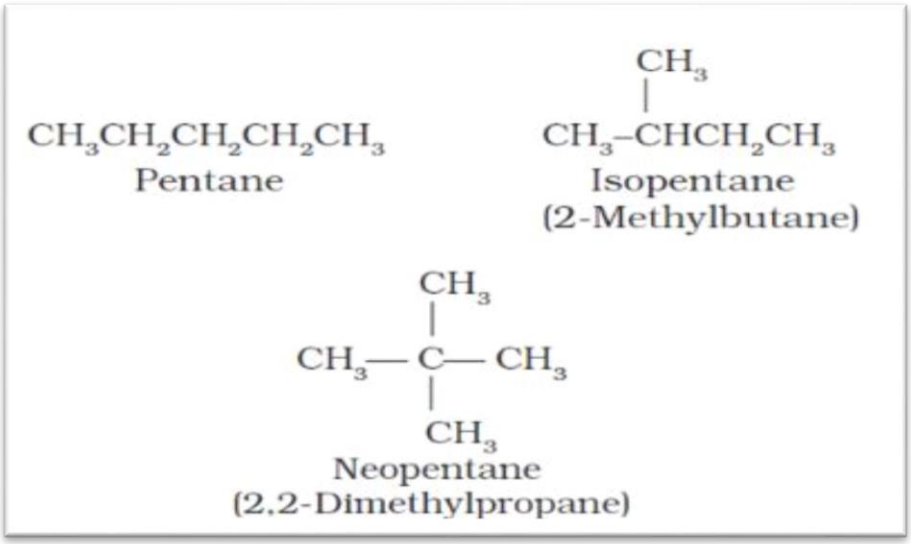
This is the existence of organic compounds having the same molecular formula but different structural formula

Types of isomerism

1. Chain isomerism
2. Positional isomerism
3. Functional group isomerism
4. Geometric or Cis-Trans isomerism
5. Optical isomerism

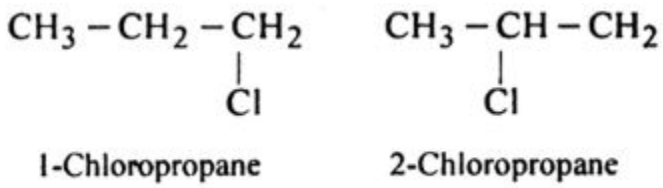
Chain Isomerism

It is also known as skeletal isomerism. Chain isomers differ in the branching of carbon. Example; C_5H_{12}



Position Isomerism

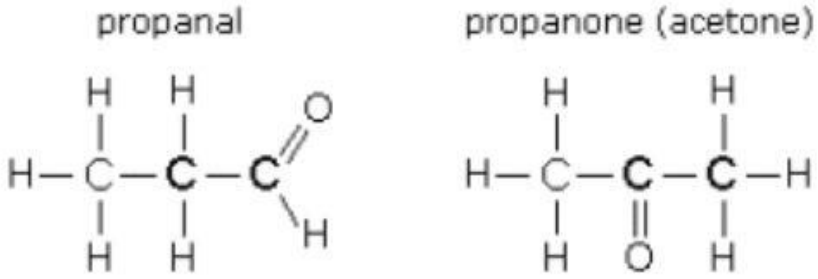
The positions of the functional groups or substituent atoms are different in position isomers. Example; C_3H_7Cl



1-Chloropropane 2-Chloropropane

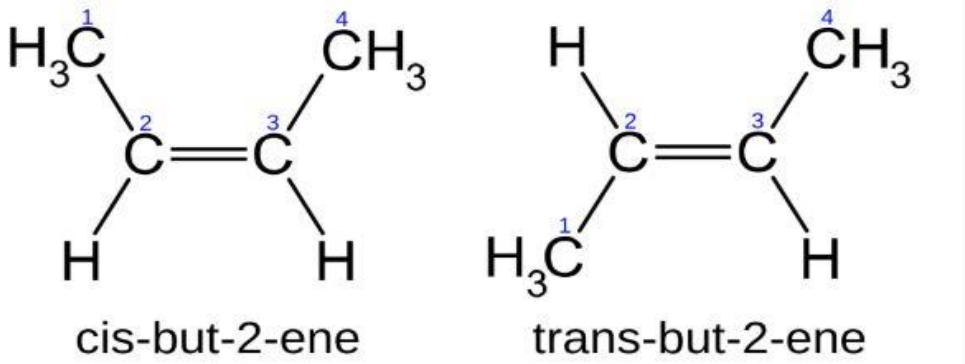
Functional Isomerism

it refers to the compounds that have the same chemical formula but different functional groups attached to them. Example: C_3H_6O



Geometric Isomerism

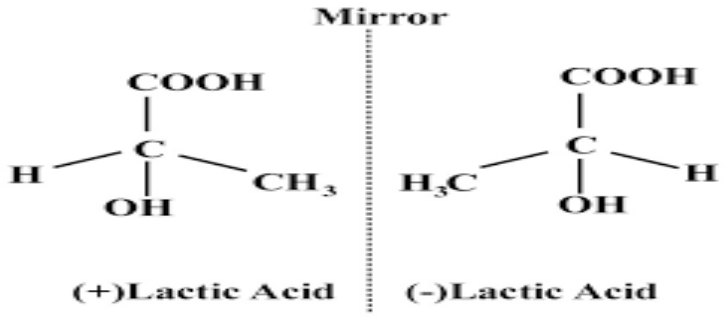
It is popularly known as cis-trans isomerism. These isomers have different spatial arrangements of atoms in three-dimensional space. Example; But-2-ene molecule is provided



