

CHEMISTRY

CHEMICAL BOND FORMATION

Concept of chemical bond formation

In the formation of chemical bonds, electrons are either shared between atoms or are transferred from one atom to another. There are three main types of chemical combination (chemical bonding) and they include:

- Electrovalent or ionic bonding.
- Covalent bonding.
- Co-ordinate covalent bonding.

Though there are other types of chemical bonding - hydrogen bond, metallic bonds and van der Waals force.

ELECTROVALENT OR IONIC BONDING

This involves the transfer of electrons from one atom to another to attain a stable electronic configuration. Ions are always formed; hence it is also called ionic bonding. Here, atoms of elements with one, two, and three electrons in the outermost shells lose such number of electrons to attain stability. It is characterized by transfer of electrons from metallic atoms to non-metallic atoms during a chemical reaction. It involves the donor-acceptor principle. Atoms of metallic elements in group I (alkaline metals), group II (alkaline earth metals) and group III (transition metals) of the periodic table are mostly the donors of the electrons while the non-metallic elements of group V, VI and VII are the electron acceptors.

Eg: the formation of NaCl (the common salt). Here, the sodium atom which is an electron donor as it is a metallic atom of group I (electronic configuration of Sodium = 2,8,1) will react with the chlorine atom which is an electron acceptor as it is a non-metallic atom of group VII (electronic configuration of Chlorine = 2,8,7) to form the sodium ion (2,8) and chloride ion (2,8,8). Other examples of electrovalent compounds include the formation of magnesium oxide, formation of calcium chloride and formation of magnesium chloride.

PROPERTIES OF ELECTROVALENT (IONIC) COMPOUNDS

Ionic compounds do not contain molecules, instead they consist of aggregates of oppositely charged ions arranged in an orderly pattern of three dimensional crystal lattices.

They are solids at room temperature and do not vapourise easily.

They have high boiling and melting points because of the strong electrovalent bonds between the ions.

They readily dissolve in water and other polar solvents.

They are good conductors of electricity when in molten state or in solution i.e. they are electrolytes.

This is because the ions are free to move about when the compound is in liquid state.

They do not dissolve in non-polar solvents such as benzene, toluene, ether and trichloromethane.

COVALENT BONDING

In covalent bonding, electrons are not transferred but are shared. This is referred to as covalency and the bond so formed is called covalent. Sharing of electron occurs between atoms of comparable electronegativities and atoms of the same elements. In covalent bonding, molecules and not ions are formed, because the shared electrons may be regarded as revolving in orbits controlled by both nuclei. A shared pair of electron in covalent bond is represented by a horizontal bar "-" between the two atoms, eg H-H, Cl-Cl and H-Cl.

Considering two hydrogen atoms (H_2) in covalency, the atoms contribute one electron each to a "shared-pair", to obtain an approximation of the external duplet configuration of helium by making two electrons do the work of four electrons.

PROPERTIES OF COVALENT COMPOUNDS

Covalent compounds consist of molecules which have a definite shape.

They are gases or volatile liquids because their molecules being electrically neutral are not bound by strong attractive forces.

They have low melting and boiling points.

Covalent compounds readily dissolve in a non-polar organic solvent such as benzene, toluene and carbon disulphide.

Covalent compounds do not conduct electricity ie, they are non-electrolytes. This is because the molecules do not contain charged particles.

CO-ORDINATE COVALENT (DATIVE) BONDING

Coordinate covalency is another type of covalent bonding in which equal contribution and sharing of electron are not observed. Rather, it is characterized by the fact that the two shared pair electrons are both supplied by one of the reacting atoms. Such a pair of electron is called "lone pair of electron". Thus, a co-ordinate bond is formed when one of the reactants possesses a lone pair of electrons ie, a pair of electrons not directly concerned in existing valency bonds. The lone pair of electrons is donated to an atom needing them to complete an electron octet or duplet of great stability.

Eg: formation of hydroxonium ion (H_3O^+) and ammonium ion (NH_4^+).

