CHEMISTRY

FOR
Senior Secondary School

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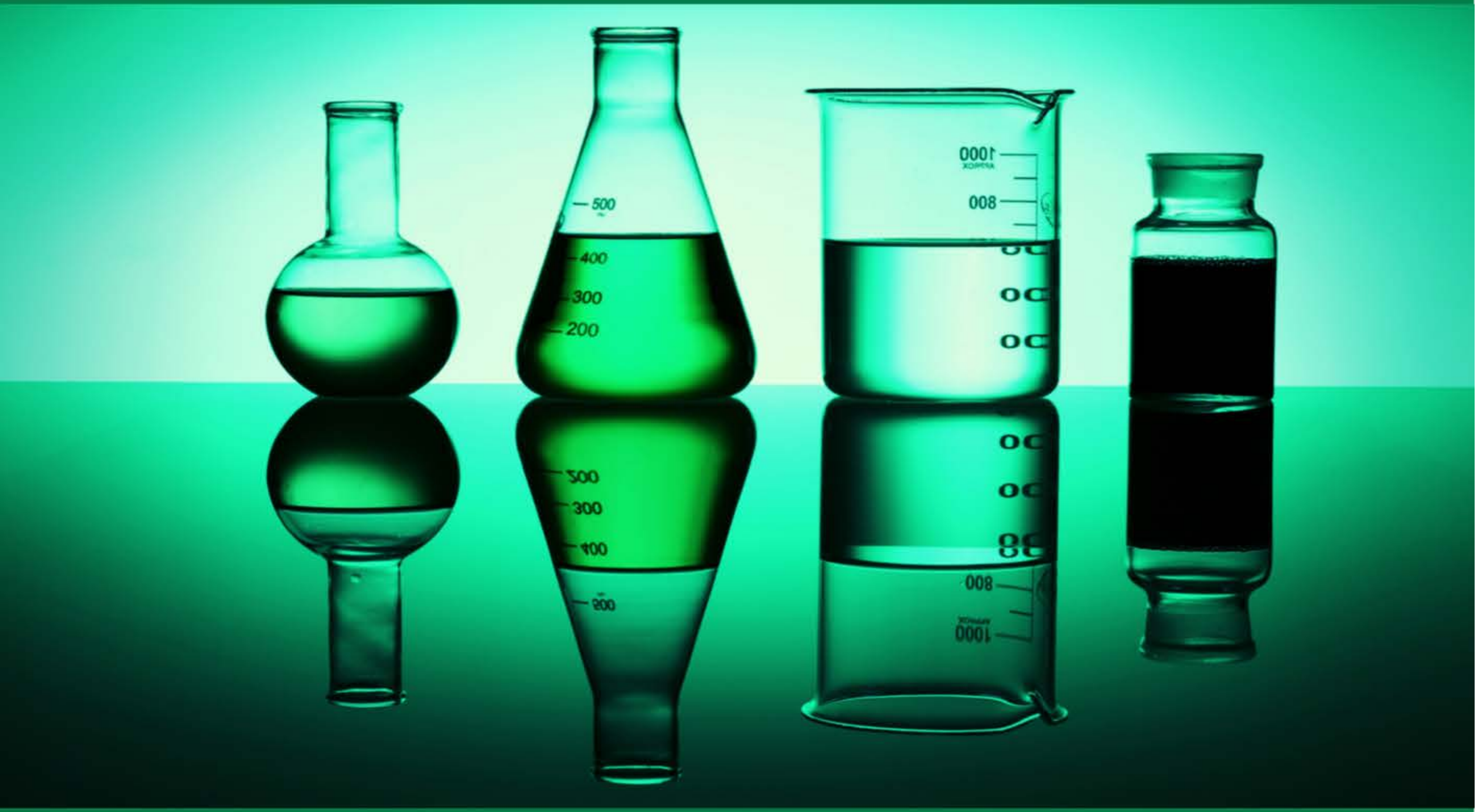

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SS 3
FIRST TERM NOTES ON CHEMISTRY

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FIRST TERM

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Chemistry SS 3 First Term

Topic: Alkanoic Acids

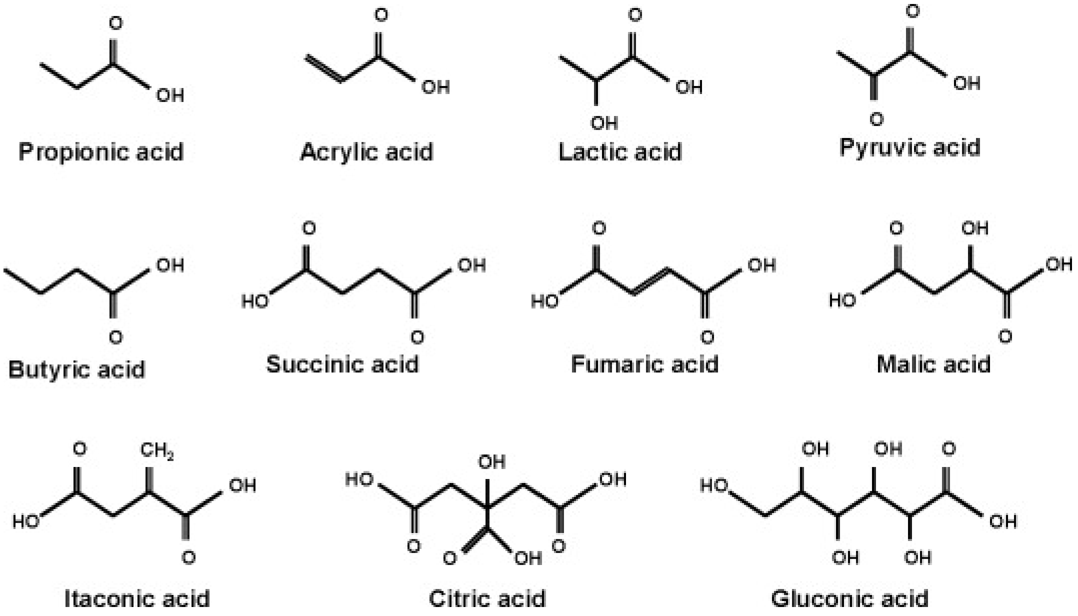
Alkanoic acids are also known as carboxylic acids. A carboxylic acid can he identified from the carboxyl functional group and the '-oic' name ending.

General formula of carboxylic (alkanoic acids) : $C_nH_{2n+1}COOH$ or R-COOH

Examples of Carboxylic (Alkanoic) Acids

Formula	longest carbon chain	C-C single bonds	functional group	Name	occurrence
HCOOH	C_1 : meth	-an-	-COOH (oic acid)	methanoic acid (formic acid)	ants
CH_3COOH	C_2 : eth	-an-	-COOH (oic acid)	ethanoic acid (acetic acid)	vinegar
C_2H_5COOH	C_3 : prop	-an-	-COOH (oic acid)	propanoic acid (propionic acid)	dairy products
C_3H_7COOH	C_4 : but	-an-	-COOH (oic acid)	butanoic acid (butyric acid)	rancid butter
C_4H_9COOH	C_5 : pent	-an-	-COOH (oic acid)	pentanoic acid (valeric acid)	valerian root

Structural Examples of carboxylic acids



Nomenclature (Naming Alkanoic Acids)

Alkanoic acids are named as follows:

- ·The number of carbon atoms in the longest carbon atom chain is noted
- ·The corresponding alkane is then named
- ·Finally, the name of this corresponding alkane is modified by removing the ane and replacing it with alkanoic acid

For example:

thylpentanoic acid ,

2-ethylpentanoic acid ,

benzoic acid

Preparation of ethanoic acid

The Complete Oxidation of Ethanol to Ethanoic Acid by acidified sodium heptaoxochromate(VI) solution. Ethanol undergoes oxidation first to ethanal and then to ethanoic acid.

The reaction of sodium dichromate(VI) solution with ethanol gives a carboxylic acid, ethanoic acid, a dilute solution of which is sold as vinegar.

Ethanoic acid can also be prepared by

- distilling anhydrous sodium ethanoate, CH_3COONa with concentrated H_2SO_4
- or boiling methyl cyanide CH_3CN with an acid

$CH_3COONa_{(aq)} + H_2SO_{4(aq)} \rightarrow CH_3COOH_{(g)} + NaHSO_{4\,(aq)}$

$CH_3CN_{(aq)} + HCl_{(aq)} \rightarrow CH_3COOH_{(g)} + NH_4Cl_{(aq)}$

Physical Properties

1. Ethanoic acid is usually a colourless liquid with a characteristics sharp and pungent smell
2. It is soluble in water and a dilute solution has the usual sour taste of acid
3. It has a boiling point of 118^0C
4. Pure anhydrous ethanoic acid freezes into ice-like crystals at temperature below 17^0C
5. It turns blue litmus paper red
6. Dilute solution has a sour taste

Chemical Properties of Carboxylic (Alkanoic) Acids

1. Carboxylic (alkanoic) acids are weak acids, the acid dissociation constant, K_a, is small.
2. Soluble carboxylic (alkanoic) acids dissociate slightly in water.

Neutralization Reactions

Neutralization: acid + base → salt + water

Carboxylic (alkanoic) acid + base → salt (metal alkanoate) + water

$RCOOH + MOH \rightarrow RCOO^-M^+ + H_2O$

e.g. $CH_3COOH + NaOH \rightarrow CH_3COO^-Na^+ + H_2O$

Ethanoic acid + sodium hydroxide → sodium ethanoate + water

Soluble salts of long-chain (fatty) acids are soaps

e.g. $C_{17}H_{35}COOH + NaOH \rightarrow C_{17}H_{35}COO^-Na^+ + H_2O$

Stearic acid + sodium hydroxide → sodium stearate + water

Reaction with Carbonates

acid + carbonate → salt + carbon dioxide gas + water

Carboxylic (alkanoic) acid + metal carbonate → metal alkanoate + carbon dioxide + water

e.g. $2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COO^-Na^+ + CO_2 + H_2O$

Ethanoic acid + sodium carbonate → sodium ethanoate + carbon dioxide + water

e.g. $CH_3COOH + NaHCO_3 \rightarrow CH_3COO^-Na^+ + CO_2 + H_2O$

Ethanoic acid + sodium bicarbonate → sodium ethanoate + carbon dioxide + water

Reaction with Active Metals

Acid + metal → salt + hydrogen gas

Carboxylic (alkanoic) acid + metal → metal alkanoate + hydrogen

e.g. $2CH_3COOH + 2Na(s) \rightarrow 2CH_3COO^-Na^+ + H_{2(g)}$

Ethanoic acid + sodium → sodium ethanoate + hydrogen

Esterification Reactions

Esters are produced in a condensation reaction between a carboxylic (alkanoic) acid and an alkanol (alcohol).

This is known as an esterification reaction.

carboxylic (alkanoic) acid + alkanol (alcohol)   ester + water

e.g. $2CH_3COOH + CH_3OH \quad CH_3COOCH_3 + H_2O$

Ethanoic acid + methanol   methyl ethanoate + water

Uses

1. It can be used as a solvent
2. It is used in food industries as vinegar for preserving and flavouring food
3. It is used In the manufacture of cellulose ethanoate which is used for making synthetic fibres, such as rayon
4. It is used in making compounds like ethyl ethanoate, ethanoic anhydride (used in aspirin), cellulose ethanoate (used for packing), propanone etc

Assessment

1. Ethanoic acid is usually a colourless liquid with a characteristics sharp and ……. smell
   a. pungent
   b. annoying
   c. foul
   d. dirty

2. Esters are produced in a condensation reaction between a carboxylic (alkanoic) acid and an alkanol (alcohol) known as …….
   a. Polymerization
   b. Esterification
   c. Dehydration
   d. Hydrolysis
3. Ethanoic acid reacts with active metal to give off ……….. gas
   a. Oxygen
   b. Hydrogen
   c. Carbon
   d. OH
4. Boiling point of Ethanoic acid is …….
   a. 117^{0}C
   b. 119^{0}C
   c. 118^{0}C
   d. 120^{0}C
5. It is used in food industries as vinegar for preserving and flavouring food. True/False

Answers

1. A
2. B
3. B
4. C
5. True

WEEK 2

Chemistry SS3 First Term

Topic: Alkanoates

Alkanoates or Esters

Ethyl Ethanoates

All esters are similar chemically although they may vary in degree of reactivity. Ethyl ethanoate is one of the simple esters. Its molecular formula is $CH_3COOC_2H_2$.

Properties

Ethyl ethanoate is prepared by the esterification between ethanol and glacial ethanoic acid at 150°C in the presence of concentrated tetraoxosulphate (vi) acid.

$C_2H_5OH_{(aq)} + CH_3COOH_{(l)} = CH_3COOC_2H_{5(l)} + H_2O_{(l)}$

Preparation of Alkanoates

1. **Acylation**. Esters are prepared by the acylation of alcohols or phenols. The acylating agents can be any of the following:

   Carboxylic acid / H 2SO 4 or Acyl chloride or Acid anhydride

   (i) Condensation of alcohols with carboxylic acid This reaction involves esterification of alkanols by alkanoic acid

   (ii) Esterification through acid derivatives

2. **By Reaction of Acids with Diazomethane**. Acids on being treated with ethereal solution of diazomethane yield methyl esters.

   $RCOOH + CH_2N_2$ à $RCOOCH_3 + N_2$

   Acid Diazo Ester
   methane

3. **By Tischenko Reaction**. When aldehydes containing a-hydrogen atoms are treated with aluminium ethoxide. They undergo condensation to produce esters.

Physical Properties of Alkanoates

1. **Physical state**. Esters are colourless, volatile and oily liquids with a characteristic fruity smell. The smell of the most of the flowers and fruits is due to esters present in them. The characteristic tastes and smells of different esters find applications in the manufacture of artificial flavouring and perfuming agents. The flavours of some of the esters are given below:

Ester	Flavour	Ester	Flavour
n-Pentyl ethanoate	Banana	Amyl but)'rate	Apricot
Octyl ethanoate	Orange	Isobutyl	Raspberry
Ethyl butanoate	Pineapple	Benzyl ethanoate	Jasmine

2. **Solubility**. Esters are sparingly soluble in water but are quite miscible in organic solvents like alcohols and ethers. In fact, most of the esters are themselves very good solvents for plastics and nitrocellulose.
3. **Boiling points**. The boiling points of esters are always less than the corresponding carboxylic acids because esters do not form hydrogen bonds.

Chemical Properties

1. **Hydrolysis.**Esters are hydrolysed slowly by water at boiling temperature. The reaction is catalysed by small amount of acid or base. The basic hydrolysis is also known as saponification. It is because of the fact that the esters with high molecular mass acids (C_{12}-C_{17}) give soap on hydrolysis with a base. Soaps are sodium or potassium salts of carboxylic acids with high molecular mass (C_{12}-C_{17}). Ethyl ethanoate can be hydrolyzed by water into its component acid and alkanol again. The reaction is catalyzed by hydrogen or hydroxide ions i.e dilute acid or alkali$CH_3COOC_2H_{5(l)} + H_2O_{(l)} \rightarrow C_2H_5OH_{(aq)} + CH_3COOH_{(l)}$
2. **Reduction**. Esters are reduced to alcohols by the reducing agents like (sodium/ethanol) or (lithium aluminium hydride).
3. **Reaction with Ammonia**. Esters on treatment with alcoholic ammonia yield acid amides. This reaction is known as ammonolysis of esters.
4. **Reaction with Phosphorus Pentachloride**. Esters are converted into acid chlorides and alkyl halides by heating with phosphorus pentachloride.

   $RCOOR' + PC1_5 \rightarrow RCOCl + R'Cl + POC1_3$

$C_6H_5COOC_2H_5 + PCl \rightarrow C_6H_5\ COCl + C_2H_2OH$
Ethyl benzoate Benzoyl chloride

5. **Alcoholysis**. An ester on refluxing with a large excess of an alcohol in the presence of a little acid or alkali, undergoes exchange of alcohol residues, i.e., alkoxy parts as shown below:
   This reaction is known as alcoholysis or trans-esterification.

Uses of Esters

They are mainly used as solvents for cellulose nitrate and quick drying substances like paints, nail varnishes, lacquer and adhesives. The commonly known thinner water is a mixture of esters. Esters are used in perfumes and cosmetics and artificial flavouring for foods. Certain volatile **esters** are **used** as solvents for lacquers, paints, and varnishes; for this purpose, large quantities of ethyl acetate and butyl acetate are commercially produced.

1. Esters that are have fragrant odours are used as a constituent of perfumes, essential oils, food flavourings, cosmetics, etc
2. Esters are used as an organic solvent
3. Natural esters are found in pheromones
4. Naturally occurring fats and oils are fatty acid esters of glycerol
5. Phospoesters form the backbone of DNA molecules
6. Nitrate esters, such as nitroglycerin, are known for their explosive properties
7. Polyesters are used to make plastics
8. Esters are used to make surfactants E.g. soap, detergents

ASSESSMENT

1. How is Ethyl ethanoate prepared?
2. What are some of the uses of Esters?
3. What are the chemical properties of Esters?

WEEK: 3

Chemistry SS3 First Term

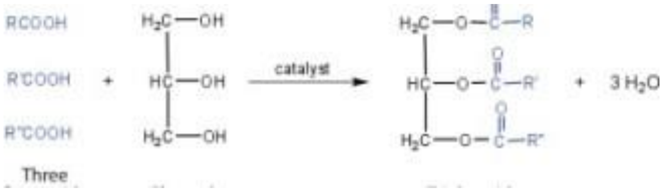
Topic: Fats and Oils

Fats and oils are naturally-occurring esters of three long carboxylic acids called fatty acid with a special type of alcohol called glycerol (propane- 1,2,3-triol). Glycerol has three carbon atoms, each with an –OH group on. These fats and oils belong to a group of compounds called lipids.

Fats are solid at room temperature, whereas oils are liquids. Animals and plants produce oils and fats as an energy store. Fats and oils are the most abundant lipids in nature. They provide energy for living organisms, insulate body organs, and transport fat-soluble vitamins through the blood.

Structures of Fats and Oils

Fats and oils are called triglycerides because they are esters composed of three fatty acid units joined to glycerol, a trihydroxyl alcohol:



Saturated and Unsaturated Fats and oils

Fatty acids can be saturated or unsaturated

The saturated fatty acids have single bond in their hydrocarbons while the unsaturated ones have double bonds. Esters produced from saturated fatty acids are usually solids at room temperature and they are called fats while the esters produced from unsaturated fatty acids are liquids at room temperature and are called oils.

Sources of Fats and Oils

- Animal sources generally provide fats, for example, dripping from beef, lard from pork and tallow from lamb. These fats are solid at room temperature and only become liquid when heated.

- Vegetable sources generally provide oils. Ester oils can be obtained from olives and seeds such as corn seed, sunflower seed, peanuts and soya beans, liquids at room temperature.
- Marine sources can provide both fats and oils, Sea mammals providing fats and oils being obtained from fish.

Properties of Fats and Oils

1. Both fats and oils are insoluble in water and they decompose at temperature above 300°C.
2. Since they are esters their main reactions are saponification and hydrolysis.

Uses of Fats and Oil

1. Fats and oils are used as essential ingredients of food
2. Sometimes they are used in natural form such as groundnut oil, palm oil for such industrial products as margarine
3. They are used as raw materials for making soap e.g. palm oil and coconut oil
4. They are used in making paint, candles and varnishers

Hydrolysis of Fats and Oils

Fats and oils contain ester links formed when glycerol has reacted with fatty acids. These ester links can be broken when they react with water, splitting the molecule back into an acid and an alcohol.