Optical Isomerism

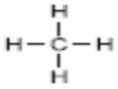
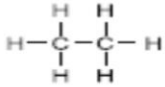
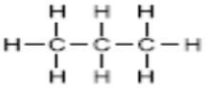
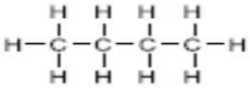
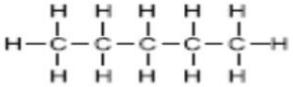
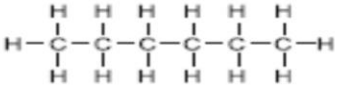
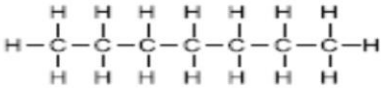
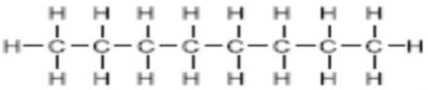
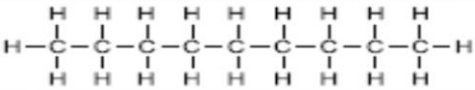
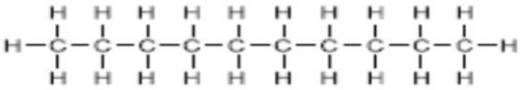
Compounds that exhibit optical isomerism feature similar bonds but different spatial arrangements of atoms forming non-superimposable mirror images. These optical isomers are also known as enantiomers.

Dextro enantiomers rotate the plane of polarized light to the right whereas laevo enantiomers rotate it to the left, as illustrated below.



The alkanes

The Alkanes are saturated hydrocarbons with a general formula: CnH2n+2. Sp^3 hybridized.

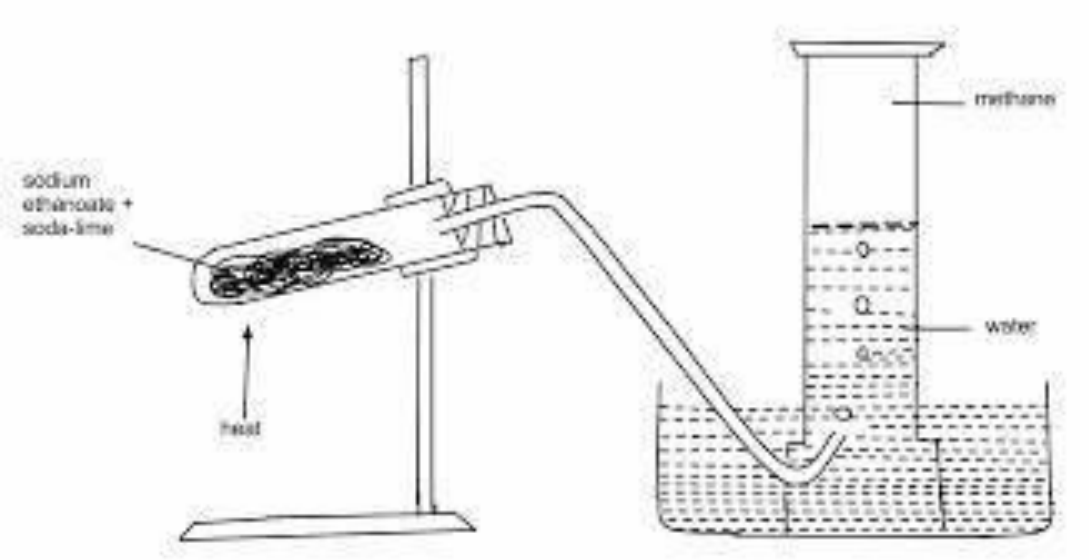
Name	Molecular Formula	Condensed Formula	Structural Formula
Methane	CH_4	CH_4	
Ethane	C_2H_6	H_3CCH_3	
Propane	C_3H_8	$H_3CCH_2CH_3$	
Butane	C_4H_{10}	$H_3C(CH_2)_2CH_3$	
Pentane	C_5H_{12}	$H_3C(CH_2)_3CH_3$	
Hexane	C_6H_{14}	$H_3C(CH_2)_4CH_3$	
Heptane	C_7H_{16}	$H_3C(CH_2)_5CH_3$	
Octane	C_8H_{18}	$H_3C(CH_2)_6CH_3$	
Nonane	C_9H_{20}	$H_3C(CH_2)_7CH_3$	
Decane	$C_{10}H_{22}$	$H_3C(CH_2)_8CH_3$	

Laboratory preparation of Alkanes (methane, CH_4)

Methane is usually prepared by heating anhydrous sodium ethanoate with an alkali, usually soda lime. soda lime is used in preference to caustic soda because it is not deliquescent and does not attack glass readily.

Anhydrous sodium ethanoate is ground with an equal mass of soda lime and heated in a hard glass test tube. Methane is given off and can be collected over water.

$$CH_3COONa + NaOH \rightarrow Na_2CO_3 + CH_4$$



The other alkanes in the series can be prepared by heating an appropriate sodium salt with soda lime.