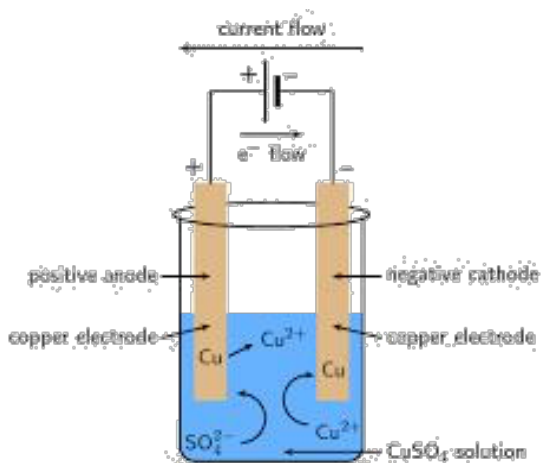
ELECTROLYSIS

Electrolysis is a process by which electric current is passed through a substance to effect a chemical change. The chemical change is one in which the substance loses or gains an electron (oxidation or reduction). The process is carried out in an electrolytic cell (an apparatus consisting of positive and negative electrodes held apart and dipped into a solution containing positively and negatively charged ions). The substance to be transformed may form the electrode, may constitute the solution, or may be dissolved in the solution. Electric current (i.e. electrons) enters through the negatively charged electrode (cathode); components of the solution travel to this electrode, combine with the electrons, and are transformed (reduced). The products can be neutral elements or new molecules. Components of the solution also travel to the other electrode (anode), give up their electrons, and are transformed (oxidized) to neutral elements or new molecules. If the substance to be transformed is the electrode, the reaction is often one in which the electrode dissolves by giving up electrons.

Electrolysis is used extensively in metallurgical processes, such as in extraction (electrowinning) or purification (electrorefining) of metals from ores or compounds and in deposition of metals from solution (electroplating). Metallic sodium and chlorine gas are produced by the electrolysis of molten sodium chloride; electrolysis of an aqueous solution of sodium chloride yields sodium hydroxide and chlorine gas. Hydrogen and oxygen are produced by the electrolysis of water.

TERMS USED IN ELECTROLYSIS

ELECTRODES: The electrodes are conductors (poles of metals or carbon) by which an electric current enters or leaves the electrolyte. The positive electrode is called the anode while the negative electrode is called the cathode. Electrons leave the electrolyte through the anode and enters the electrolyte through the cathode.

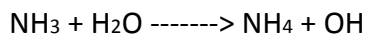


ELECTROLYTE: An electrolyte is a compound which either is solution or in a molten form conduct electric current and is decomposed at the electrodes in the process. Examples of electrolytes are acid, alkalis and salts.

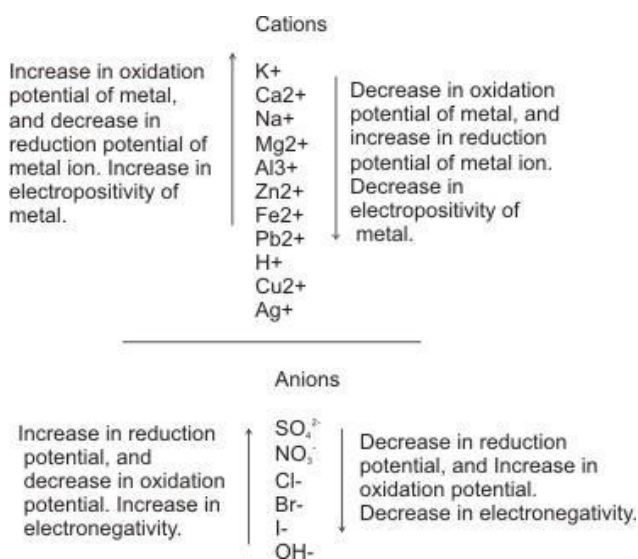
NON-ELECTROLYTE: A non electrolyte is a compound which does not conduct electricity either in a solution or in a molten state or become decomposed by it. A typical example is the sugar solution.

STRONG ELECTROLYTE: They are those electrolytes in which ionization is complete in a solution. All mineral acids, caustic alkalis and salts are completely ionized in solution. Example includes tetraoxosulphate VI acid.

WEAK ELECTROLYTE: They are those that are partially ionized in solution. The solution consists of ions and unionized molecules. A solution of ammonia in water is a weak electrolyte because it contains only small proportion of ammonium and hydroxide ions.



ELECTROCHEMICAL CELL: The electrochemical series (see below) is an orderly arrangement of metals and their ions based on how well the ions accept electrons and become reduced. The lower the position of metals and their ions in the series, the more likely their ions are reduced at the cathode, hence the more the preference for them been discharged. During electrolysis, reduction occurs at the cathode.