This process is known as hydrolysis of an ester. It can be described using the following word equation:

ester + water → acid + alcohol

Hydrogenation of Oils

The hydrogenation of oils is also known as hardening of oil. This is done by passing hydrogen into unsaturated oil at about 180°C and 5 atmosphere of pressure and in the presence of finely divided nickel as catalyst. In the process, the unsaturated part of the oil is saturated and the oil becomes hardening into fat.

Margarine is made by mixing such hardening oils with vitamins, salt, skimmed milk and colouring materials.

Formation of Soap (Saponification)

Saponification is a process by which triglycerides are reacted with sodium or potassium hydroxide to produce glycerol and a fatty acid salt, called 'soap'. In other word, Saponification is the alkaline hydrolysis of the fatty acid esters.

Natural soaps are sodium or potassium salts of fatty acids, originally made by boiling lard or other animal fat together with lye or potash (potassium hydroxide). Hydrolysis of the fats and oils occurs, yielding glycerol and crude soap.

In the industrial manufacture of soap, tallow (fat from animals such as cattle and sheep) or vegetable fat is heated with sodium hydroxide. Once the saponification reaction is complete, sodium chloride is added to precipitate the soap. The water layer is drawn off the top of the mixture and the glycerol is recovered using vacuum distillation. Dyes, perfumes and disinfectants are added as required before the soap is passes into bars.

Detergents

Detergents are substances which act with water to make things clean. The can be conveniently classified into two main types – soapy and soapless detergents

Soapy Detergents: are detergents made from soap. They are made by heating vegetable oils like palm oil with a strong alkali like sodium hydroxide. Soap is also biodegradable, i.e. it can easily be decomposed by bacteria into simple inorganic substances.

Soapless Detergents: Most of the soapless detergents are made from petroleum fractions. Usually the hydrocarbon is reacted with sulphuric acid, and the product neutralized with sodium hydroxide to obtain the soapless detergent. They are non-biodegradable and so create water pollution problems when their forms clog up waterways.

Detergent helps to remove dirt in different ways:

1.) They help water to spread out and completely soak a surface. They are good wetting agents.

2.) They form an emulsion with the dirt. They are emulsifying agents.

3.) As a wetting agent, detergent help to reduce the surface tension of water, which tends to pull water molecules together and making water itself to be a bad wetting agent.

As an Emulsifying Agent

Detergent has two main parts;

1. A long hydrocarbon chain which is soluble in the grease or oil of the dirt. This part is not soluble in water and described as hydrophobic

2. An ionic or polar part which in not soluble in the dirt but is soluble in water. This part is described as hydrophilic, $COO^- Na^+$ or $COO^- K^+$

Mode of Action

When detergent is added to grease, the grease soluble hydrophobic tail dissolve in the grease and the hydrophilic parts that bring along with a negative charge are insoluble in the grease and so they remain outside. The surface of the grease becomes negatively charge, and if stirring is applied, very large of colloidal particles of grease and detergent are formed. They are held in aqueous solution by the attraction of the hydrophilic parts for the water molecules, but are prevented from coming together because similarly charged on surface of the particles cause repulsion between each other. Thus they form an emulsion of dirty water.

Differences between Soaps and Soapless Detergent

1) Soap from scum with hard water (which contains dissolve calcium or magnesium ions), while soapless detergent is not affected.

2) Soaps are made from edible animal or vegetable oils while soapless detergents are made from petroleum, which is cheaper and edible.

Assessment

1. ……… is a process by which triglycerides are reacted with sodium or potassium hydroxide to produce glycerol and a fatty acid salt, called ‘soap’.
2. Fats are ……. at room temperature.
3. ……… are substances which act with water to make things clean
4. Mention 4 sources of fats and oil

Answers

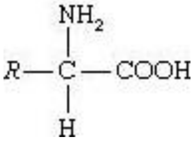
1. Saponification
2. Solid
3. Detergents

WEEK: 4

Chemistry SS3 First Term

Topic: Amino Acids

Amino acids are the basic structural units of proteins. Amino acids are organic compounds which contain both an amino group and a carboxyl group, that is, any of a group of organic molecules that consist of a basic amino group ($-NH_2$), an acidic carboxyl group ($-COOH$). Each molecule contains a central carbon (C) atom, termed the α-carbon, to which both an amino and a carboxyl group are attached. The remaining two bonds of the α-carbon atom are generally satisfied by a hydrogen (H) atom and the R group. The formula of a general amino acid is:



$$R-\overset{NH_2}{\underset{H}{C}}-COOH$$

The amino acids differ from each other in the particular chemical structure of their R group.

There are 20 naturally occurring amino acids of biological importance. The human body can synthesize all of the amino acids necessary to build proteins except for the ten called the “essential amino acids”. They can be supplied by a combination of cereal grains (wheat, corn, rice, etc.) and legumes (beans, peanuts, etc.). The 10 amino acids that we can produce are alanine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine and tyrosine. Tyrosine is produced from phenylalanine, so if the diet is deficient in phenylalanine, tyrosine will be required as well. The essential amino acids (that we cannot produce internally) are arginine (required for the young, but not for adults), histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. These amino acids are required in the diet. Plants, of course, must be able to make all the amino acids. Humans, on the other hand, do not have all the enzymes required for the biosynthesis of all of the amino acids.”

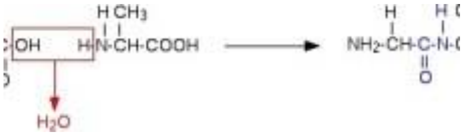
Peptides

Peptides are amides formed by the interaction between amino groups and carboxyl groups. The bond joining the α – amino group of one amino acid and the α – carboxyl group of another amino acid is called peptide bond. Two amino acids react to form a dipeptide, three to form a tripeptide etc. If a numbe of amino acids are linked by peptide bonnds, a polypeptide is formed. A polypeptide chain has an amino acid end and a carboxyl end. It consists of a regular repeating part or main chain and a variable part. or side chain.

Proteins

Proteins are highly complex substance that is present in all living organisms. Proteins are of great nutritional value and are directly involved in the chemical processes essential for life. A protein molecule is very large compared with molecules of sugar or salt and consists of many amino acids joined together to form long chains, much as beads are arranged on a string. There are about 20 different amino acids that occur naturally in proteins. Proteins of similar function have similar amino acid composition and sequence. When proteins are eaten, they are hydrolysed in the stomach to give a large variety of amino acids, which are then carried by the blood stream to all parts of the body. Some are used to build cell proteins in the growing body or repair damaged cells. Proteins are made up of polypeptide chains. The amino acid sequence in the polypeptide chain of a protein is specified by genes.

Glycine and alanine can combine together with the elimination of a molecule of water to produce a dipeptide.



In each case, the linkage shown in blue in the structure of the dipeptide is known as a peptide link.

If you joined three amino acids together, you would get a tripeptide. If you joined lots and lots together (as in a protein chain), you get a polypeptide.

Occurrence

Proteins are found in all living systems as structural components and as biologically important substances such as hormones, enzymes and pigments. Proteins in our food can be divided into first class and second class proteins. First class proteins contain essential amino acids and they are mainly of animal origin. Examples are lean meat, fish, eggs, milk and cheese. Second class proteins are mainly vegetable proteins such as beans and peas.

The relationship between amino acid side chains and protein conformation

The defining feature of an amino acid is its side chain (at top, blue circle; below, all colored circles). When connected together by a series of peptide bonds, amino acids form a polypeptide, another word for protein. The polypeptide will then fold into a specific conformation depending on the interactions (dashed lines) between its amino acid side chains.

Some important proteins are:

1. Insulin (a hormone)
2. Haemoglobin (Oxygen-carrying pigment in the blood).
3. Ribonuclease (an enzyme)
4. Collagen (a muscle protein)

The hydrolysis is catalysed by an acid or base. The amino acids obtained on hydrolysis can be separated and identified by using paper chromatography.

Test for Proteins

1. Biuret Test: If copper (II) tetraoxosulphate (VI) is added to a solution of a protein and the resulting solution made alkaline with sodium hydroxide solution, a violet colour develops.
2. Million's Reagent Test: Add a drop or two of million's reagent to some egg – white solution in a test tube. The formation of a white precipitate which turns brick red on heating indicates the presence of protein.

3. Trioxonitrate (V) acid Test: Add three or four drops of concentrated trioxonitrate (V) acid to $2cm^3$ of egg-white solution. The formation of an intense yellow colour indicates the presence of proteins.

Properties

Denaturation – Proteins usually form colloidal solutions. When such solutions are heated, the proteins precipitate or coagulate. This is due to the irreversible changes in the molecular shapes of the proteins, and the proteins are said to have been denatured. Proteins are easily denatured by

- temperatures above 40C
- certain organic solvents and chemical reagents
- variations in pH

Hydrolysis

Proteins can be hydrolyzed to give amino acids by boiling them with solutions of hydrochloric acid. Hydrolysis is carried out using suitable enzymes.

Assessment

Explain the denaturation of protein.

Mention 3 examples of proteins

WEEK: 5

Chemistry SS3 First Term

Topic: Polymers

Polymers are giant molecules which are formed by joining together a large number of much smaller molecules thus, forming a long chain. The smaller molecule, which is the starting material, is known as monomer (meaning one unit). The molecular size of a given polymer is not fixed.

There are two types of polymers: synthetic and natural.

Synthetic polymers: are derived from petroleum oil, and made by scientists and engineers. Examples of synthetic polymers include nylon, polyethylene, polyester, Teflon, and epoxy.

Natural polymers: occur in nature and can be extracted. They are often water-based. Examples of naturally occurring polymers are silk, wool, DNA, cellulose and proteins. Rubber and many resins are also natural polymers found in plants.Polymerization is any process in which relatively small molecules, called monomers, combine chemically to produce a very large chain-like or network molecule, called a polymer. The monomer molecules may be all alike, or they may represent two, three, or more different compounds. Usually at least 100 monomer molecules must be combined to make a product that has certain unique physical properties—such as elasticity, high tensile strength, or the ability to form fibres. The formation of stable covalent chemical bonds between the monomers sets polymerization apart from other processes, such as crystallization, in which large numbers of molecules aggregate under the influence of weak intermolecular forces.

Two classes of polymerization usually are condensation and addition polymerization.

Condensation polymerization is the process whereby two or more monomers link together to form the polymer with the elimination of a small molecule. In condensation polymerization, each step of the process is accompanied by formation of a molecule of some simple compound, often water. Two most important condensation polymers are nylon and terylene.

Addition polymerization is the process whereby two or more of the same monomers link together to form the polymer without elimination of any small molecules. In addition polymerization, monomers react to form a polymer without the formation of by-products. Addition polymerizations usually are carried out in the presence of catalysts, which in certain cases exert control over structural details that have important effects on the properties of the polymer. Addition polymers include poly(ethene), poly(chloroethene), perspex, etc.
Other Terms

Linear polymers: which are composed of chain-like molecules, may be viscous liquids or solids with varying degrees of crystallinity. A number of them can be dissolved in certain liquids, and they soften or melt upon heating.

Cross-linked polymers: in which the molecular structure is a network, are thermosetting resins (*i.e.,* they form under the influence of heat but, once formed, do not melt or soften upon reheating) that do not dissolve in solvents.

Note: Both linear and cross-linked polymers can be made by either addition or condensation polymerization.

Plastics

Plastics are natural/synthetic materials. They are produced by chemically modifying natural substances or are synthesized from inorganic and organic raw materials. They are giant molecules which are products of polymerization of simple unsaturated compounds like ethene, propene or substituted unsaturated compounds like styrene (phenylethene) and vinyl chloride chloroethene. Plastics also include synthetic fibres like nylon and terylene. Plastics are either:
Thermoplastic: This can soften upon heating and return to their original form. They are easily molded and extruded into films, fibers and packaging. Examples include polyethylene (PE), polypropylene (PP) and polyvinyl chloride (PVC).
Thermoset or thermosetting plastics: Once cooled and hardened, these plastics retain their shapes and cannot return to their original form. They are hard and

durable. Thermosets can be used for auto parts, aircraft parts and tires. Examples include polyurethanes, polyesters, epoxy resins and phenolic resins.

Polyethylene, LDPE and HDPE: The most common polymer in plastics is polyethylene, which is made from ethylene monomers (CH2=CH2). The first polyethylene was made in 1934. Today, we call it low-density polyethylene (LDPE) because it will float in a mixture of alcohol and water. In LDPE, the polymer strands are entangled and loosely organized, so it's soft and flexible. It was first used to insulate electrical wires, but today it's used in films, wraps, bottles, disposable gloves and garbage bags.

In the 1950s, Karl Ziegler polymerized ethylene in the presence of various metals. The resulting polyethylene polymer was composed of mostly linear polymers. This linear form produced tighter, denser, more organized structures and is now called high-density polyethylene (HDPE). HDPE is a harder plastic with a higher melting point than LDPE, and it sinks in an alcohol-water mixture. HDPE was first introduced in the hula hoop, but today it's mostly used in containers.

Polyvinyl Chloride (PVC): PVC is a thermoplastic that is formed when vinyl chloride (CH2=CH-Cl) polymerizes. When made, it's brittle, so manufacturers add a plasticizer liquid to make it soft and moldable. PVC is commonly used for pipes and plumbing because it's durable, can't be corroded and is cheaper than metal pipes. Over long periods of time, however, the plasticizer may leach out of it, rendering it brittle and breakable.

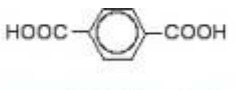
Polystyrene (Styrofoam): Polystyrene is formed by styrene molecules. The double bond between the CH2 and CH parts of the molecule rearranges to form a bond with adjacent styrene molecules, thereby producing polystyrene. It can form a hard impact-resistant plastic for furniture, cabinets (for computer monitors and TVs), glasses and utensils. When polystyrene is heated and air blown through the mixture, it forms Styrofoam. Styrofoam is lightweight, moldable and an excellent insulator.

Polypropylene (PP): In 1953, Karl Ziegler and Giulio Natta, working independently, prepared polypropylene from propylene monomers (CH2=CHCH3) and received the Nobel Prize in Chemistry in 1963. The various forms of polypropylene have different melting points and hardnesses. Polypropylene is used in car trim, battery cases, bottles, tubes, filaments and bags.

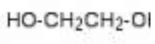
Nylon: Nylon fibre is obtained by heating hexane dioc acid (adipic acid) with hexane 1,6 diamine. *Nylon was originally developed as a textile but is available in many forms with vastly different properties. Engineering nylon grades are easy to machine with good resistance to biological attack. Unfortunately nylons can absorb moisture from the atmosphere and can degrade in strong sunlight (they are unstable in ultraviolet light) unless a stabilizing chemical is added at the initial manufacture of the plastic. Nylons are easy to mould. Nylons also have a natural 'oily' surface that can act as a natural lubricant. Nylons are used for everything from clothes through to gears and bearings. It is also slippery and can be used to make washers, spacers and bushes.*

Epoxy Resin: is a thermosetting polymer formed from reaction of an epoxide resin with polyamine hardener. The resin consists of monomers or short chain polymers with an epoxide group at either end. Most common epoxy resins are produced from a reaction between epichlorohydrin and bisphenol A. Epoxy resin has various uses such as; the resins that are cured through exposure with ultra violet light are normally used in optoelectronics, fibre optic and dentistry. Industrial tooling applications normally use resin to make laminates, fixtures, castings and moulds. In the electronic world, epoxy resin is used to make transformer, insulator, switch gear and generators.

Terylene: This is a polyester that is also known as Dacron in the U.S.A. It is formed by the condensation of benzene- 1,4- dicarboxylic acid (terephthalic acid) and ethane- 1,2- diol (ethylene glycol), using an acid catalyst.



enzene-1,4-dicarboxylic acid



ethane-1,2-diol

Terylene is another synthetic fibre which is mainly used in the manufacture of synthetic textiles. Terylene is mostly used for clothing, ropes, sheets, sails and many others.

Natural Rubber

Rubber is obtained from the rubber tree, *Hevea brasiliensis*. When the bark of the tree is cut, a thick white liquid called latex oozes out. if the latex is collected and heated, it changes into an elastic solid called rubber. This rubber is of little use because it is soft and sticky. Chemically, it consists of 2-methyl buta-1,3-diene monomers known previously as isoprene. When the monomers polymerize, they form a long polymeric chains which have only a limited number of cross-links between them. By adding sulphur and heating, the soft rubber becomes hard.

Vulcanization is chemical process by which the physical properties of natural or synthetic rubber are improved. In its simplest form, vulcanization is brought about by heating rubber with sulfur. Finished rubber has higher tensile strength and resistance to swelling and abrasion, and is elastic over a greater range of temperatures.

Synthetic Rubber

1,3-Butadiene is an important industrial chemical used as a monomer in the production of synthetic rubber. Buta-1,3-diene co-polymerize with phenylethene to form the tyre of synthetic rubber known as bunas or styrene butadiene rubber (SBR).

Assessment

1. ……… are giant molecules which are formed by joining together a large number of much smaller molecules thus, forming a long chain.
2. Explain Epoxyresin.
3. What do you understand by Polystyrene?

Answers

1. Polymers

WEEK: 6

Chemistry SS 3 First Term

Topic: Carbohydrates

Carbohydrates (saccharides) – Molecules consist of carbon, hydrogen and oxygen atoms. It is a major food source and a key form of energy for most organisms. When combined together to form polymers, carbohydrates can function as long term food storage molecules, as protective membranes for organisms and cells, and as the main structural support for plants and constituents of many cells and their contents. Carbohydrates are naturally occurring organic compounds. The general molecular formular is $C_x(H_2O)_{y.}$

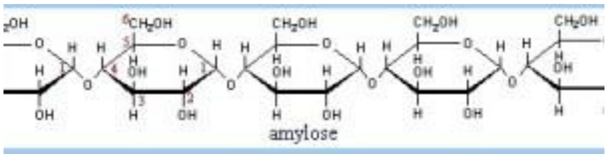
Types of Carbohydrates

Carbohydrates can be classified into two i.e. simple and complex sugars.

1. Simple carbohydrates: These are also called simple sugars. They are crystalline, soluble in water and have a sweet taste. Structurally, they can be further divided into monosaccharides e.g. glucose, and disaccharides e.g. sucrose
2. Complex carbohydrates: These are also called polysaccharides. They are non-crystalline, insoluble and tasteless substances, e.g. starch and cellulose. Starches include grain products, such as bread, crackers, pasta, and rice.

Monosaccharides

A monosaccharide or simple sugar has a formula that is some multiple of CH_2O. For instance, glucose (the most common monosaccharide) has a formula of $C_6H_{12}O_6$. This is the smallest possible sugar unit. Examples include glucose, galactose or fructose. Monosaccharides cannot be split into smaller units by the action of dilute acids. Monosaccharides are classified according to the number of carbon atoms they possess: trioses have three carbon atoms; tetroses, four; pentoses, five; hexoses, six; etc. Each of these is further divided into aldoses and ketoses, depending on whether the molecule contains an aldehyde group (–CHO) or a ketone group (–CO–). For example glucose, having six carbon atoms and an aldehyde group, is an aldohexose whereas fructose is a ketohexose. These aldehyde and ketone groups confer reducing properties on monosaccharides: they can be oxidized to yield sugar acids.



Glucose

Glucose commonly known as grape sugar or dextrose is present in fruits such as grapes, honey and also sap of plants. It is the main source of energy for mineral tissues and its present in the blood of animals.

Preparation

Glucose can be prepared from the hydrolysis of starch with dilute acid.

$(C_6H_{10}O_5)_n + nH_2O \rightarrow nC_6H_{12}O_6$

Properties

If Glucose is heated with concentrated teteraoxosulphate(vi) acid, it will be dehydrated to form a black residue of carbon.