Physical properties of methane

1. Colourless and odourless gas
2. Slightly soluble in water
3. Less dense than air
4. No action on litmus

Chemical properties

1. Combustion: methane burns in air with a pale blue non-luminous flame.
   $CH_4(g) + 2O_2(g) \rightarrow 2H_2O(g) + CO_2(g)$

2. Substitution reaction (chlorination): methane reacts with chlorine in the presence of UV light, which acts as a catalyst, to yield a mixture of products

$$CH_4 + Cl_2 \xrightarrow{h\nu} CH_3Cl + HCl$$
Chloromethane

$$CH_3Cl + Cl_2 \xrightarrow{h\nu} CH_2Cl_2 + HCl$$
Dichloromethane

$$CH_2Cl_2 + Cl_2 \xrightarrow{h\nu} CHCl_3 + HCl$$
Trichloromethane

$$CHCl_3 + Cl_2 \xrightarrow{h\nu} CCl_4 + HCl$$
Tetrachloromethane

Uses

1. Used as a domestic fuel
2. Used for making hydrogen, carbon black, carbon (IV) sulphide e.t.c

Alkenes

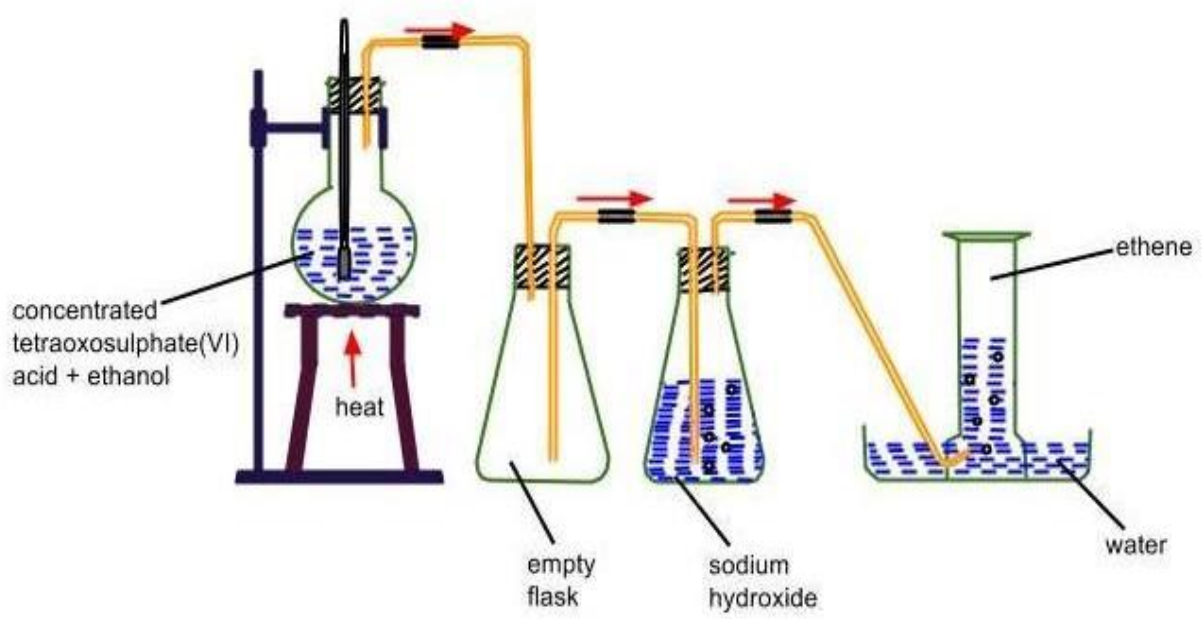
The alkenes are homologous series of hydrocarbons with a general molecular formula C_nH_{2n}. they are sp^2 hybridized and unsaturated

IUPAC Name	Molecular Formula	Condensed Structural Formula	Melting Point (°C)	Boiling Point (°C)
ethene	C_2H_4	$CH_2=CH_2$	–169	–104
propene	C_3H_6	$CH_2=CHCH_3$	–185	–47
1-butene	C_4H_8	$CH_2=CHCH_2CH_3$	–185	–6
1-pentene	C_5H_{10}	$CH_2=CH(CH_2)_2CH_3$	–138	30
1-hexene	C_6H_{12}	$CH_2=CH(CH_2)_3CH_3$	–140	63
1-heptene	C_7H_{14}	$CH_2=CH(CH_2)_4CH_3$	–119	94
1-octene	C_8H_{16}	$CH_2=CH(CH_2)_5CH_3$	–102	121

Laboratory preparation of Ethene

Ethene is prepared by dehydration of ethanol. On heating ethanol with sulphuric acid in the ratio 1:2 at a temperature of 170 ° C, ethene forms. The reaction occurs in two stages

$$C_2H_5OH + H_2SO_4 \rightarrow C_2H_5HSO_4 + H_2O$$
$$C_2H_5HSO_4 \rightarrow C_2H_4 + H_2SO_4$$



Physical properties (ethene)

1. Colourless gas with a faint sweetish smell.
2. Ethene is completely soluble in organic solvents and slightly soluble in water.
3. It is lighter than air.
4. No action on litmus
5. Boiling point of ethene is -102 ° C and melting point is –169° C.

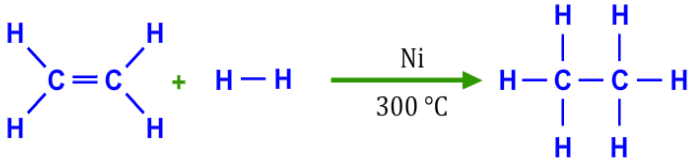
Chemical properties of Ethene

1. **Combustion:** Ethene on combustion produce carbon dioxide, water and heat.

$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O + Heat$.

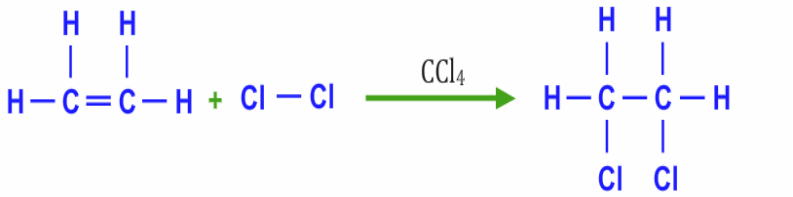
2. **Addition reaction:** A chemical reaction is said to be an addition reaction if two substances combine and form a third substance. In general, unsaturated hydrocarbons like alkenes and alkynes prefers to undergo addition reactions.
   In addition reactions, molecules add across double bond or triple bond.

   i. **Addition of hydrogen to ethene:** Gives ethane after catalytic hydrogenation in presence of nickel.



Ethene Ethane

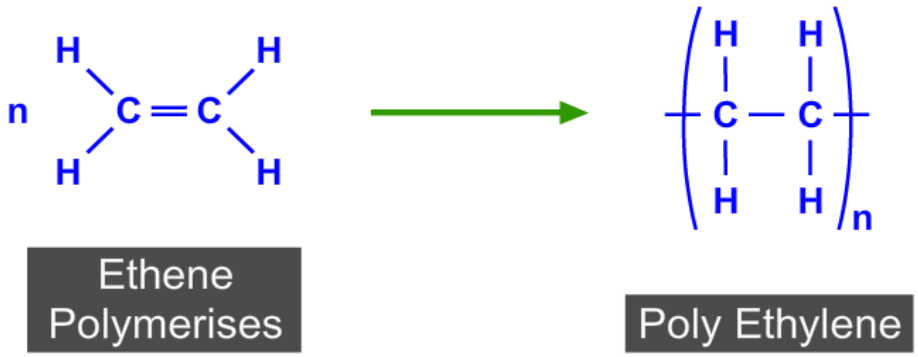
   ii. **Addition of chlorine:** When treated with halogens, ethene forms 1, 2-dihaloethanes.



Ethene Chlorine 1, 2-Dichloroethane

3. **Polymerization:** Polymerization is a process in which large number of unsaturated hydrocarbons join together to form a big molecule. The big molecule formed in this process is called a polymer.

   The polymer polythene is formed by the polymerization of ethene at high temperature and pressure.



Where, n = more than 1000

Uses

1. To ripen green fruits
2. An essential ingredient in manufacture of synthetic chemicals such as ethylene glycol, diethyl ether, ethylene oxide and mustard gas
3. To manufacture polymers like poly ethylene and poly vinyl chloride
4. It is also useful in the synthesis of important chemicals useful in industries.

Assignment

With the aid of equations, describe the addition reaction of ethene with

1. Hydrogen halides
2. Bromine water
3. Tetraoxosulphate (VI) acid
4. Tetraoxomanganate (VII)
5. With air or oxygen

Alkynes

The alkynes are homologous series of hydrocarbons with a general molecular formula C_nH_{2n-2}. They are SP hybridized and Unsaturated

Table 01: Structure of Terminal Alkynes

Name	Chemical formula	Structure
Ethyne	C_2H_2	HC≡ CH
Propyne	C_3H_4	HC≡ C-CH_3
Butyne	C_4H_6	H-C≡C-CH_2CH_3
Pentyne	C_5H_8	H-C≡C-CH_2-CH_2CH3
Hexyne	C_6H_{10}	H-C≡C-$CH_2CH_2CH_2CH_3$
Heptyne	C_7H_{12}	H-C≡C-$CH_2CH_2CH_2CH_2CH_3$
Octyne	C_8H_{14}	HC≡C-CH_2 $CH_2CH_2CH_2CH_2CH_3$

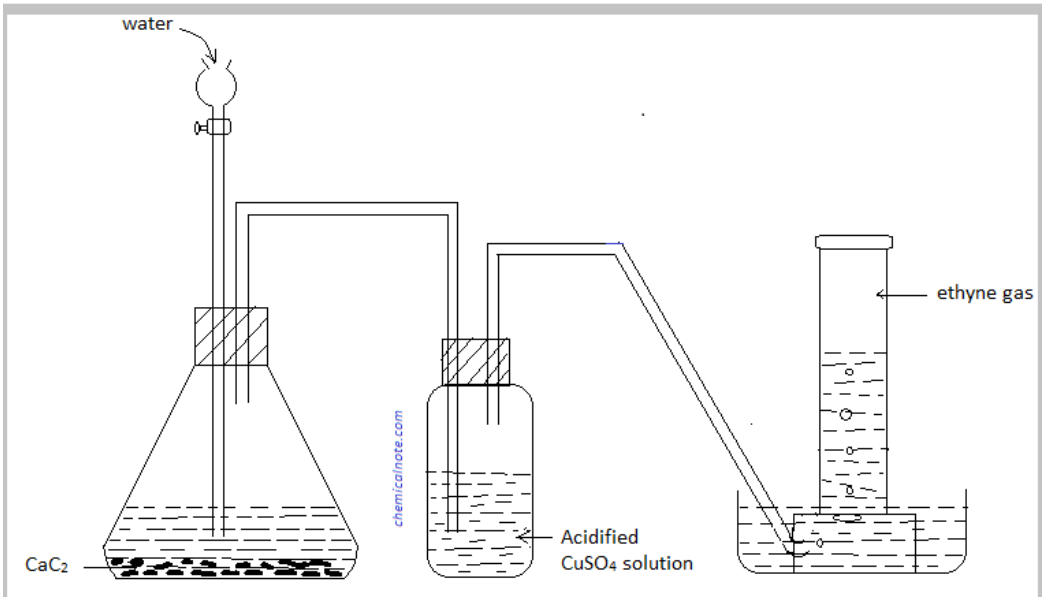
Note: *Alkynes with internal tripple bonds can be made by varying the position in the tripple bond*