Disaccharides

A disaccharide is a derived or condensed from two molecules of monosaccharides by the elimination of one molecule of water.

monosaccharide + monosaccharide ↔ dissacharide + water

Sucrose

Sucrose or cane sugar is the common granulated sugar which we use to sweeten food. It occurs naturally in many plants and fruits. e.g. pineapple, carrots, sorghum and sap of sugar maple tree.

Preparation

Sucrose is prepared from juices of sugar cane and sugar beet. The cane or beet is shredded and crushed between rollers and the juice is extracted with water warmed to about 80^0C. The solution is then purified by treatment with slaked lime and carbon(iv) oxide. The purified solution is concentrated by distillation under reduced pressure. On cooling, the concentrated solution, brown crystals of sugar separate out. The remaining liquid called molasses still contains a reasonable amount of sugar and is used in ethanol production. The brown sugar obtained is impure. It is refined by treatment with slaked lime and carbon (iv) oxide, and decolorized with animal charcoal.

Properties

Sucrose is a colourless crystalline solid. It has a very sweet taste and dissolves readily in water but not alkanol.

Sucrose chars on strong heating or warming with concentrated tetraoxosulphate (vi) acid.

If sucrose is heated to a temperature of about 210 celcius which is above melting point but below its charring temperature, a yellowish – brown substance known as caramel. Caramel is used for flavouring and in confectionery.

sucrose + water ↔ glucose + fructose

Sucrose is used to sweeten food and beverages, and for preserving food. It is also used to produce ethanol by fermentation.

Polysaccharides

Preparation of Starch

The raw material to be used is peeled cassava tubers which should be washed and ground into pulp. Water is then added to the pulp to extract starch. It forms suspension and this can stay for sometime before the water above is decanted and starch residue is allowed to dry.

Physical Properties of Starch

1. Starch is a white odourless, tasteless powder with the formula $(C_6H_{10}O_5)_n$
2. It is insoluble in cold water but soluble in hot water forming a viscous solution which sets into a jelly on cooling

Chemical Properties of Starch

1. Starch gives the familiar characteristics deep blue colour with iodine solution
2. Hot dilute acids hydrolyse starch into maltose and glucose
3. It does not reduce Fehling's solution
4. It decomposes on heating in the presence of the enzyme diastase to form maltose sugar.

Test for Starch

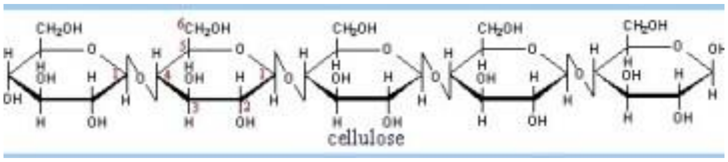
Add a few drops of iodine to some boiled starch, a dark blue colouration which disappears on cooling results.

Uses of Starch

1. It is used for stiffening linen
2. It is used to produce ethanol and glucose
3. It is used mainly as food

Cellulose

Cellulose is the highest of the polysaccharides. It is the main component of plant cell walls and plant fibres. The principal industrial sources are cotton and wood each of which contains about 50% of cellulose. Other sources of cellulose for textile purposes are floxi china grass, hemp and jute.



Physical Properties of Cellulose

1. It forms transparent fibres when it is pure
2. It is insoluble in water and in most organic solvents

Chemical Properties of Cellulose

1. Cellulose can be completely hydrolysed to glucose by hot acids
2. Hydrolysis of cellulose can also be carried out readily by the enzyme cellulose which is produced by micro organisms present in the digestive system of termites and herbivorous animals.

Uses of Cellulose

1. It is used in the manufacture of explosives, surface coatings, paper, textiles and ropes
2. In the manufacture of gum, cotton and explosives

Assessment

1. Chemical formular for starch is ………
   a. $(C_5H_{10}O_5)_n$
   b. $(C_6H_{12}O_5)_n$

c. $(C_6H_{10}O_5)_n$
d. $(C_6H_{11}O_5)_n$

2. A …………… is derived or condensed from two molecules of single sugar by the elimination of one molecule of water.
   a. Disaccharide
   b. Monosaccharide
   c. Polysaccharide
   d. Starch
3. Carbohydrates consists of ……
   a. C, H, N
   b. C, H, O
   c. C and H
   d. C and O
4. sucrose + water ↔ glucose + ………
   a. glucose
   b. galactose
   c. fructose
   d. maltose
5. Test for starch -Add a few drops of iodine to some boiled starch, a ……….. colouration which disappears on cooling results
   a. Blue
   b. Bluish-green
   c. Dark green
   d. Dark blue

Answers

1. C
2. A
3. B
4. C
5. D

WEEK 7

Chemistry SS 3 First Term

Topic: Metals and Their Compounds

Metals

Physical Properties of Metals

The physical properties of elements are dependent on

- the arrangement of their atoms or molecules in crystal lattices when in solid state
- the bonds that bind the atoms or molecules in the solid, liquid or gaseous state.

Most metals are solid at room temperature and exist as crystal lattices in which their atoms are held together by strong metallic bonds. metals have the following physical properties

1. High melting and boiling points
2. Characteristic lustre
3. Malleability – can be hammered into sheets
4. Ductility – can be drawn into a thin wire
5. Sonorousity – give off a note when hit
6. Hard but not brittle with great tensile strength
7. Relatively high densities
8. Good conductors of heat and electricity

Some metals do not exhibit all the above properties e.g

Mercury is a liquid with a melting point of -39^oC. Sodium and potassium are light, soft metals with low melting points of 97^oC and 63^oC respectively.

Chemical Properties

1. ionization behaviour – metallic ions have few valence electrons and so have a great tendency to form positive ions by losing electrons. i.e. they are electropositive
2. reducing and oxidizing agents – metals are reducing agents because they donate electrons readily during chemical reactions.
3. reaction with acids – a metal is more electropositive than hydrogen readily displaces the hydrogen ion from an acid. This is a redox reaction with the metallic

ions donating electrons to form metallic ions and the hydrogen ions accepting electrons to form gaseous hydrogen.

4. nature of oxides – most metals react with oxygen to form basic oxides which are mainly ionic compounds.Soluble basic oxides form alkalis. Some metals like aluminium and zinc form amphoteric oxides.

Occurrence of Metals

Element which have low chemical reactivity generally occur native or free or metallic state. Eg. Au, Pt, noble gas etc. element which are chemically reactive, generally occur in the combined state. Eg. Halogen, chalcogens etc. the natural materials in which the metals occur in the earth are called minerals. The minerals from which the metals is conveniently and economically extracted is called an ore. All the ores are minerals but all ores cannot be ores. Ores may be divided into four groups.

- **Metallic core** (siderophile) of the earth crust contains (Mn, Fe, Co, Ni, Cu, Ru, Rb, Pd, Ag, Re, Os, Ir, Pt, Au). Entire composition of metals in the earth crust may be given as, Au(8.3%); Ca(3.6%); Na(2.8%); K(2.6%); Mg(2.1%); Ti(0.4%); Mn(0.1%); Fe(5.1%) other metals (0.1%).
- **Native ores:** These ores contains metals in free state, e.g. silver, gold, platinum, mercury, copper, etc. These are found usually associated with rock or alluvial materials like clay, sand, etc. sometime lumps of pure metals are also found. These are termed nuggets. Irons is found in free state are meteorites which also have 20 to 30% nickel.
- **Sulphurised and arsenical ores**: these ores consist of sulphides and arsenides in simple and complex forms of metals. Some or ores are:

Metal	**Name of the ore**	**Compositions**
Pb	Galena	Pbs
Zn	Zinc blender	Zns
Ag	Cinnabar	Hgs
Fe	iron pyrites	Fes2
Ni	Kufer nickel	NiAs

Cu	Copper pyrites	Cu_2s

III. **Oxidized ores:** In these ores, metals are present as their oxides or oxysalts such as carbonates, nitrates, sulphates, phosphates, silicates, etc.
Important ores of this groups are listed below,

Oxides

Haemalite	Fe_2O_3
Magnetite	Fe_2O_4
Limonite	$Fe_2O_3.3H_2O$
Bauxite	$Al_2O_3.2H_2O$
Corundum	Al_2O_3
Diaspore	$Al_2O_3.H_2O$
Chromite	$FeO.Cr_2O_3$
Chromeochre	$FeO.Cr_2O_3$
Tinstone (Cassiterite)	Cr_2O_3
Chrysoberyl	$BeO.Al_2O_3$
Cuprite (Rubby copper)	Cu_2O
Pyrolusite	MnO_2
Zincite	Zno
Rutile	TiO_2
Llmenite	$FeO.TIO_2$

Carbonates

Magnesite	$MgcO_3$
Lime stone	$CaCO_3$
Dolomite	$CaCO_3.MgCO_3$
Calamine	$ZnCO_3$
Malachite	$CuCO_3.Cu(OH)_2$
Azurite	$Cu(OH)_2.2CuCO_3$
Cerussite	$PbCO_3$
Siderite	$FeCO_3$

Nitrates	
Chile saltpeter	NaNO3
Salt petre	KNO3
Sulphates	
Epsom salt	MgSO4.7H2O
Barites	BasO4
Gypsum	CaSO4.2H2O
Glauber’s salt	Na2SO4.10H2O
Anglesite	PbSO4
Schonite	K2SO4.MgSO4.6H2O
Polyhalite	K2SO4.MgSO4.CaSO$.2H2O
Phosphates and Silicates	
Lepidolite	(Li, Na, K)2Al2(SiO3)(F,OH)2
Petalite	liAl(Si2O5)2
Triphylite	(Li, Na)3PO4,(Fe, Mn)3(PO4)2

- **Halide ores :** Metallic halides are few in nature, chlorides are most common . for example,
  Comman salt NaCl.

Extraction of Metals

General Principles

Metals found in combined forms exist as positive ions. During extraction, the metallic ions can be reduced to their corresponding metal atoms. This can be done electrolytically or by chemical and thermal methods. The method chosen depends on the stability of the ore which in turn depends on the position of the metal in the activity series.

1. Mining of ore containing rock

The composition of rock around the world varies greatly and locations with metal bearing ore have been sought ever since man was able to extract metals. Nowadays the search is still going on for important deposits of rock with high percentages of the mineral in question. This search is now taking place under the sea and in other inhospitable environments.

Recently, for example, rock containing an appreciable percentage of rare earth elements has been discovered under the pacific ocean. This is a particularly important discovery as virtually 99% of known working deposits are in china and rare earths are essential in the manufacture of the strong neodymium magnets needed for the computer industry

2. Separation, purification or preparation of useful ore

Very few metal ores occur in a pure enough form to be used directly in the extraction process. The first stage is to separate the useful ore from the rock. This may not be necessary in some cases, for example, the extraction of iron, but essential in the extraction of aluminium.

This separation may be physical, such as floatation, or chemical such as digestion of the required compound in a strong base or acid followed by re-precipitation and filtration.

Most ores are either oxides or sulfides. The sulfides are usually converted to oxides by roasting in air. This tends to release sulfur in the form of sulfur(IV) oxide, a pollutant and acidic gas. However, it is also a useful gas in that it is used for the manufacture of sulfuric acid by the contact process.

3. Extraction of metal from ore

Metals are all electropositive and need to be reduced to become metallic elements. Hence, all extraction processes use reduction. For the less reactive metals chemical reduction suffices, but for the more reactive metals electrochemical reduction is needed.

4. Purification of metal

Metals that are extracted by reductive processes usually need to be further processed to make them industrially useful.

Uses of Metals

Metals are very useful to people. They are used to make tools because they can be strong and easy to shape. Iron and steel have been used to make bridges, buildings, or ships.

Some metals are used to make items like coins because they are hard and will not wear away quickly. For example copper (which is shiny and red in color), aluminium (which is shiny and white), gold (which is yellow and shiny), and silver and nickel (also white and shiny).

Some metals, like steel, can be made sharp and stay sharp, so they can be used to make knives, axes or razors.

Rare metals with high value, like gold, silver and platinum are often used to make jewellery. Metals are also used to make fasteners and screws. Pots used for cooking can be made from copper, aluminium, steel or iron. Lead is very heavy and dense and can be used as ballast in boats to stop them from turning over, or to protect people from ionizing radiation.

Assessment

1. Most metals exist in nature as
   a. crusts
   b. alloys
   c. ores
   d. felspar
2. Most metals are malleable with high densities and have high boiling points except
   a. Zn
   b. K
   c. Sn
   d. Ca
3. Method adopted in extracting a particular metal from its ore depends on
   a. the fragile nature of the metal
   b. the location of the ore in the earth's crust
   c. the stability of the ore which depends on the position of the ore in E.C.S
   d. the availability of power in the country
4. Metals found in combined forms exist as ……… ions
   a. positive
   b. negative
   c. neutral
   d. none of the above

Answers

1. C
2. B
3. C
4. A

WEEK 8

Chemistry SS 3 First Term
Topic: Calcium and Aluminium
Calcium

Calcium is too reactive to occur as a free metal in nature. It occurs abundantly in the combined state as calcium trioxocarbonate (iv) in limestone, marble, chalk, aragonite, calcite, coral, dolomite, calcium fluoride. etc In Nigeria, limestone is found at Nkalagu in Ebonyi, Ewekoro at Abeokuta and Ukpilla in Delta state.

Extraction

Since calcium are very stable, metallic calcium is commonly extracted electrolytically from fused calcium chloride a byproduct of solvay process. Some calcium chloride is usually added to the fused calcium chloride to lower the melting point from 850^oC to about 650^oC. The mixture is placed in a large crucible lined on the inside with graphite which serves as the anode of the cell. The cathode consists of iron rod which just touches the surface of the electrolyte. As electrolysis proceeds metallic calcium collects on the cathode which is gradually raised so that an irregular stick of calcium is formed on it. Chlorine is liberated at the cathode.

Chemistry of the Reaction

At the cathode – the calcium ions receive two electrons each to become reduced to the metal.

At the anode – two chloride ions give up an electron each to become atomic chlorine. The two atoms then combine to become liberated as a gaseous molecule.

$Cl^- \rightarrow Cl^- + e^-$

$Cl + Cl \rightarrow Cl_2$

Overall electrolytic reaction

$Ca_{2(l)} + 2Cl^-_{(l)} \rightarrow Ca_{(s)} + Cl_{2(g)}$

Physical Properties of Calcium

1. Appearance – Silvery grey solid
2. Relative density is 1.55
3. Calcium is malleable and ductile
4. It has relatively low tensile strength
5. Melting point is 850°C
6. Calcium is a good conductor of heat and electricity

Chemical Properties of Calcium

Reaction with air – Calcium is a very electropositive and reactive metal. On exposure to air, it rapidly tarnishes ad loses its metallic lustre due to the formation of white film of calcium oxide or quick lime on the surface of the metal. When calcium is heated in air, it burns with a brick red flame to form calcium oxide

$2Ca_{(s)} + O_{2(g)} \rightarrow 2CaO_{(s)}$

$CaO_{(s)} + H_2O(l) \rightarrow Ca(OH)_{2(g)}$

Reaction with non-metals – on heating, calcium combines directly with nitrogen, chlorine, Sulphur and hydrogen

$3Ca_{(s)} + N_{2(g)} \rightarrow Ca_3N_{2(s)}$

$Ca_{(s)} + Cl_{2(g)} \rightarrow CaCl_{2(s)}$

Reaction with water – Calcium reacts slowly with cold water and rapidly with warm water to form calcium hydroxide and hydrogen

$Ca_{(s)} + 2H_2O_{(g)} \rightarrow Ca(OH)_{2(aq)} + H_{2(g)}$

Reaction with Ammonia – if ammonia is passed over heated calcium, it reacts as follows

$3Ca_{(s)} + 2NH_{3(g)} \rightarrow Ca_3N_{2(s)} + 3H_{2(g)}$

Test for calcium ions

Flame test – calcium compounds give an orange – red colour to a non-luminous flame. Moisten the unknown compound with a few drops of concentrated hydrochloric acid. Dip the tip of a clean platinum wire into the mixture and hold it in a non-luminous Bunsen flame. If a bright brick red flame through a blue glass is produced, the unknown ions of the compound are calcium ions.

With sodium hydroxide – Add a few drops of NaOH solution to an unknown salt. The formation of white precipitate which is insoluble in excess sodium hydroxide indicate the presence of calcium ions

Uses of Calcium

1. Calcium is used as a deoxidant in steel castings and copper alloys.
2. It is also used in the manufacture of calcium fluoride and calcium hydride.
3. It is used in the extraction of uranium
4. It is needed in the diet of young children for development of strong bones and teeth
5. Calcium metal is used as a reducing agent in preparing other metals such as thorium and uranium. It is also used as an alloying agent for aluminium, beryllium, copper, lead and magnesium alloys.
6. Calcium compounds are widely used. There are vast deposits of limestone (calcium carbonate) used directly as a building stone and indirectly for cement.
7. Gypsum (calcium sulfate) is used by builders as a plaster and by nurses for setting bones, as 'plaster of Paris'.

Aluminium

Aluminium is the most common metal in the Earth's crust, making up 7.5% by mass. Its main ore is bauxite-a clay mineral which you can think of as impure aluminium oxide. It is the most important element in group III.

Extraction of Aluminium

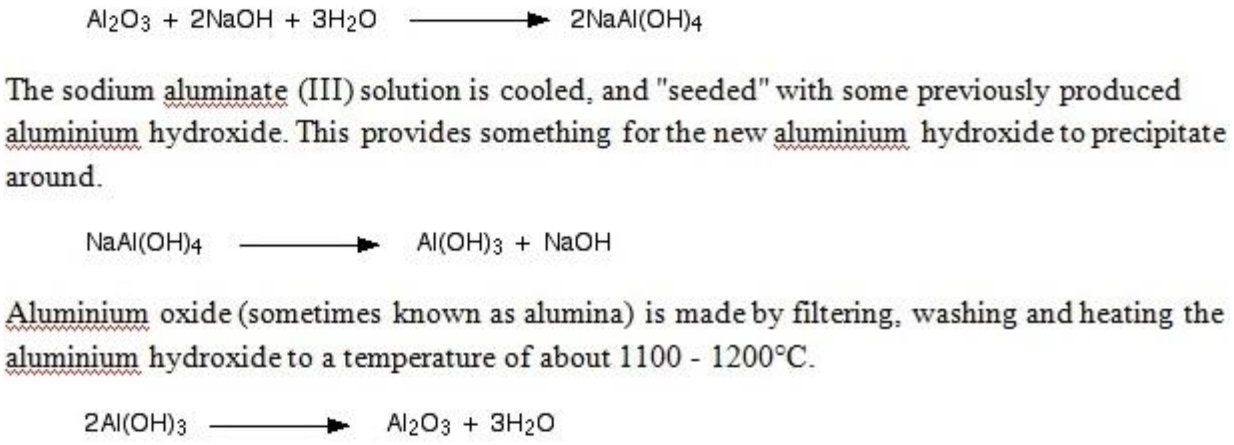
Aluminium is obtained largely from the ore bauxite ($Al_2O_3.2H_2O$). Its production is a two-step process: the purification of bauxite and extraction by electrolysis.

Purifying the bauxite (aluminium oxide) – the Bayer Process

Crushed bauxite is treated with moderately concentrated sodium hydroxide solution. The concentration, temperature and pressure used depend on the source of the bauxite and exactly what form of aluminium oxide it contains. Temperatures are typically from 140°C to 240°C; pressures can be up to about 35 atmospheres.

High pressures are necessary to keep the water in the sodium hydroxide solution liquid at temperatures above 100°C. The higher the temperature, the higher the pressure needed.