Laboratory preparation of Ethyne (acetylene)

Calcium Carbide (CaC_2) is made to react with cold water. The reaction is performed on a heap of sand inside the flask to prevent the flask from cracking as large amount of heat is released.

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$$

the ethyne produced is passed through acidified copper sulphate to remove phosphine, PH_3, as impurity



Physical properties

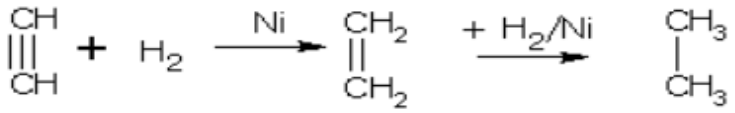
1. Ethyne (acetylene) is a colorless gas with ether-like odour when pure. Ethyne prepared from calcium carbide has garlic odour due to the presence of impurities like phosphine (PH_3) and hydrogen sulphide (H_2S).
2. Ethyne is slightly soluble in water, but highly soluble in organic solvents like acetone and alcohol.
3. It is lighter than air.
4. It is a poisonous gas. Liquid ethyne (acetylene) is highly explosive.
5. It has a boiling point of -84^0C.

Chemical properties of Ethyne

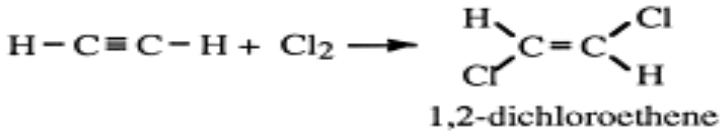
1. **Combustion:** Ethyne on combustion produce carbon dioxide, water and heat.

   $2\mathbf{C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O + Heat}$.
2. **Addition reaction:**

   i. Addition of hydrogen to ethyne gives ethane after catalytic hydrogenation in presence of nickel**.**



ii. Addition of halogen forms 1,1,2,2-tetrahaloethanes**.**



1,2-dichloroethene

1,1,2,2-tetrachloroethane
which is used as a solvent

3. Substitution reaction

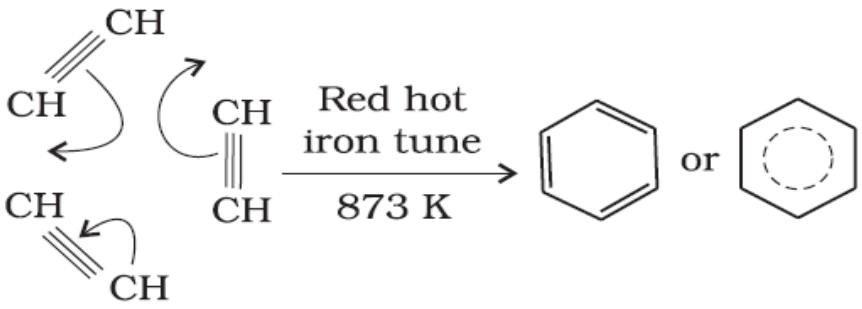
i. Terminal alkynes react with ammoniacal solution of copper(I) chloride at room temperature. A reddish-brown precipitate of copper(I) dicarbide is formed.

$C_2H_{2(g)} + 2CuCl_{(aq)} \rightarrow Cu_2C_{2(s)} + 2HCl_{(aq)}$

ii. Terminal alkynes react with ammoniacal solution of $AgNO_3$ at room temperature. A whitish-yellow precipitate of silver dicarbide is formed.

$C_2H_{2(g)} + 2AgNO_{3(aq)} \rightarrow Ag_2C_{2(s)} + 2HNO_{3(aq)}$

4. Polymerization: ethyne polymerize to form the aromatic hydrocarbon, benzene, when it is passed through a hot tube containing a complex orgno-nickel catalyst.



Ethyne Benzene

Uses

1. Substances like ethanol, acetic acid, vinyl polymer and plastic like substances can be prepared from it.
2. **Ethyne** is **used** in oxyacetylene flame **used** for welding of metals.
3. On kite flying day, acetylene gas is filled in rubber balloons and the balloons are flown high in the sky.

Summary

	Alkanes	**Alkenes**	**Alkynes**
1	Saturated	Unsaturated	Unsaturated
2	Sp3 hybridized	Sp2 hybridized	Sp Hybridized
3	It is prepared by heating anhydrous sodium ethanoate, CH_3COONa, with an alkali usually soda-lime **$CH_3COONa + NaOH \rightarrow Na_2CO_3 + CH_4$**	This is prepared by the reaction of an alcohol with hot H_2SO_4 in the ratio 1:2 **$CH_3CH_2OH + H_2SO_4 \rightarrow CH_2CH_2 + H_2O + H_2SO_4$**	It is prepared by the reaction of calcium carbide, CaC_2, with water **$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$**
4	Burns with a blue flame (least smoky)	Yellow luminous flame (smoky)	Smoky flame
5	They undergo substitution reaction	They undergo addition reaction	They also undergo addition reaction
6	Does not react with bromine water	Decolorizes bromine water	Decolorizes bromine water
7	No reaction with acidified $KMnO_4$	Decolorizes acidified $KMnO_4$	Decolorizes acidified $KMnO_4$
8	No reaction with acidified $K_2Cr_2O_7$	Changes acidified $K_2Cr_2O_7$ from orange to green	Changes acidified $K_2Cr_2O_7$ from orange to green

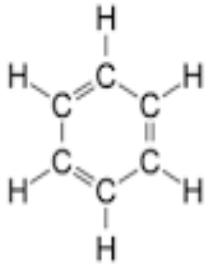
9	Deos not react with $AgNO_3/Ag_2O$	Does not react with $AgNO_3$	$AgNO_3/Ag_2O$ reacts with terminal alkynes to produce a white ppt
10	No reaction with Copper (I) Chloride, CuCl	No reaction with CuCl	CuCl reacts with terminal alkynes to produce a reddish brown ppt
11	They do not polymerize	They polymerize	They polymerize

Assignment.

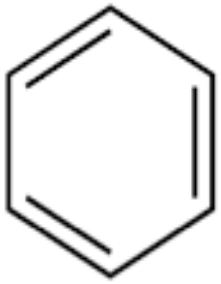
1. How would you differentiate between three hydrocarbons; alkane, alkene and alkyne by chemical test?
2. With the aid of equations, describe the addition reaction of ethyne with
   i. Hydrogen halides
   ii. water
   iii. Tetraoxomanganate (VII)

Benzene

Benzene, C_6H_6, is the simplest member of a large family of hydrocarbons, called aromatic hydrocarbons. These compounds contain ring structures and exhibit bonding that must be described using the resonance hybrid concept of valence bond theory or the delocalization concept of molecular orbital theory. The resonance structures for benzene, C_6H_6, are:



(1)

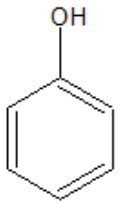


(2)

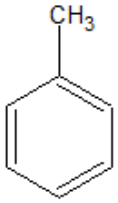
(3)

Derivative of benzene

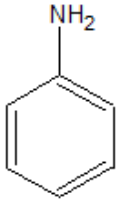
Examples of simple **benzene derivatives** are phenol, toluene, and aniline, abbreviated PhOH, PhMe, and $PhNH_2$, respectively.



phenol



toluene



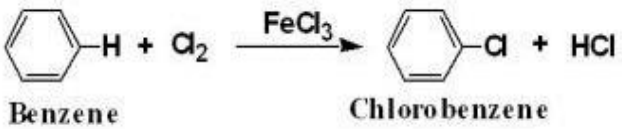
aniline

Physical properties of benzene

1. It is a colourless liquid with a sweet smell
2. It is insoluble in benzene
3. It has a boiling point of 80^0c

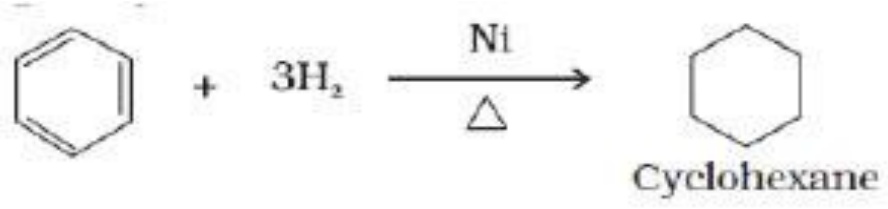
Chemical properties

1. Substitution reaction

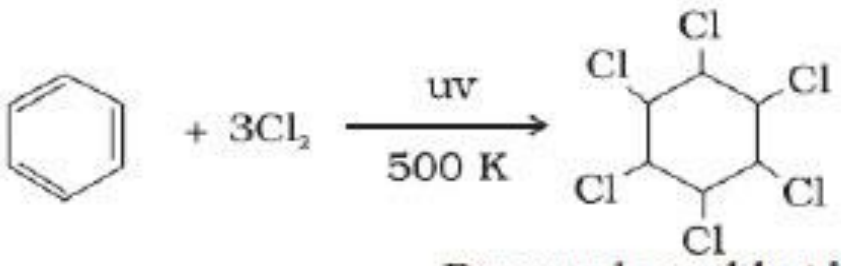


Benzene Chlorobenzene

2. Addition reaction



Cyclohexane



Benzene hexachloride,
(BHC)

Petroleum

Petroleum also known as crude oil is a dark, sticky liquid comprising mainly branched and unbranched alkanes and cycloalkanes.