With hot concentrated sodium hydroxide solution, aluminium oxide reacts to give a solution of sodium aluminate (III) ($NaAl(OH)_4$).



$$Al_2O_3 + 2NaOH + 3H_2O \longrightarrow 2NaAl(OH)_4$$

The sodium aluminate (III) solution is cooled, and "seeded" with some previously produced aluminium hydroxide. This provides something for the new aluminium hydroxide to precipitate around.

$$NaAl(OH)_4 \longrightarrow Al(OH)_3 + NaOH$$

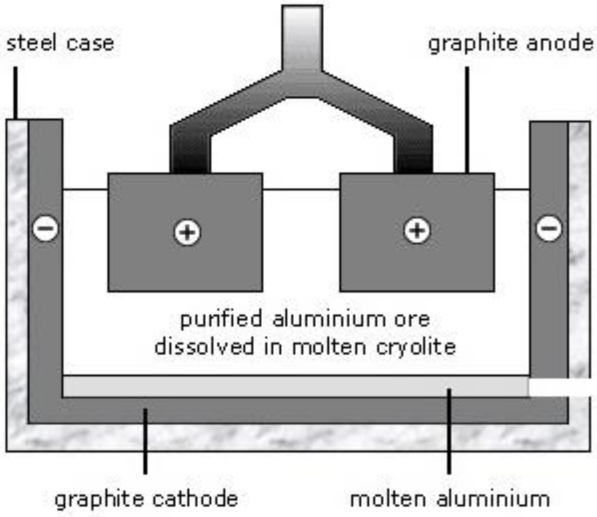
Aluminium oxide (sometimes known as alumina) is made by filtering, washing and heating the aluminium hydroxide to a temperature of about 1100 - 1200°C.

$$2Al(OH)_3 \longrightarrow Al_2O_3 + 3H_2O$$

Extraction of Aluminium by Electrolysis

After purification, aluminium oxide is mixed with cryolite (sodium aluminium fluoride) Na_3AlF_6 to lower the melting point from 2000º to 1000º, which saves money. This mixture is heated and the molten liquid used as the electrolyte. Both electrodes are made of graphite (carbon). The anode (+ve) is graphite and the cathode (-ve) is a graphite lining to a steel case.

The anode disintegrates. The hot oxygen produced here reacts with the hot carbon anode to give carbon dioxide. Hence it must be replaced regularly.



Remember graphite is carbon.

Aluminium ions are attracted to the cathode (the negative electrode) and are reduced to aluminium by gaining electrons.

Al^{3+} (l) + $3e^{-} \rightarrow$ Al (l)

The molten aluminium produced sinks to the bottom of the cell.

The oxide ions are attracted to the anode and lose electrons to form oxygen gas.

$2O^{2-}$ (l) $\rightarrow O_2$ (g) + $4e^{-}$

Note: The extraction of aluminium is an expensive process because the large amount of electricity needed to keep the electrolytes molten is expensive. Hence using cryolite saves energy and money, as it acts as a solvent for the aluminium oxide and melts at a much lower temperature.

Physical Properties of Aluminium

1. Aluminium is a silvery white metal which is comparatively soft
2. It is a strong, malleable metal element.
3. It has a low density.
4. It is resistant to corrosion
5. It is a good conductor of heat and electricity.
6. It can be polished to give a highly reflective surface.

Chemical Properties of Aluminium

- Action with air: Aluminium burns in air at high temperature to form the oxide and the nitride
  $4Al\ (s) + 3O_2\ (g) \longrightarrow 2Al_2O_3\ (s)$

- Reaction with non-metals: On heating, aluminium combines directly with non-metals like the halogens, sulphur, nitrogen, phosphorus and carbon with evolution of heat
  $2Al\ (s) + 3Cl_2 \longrightarrow 2AlCl_3\ (s)$

- Action with acids: Aluminium reacts more rapidly with the concentrated hydrochloric acid to displace hydrogen but more slowly with dilute one
  $2Al\ (s) + 6HCl\ (aq) \longrightarrow 2AlCl_3\ (aq) + 3H_2\ (g)$

- Reaction with alkalis: Aluminium reacts with both sodium and potassium hydrogen solutions giving hydrogen gas and soluble tetrahydroxoaluminate (III)

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

- Reaction with Iron (III) oxide: Aluminium reduces iron (III) oxide to molten iron. The reaction is used in thermit process and it gives out a great deal of energy
  $2Al\ (s) + Fe_2O_3\ (s) \longrightarrow Al_2O_3\ (s) + 2Fe\ (s)$

Uses

1. Low density and strength make aluminium ideal for construction of aircraft, lightweight vehicles, and ladders.
2. An alloy of aluminium called duralumin is often used instead of pure aluminium because of its improved properties.
3. Easy shaping and corrosion resistance make aluminium a good material for drink cans and roofing materials.
4. Corrosion resistance and low density leads to its use for greenhouses and window frames.

5. Good conduction of heat leads to its use for boilers, cookers and cookware.
6. Good conduction of electricity leads to its use for overhead power cables hung from pylons (low density gives it an advantage over copper).
7. High reflectivity makes aluminium ideal for mirrors, reflectors and heat resistant clothing for fire fighting.

Assessment

Explain the method of extraction of Aluminium in few lines and bullet points.

Mention 3 uses of Calcium

WEEK 9

Chemistry SS3 First term

Topic: Tin and Copper

Tin

Tin does not occur naturally as a free element. The main source is the mineral cassiterite or tin stone, SnO_2. In Nigeria was mined in 1930 at Jos Plateau.

Extraction from its Ores

Tin ore is crushed and washed with water. This is called the concentration of the ore. The tin ore is roasted in air to remove impurities, such as arsenic and antimony as volatile oxides. The product is mixed with powdered charcoal and heated to 1300^oC. to reduce the oxide. Molten tin is tapped off. Iron compounds, which might be present as impurities are removed by electromagnetic separation. The metal is extracted from its ore by carbon reduction. The concentrated ore is mixed with coke and heated in a furnace.

$SnO_{2(s)} + 2C_{(s)} \rightarrow Sn_{(l)} + 2CO_{(g)}$

The tin obtained is purified. It is separated from copper, iron and any other element present as impurities by either thermal -heating beyond it melting point of 232 K, and running off the molten tin, leaving behind any less fusible impurities – or by electrolytic means.

Much purer tin is obtained by the electrolysis of aqueous solution of tin(II) chloride, $SnCl_2$ – the impure tin is made anode, while the cathode is pure tin.

Test for Tin ions

Hydrogen Sulphide – Pass hydrogen sulphide into a solution of the unknown salt acidified with dilute hydrochloric acid. Tin(ii) ions are present if a brown precipitate which dissolves in yellow ammonium sulphide and in hot concentrated hydrochloric acid is obtained

Mercury (ii) chloride- The formation of a white precipitate of mercury(i) chloride would indicate the presence of tin(ii) ions.

Physical Properties of Tin

1. Tin is solid, with silvery white appearance with lustre.
2. It's melting point is 232°C.
3. It is malleable and soft (enough to be cut with a knife).
4. It is a good conductor of heat and electricity.
5. It exists in three different forms. These are grey tin of density 5.76 g/cm^3; white tin of density 7.28 g/cm^3; and rhombic tin of density 6.6 g/cm^3. These allotropes (the different forms) can be converted from one to another by changes in temperature.

grey white rhombic

Grey 13.2°C White 161°C Rhombic

6. Tin is not ductile enough to be drawn into wires.

Chemical properties of Tin

1. Reaction with Oxygen – it does not react with oxygen, except at temperature above 1300°C.

$Sn_{(s)} + O_{2(g)} \rightarrow SnO_{2(s)}$ at temperatures greater than 1300°C

Hence, It does not corrode or explode in air.

2. With nitrogen and carbon – no reaction occurs.
3. With non metals, example, chlorine – it reacts when heated with chlorine to form tin(IV) chloride.

$Sn_{(s)} + 2Cl_{2(g)} \rightarrow SnCl_{4(s)}$

4. With acids – it reacts with acids to different degrees at different concentrations and temperatures. With dilute HCl – no reaction occurs.

With Concentrated HCl the reaction is rapid, producing tin(II) chloride.

$Sn_{(s)} + 2HCl_{(aq)} \rightarrow SnCl_{2(s)} + H_{2(g)}$

With dilute H_2SO_4 – no reaction occurs. With hot concentrated H_2SO_4 a reaction occurs to release SO_2.

$Sn_{(s)} + 2H_2SO_2 \rightarrow SnSO_{4(aq)} + SO_{2(g)} + 2H_2O_{(g)}$

With dilute HNO_3 – tin reacts with dilute HNO_3, forming $Sn(NO_3)_2$ and hydrogen.
With conc. HNO_3 – tin reacts with conc. HNO_3 , forming SnO_2.

5. With alkalis – it forms trioxostannate(IV) salts and hydrogen with conc. solutions of alkalis.

$Sn_{(s)} + 2NaOH_{(aq)} + H_2O_{(l)} \rightarrow Na_2SnO_{3(aq)} + 2H_{2(g)}$

Uses of Tin

There are a number of ways tin can be used. These include:

1. For coating steel – the coating is done by electrolytic method. Tin prevents corrosion in steel, such may be used to can food and drinks.
2. For making alloys together with lead, antimony and copper. Alloys of tin are important, such as soft solder, pewter, bronze and phosphor bronze. A niobium-tin alloy is used for superconducting magnets.
3. Due to its resistance to atmospheric corrosion and low melting point, it can be used to make sheet glass.
4. The most important tin salt used is tin(II) chloride, which is used as a reducing agent and as a mordant for dyeing calico and silk. Tin(IV) oxide is used for ceramics and gas sensors. Zinc stannate (Zn_2SnO_4) is a fire-retardant used in plastics.
5. Some tin compounds have been used as anti-fouling paint for ships and boats, to prevent barnacles. However, even at low levels these compounds are deadly to marine life, especially oysters. Its use has now been banned in most countries.
6. A very important application of tin is tin-plating. Tin-plating is the process by which a thin coat of tin is placed on the surface of steel, iron, or another metal. Tin is not affected by air, oxygen, water, acids, and bases to the extent that steel, iron, and other metals are. So the tin coating acts as a protective layer.
7. Another tin alloy is Babbitt metal. Babbitt metal is a soft alloy made of any number of metals, including **arsenic,** cadmium, **lead,** or tin. Babbitt metal is used to make ball bearings for large industrial machinery. The Babbitt metal is laid down as a thin coating on heavier metal, such as iron or steel. The Babbitt metal retains a thin layer of lubricating oil more efficiently than iron or steel.

Copper

Copper was one of the first metals discovered and used by man. It is a stable metal readily obtained from its compounds. Copper ores are widely found around the world. The main ores are copper pyrites ($CuFeS2$), malachite ($CuCO3.Cu (OH)2$), chalcocite ($CuS2$) and cuprite (CuO).

Extracting copper from its ores

The method used to extract copper from its ores depends on the nature of the ore. Sulphide ores such as chalcopyrite (copper pyrites) are converted to copper by a different method from silicate, carbonate or sulphate ores.

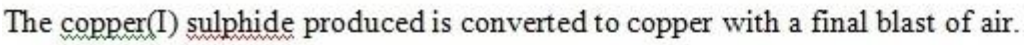
The process:

The concentrated ore is heated strongly with silicon dioxide (silica) and air or oxygen in a furnace or series of furnaces.

- The copper(II) ions in the chalcopyrite are reduced to copper(I) sulphide (which is reduced further to copper metal in the final stage).
- The iron in the chalcopyrite ends up converted into an iron(II) silicate slag which is removed.
- Most of the sulphur in the chalcopyrite turns into sulphur dioxide gas. This is used to make sulphuric acid via the Contact Process.

An overall equation for this series of steps is:

$$2CuFeS_2 + 2SiO_2 + 4O_2 \longrightarrow Cu_2S + 2FeSiO_3 + 3SO_2$$



The copper(I) sulphide produced is converted to copper with a final blast of air.

$$Cu_2S + O_2 \longrightarrow 2Cu + SO_2$$

The end product of this is called blister copper – a porous brittle form of copper, about 98 – 99.5% pure.

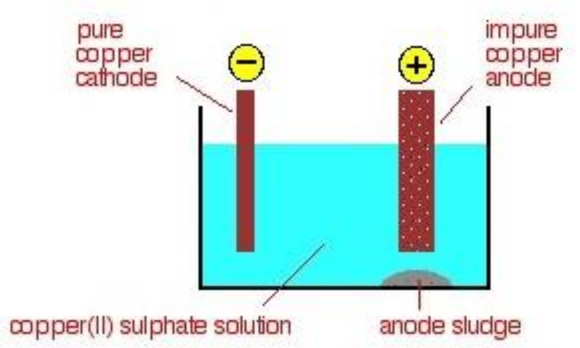
Purification of copper

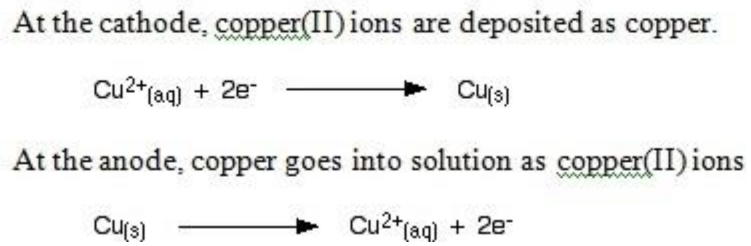
When copper is made from sulphide ores by the first method above, it is impure. The blister copper is first treated to remove any remaining sulphur (trapped as bubbles of sulphur dioxide in the copper – hence “blister copper”) and then cast into anodes for refining using electrolysis.

Electrolytic refining

The purification uses an electrolyte of copper(II) sulphate solution, impure copper anodes, and strips of high purity copper for the cathodes.

The diagram shows a very simplified view of a cell.





At the cathode, copper(II) ions are deposited as copper.

$$Cu^{2+}_{(aq)} + 2e^- \longrightarrow Cu_{(s)}$$

At the anode, copper goes into solution as copper(II) ions

$$Cu_{(s)} \longrightarrow Cu^{2+}_{(aq)} + 2e^-$$

For every copper ion that is deposited at the cathode, in principle another one goes into solution at the anode. The concentration of the solution should stay the same. All that happens is that there is a transfer of copper from the anode to the cathode. The cathode gets bigger as more and more pure copper is deposited; the anode gradually disappears.

In practice, it isn't quite as simple as that because of the impurities involved.

Physical properties of copper

1. Copper is a heavy, reddish-brown metal
2. It is very malleable and ductile
3. It has a density of 8.95 g cm^{-1}
4. It is a good conductor of heat and electricity
5. It has a high melting point of 1083^oC
6. It has a boiling point of 2300^oC
7. It also forms alloys very readily

Chemical properties of Copper

- Reaction with Air: It is resistant to pure dry air, but over a long period of time in a moist, impure atmosphere, it becomes coated with green, basic copper(II) tetraoxosulphate (VI) $CuSO_4.3Cu(OH)_2$ and trioxocarbonate (IV).

On heating in air or oxygen, copper is readily oxidized to give black copper (II)oxide
$2Cu(s) + O_2(g) ——–> 2CuO(s)$

- Effect of Acids: Copper is lower than hydrogen in the electrochemical series, hence, it is not capable of displacing hydrogen from dilute acids. It is however attacked by oxidizing acids like trioxonitrate (V) acid and tetraoxosulphate (VI) acids

$3Cu(s) + 8HNO_3(aq) ——> 3Cu(NO_3)_2(s) + 4H_2O(l)\ 2NO(g)$

- Displacement Reaction: Because of its low position in the activity and electrochemical series, copper is easily displaced from its compound

$CuSO_4(aq) + Fe(s) ——-> FeSO_4(aq) + Cu(s)$

- Hydrogen gas reduces copper oxides to the metal

$CuO(s) + H_2(g) ——> Cu(s) + H_2O(l)$

Test For Copper(II) Ions

With sodium hydroxide: Add a few drops of sodium hydroxide solution to a solution of copper salt. The formation of a blue precipitate which is insoluble in excess sodium hydroxide confirms the presence of copper(II) ions
$Cu^{2+}(aq) + 2NaOH(aq) ——-> Cu(OH)_2(s) + Na^+(aq)$

Uses of Copper

Amongst other things copper is used for:

1. Electrical wiring. It is a very good conductor of electricity and is easily drawn out into wires.
2. Domestic plumbing. It doesn’t react with water, and is easily bent into shape.

3. Boilers and heat exchangers. It is a good conductor of heat and doesn't react with water.
4. Baking brass. Brass is a copper-zinc alloy. Alloying produces a metal harder than either copper or zinc individually. Bronze is another copper alloy – this time with tin.
5. Coinage. In the UK, as well as the more obvious copper-coloured coins, "silver" coins are also copper alloys – this time with nickel. These are known as cupronickel alloys. UK pound coins and the gold-coloured bits of euro coins are copper-zinc-nickel alloys.

Assessment

1. Tin exists in 3 different forms. Mention them?
2. How can Tin be extracted?
3. The method of extraction of copper depends on what?
4. Mention 4 uses of copper

WEEK 10

Chemistry SS3 First Term

Topic: Iron

Iron

Iron is the most important element in the industry. It is the second most abundant element on the earth crust after aluminium, but often occurs as a free metal.

The common ores are haematite found in united states, Australia and USSR. It can also occur as impure iron (III) oxide (Fe_2O_3), Magnetite or magnetic iron ore (Fe_3O_4) is found in Sweden and in North America.

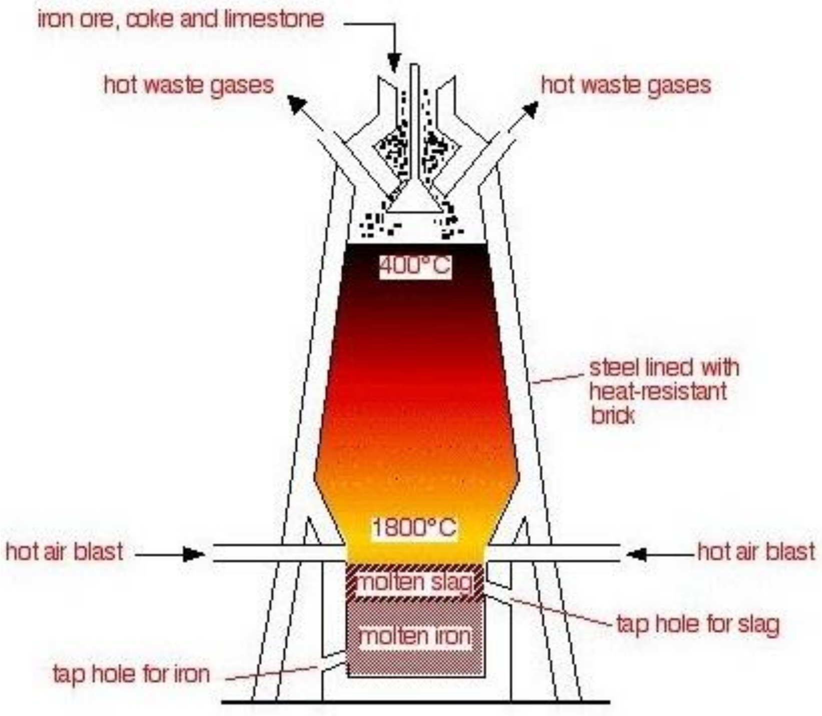
Siderite or spathic iron ore, ($FeCO_3$), found in Great Britain. Iron also occurs as iron pyrites (FeS_2) and limonite ($Fe_2O_3.3H_2O$).

Iron is widely present as trioxosilicate (IV) in clay soils. Iron ore is available in Itakpe, Ajaokuta, Jebba and Lokoja all in Kwara State (Nigeria).