Crude oil is usually found together with natural gas in underground deposited hundreds or thousands of meters below the surface of the earth. The oil is trapped between layers of non-porous rocks and the gas is often found above the oil. Deep wells have to be drilled to get them out

Crude oil and natural gas were formed by the decay of tiny sea creatures and plants which sank to the sea bed when they died. The dead creatures and plants were slowly covered by mud and sand. Eventually, the action of heat and pressure on the remains of these organism over millions of years produced crude oil and natural gas

Assignment

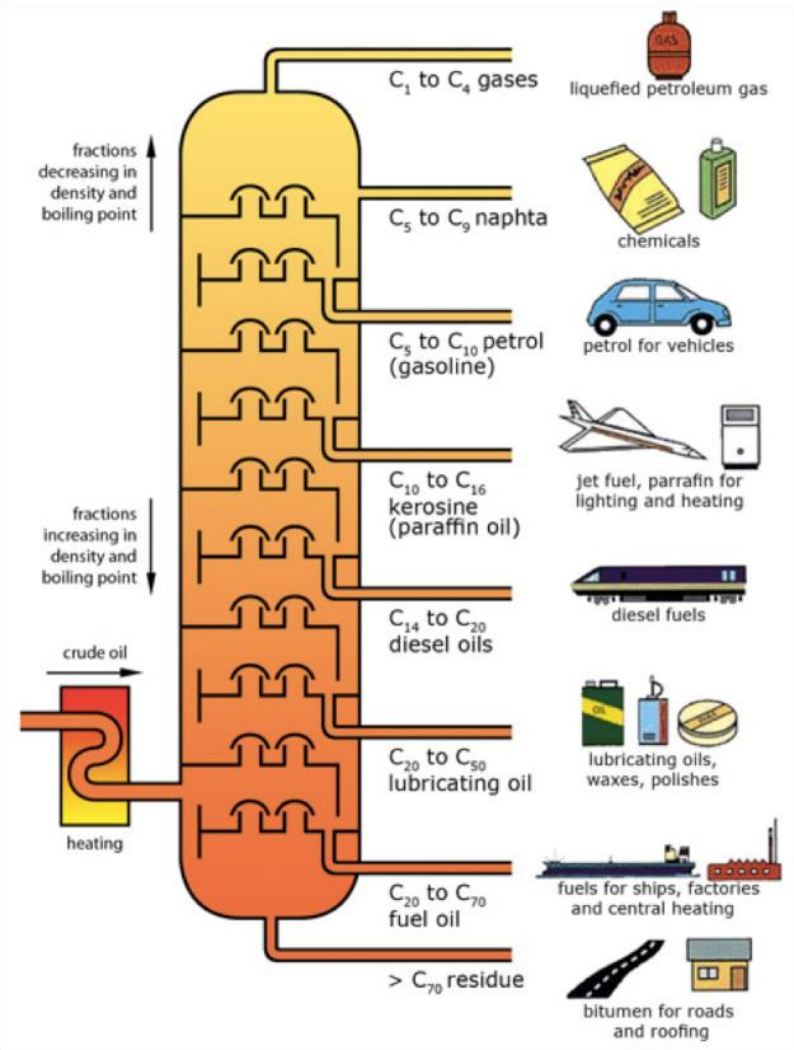
write short note on

1. Nigeria and world crude oil reserves,

2. location of refineries in Nigeria

Fractional distillation of crude oil

Crude oil must be separated into fractions before it can be useful. The separation of crude oil into useful fractions is called refining the oil. Each fraction of crude oil is a mixture of hydrocarbons which boils over a certain range of temperatures



Petroleum Fractions and their Uses

Fraction distilled from crude oil	Boiling point range (°C)	Carbon chain length	Hydrocarbons present	Uses
Refinery Gas	-160 to -5	1-4	Methane CH_4 Ethane C_2H_6 Propane C_3H_8 Butane C_4H_{10}	Home heating and cooking, camping fuel
Gasoline(petrol)	40-110	5-8	Octane C_8H_{18}	Car fuel
Naphtha	110-180	8-10	Decane $C_{10}H_{22}$	Plastics
Kerosene (paraffin)	180-260	10-16	Dodecane $C_{12}H_{26}$	Jet aircraft fuel
Diesel	260-320	16-20	Hexadecane $C_{16}H_{34}$	Fuel for buses and lorries
Fuel Oil	320-400	20-50	Icosane $C_{20}H_{42}$	Industrial heating systems
Bitumen/ Residue	400-600	>50		Surfacing roads

What is cracking and Reforming?

Cracking

- Cracking Is thermal decomposition of a heavy petroleum fraction to produce petrol/gasoline
- Cracking is used to produce high grade petrol
- Cracking is used to produce short chain alkanes
  $C_{18}H_{38(l)} \rightarrow C_6H_{14(l)} + 6C_2H_{4(g)}$
- Cracking is used to produce hydrogen
  $C_{18}H_{38(l)} \rightarrow C_8H_{16(l)} + C_{10}H_{20(l)} + H_{2(g)}$

Reforming

- Reforming is the process of restructuring hydrocarbons molecules involving heat, high pressure and the use of a catalyst. Depending on the conditions, straight chain alkanes may be converted to branched alkanes or aromatics. These products are useful in providing better quality petrol. Eg
  $C_6H_{14(l)} \rightarrow C_6H_{6(l)} + 4H_2$

- the condition for this reaction is
  - a temperature of 500^0 C
  - a catalyst and
  - a pressure of about 20 atm

The petrochemical industry

About 90% of the crude oil produced is used as a fuel to generate electricity and drive motor vehicles. Another 10% is used as petrochemical feed stock.

Crude oil is

- Used As petrochemical feed stock

- A source of hydrocarbons (e.g methane, ethane, propane e.t.c).
  Used for manufacturing:
  - polymers
  - fertilizers and pesticides
  -cosmetics
  - solvents
  -dyes

- Used for the synthesis of other organic compounds
  (alcohols, alkanoic acids, ethers, aldehydes, amines e.t.c)

Quality of Petrol

Under high compression, petrol vapour in car engines often explodes before electrical sparking. This produces a knocking sound. Low grade petrol consisting of mainly straight chain alkanes, knocks easily. As petrol burns prematurely, the energy is wasted

Octane number is a value used to indicate the resistance of motor fuel to knock. The fuel knock is compared on a scale with a mixture of 2,2,4-trimethylpentane (iso-octane) that has a rating of 100(minimum knock) and heptane has a rating of zero (bad knock)

Hydrocarbon	*Road Index Octane Number*
Heptane	0
2-Methylheptane	23
Hexane	25
2-Methylhexane	44
1-Heptene	60
Pentane	62
1-Pentene	84
Butane	91
Cyclohexane	97
2,2,4-Trimethylpentane (isooctane)	100
Benzene	101
Toluene	112

Natural Gas

Natural gas is usually found together with crude oil in between rock layers it is predominantly methane (about 90%). Other gases present include ethane propane, butane pentane and a small fraction of carbon dioxide, nitrogen and helium

Packaging as liquefied natural gas (LNG)

Liquefied natural gas (LNG) is natural gas (predominantly methane, CH_4, with some mixture of ethane, C_2H_6) that has been cooled down to liquid form for ease and safety of non-pressurized storage or transport. It takes up about 1/600th the volume of natural gas in the gaseous state.
It is odorless, colorless, non-toxic and non-corrosive. Hazards include flammability after vaporization into a gaseous state, freezing and asphyxia.
The liquefaction process involves removal of certain components, such as dust, acid gases, helium, water, and heavy hydrocarbons, which could cause difficulty downstream. The natural gas is then condensed into a liquid at close

Uses of natural gas

Natural gas is a non-renewable hydrocarbon used as a source of **energy** for heating, **cooking**, and electricity generation. It is also used as a **fuel** for vehicles and as a chemical feedstock in the manufacture of plastics and other commercially important organic chemicals.

Alternative Sources of Energy

What is renewable energy?

Renewable energy is energy that has been derived from earth's natural resources that are not finite or exhaustible, such as wind and sunlight. Renewable energy is an alternative to the traditional energy that relies on fossil fuels, and it tends to be much less harmful to the environment.

Renewable energy sources

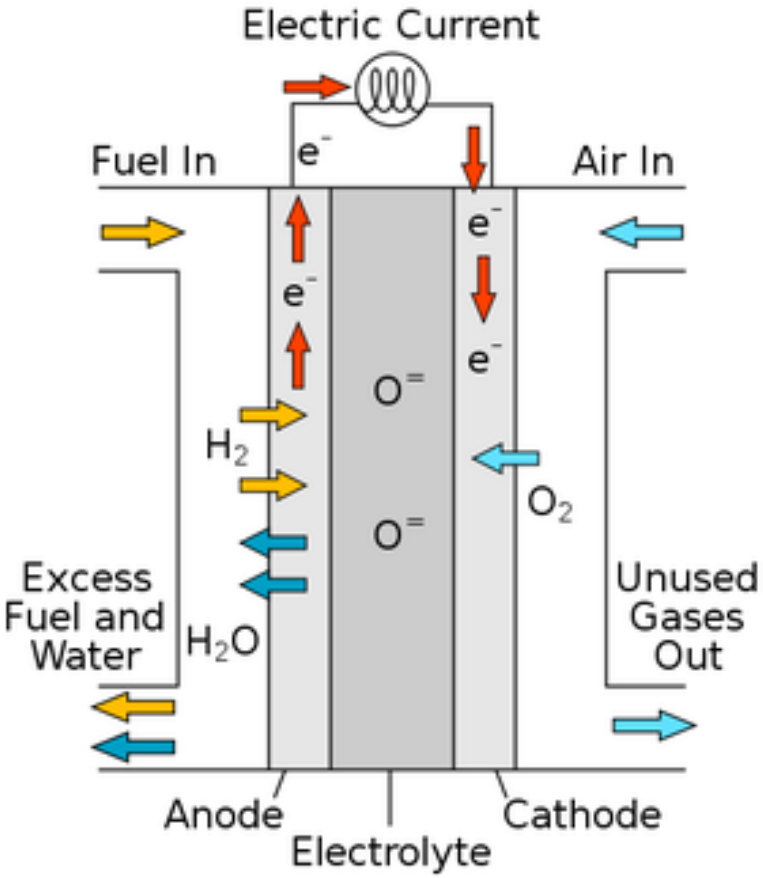
Solar, Wind, Hydroelectric, Geothermal, Ocean, Hydrogen, Biomass

Hydrogen as a potential future fuel

Hydrogen energy involves the use of hydrogen and/or hydrogen-containing compounds to generate energy to be supplied to all practical uses needed with high energy efficiency, overwhelming environmental and social benefits, as well as economic competitiveness

Fuel cells

- In a fuel cell there are two electrodes, usually platinum, in an electrolyte and the reactants are continually being supplied to the electrodes. This type of cell can supply electrical energy continuously.
- When hydrogen react with oxygen to form water in a fuel cell, electrical energy is produced
- Fuel cells prove a potable convenient source of power. Hydrogen fuel cells are used in space to provide the electrical power for space shuttles and other space vehicles



Assignment

1. What are the advantages and disadvantages of fuel cell?
2. Explain how photosynthesis can provide renewable energy source