Extraction of Iron

The extraction of iron from iron ore (haematite), using coke, limestone and air in a blast furnace

Haematite is basically iron oxide, and the oxygen must be removed to leave the iron behind. Reactions in which oxygen is removed are called reduction reactions. Since carbon is more reactive than iron, it can displace the iron from its oxide. Hence the method for extraction of iron is called 'reduction by carbon'.



Blast furnace diagram

Coke is impure carbon, and it burns in the hot air blast to form carbon dioxide. This is a strongly exothermic reaction which makes it an important reaction, as it helps heat up the blast furnace. The iron ore, coke and limestone enter the blast furnace at the top. The hot waste gases at the top of the furnace are piped away and used to heat the air blast at the bottom.

$C (s) + O_2 (g) \longrightarrow CO_2 (g)$

At high temperatures in the furnace, the carbon dioxide is reduced by more carbon to give carbon monoxide.

$CO_2 (g) + C (s) \longrightarrow 2CO (g)$

It is the carbon monoxide which is the main reducing agent in the furnace-especially in the cooler parts.

Assuming that the iron ore is haematite, Fe_2O_3:

$Fe_2O_3 (s) + 3CO (g) \longrightarrow 2Fe (l) + 3CO_2 (g)$

Due to the high temperatures, the iron produced melts and flows to the bottom of the furnace, where it can be tapped off.

In the hotter parts of the furnace, some of the iron oxide is also reduced by carbon itself.

Fe_2O_3 (s) + 3C (s) ——> 2Fe (l) + 3CO (g)

Notice that carbon monoxide is formed, rather than carbon dioxide, at these temperatures.

However some use this equation instead:

iron oxide + carbon → iron + carbon dioxide

$2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$

The limestone is added to the furnace to remove impurities in the ore which would otherwise clog the furnace with solid material.

The furnace is hot enough for the limestone (calcium carbonate) to undergo thermal decomposition. It splits up into calcium oxide and carbon dioxide. This is an endothermic reaction (it absorbs heat) and it is important not to add too much limestone to avoid cooling the furnace.

$CaCO_3$ (s) ——> CaO (s) + CO_2 (g)

Calcium oxide is a basic oxide, and its function is to react with acidic oxides such as silicon dioxide, SiO_2. Silicon dioxide is the main constituent of sand, and is typical of the sort of impurities that need to be removed from the furnace.

CaO (s) + SiO_2 (s) —–> $CaSiO_3$ (l)

The product is calcium silicate. This melts and trickles to the bottom of the furnace as a molten slag, which floats on top of the molten iron as it is less dense, and can be tapped off separately. Slag is used

Uses of iron

- Cast iron

Molten iron straight from the furnace can be cooled rapidly and solidified by running it into sand moulds. This is known as pig iron. If the pig iron is remelted and cooled under controlled conditions, cast iron is formed. This is very impure iron, containing about 4% carbon as its main impurity. Although cast iron is very hard, it is also very brittle and tends to shatter if it is hit hard. It is used for things like manhole covers, gutterings and drainpipes, and cylinder blocks in car engines.

- Mild steel

Mild steel is iron containing up to about 0.25% carbon. This small amount of carbon increases the hardness and strength of the iron. It is used for (among other things) wire, nails, car bodies, ship building, girders and bridges.

- Wrought iron

This is pure iron. It was once used to make decorative gates and railings but has now been largely replaced by mild steel. The purity of the iron makes it very easy to work because it is fairly soft, but the softness and lack of strength mean that it isn't useful for structural purposes.

- High-carbon steel

High carbon steel is iron containing up to 1.5% carbon. Increases the carbon content makes the iron harder, but at the same time it gets more brittle. High-carbon steel is used for cutting tools and masonry nails. Masonry nails are designed to be hammered into concrete blocks or brickwork where a mild steel nail would bend. If you miss-hit a masonry nail, it tends to break into two bits because of its increased brittleness.

- Stainless steel

Stainless steel is an alloy of iron with chromium and nickel. Chromium and nickel form strong oxide layers in the same way as aluminium, and these oxide layers protect the iron as well. Stainless steel is therefore very resistance to corrosion.

Obvious uses include kitchen sinks, saucepans, knives and forks, and gardening tools. But there are also major uses for it in the brewing, dairy and chemical industries where corrosion- resistant vessels are essential

Types of iron	Iron mixed with	Some uses
Wrought iron	(pure iron)	Decorative work such as gates and railings
Mild steel	Up to 0.25% carbon	Nails, car bodies, ship building, girders
High-carbon steel	0.25-1.5% carbon	Cutting tools, masonry nails

Cast iron	About 4% carbon	Manhole covers, guttering, engine blocks
Stainless steel	Chromium and nickel	Cutlery, cooking utensils, kitchen sinks

Physical Properties of Iron

1. Pure iron is a grey metal with density 7.8g cm^{-3}
2. It melts at 1535°C and boils at 2800°C
3. It is very malleable and ductile
4. It is a good conductor of heat and electricity
5. It can easily be magnetized

Chemical Properties of Iron

- Reaction With Air: It burns in air to form reddish hydrated iron (III) oxide of variable composition

$4Fe(s) + 3O_2(g) + 2xH_2O(l)$ ——-> $2Fe_2O_3.xH_2O$

- When finely divided iron is heated in air it burns at high temperature to form magnetic iron oxide, which behaves like a compound oxide

$3Fe(s) + 2O_2(g)$ ——> Fe_3O_4 (s)

- Reaction With Steam: When steam is passed over red-hot iron filings, tri iron tetraoxide and hydrogen are produced and the reaction is reversible

$Fe(s) + 4H_20$ <——> $Fe_3O_4(s) + 4H_2(g)$

Order of reactivity	Symbol	Method of Extraction
Potassium	K	Electrolysis

The metal compound is:

1. Melted, then
2. Has electricity passed through it

Assessment

1. What are the uses of the following Iron
   – Cast Iron
   – Stainless steel
   – Wrought Iron
2. Stainless steel is an alloy of iron with ………. and ………
3. Mention 2 common ores of iron ……… and ………

SS 3
SECOND TERM NOTES ON CHEMISTRY

TABLE OF CONTENT

SECOND TERM

WEEK 1

TOPIC: NUCLEAR CHEMISTRY

Nuclear Reactions

Rutherford in 1919 transmitted nitrogen isotope into an oxygen isotope. The nitrogen was subjected to the action of swift alpha – particles derived from radium salt.

Transmutation is the process by which radioactive elements change into different elements.

Nuclear reaction is a process in which two nuclei or nuclear particles collide, to produce different products than the initial particles.

Nuclear fission and nuclear fusion both are nuclear phenomena that release large amounts of energy, but they are different processes which yield different products. Learn what nuclear fission and nuclear fusion are and how you can tell them apart.

Nuclear Fission

Nuclear fission takes place when an atom's nucleus splits into two or more smaller nuclei. These smaller nuclei are called fission products. Particles (e.g., neutrons, photons, alpha particles) usually are released, too. This is an exothermic process releasing kinetic energy of the fission products and energy in the form of gamma radiation. Fission may be considered a form of element transmutation since changing the number of protons of an element essentially changes the element from one into another.

Nuclear Fission Example:

$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{90}_{38}Sr + ^{143}_{54}Xe + 3^{1}_{0}n$

Nuclear Fusion

Nuclear fusion is a process in which atomic nuclei are fused together to form heavier nuclei. Extremely high temperatures (on the order of 1.5×10^{7}°C) can force nuclei together. Large amounts of energy are released when fusion occurs.

Nuclear Fusion Examples

The reactions which take place in the sun provide an example of nuclear fusion:

$^{1}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He$

$^{3}_{2}He + ^{3}_{2}He \rightarrow ^{4}_{2}He + 2^{1}_{1}H$

$^{1}_{1}H + ^{1}_{1}H \rightarrow ^{2}_{1}H + ^{0}_{+1}\beta$

Comparison between Nuclear Fission and Fusion

	Nuclear Fission	Nuclear Fusion
Definition:	Fission is the splitting of a large atom into two or more smaller ones.	Fusion is the fusing of two or more lighter at into a larger one.
Natural occurrence of the process:	Fission reaction does not normally occur in nature.	Fusion occurs in stars, such as the sun.
Byproducts of the reaction:	Fission produces many highly radioactive particles.	Few radioactive particles are produced by fu reaction, but if a fission “trigger” is used, radioactive particles will result from that.
Conditions:	of the substance and high-speed neutrons are required.	High density, high temperature environmen required.
Energy Requirement:	Takes little energy to split two atoms in a fission reaction.	Extremely high energy is required to bring tw more protons close enough that nuclear forc overcome their electrostatic repulsion.
Energy Released:	The energy released by fission is a million times greater than that released in chemical reactions; but lower than the energy released by nuclear fusion.	The energy released by fusion is three to fou greater than the energy released by fission.
Nuclear weapon:	One class of nuclear weapon is a fission bomb, also known as an atomic bomb or atom bomb.	One class of nuclear weapon is the hydroge which uses a fission reaction to “trigger” a fu reaction.

Comparison of Nuclear Reaction and Ordinary Chemical Reaction

Nuclear Reaction	Ordinary Chemical Reaction
During nuclear reactions, the nuclei of atoms undergo change and therefore new elements are formed as a result of such reactions.	During chemical reactions, elements do not lose their id In these reactions, only the electrons in the outermost s atoms participate whereas the nuclei of atoms remain unchanged.
Reactivity of an element towards nuclear reactions is nearly independent of oxidation state of the element. For example, Ra element or Ra^{2+} ion in RaC_2 behave s similarly during nuclear reactions.	Reactivity of an element towards chemical reactions dep upon the oxidation state of the element. In ordinary che reactions, Ra and Ra^{2+} behave quite differently.
In nuclear reactions, isotopes behave quite differently. For example, U-235 undergoes fission quietly readily but U-238 does not.	Different isotopes of an element have nearly same che reactivity.
Rate of a nuclear reaction is independent of temperature and pressure.	Rate of a chemical reaction is largely affected by temper and pressure.

A nuclear reaction cannot be reversed.	A chemical reaction can be reversed.
Nuclear reactions are accompanied by large energy changes.	Chemical reactions are accompanied by relatively small changes.

Assessment

What is the most significant difference between Nuclear fission and fusion?

What does Transmutation mean?

WEEK 2

TOPIC: NUCLEAR CHEMISTRY (II)

Introduction to Radioactivity

Antoine Henri Becquerel, a French scientist, 1896, was conducting an experiment which started with the exposure of a uranium-bearing crystal to sunlight. Once the crystal had sat in the sunshine for a while, he placed it on a photographic plate. As he had anticipated, the crystal produced its image on the plate. Becquerel theorized that the absorbed energy of the sun was being released by the uranium in the form of x-rays. The husband and wife team of Pierre and Marie Curie in 1898 became interested in Becquerel's discovery. While experimenting with their own uranium-containing ore, they came up with the term "radioactivity" to describe the spontaneous emissions that they studied. This word is still used today to describe this special characteristic of some elements (radioisotopes).

While comparing the activity of pure uranium to a uranium ore sample, they found that the ore was significantly more radioactive than the pure material. They concluded that the ore contained additional radioactive components besides the uranium. This observation led to the discovery of two new radioactive elements which they named polonium and radium.

Radioactivity is the spontaneous disintegration of atomic nuclei. In other word, Radioactivity is the energy and mass released by spontaneous changes in the nucleus of an atom.

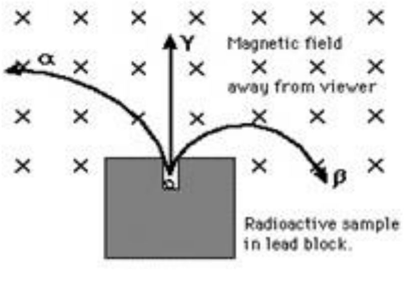
Radiation is energy that travels ('radiates') as waves or particles. Heat, light, sound, microwaves, radar, radio waves, X-rays, alpha and beta particles, and gamma rays are all forms of radiation.

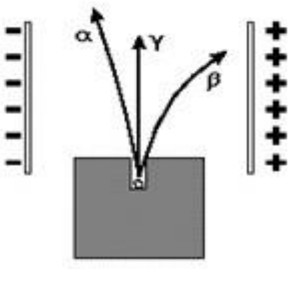
All substance is made of atoms. These have electrons (e) around the outside, and a nucleus in the middle. The nucleus consists of protons (p) and neutrons (n), and is extremely small. In some types of atom, the nucleus is unstable, and will decay into a more stable atom.

Unstable atomic nuclei will spontaneously decompose to form nuclei with a higher stability. The decomposition process is called radioactivity. The energy and particles which are released during the decomposition process are called radiation. When unstable nuclei decompose in nature, the process is referred to as natural radioactivity. When the unstable nuclei are prepared in the laboratory, the decomposition is called induced radioactivity.

Types and Nature of Radiation

There are three different types of radiation: the alpha, beta and gamma. They have different penetrating powers.





Alpha Radiation

Alpha radiation consists of a stream of positively charged particles, called alpha particles (α), which have an atomic mass of 4 and a charge of +2 (a helium nucleus). When an alpha particle is ejected from a nucleus, the mass number of the nucleus decreases by four units and the atomic number decreases by two units. For example:

${}^{238}_{92}U \rightarrow {}^{4}_{2}He + {}^{234}_{90}Th$

The helium nucleus is the alpha particle.

Properties of Alpha Particles (α)

1. They are positively charged
2. They have low penetrating power (low energy) and because of their longer wavelengths, they cannot pass through a piece of paper
3. They have very powerful ionizing effects upon any gas through which they pass
4. They also cause some substances like zinc sulphide to fluorescence.

Beta Radiation

Beta radiation is a stream of electrons, called beta particles (β). When a beta particle is ejected, a neutron in the nucleus is converted to a proton, so the mass number of the nucleus is unchanged, but the atomic number increases by one unit. For example:

${}^{234}_{90}Th \rightarrow {}^{0}_{-1}e + {}^{234}_{91}Pa$

Properties of Beta Particles (β)

1. The electron is the beta particle.
2. These rays are fast-moving stream of electrons
3. They are negatively charged
4. They are therefore deflected to the positive plate in an electric field
5. They have higher penetrating power than alpha particles with their shorter wave-length. They would not only pass through a piece of paper but also through a piece of aluminium which are metallic.
6. They have low ionizing effect on gases
7. They cause fluorescence in substances like anthracene but not zinc sulphide

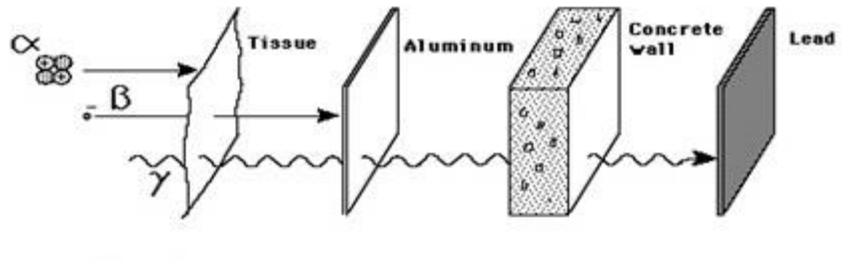
Gamma Radiation

Gamma rays are high-energy photons with a very short wavelength (0.0005 to 0.1 nm). The emission of gamma radiation results from an energy change within the atomic nucleus. Gamma emission changes neither the atomic number nor the atomic mass. Alpha and beta emission are often accompanied by gamma emission, as an excited nucleus drops to a lower and more stable energy state.

Properties of Gamma Rays (ϒ)

1. They are not particles but electromagnetic waves similar to light but are of shorter wavelength than light rays and have higher frequency.
2. They have neither mass nor charge
3. They are therefore not deflected in an electric field
4. They travel at the speed of light
5. They have very high penetrating power. Out of the three types of radioactive emission, they are the most penetrating.
6. They have the least ionizing power

Penetration of radiation



Detection of Radiation

- **Diffusion Cloud Chamber**

The Diffusion Cloud Chamber is used to view high energy alpha particles, lower energy beta particles, and electrons produced by gamma rays interacting with gas molecules. The Chamber allows for the viewing of cosmic rays without the need for dry ice or external illumination. Historically the Cloud Chamber was the first particle detector for making ionizing particles visible. Its working principle is based on supersaturated vapour. This vapour shows tracks of condensated alcohol while being penetrated by ionizing particles. Vapour clouds build up along the particle tracks, which are sometimes thin and long, sometimes thick and round or bulbous. They may appear gradually or pop up all of a sudden or move very fast like a projectile splintering into all directions.

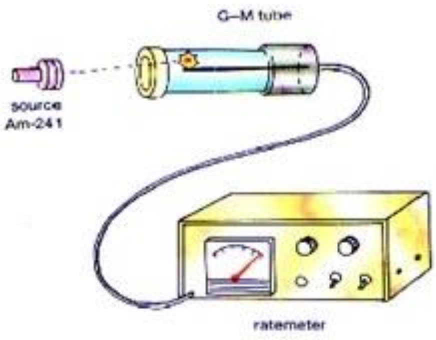
- **Geiger – Muller Counter**

The Geiger-Muller counter is a particle detector designed to detect ionizing radiation, such as alpha and beta as well as gamma radiation (although with significantly lower sensitivity than other types of detectors). It was invented by the German physicist Hans Geiger (co-discoverer of the atom nucleus) and later improved by his student Walther Muller, therefore the name Geiger-Muller counter. It is probably one of the most famous radiation detectors, mostly due to its simplicity and the distinctive audible clicks produced with the detection of individual particles.

Alternatively, except for its use in the detection of ionizing radiation, the Geiger counter is also used as a random number generator.

The main element of a Geiger counter is the Geiger-Muller tube, which is basically a chamber filled with inert gas or a mix of organic vapor and halogens. The tube contains two electrodes, the anode and the cathode, which are usually coated with graphite. The anode is represented by a wire in the center of the cylindrical chamber while the cathode forms the lateral area. One end of the cylinder, through which the radiation enters the chamber, is sealed by a mica window.

As ionizing radiation coming from the surrounding medium passes through the mica window and enters the Geiger-Muller tube, it ionizes the gas inside, transforming it into positively charged ions and electrons. The electrons eventually migrate towards the anode of the tube detector, while the positively charged ions accelerate towards the cathode. As the positive ions move towards the cathode, they collide with the remaining inert gas thus producing more ions through an avalanche effect. When this happens an electrical current is established between the two electrodes. The current is amplified and the resulting flow of electrons can be used to produce sound, light flashes or meter readings.



- **Scintillation Counter**

Certain minerals, such as zinc sulphide fluoresce or glow when exposed to radiation. The glow is made up of tiny flashes of light or scintillation and these may be seen under a microscope or counted with suitable device.

Radioactive Decay

Radioactive decay is the spontaneous radioactive disintegration of an atomic nucleus, resulting in the release of energy. Some atoms are stable. Others are unstable and ‘decay’, emitting radiation to achieve a stable state. The emissions from an unstable atom’s nucleus, as it decays, can be in the form of alpha, beta or gamma radiation.

When an atom decays, it changes into another isotope, or form, of the same element or into a completely different element, in a process called transmutation. Different isotopes of the same element differ in the number of neutrons in their nuclei. Some elements reach stability via a series of steps through several isotopes, or ‘daughter products’.

One example is uranium-238 (U-238), which, through the process of radioactive decay, will eventually become a stable isotope of lead. However, this process takes billions of years. Along the way, as the U-238 isotope’s initial energy declines, it will transmute via a series of elements, each more stable than the last – thorium, radium, radon, polonium and bismuth – before it stabilizes as lead.

Alpha decay

In alpha decay, a positively-charged particle is emitted from the nucleus of an atom. This alpha particle consists of two protons and two neutrons (the same structure as a helium-4 nucleus). Although alpha particles are normally highly energetic, they travel only a few centimeters in air and are stopped by a sheet of paper or the outer layer of dead skin.

Beta decay

In beta decay, a particle is emitted from the nucleus of an atom. This beta particle is an electron with either negative or positive electric charge. Beta particles may travel metres in air and several millimetres into the human body. Most beta particles may be stopped by a small thickness of a light material such as aluminium or plastic.

Gamma decay

Gamma decay occurs because the nucleus of an atom is at too high an energy state. The nucleus ‘falls down’ to a lower energy state, emitting a high energy photon known as a gamma particle in the process. Gamma particles travel in a wave-like pattern at the speed of light. They can only be stopped by a dense material such as lead, steel, concrete or several metres of water.

Half Life of Radioactive Elements

The half-life of a radioactive element is the time that it takes for one half of the atoms of that substance to disintegrate into another nuclear form. The decay of an isotope can be measured by its half life. These can range from mere fractions of a second, to many billions of years.

Element	Most Stable Isotope	Half-life of Most Stable Isotope
Polonium	Po-209	102 years
Astatine	At-210	8.1 hours
Radon	Rn-222	3.82 days
Radium	Ra-226	1600 years
Thorium	Th-229	7.54×10^4 years
Uranium	U-236	2.34×10^7 years

Protactinium	Pa- 234	1.18 minutes

Example Rate of Radioactive Decay Problem

$^{226}_{88}$Ra, a common isotope of radium, has a half-life of 1620 years. Knowing this, calculate the first order rate constant for the decay of radium-226 and the fraction of a sample of this isotope remaining after 100 years.

Solution

The rate of radioactive decay is expressed by the relationship: $k = 0.693/t_{1/2}$

Where k is the rate and $t_{1/2}$ is the half-life.

Plugging in the half-life given in the problem: $k = 0.693/1620$ years $= 4.28 \times 10^{-4}$/year

Radioactive decay is a first order rate reaction, so the expression for the rate is:

$\log_{10} X_0/X = kt/2.30$

Where X_0 is the quantity of radioactive substance at zero time (when the counting process starts) and X is the quantity remaining after time *t*. *k* is the first order rate constant, a characteristic of the isotope that is decaying. Plugging in the values:

$\log_{10} X_0/X = (4.28 \times 10^{-4}/\text{year})/2.30 \times 100 \text{ years} = 0.0186$

Taking antilogs: $X_0/X = 1/1.044 = 0.958 = 95.8\%$ of the isotope remains

Uses of Radioactivity

1. Radioactivity tracers are commonly used in the medical field and also in the study of plants and animals.
2. Radiation is used and produced in nuclear reactors, which controls fission reactions to produce energy and new substances from the fission products.
3. Radiation is also used to sterilize medical instruments and food.
4. Radiation is used by test personnel who monitor materials and processes by non-destructive methods such as x-rays.

Assessment

1. Radiation is detected by the following except
   a. diffusion cloud chamber
   b. scintillation counter
   c. Geiger-Muller counter
   d. pulse current
2. ……….. they came up with the term “radioactivity” to describe the spontaneous emissions that they studied.
   a. Becquerel

b. Pierre and Marie Currie
c. Geiger Muller
d. Marsden

3. Radioactive decay is expressed in terms of
   a. rate of radioactive absorption
   b. rate of radioactive stability
   c. position of element in the periodic table
   d. half life

4. The following characteristics belong to one of the basic nuclear particles (i) – Low penetrating (ii) – Powerful ionizing power on gases (iii) – Particulate
   a. Alpha particles
   b. Beta particles
   c. Gamma rays
   d. X-ray

5. Radioisotopes have wide application in
   a. medicine
   b. industries
   c. agriculture
   d. all of the above

Answers

1. D
2. B
3. B
4. A
5. D

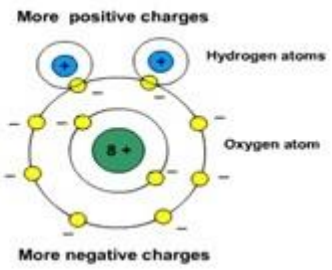
WEEK 3

TOPIC: SIMPLE MOLECULES AND THEIR SHAPES

Polar and non-polar molecules

Chemical bonding is the result of either an atom sharing one or more outer orbit electrons with another atom or an atom taking outer orbit electrons from the atom with which it is bonding. Normally, an atom has an even distribution of electrons in the orbits or shells, but if more end up on one side that the other in a molecule, there can be a resulting electrical field in that area.

Water is a polar molecule because of the way the atoms bind in the molecule such that there are excess electrons on the Oxygen side and a lack or excess of positive charges on the Hydrogen side of the molecule.



Water is a polar molecule with positive charges
on one side and negative on the other.

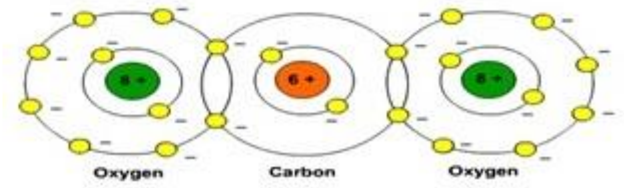
Examples of polar molecules of materials that are gases under standard conditions are:

- Ammonia (NH_3)
- Sulfur Dioxide (SO_2)
- Hydrogen Sulfide (H_2S).

Also, Ethanol is polar, since its oxygen molecule draws electrons towards it due to its high electro-negativity, causing a negative charge around itself.

Non-polar molecules

A non-polar molecule is one that the electrons are distributed more symmetrically and thus does not have an abundance of charges at the opposite sides. The charges all cancel out each other.



The electrical charges in non-polar Carbon Dioxide are evenly distributed

Examples of non-polar liquids

Most hydrocarbon liquids are non-polar molecules. Examples include:

- Toluene
- Gasoline

Alkynes are non-polar because they cannot be dissolved in water, as do polar molecules. However, alkynes but do dissolve in other non-polar substances. A rule is that like substances dissolve in like substances.

Examples of non-polar gases

Common examples of non-polar gases are the noble or inert gases, including:

- Helium (He)
- Neon (Ne)
- Krypton (Kr)
- Xenon (Xe)

Other non-polar gases include:

- Hydrogen (H_2)
- Nitrogen (N_2)
- Oxygen (O_2)
- Carbon Dioxide (CO_2)
- Methane (CH_4)
- Ethylene (C_2H_4)

Since Chloroform is more soluble in fats than in water, it is also classified as non-polar.

Rule for Solutions

The rule for determining if a mixture becomes a solution is that polar molecules will mix to form solutions and non-polar molecules will form solutions, but a polar and non-polar combination will not form a solution.

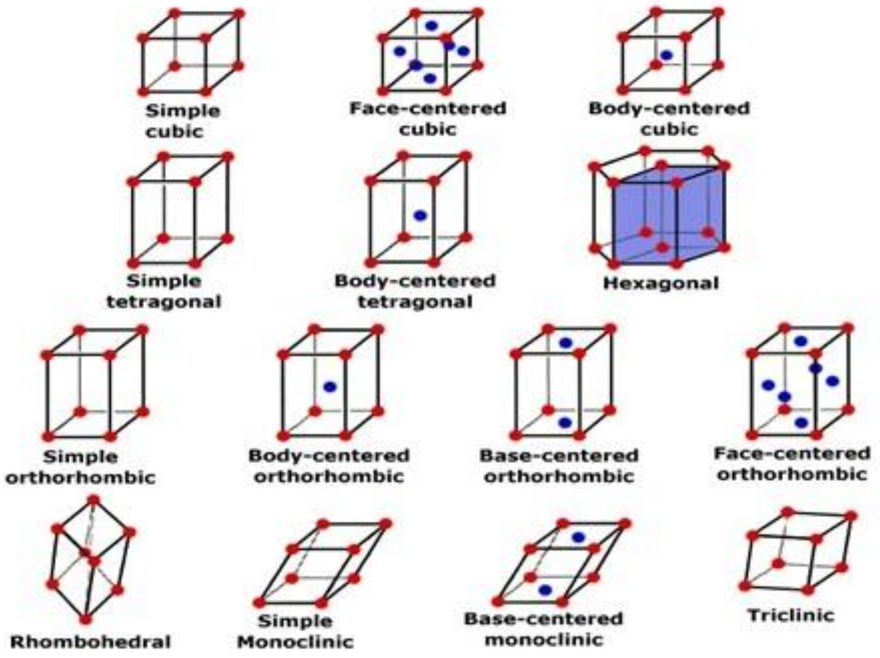
Water is a polar molecule and oil is a non-polar molecule. Thus they won't form a solution. On the other hand, since alcohol is a polar molecule, it will form a solution with water.

From these examples, we note that three factors determine whether a molecule is polar and non-polar. These are

1. The polarity of the covalent bond
2. The number and position of lone pairs
3. The shape of the molecule

General Structures of Crystals

The external shape of a crystal is the result of the spatial arrangement of the particles that make up the crystal. The three-dimensional arrangement of the particles is called the crystal lattice. The crystal lattice may be considered to be made up of unit cells which are each the smallest portion of the crystal lattice which shows the complete pattern of the particles in their relative positions



There are three kinds of unit cells based on the cubic structure. These are as follow:

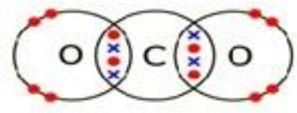
1. Simple cubic: These are structures in which the particles are placed one at each corner of the cube.
2. Face-centred cubic: These are structure in which there is a particle at each corner and one in the centre of each face of the cube
3. Body-centred cubic: These are structure in which there is a particle at each corner and one at the centre of the cube.

Covalent Compounds – Simple Molecules

Form between non-metal atoms. Each bond consists of a shared pair of electrons, and is very strong. Covalently bonded substances fall into two main types:

1. Simple molecules and
2. Giant covalent structures.

Simple molecules



These contain only a few atoms held together by strong covalent bonds. An example is carbon dioxide (CO_2), the molecules of which contain one atom of carbon bonded with two atoms of oxygen.

Properties of Simple Molecular Substances

- Low melting and boiling points – This is because the weak intermolecular forces break down easily.
- Non-conductive – Substances with a simple molecular structure do not conduct electricity. This is because they do not have any free electrons or an overall electric charge.

Hydrogen, ammonia, methane and water are also simple molecules with covalent bonds. All have very strong bonds between the atoms, but much weaker forces holding the molecules together. When one of these substances melts or boils, it is these weak 'intermolecular forces' that break, not the strong covalent bonds. Simple molecular substances are gases, liquids or solids with low melting and boiling points.

Covalent bonding – Giant Covalent structures

Giant covalent structures contain a lot of non-metal atoms, each joined to adjacent atoms by . The atoms are usually arranged into giant regular lattices – extremely strong structures because of the many bonds involved. The graphic shows the molecular structure of diamond and graphite: two allotropes of carbon, and of silica (silicon dioxide).

From left to right – graphite, diamond, silica

Properties of Giant Covalent Structures

- Very high melting points – Substances with giant covalent structures have very high melting points, because a lot of strong covalent bonds must be broken. Graphite, for example, has a melting point of more than 3,600ºC.
- Variable conductivity – Diamond does not conduct electricity. Graphite contains free electrons, so it does conduct electricity. Silicon is semi-conductive – that is, midway between non-conductive and conductive.

Graphite

Graphite is a form of carbon in which the carbon atoms form layers. These layers can slide over each other, so graphite is much softer than diamond. It is used in pencils, and as a lubricant. Each carbon atom in a layer is joined to only three other carbon atoms. Graphite conducts electricity.

Diamond

Diamond is a form of carbon in which each carbon atom is joined to four other carbon atoms, forming a giant covalent structure. It is the best example of covalent solid, which is usually octahedral in shape. As a result, diamond is very hard and has a high melting point. It does not conduct electricity. Diamond is the hardest substance known.

Silica

Silica, which is found in sand, has a similar structure to diamond. It is also hard and has a high melting point, but contains silicon and oxygen atoms, instead of carbon atoms.

The fact that it is a semi-conductor makes it immensely useful in the electronics industry: most transistors are made of silica.

Molecular Shape

While Lewis dot structures can tell us how the atoms in molecules are bonded to each other, they don’t tell us the shape of the molecule. In this section, we’ll discuss the methods for predicting molecular shape. The most important thing to remember when attempting to predict the shape of a molecule based on its chemical formula and the basic premises of the VSPER model is that the molecule will assume the shape that most minimizes electron pair repulsions. In attempting to minimize electron pair repulsions, two types of electron sets must be considered: electrons can exist in bonding pairs, which are involved in creating a single or multiple covalent bond, or non-bonding pairs, which are pairs of electrons that are not involved in a bond, but are localized to a single atom.

The VSPER Model—Determining Molecular Shape

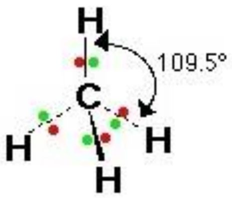
Total number of single bonds, double bonds, and lone pairs on the central atom	Structural pair geometry	Shape
2	Linear	
3	Trigonal planar	
4	Tetrahedral	

5	Trigonal bipyramidal
6	Octahedral

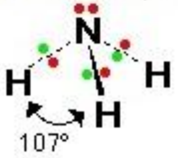
The above table represents a single atom with all of the electrons that would be associated with it as a result of the bonds it forms with other atoms plus its lone electron pairs. However, since atoms in a molecule can never be considered alone, the shape of the actual molecule might be different from what you'd predict based on its structural pair geometry. You use the structural pair geometry to determine the molecular geometry by following these steps:

1. Draw the Lewis dot structure for the molecule and count the total number of single bonds, multiple bonds, and unpaired electrons.
2. Determine the structural pair geometry for the molecule by arranging the electron pairs so that the repulsions are minimized (based on the table).
3. Use the table above to determine the molecular geometry.

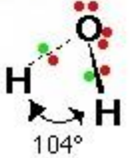
For instance, look at methane, which is CH_4:



Ammonia (NH_3), which has three sigma bonds and a lone pair, however, is trigonal pyramidal:

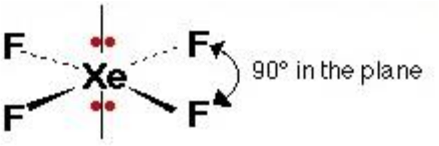


Water (H_2O) has two lone pairs and its molecular geometry is "bent," which is also called V shaped:



So as you can see, lone pairs have more repulsive force than do shared electron pairs, and thus they force the shared pairs to squeeze more closely together.

As a final note, you may remember that we mentioned before that only elements with a principal energy level of 3 or higher can expand their valence and violate the octet rule. This is because d electrons are necessary to make possible bonding to a fifth or sixth atom. In XeF_4, there are two lone pairs and four shared pairs surrounding Xe, and two possible arrangements exist:



In the axial arrangement, shared pairs are situated “top and bottom.” In the equatorial arrangement, shared pairs surround Xe. The equatorial arrangement is more stable since the lone pairs are 180˚ apart and this minimizes their repulsion. In both molecular arrangements, the electronic geometry is octahedral, with 90˚ angles. The top figure has a molecular geometry known as “seesaw,” while the bottom figure has a molecular geometry that is more stable, known as square planar.

Example

Draw the dot formula for SeF_4 and determine the hybridization at Se.

Explanation

First determine the number of valence electrons this molecule has: SeF_4 has 6 + 4(7) = 34 valence electrons, which is equal to 17 pairs of electrons.

Selenium is surrounded by four fluorines and a lone pair of electrons. That’s five sites of electron density, which translates into sp^3d hybridization. Se is from the fourth period, so it may have an expanded octet.

So, to recap, focus on the number of binding “sites” or areas of concentrated electron density:

Two areas of electron density: linear, planar molecule

Three areas of electron density: trigonal planar molecule

Four areas of electron density: tetrahedral molecule

Five areas of electron density: trigonal bipyramidal molecule

Six areas of electron density: octahedral molecule

Molecular Polarity

In chemical bonds, polarity refers to an uneven distribution of electron pairs between the two bonded atoms—in this case, one of the atoms is slightly more negative than the other. But molecules can be polar too, and when they are polar, they are called dipoles. Dipoles are molecules that have a slightly positive charge on one end and a slightly negative charge on the other. Look at the water molecule. The two lone electron pairs on the oxygen atom establish a negative pole on this bent molecule, while the bound hydrogen atoms constitute a positive pole. In fact, this polarity of water accounts for most of water’s unique physical properties. However, molecules can also contain polar bonds and not be polar. Carbon dioxide is a perfect example. Both of the C—O bonds in carbon dioxide are polar, but they’re oriented such that they cancel each other out, and the molecule itself is not polar.

Assessment

1. These are factors which determine whether a molecule is polar or non-polar except
   a. shape of the molecule
   b. number of lone pairs in an atom
   c. number of electronegative elements present
   d. polarity of covalent bond
2. These are examples of unit cell cubic structure
   a. simple cubic structure
   b. non-linear cubic structure
   c. face-centered cubic structure
   d. body centered cubic structure
3. These are intermolecular bonds or attractions except
   a. metallic bond
   b. dipole – dipole attractions
   c. van-der Waal's forces
   d. hydrogen bond
4. List the properties of simple molecular substances

Answers

1. C
2. B
3. A

WEEK 4

TOPIC: PETROLEUM OR CRUDE OIL

Crude Oil

Crude oil or Petroleum is the chief source of hydrocarbons. Petroleum which means rock oil in Latin occurs as a dark, sticky, viscous liquid. It is found in huge underground deposits in many parts of the world. Natural gas is usually found together with it. Petroleum is a mixture of gaseous liquid and solid alkanes, alkenes, cycloalkanes, aromatic hydrocarbons and others. Natural gas consists mainly of methane. Crude oil is a mixture of hydrocarbons. It exists in liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities.

Crude oil occurs in large quantities in Nigeria, especially in Bayelsa, Edo, Imo, rivers, Delta, Abia, Ondo and Cross river state. It is dark brown in colour though its composition and consistency vary from place to place. In fact, different oil producing areas yield significantly different varieties of crude oil. We have light and heavy crude oil. The light one has low metal and sulphur content, light in colour and flows easily. It is very expensive. The heavy one has high metal and sulphur content and must be heated to become fluid. It is less expensivePetroleum is a naturally occurring, yellow-to-black liquid found in geological formations beneath the Earth’s surface, which is commonly refined into various types of fuels. Components of petroleum are separated using a technique called fractional distillation.

It consists of hydrocarbons of various molecular weights and other organic compounds

Origin of Crude Oil and Natural Gas

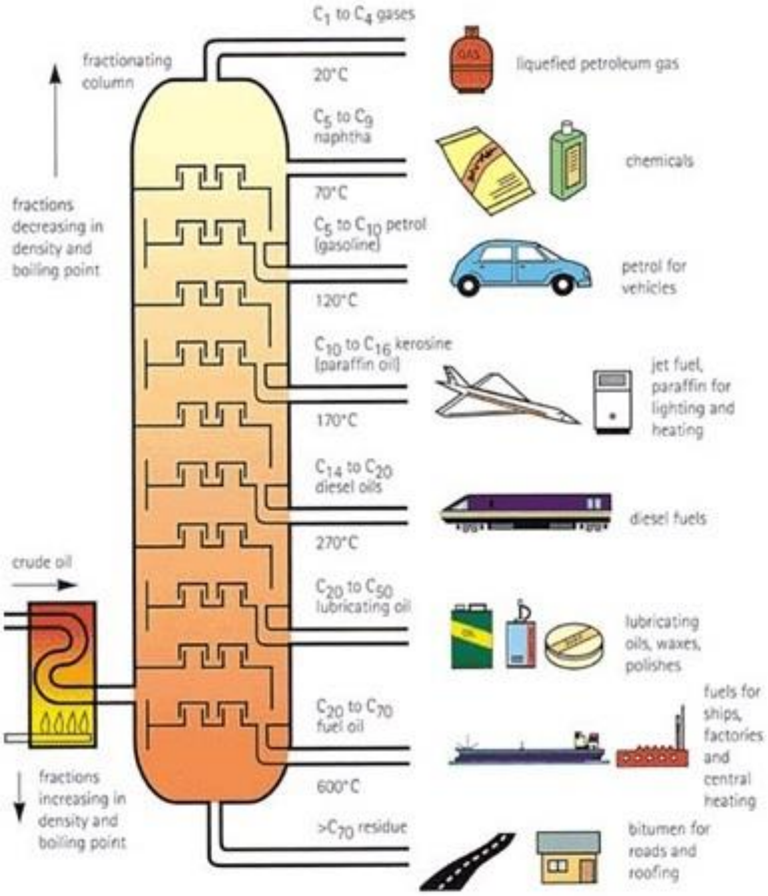
They are formed from the remains of marine algae and animals. When these tiny aquatic organisms died, their remains gradually settled on the seabeds. Over the years, the remains became covered by mud, silt and other sediments. As the sediments piled up, their mass exerted a great pressure on the lower layers, changing them to hard sedimentary rocks. During this process, bacterial activity, heat and pressure probably changed the plant and animal remains into crude oil and natural gas.

Refining of Crude Oil

Petroleum or crude oil occurs naturally. it contains many useful products also called fractions. These are separated by the method of fractional distillation. This process of obtaining useful fractions from petroleum is called refining.

The process of dividing petroleum into fractions with different boiling range volatilities and free from impurities is called refining.
The process of turning petroleum into a useful form is done in a crude oil refinery. The steps for making crude oil into oil, petrol or whatsoever are fractional distillation, cracking and reforming.

Petroleum is refined by fractional distillation. The process of separating a mixture into a series of fractions of different volatilities by means of distillation is known as fractional distillation.
In the process of fractional distillation, a mixture of different liquids is evaporated followed by condensation. Different liquids are evaporated according to their boiling point and they are collected in different chambers of distillation tower



Fractional distillation of Crude Oil

Fractional Distillation of Crude Oil

Fractional distillation differs from distillation only in that it separates a mixture into a **number of different parts**, called **fractions**. A tall column is fitted above the mixture, with several condensers coming off at different heights. The column is hot at the bottom and cool at the top. Substances with high boiling points condense at the bottom and substances with low boiling points condense at the top. Like distillation, fractional distillation works because the different substances in the mixture have different boiling points.

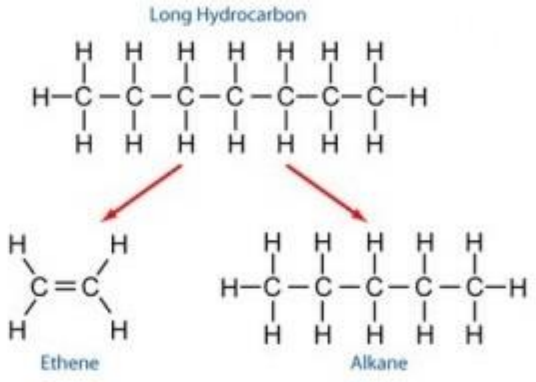
Fractions of petroleum from refining are petroleum gases (Methane, butane, etc.), petrol or gasoline, kerosene, diesel, lubricating oil and bitumen (asphalt). Because they have different boiling points, the substances in crude oil can be separated using fractional distillation. The crude oil is evaporated and its vapours allowed to condense at different temperatures in the fractionating column. Each fraction contains hydrocarbon molecules with a similar number of carbon atoms.

The mixture is inserted at the bottom, where mostly everything will condense as the temperature is 350°C and more. The condensed crude oil will rise to the next fraction above, which has a very high temperature as well, but a slightly smaller one. Only the part of the mixture, which boiling point is under the temperature of the fraction, will condense and rise to the next fraction. The part of the mixture, whose boiling point is higher than the temperature inside the distillation fraction, will stay there and be pumped out.

Crude oil is heated until it boils and then the hydrocarbon gases are entered into the bottom of the fractionating column. As the gases go up the column the temperature decreases.
The hydrocarbon gases condense back into liquids and the fractions are removed from the sides of the column. The different fractions have different uses.The smaller the hydrocarbon molecule, the further it rises up the column before condensing.
The fractionating column operates continuously. The temperatures shown are approximate. A sample of crude oil may be separated in the laboratory by fractional distillation. The collection vessel is changed as the temperature rises to collect the different fractions.

Cracking

After the fractional distillation process, the separated mixtures have to be cracked down. This means that a long molecule will be split up in smaller parts.
Firstly, single bonds will be broken down. This results into some lone electrons.
The lone electrons form double bonds. Thus, hydrogen will disconnect from the carbon atom. Hydrogen (H_2) remains as a side product. The loss of hydrogen in these smaller organic molecules is logical, because when they are lost, more lone electrons remain with what the previous lone electrons can make a bond.



Reforming

After cracking, the molecules are ready to undergo the reforming process.
This is given by the octane number. The octane number is very important in petrol. It tells what the percentage of pure heptane (in the earlier days it was octane – that is why it is called octane number) in petrol is. This is of great importance for the chemical behaviour. The quality of petrol is improved by adding mixtures to pure heptane. The chains of heptane are heated up (where platinum is used as a catalyst). So they can change. After the heating process, it shows a higher amount of branched chains. This increases the octane number.

Example: When the petrol you buy has a 98 in the name, then it means that 98% are branched chains and 2% of the mixture is pure heptane (or another pure molecule).

Octane Number

The octane number or octane rating of petrol is a measure of the proportion of branched chain hydrocarbons in a given blend of gasoline (petrol).

In other words, Octane number is a standard which determines the knocking ability and quality of gasoline. Higher is the octane number of a gasoline, lower is the knocking it produces.

Gasoline is composed of C7 – C9 hydrocarbons i.e. heptanes, octane and nonane. These hydrocarbons are present in their straight chain or branched chain isomers. It has been shown that straight chain hydrocarbons burn too rapidly in the car engine thus, causing irregular motion of the pistons which results in rattling noise. This rattling noise is known as "Knocking".

Knocking

Knocking is a sharp metallic sound produced in the internal combustion engine. Knocking is caused by the low octane number of gasoline

Synthetic Petrol

Synthetic petrol is made from materials such as coal, coke and hydrogen which do not occur in crude petroleum. Synthetic petrol can be gotten from two sources

1. From coal: When powdered coal is heated with hydrogen in the presence of iron or tin as catalyst at 500°C and 200 atmospheric pressure, it is converted into an oily mixture of hydrocarbons. The mixture is separated by distillation into a petrol fraction boiling at 200°C and a heavy oily residue which can be further treated with fresh coal to obtain more petrol
2. From Coke: When steam is passed over heated coke at 1000°C, a mixture containing equal volumes of carbon (II) oxide and hydrogen known as water gas is obtained
    1. $C_{(s)} + H_2O_{(l)} \longrightarrow CO_{(g)} + H_{2(g)}$

The water gas can be hydrogenated to a mixture of hydrocarbons by adding hydrogen and passing it over finely divided nickel as catalyst at 200°C. About half of the product is petrol, the less volatile fraction is used as fuel for diesel engines

Fractions of Crude Oil

1. Petroleum gases – These gases are liberated at the top of the column at temperatures below 40° They are mainly hydrocarbons consisting of one of four carbon atoms per molecule, e.g methane, ethane, propane, butane and ethane. They are used mainly as fuels for homes and industries and for manufacture of products like hydrogen, sulphide and ethyne
2. Petroleum ethers and ligroin – This is the mixture of very volatile liquids consisting of hydrocarbons with five or seven carbon atoms per molecule. The petroleum ether or light petroleum distils over between 2°C to 60°C, while the ligroin or light naphtha distils over between 60°C to 100°
3. Petrol – Petrol or gasoline is a mixture of hydrocarbons consisting of four to twelve carbon atoms per molecule. It is a volatile liquid which distils over in the temperature range of 40°C to 200° Petrol is used as a fuel for aeroplanes and motor vehicles. It is a good solvent for paints and grease

4. Kerosene – Kerosene contains hydrocarbons with twelve to eighteen carbon atoms per molecule. It distils over in the temperature of 200^{o}C to 250^{o} it is a fairly volatile liquid and is used as a fuel for lighting and heating and for driving tractors and some modern jet engines. It is a good solvent for paint and grease
5. Gas oil and Diesel oil – They have twenty to twenty five carbon atoms per molecule. They distil over in the temperature of 250^{o}C to 350^{o} They are mainly used as fuel for heating and diesel engines and as raw materials of the cracking process
6. Lubricating oils – They are heavy oils. They consist of hydrocarbons with more than twenty five carbon atoms per molecule. They distil over in the temperature of 350^{o}C to 500^{o} They are viscous liquids used for lubricating moving parts of engines and machines. Grease belongs to this group. Vaseline and paraffin wax are solid long chain hydrocarbons which are obtained from re-distillation of heavy oils.
7. Bitumen and other residues – these are solid residues left behind at temperatures above 500^{o} Bitumen are used for surfacing roads and airfields while other residues may be used as fuel, in protective paints and water proofing roofs.

Assessment

1. ……… is the chief source of hydrocarbons
2. ………. of petrol is a measure of the proportion of branched chain hydrocarbons in a given blend of gasoline (petrol).
3. ……….. involves the separation of a mixture into a number of different parts, called fractions.
4. ……….. is a sharp metallic sound produced in the internal combustion engine
5. Mention 4 fractions of crude oil

Answers

1. Crude oil/Petroleum
2. Octane Number
3. Fractional Distillation
4. Knocking
5. Kerosene, Petrol, Bitumen, Diesel, Gas oil, Lubricating oil

WEEK 5

TOPIC: VOLUMETRIC ANALYSIS

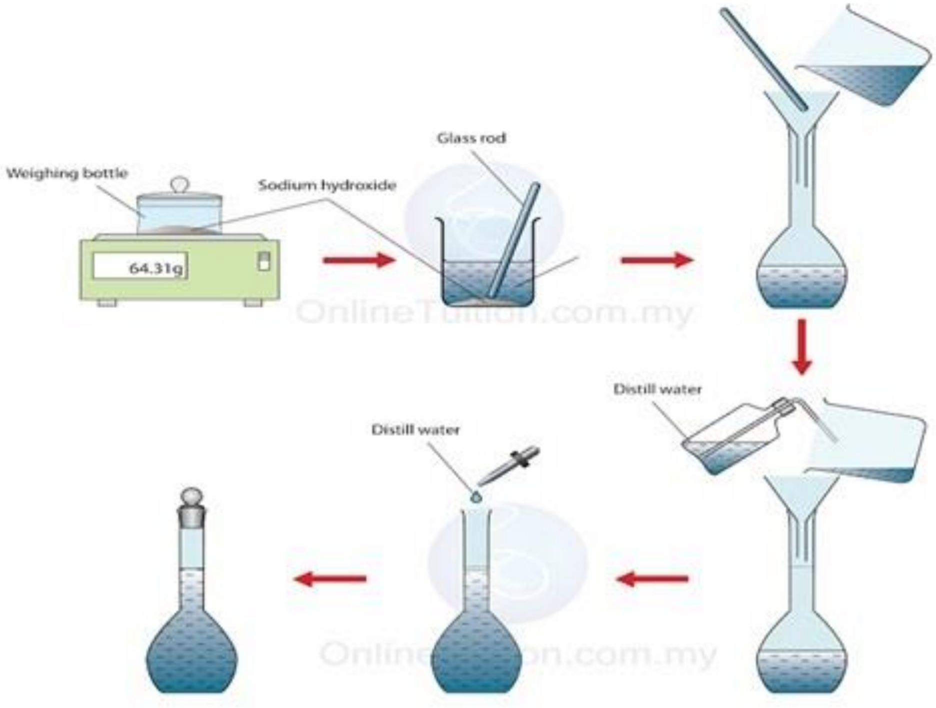
Introduction

Volumetric analysis is an analytical method or procedure for working out the titre or concentration of an analyte in a solution. This is done by measuring the volume of a standard solution of an appropriate reagent whose precise concentration is already known.

Preparing A Standard Solution

1. A standard solution is a solution in which its concentration is known.
2. The steps taken in preparing a standard solution are:

- Determine the volume and concentration that you want to prepare.
- Calculate the mass of solute needed to give the required volume and concentration.
- Weigh the solute
- Dissolve the solute completely dissolved in distilled water and then transfer it to a volumetric flask partially filled with distilled water.
- Add distilled water to the calibration mark of the volumetric flask.
- Invert the flask and shake it to make sure thorough mixing.



Acid Base Titration

Some materials used during acid – base titration and precautions in using some of them

1. weighing balance
2. chemical balance
3. pipette
4. burette
5. retort stand
6. filter paper
7. funnel
8. white tile
9. standard volumetric flask
10. conical flask

Pipette

- rinse the pipette with the solution it will be measured with e.g. base
- avoid air bubbles in the pipette
- make sure the mark to be read is at same level with your eye
- do not blow the last drop on the burette

Burette

- rinse the burette with acid or allow it to drain after rinsing
- make sure the burette jar is filled
- avoid air bubbles in the burette
- make sure that burette is not leaking4remove the funnel befor taking your reading
- avoid inconsistent burette reading

Conical flask

- do not rinse with any of the solutions used in the titration but with distilled water
- wash down with distilled water any drop of the solution that stick by the sides of the conical flask

Concentration of a Solution

1. The concentration of a solution tells you how much solute is dissolved in 1 unit volume of solution.
2. The volume of a solution is measured in dm^3 (litres) $1\ dm^3 = 1000\ cm^3$.
3. The amount of solute can be measured in grams or moles.
4. 2 units of concentration used in chemistry are $g\ dm^{-3}$ and $mol\ dm^{-3}$

Concentration in $g\ dm^{-3}$

1. Concentration is the number of moles of solute per liter of solution.
2. A concentration of $10\ g\ dm^{-3}$ means there is 10 g of solute dissolved in1 dm^3 of solution.

Concentration=Mass of solute (g) / Volume of solution (dm^3)

Example 1:
Calculate the concentration of the solution if 28g of NaOH is dissolve in $250cm^3$ of water.
Answer:
Mass of solute = 28g
Volume of solvent = $250cm^3 = 0.25dm^3$

Concentration = Mass / Volume

$=28g / 0.25dm^3$

$=112g/dm^3$

Concentration in $mol\ dm^{-3}$ (Molarity)

1. Molarity is probably the most commonly used unit of concentration. It is the number of moles of solute per liter of solution.
2. A concentration of $2\ mol\ dm^{-3}$ means there are 2 moles of solute dissolved in $1\ dm^3$ of solution.

Molarity=Mole of solute(mol) / Volume of solution(dm^3)

Example 2:
What is the molarity of a solution made when water is added to 0.2 mol of $CaCl_2$ to make $100\ cm^3$ of solution? [RAM: Ca = 40; Cl = 35.5]

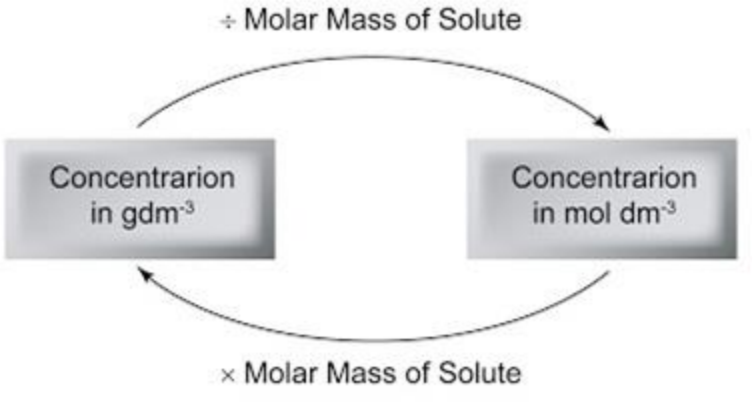
Answer:
Number of mole of solute = 0.2 mol
Volume of solvent = $100\ cm^3 = 0.1\ dm^3$

Molarity = Number of Mole / Volume

$= 0.2mol / 0.1dm^3$

$=2mol/dm^3$

Conversion of Concentration Unit



1. The chart above shows how to convert the units of concentration from g dm^{-3} to mol dm^{-3} and vice versa.
2. The molar mass of the solute is equal to the relative molecular mass of the solute.

Example 3:
The concentration of a Potassium chloride solution is 14.9 g dm^{-3}. What is the molarity (mol dm^{-3}) of the solution? [Relative Atomic Mass: Cl = 35.5; K = 39]

Answer:
Relative Formula Mass of Potassium Chloride (KCl)
= 39 + 35.5 = 74.5

Molar Mass of Potassium Chloride = 74.5 g/mol

Molarity of Potassium Chloride

Molarity = ConcentrationMolar Mass=14.9*gdm*−374.5*gmol*−1=0.2*mol*/*dm*3

Molarity and Number of Moles

Number of mole of solute in a solution can be calculated by using the following formula

$n=MV / 1000$

where
n = number of mole of solute
M = molarity of the solution
V = volume of the solution in cm^3

Example 4
How many moles of zinc sulphate is present in $200cm^3$ of 0.1 mol dm^{-3} zinc sulphate solution?
Answer:
Molarity, M = 0.1 mol dm^{-3}
Voloume, V = $200cm^3$

$n=MV / 1000$

n= (0.1)(200) / 1000 = 0.02mol

Example 5
A solution of barium hydroxide have molarity 0.1 mol dm^{-3}. What is the concentration of the solution in g dm^{-3}? [Relative Atomic Mass: Ba = 137; O = 16; H = 1]
Answer:
Relative Formula Mass of barium hydrokxide, $Ba(OH)_2$
= 137 + 2(16+1) = 171

Molar Mass of Potassium Chloride = 171 g/mol

Concentration = Molarity × Molar Mass

$=0.1 mol/dm^3 \times 171 gmol^{-1} = 17.1 gmol^{-1}$

Solubility of substance

The term solubility refers to the maximum amount of material that will dissolve in a given amount of solvent at a given temperature to produce a stable solution.

Calculations on Solubility

Examples 1: If 12.2 g of lead(II) trioxonitrate(V) were dissolved in 21 g of distilled water at 20°C, calculate the solubility of the solute in mol dm^{-3}.

Solution:

Molar mass of $Pb(NO_3)_2$ = 331 g

12.2 g of $Pb(NO_3)_2$ = 12.2/331 = 0.037 mole

21 g of water at 20°C dissolved 0.037 mole of $Pb(NO_3)_2$

1000 cm3 of water at 20 °C dissolved 1000 x 0.037 / 21

= 1.76 moles of $Pb(NO_3)_2$

At 20°C, the solubility of $Pb(NO_3)_2$ in water is 1.76 mol dm^{-3}

Using formula Method

Solubility = mass/molar mass x 1000/vol

= 12.2/331 x 1000/21

= 1.7751 mol dm^{-3}

= 1.76 mol dm^{-3}

Example 2: The solubility of potassium trioxonitrate (V) is exactly 1800 g per 1000 g water at 83°C and 700 g per 1000 g water at 40°C. Calculate the mass of potassium trioxonitrate (V) that will crystallize out of solution if 155 g of the saturated solution at 83 °C is cooled to 40°C.

Solution:

	Solvents	+	Solution	= Solution
Masses involved at 83°C	1000 g		1800 g	= 2800 g
Masses involved at 40°C	1000 g		700 g	= 1700 g

Solute deposited on cooling from 83°C to 40°C = 2800 – 1700 = 1100 g

On cooling from 83°C to 40°C,

2800 g of saturated solution deposit 1100 g of solute

155 g of saturated solution will deposit = 1100 x 155 / 2800

= 60.89 g of solute

A titration calculation

The method for titration calculations is the one you have used for mole calculations already:

1. Write a balanced equation for the reaction.
2. Find the number of moles of the known substance.
3. Use the balanced equation to find the number of moles of the unknown substance.
4. Work out the mass, concentration or volume of the unknown.

The formula:

$M_AV_A/M_BV_B = N_A/N_B$

M_A = Molarity of acid in mol/dm^3

V_A = Volume of the acid in cm^3

M_B = Molarity of base in mol/dm^3

V_B = Volume of the base in cm^3

N_A = Number of moles of acid

N_B = Number of moles of base

Example 1: Calculate:

(a) the mass of anhydrous Na_2CO_3 present in 300cm^3 of 0.1M

(b) the number of Na_2CO_3 particles present in the solution (Na = 23, C = 12, O = 16)

Solution:

(a) Molarity of the Na_2CO_3 solution = 0.1 M

Molar mass of Na_2CO_3 = 23 x 2 + 12 + 16 x 3 = 106g/mol

Concentration (g/dm^3) = Molarity x molar mass

0.1 x 106

= 10.6g/dm^3

This means 1000cm^3 of 0.1M solution contain 10.6g of Na_2CO_3

300cm^3 of 0.1 M solution will contain: 300 x 10.6 / 1000

= 3.18g of Na_2CO_3

(b) Number of Na_2CO_3 particles = molarity x 6.02 x 10^{23}

0.1 x 6.02 x 10^{23}

= 0.602 x 10^{23}

This means 1000cm^3 of 0.1 M solution contain 0.602 x 10^{23} Na_2CO_3 particles

300cm^3 of 0.1M solution contain

Example 2: 20.30cm^3 of hydrochloric acid solution was titrated against 25cm^3 of 0.1M sodium hydroxide solution. Calculate:

(i) the concentration of the acid in mol/dm^3

(ii) the concentration of the acid in g/dm^3

Solution:

Equation of reaction

$HCl (aq) + NaOH (aq) \longrightarrow NaCl (aq) + H_2O (l)$

1 : 1

(i) M_A =?, M_B = 0.1 M, V_A = 20.30cm^3, V_B = 25cm^3, N_A = 1, N_B = 1

$M_AV_A/M_BV_B = N_A/N_B$

$M_A = M_BV_B N_A / V_A N_B$

M_A = 0.1 x 25 x 1 / 20.30 x 1

M_A = 0.123 mol/dm^3

(ii) Molarmass of Acid = 36.5 g/mol, Concentration of Acid in mol/dm^3 = 0.123 mol/dm^3

Concentration of Acid in g/dm^3 = Concentration of Acid in mol/dm^3 x Molarmass

= 0.123 x 36.5

= 4.49 g/dm^3

Assessment

1. Calculate the concentration of the solution if 25g of NaOH is dissolve in 500cm^3 of water.
2. 32.30cm^3 of hydrochloric acid solution was titrated against 25cm^3 of 0.2M sodium hydroxide solution. Calculate: a. the concentration of the acid in mol/dm^3 b. the concentration of the acid in g/dm^3
3. If 21.2 g of Calcium Trioxocarbonate were dissolved in 15 g of distilled water at 30^{o}C, calculate the solubility of the solute in mol dm^{-3}.
4. The concentration of a Potassium chloride solution is 28.9 g dm^{-3}. What is the molarity (mol dm^{-3}) of the solution? [Relative Atomic Mass: Cl = 35.5; K = 39]

WEEK 6

TOPIC: QUALITATIVE ANALYSIS

Identification of Ions

There are 10 cations and 4 anions to be studied:

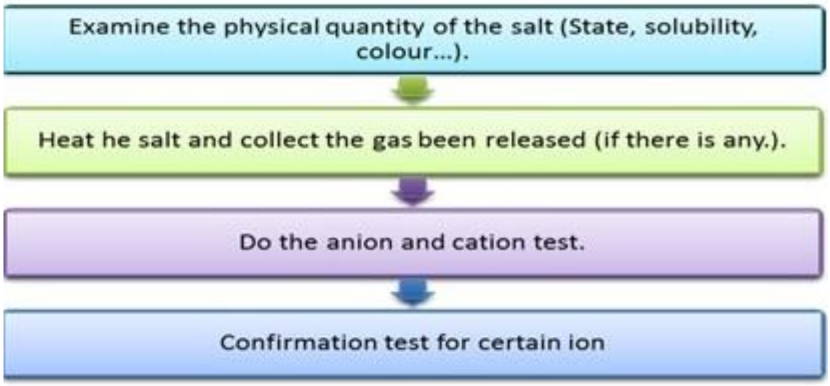
Cation

Sodium	Na^+	Iron (II)	Fe^{2+}
Calcium	Ca^{2+}	Iron (III)	Fe^{3+}
Magnesium	Mg^{2+}	Lead(II)	Pb^{2+}
Aluminium	Al^{3+}	Copper (II)	Cu^{2+}
Zinc	Zn^{2+}	Ammonium	NH_4^+

Anion

Chloride ion	Cl^-
sulphate ion	SO_4^{2-}
nitrate ion	NO_3^-
carbonate ion	CO_3^-

Steps in qualitative analysis



Examine the physical quantity of the salt (State, solubility, colour...).

Heat he salt and collect the gas been released (if there is any.).

Do the anion and cation test.

Confirmation test for certain ion

Colour of Ions

Salt or metal oxide	Solid	Aqueous solution

Salt of Sodium, Calcium, Magnesium, Aluminium, zinc, Lead, ammonium	White	Colourless
Salt of Chloride, sulphate, nitrate, carbonate	White	Colourless
Salt of Copper(II) –		
Copper(II) Carbonate	Green	–
Copper(II) sulphate, Copper(II) nitrate, Copper(II) chloride	Blue	Blue
Copper(II) oxide	Black	–
Salt of Iron (II): Iron(II) sulphate; Iron(II) nitrate; Iron(ID chloride	Green	Green
Salt of Iron (III): Iron(III) sulphate; Iron(III) nitrate; Iron(III) chloride	Brown	Brown
Zink oxide	Yellow when it is hot and white when it is cold.	–
Lead(II) oxide-	Brown when it is hot and yellow when it is cold.	–
Magnesium oxide, Aluminium oxide	White	Insoluble
Potassium oxide, Sodium oxide, Calcium oxide	White	Colourless

Heating Effect on Carbonate Salts

1. All carbonates salts except potassium carbonate and sodium carbonate can be decomposed by heat to produce carbon dioxide gas.
2. Table below shows the effect of heating on metal carbonate.

Carbonate Salt	**Equation of The Reaction**
Potassium carbonate Sodium carbonate	Will not decompose by heat
Calcium carbonate Magnesium carbonate Aluminium carbonate Zinc carbonate Iron (III) carbonate	Calcium carbonate

Lead(II) carbonate
Copper(II) carbonate

$CaCO_3 \rightarrow CaO + CO_2$

Aluminium carbonate

$Al_2(CO_3)_3 \rightarrow Al_2O_3 + 3CO_2$

Copper carbonate

$CuCO_3 \rightarrow CuO + CO_2$Mercury(II) carbonate
Silver carbonate
Aurum(II) carbonateSilver carbonate

$2Ag_2CO_3 \rightarrow 2Ag + 2CO_2 + O_2$Ammonium carbonate$(NH_4)_2CO_3 \rightarrow 2NH_3 + 2CO_2 + H_2O$

Heating Effect on Nitrate Salts

1. All nitrates salts decompose when heated.
2. Table below shows the products formed when different nitrate salts are heated.

Nitrate Salt	**Equation of The Reaction**
Ammonium nitrate	Ammonium nitrate decompose to nitrogen monoxide and water vapour when heated.

$NH_4NO_3 \rightarrow N_2O + 2H_2O$Potassium nitrate
Sodium nitratePotassium nitrate

$2KNO_3 \rightarrow 2KNO_2 + O_2$

Sodium nitrate

$2NaNO_3 \rightarrow 2NaNO_2 + O_2$Calcium nitrate
Magnesium nitrate
Aluminium nitrate
Zink nitrate
Iron (III) nitrate
Lead(II) nitrate
Copper(II) nitrateMagnesium nitrate

$2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$

Iron(III) nitrate

$4Fe(NO_3)_3 \rightarrow 2Fe_2O_3 + 12NO_2 + 3O_2$

Lead(II) nitrate

$2Pb(NO_3)_2$ → $2PbO + 4NO_2 + O_2$Mercury(II) nitrate
Silver(I) nitrate
Aurum(II) nitrateSilver nitrate

$2AgNO_3$ → $2Ag + 2NO_2 + O2$

Heating Effect on Sulphate Salts

1. Most sulphate salts do not decompose by heat. For instance, sodium sulphate, potassium sulphate, and calcium sulphate are not decomposable by heat.
2. Only certain sulphate salts are decomposed by heat when heated strongly.

For instance:

Strong heating of green crystal iron (II) sulphate will release steam, sulphur dioxide, sulphur trioxide and leave behind a reddish solid iron (III) oxide residue. The steam released comes from the hydrated water of the crystallize salt.

$2FeSO_4.7H_2O$ → $Fe_2O_3(p) + SO_2(g) + SO_3(g) + 14H_2O(g)$

Meanwhile, zinc sulphate, copper (II) sulphate, and iron (III) sulphate decompose when heated strongly to evolve sulphur (VI)oxide gas and form a metal oxide.
Example
Zinc sulphate

$ZnSO_4$ → $ZnO + SO_3$
Copper (II) sulphate

$CuSO_4$ → $CuO + SO_3$
Iron (III) sulphate

$Fe_2(SO_4)_3$→ $Fe_2O_3 + 3SO_3$

When ammonium sulphate is heated strongly, this white solid sublimate and is decomposed to form ammonia gas and sulphuric acid.

$(NH_4)_2SO_4$ → $NH_3 + H_2SO_4$

Identifying Gases

- **Oxygen (Glowing wooden splinter)**

A glowing wooden splinter is inserted into the test tube that contain the gas.

The gas rekindles the glowing wooden splinter.

- **Hydrogen (Lighted Wooden Splinter)**

A lighter wooden splinter is brought close to the mouth of the test tube that contain the gas.

A “pop” sound is produced.

- **Carbon dioxide (Lime Water)**

The gas is directed to flow through lime water.

The lime water turn chalky.

- **Sulphur Dioxide (Potassium Dichromate(VI))**

The gas is directed to flow through potassium dichromate(VI) solution.

The orange colour of potassium dichromate(VI) solution become green.

- **Chlorine (Moist Litmus Paper)**

Moist blue litmus paper is inserted into the test tube that contain the gas.

The blue litmus paper turn red and then white.

- **Ammonia Gas (Moist litmus paper)**

Moist red litmus paper is inserted into the test tube that contain the gas.

The red litmus paper turn blue.

Identifying Anions – Carbonate

The carbonate salts react with acid produce carbon dioxide and water. This chemical property of carbonate is used to test the presence of carbonate in a salt.

$CO_3^{2-} + 2H^+ \rightarrow H_2O + CO_2$

- During the test, some dilute hydrochloric acid / nitric acid /sulphuric acid is added to the carbonate salt.

- If the salt contain carbonate, effervescence occurs.
- If the gas given off is passed through lime water, the lime water will turns chalky.
- This indicates that the gas is carbon dioxide, and hence the salt contain carbonate.

Identifying Anions – Sulphate

All salts of sulphate are soluble in water, except lead(II) sulphate, barium sulphate and calcium sulphate.

The insolubility of barium sulphate is used to test for the presence of sulphate in a salt.

1. 2 cm^3 of dilute hydrochloric / nitric acid is added to 2 cm^3 of sulphate solution. This is to check whether carbonate is presence in the solution or not because carbonate may give the same result as sulphate.
2. If not effervescence, then 2 cm^3 of barium chloride is added into the solution.
3. If sulphate ions are presence, a white precipitate will form. The precipitate is barium sulphate.
4. This is actually the double decomposition reaction that you have learned in preparation of insoluble salt.

$Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$

Identifying Anions – Chloride

All the salts of chloride are soluble in water except lead(II) chloride, silver(I) chloride and mercury chloride.The insolubility if silver(I) chloride is used in the test of presence of chloride.

1. 2 cm^3 of dilute nitric acid is added to 2 cm3 solution of chloride ions. This is the check if carbonate ions are presence because carbonate ions may give the same result.
2. If there is no effervescence, 2 cm^3 of silver nitrate solution is then added into the mixture.
3. A white precipitate will form if chloride is presence in the salt.
4. The precipitate is silver chloride

$Ag^+ + Cl^- \rightarrow AgCl$

Identifying Anions – Nitrate

Test 1

Add dilute sodium hydroxide and a little aluminium powder. If a nitrate is present, ammonia gas is produced. The gas can be identified as it turns moist red litmus paper blue.

Test 2

1. About $2cm^3$ of dilute sulphuric acid is added into the solution that wants to be tested and then followed by $2cm^3$ iron (II) sulphate solution.
2. A few drops of concentrated sulphuric acid are carefully drop through the inclined side of the test tube without shaking the test tube.
3. A brown ring will form in the middle of the solution.
4. Explanation: Iron (II) sulphate reduce nitric acid (from the reaction between nitrate ion and concentrated sulphuric acid) to nitrogen monoxide. Afterwards, nitrogen monoxide combines with iron (II) sulphate to form the compound $FeSO_4.NO$ which is brown in colour (brown ring).

Identifying Cations – Test with Sodium Hydroxide and Ammonia Solution

- Cations can be identified by their reaction with aqueous sodium hydroxide and aqueous ammonia.
- Sodium hydroxide and aqueous ammonia produce hydroxide ion which will react with most anion to form precipitate.

$NaOH + H_2O \rightarrow Na^+ + 2OH^- + H^+$

$NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

- Different cations like aluminium Al^{3+}, calcium Ca^{2+}, copper(II) Cu^{2+}, iron(II) Fe^{2+}, iron(III) Fe^{3+}, lead(II) Pb^{2+}, zinc Zn^{2+} produce different coloured precipitates, which may or may not dissolve in excess alkali.
- $Zn(OH)_2$, $Al(OH)_3$ and $Pb(OH)_3$ dissolve in excess NaOH solution, this is because $Zn(OH)_2$, $Al(OH)_3$ and $Pb(OH)_3$ are amphoteric, they can react with NaOH to form salt and water.
  $Zn(OH)_2 + 2NaOH \rightarrow Na_2ZnO_2 + 2H_2O$
  $Al_2(OH)_3 + 3NaOH \rightarrow Na_3Al_2O_3 + 3H_2O$
  $Pb(OH)_2 + 2NaOH \rightarrow Na_2PbO_2 + 2H_2O$
- Table below shows the summary of the precipitate form by different cation.

	NaOH(ak)	**NH_3(ak)**
Na^+	–	–
Ca^{2+}	White precipitate.	–
Mg^{2+}	White precipitate.	White precipitate.
Al^{3+}	White precipitate.	

Dissolve in excess NaOH solution. White precipitate.**Zn^{2+}**White precipitate.

Dissolve in excess NaOH solution. White precipitate.

Dissolve in excess NH_3 solution.**Pb^{2+}**White precipitate.

Dissolve in excess NaOH solution. White precipitate.**Fe^{2+}**Dirty green precipitate.Dirty green precipitate.**Fe^{3+}**Red brown precipitate.Red brown precipitate.**Cu^{2+}**Blue precipitate.Blue precipitate.

Dissolve in excess NH_3 solution and form a blue solution.**NH_4^+**—

Identifying Cations – Test with Chloride Ions

1. Out of the 10 cations, only lead(II) ions will form a precipitate with chloride ions.
2. This is because lead(II) chloride is insoluble in water.
3. The chemical reaction is a double decomposition reaction.

$Pb^{2+} + 2Cl^- \rightarrow PbCl_2$

1. Lead(II) chloride will dissolve in hot water.

	HCl or NaCl
Na^+	–
Ca^{2+}	–
Mg^{2+}	–
Al^{3+}	.-
Zn^{2+}	–
Pb^{2+}	White precipitate. Dissolve in hot water
Fe^{2+}	–
Fe^{3+}	–
Cu^{2+}	–
NH_4^+	–

Identifying Cations – Test with Sulphate Ions

1. Out of the 10 cations, only calcium ions and lead(II) ions will form a precipitate with sulphate ions.
2. This is because both calcium sulphate and lead(II) sulphate are insoluble in water.
3. The chemical reaction is a double decomposition reaction.

$Pb^{2+} + SO_4^{2-} \rightarrow PbSO_4$
$Ca^{2+} + SO_4^{2-} \rightarrow CaSO_4$

	H_2SO_4 or Na_2SO_4
Na^+	–
Ca^{2+}	White precipitate.
Mg^{2+}	–
Al^{3+}	–
Zn^{2+}	–
Pb^{2+}	White precipitate.
Fe^{2+}	–

Fe^{3+}	–
Cu^{2+}	–
NH_4^+	–

Identifying Cations – Test with Carbonate Ions

1. All ions, except sodium ions and ammonium ions will form precipitate with carbonate.
2. This is because sodium carbonate and ammonium carbonate are soluble in water.

	Na_2CO_3
Na^+	–
Ca^{2+}	White precipitate.
Mg^{2+}	White precipitate.
Al^{3+}	White precipitate.
Zn^{2+}	White precipitate.
Pb^{2+}	White precipitate.
Fe^{2+}	Green precipitate.
Fe^{3+}	Brown precipitate.
Cu^{2+}	Blue precipitate.
NH_4^+	–

Identifying Cations – Test with Iodide Ions

1. Iodide ions will form precipitate with lead(II) ions and copper(II) ions.
2. You only need to know the reaction between lead(II) ions and iodide ions.
3. The yellow precipitate formed will dissolve in hot water.
   $Pb^{2+} + 2I^- \rightarrow PbI_2$

	KI
Na^+	–
Ca^{2+}	–
Mg^{2+}	–
Al^{3+}	–

Zn^{2+}	–
Pb^{2+}	Yellow precipitate. Dissolve in hot water
Fe^{2+}	–
Fe^{3+}	A red brown solution formed.
Cu^{2+}	White precipitate form in brown solution
NH_4^+	–

Identifying Cations – Tests to Distinguish Iron(II) and Iron(III) ions.

Some Tests to Distinguish Fe^{2+} ion From Fe^{3+} Ion

1. The presence of Fe^{2+} ion and Fe^{3+} ion in a salt can be confirmed by using solution of potassium hexacyanoferrate (II), solution of potassium hexacyanoferrate (III) and potassium thiocyanate.
2. Table below shows the observation of the tests.

Reagent	**Observation**	**Ion presents**
Solution of potassium hexacyanoferrate (II)	Light blue precipitate	Fe^{2+}
	Dark Blue precipitate	Fe^{3+}
Solution of potassium hexacyanoferrate (III)	Dark blue precipitate	Fe^{2+}
	Greenish brown solution	Fe^{3+}
Potassium thiocyanate	Pinkish solution	Fe^{2+}
	Blood red solution	Fe^{3+}

Assessment

1. How can the following gas be tested for
   a. Oxygen
   b. Hydrogen
   c. Chlorine
   d. Hydrogen Sulphide
2. What are the heating effects of the following
   a. Carbonate salts
   b. Nitrate salts