Example, in the presence of H⁺ and Na⁺ in a solution, and if all other factors are constant, H⁺ will accept electrons more readily and subsequently be discharged at the cathode in preference to Na⁺. The

electrochemical series also shows the arrangement of negatively charged particles which migrate to the anode. In the same way as above, the lower the position of a negatively charged particle in the series, the more likely it gives off electrons and become oxidized at the anode.

FACTORS AFFECTING SELECTIVE/PREFERENTIAL DISCHARGE OF IONS

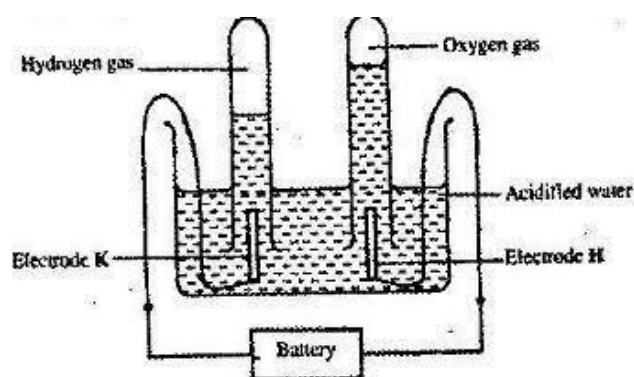
During the electrolysis of a given electrolyte, two or more ions of similar charges may be present in a solution. Such ions can be derived from the solute as well as from the solvent. For example, Cu^{2+} , H^+ , OH^- and SO_4^{2-} will be present in aqueous solution of copper II tetraoxosulphate VI solution. In such a case, one of the ions with similar charges is selected preferentially for this charge at each of the electrodes. The three factors that govern the selective or preferential discharge of ions are as follows: a. The position of the ions in the activity or electrochemical series. b. The relative concentration of the ions in the electrolyte.

c. The nature of the electrolyte used.

ELECTROLYSIS OF SOLUTIONS

Electrolysis of acidified water (dilute tetraoxosulphate VI acid)

Water is a poor conductor of electricity, but it does contain some hydrogen ions, H^+ and hydroxide ions, OH^- . These ions are formed when a small proportion of water molecules naturally dissociate. If water is acidified with a little dilute tetraoxosulphate VI acid: H^+ ions are attracted to the cathode, gain electrons and form hydrogen gas. OH^- ions are attracted to the anode, lose electrons and form oxygen gas.



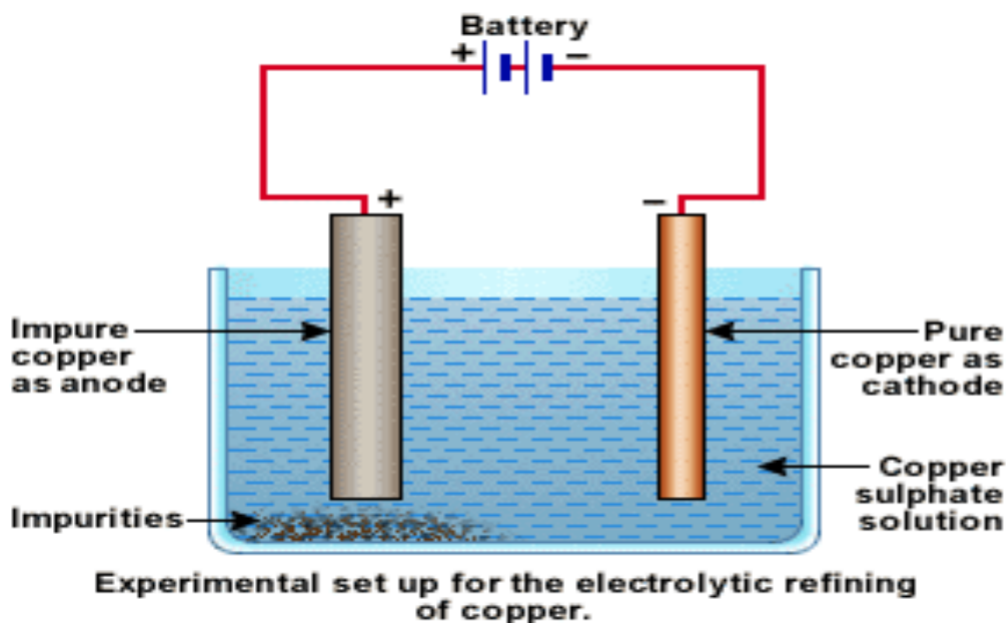
The overall balanced equation for the process is: $2\text{H}_2\text{O}(\text{l}) \rightarrow 2\text{H}_2(\text{g}) + \text{O}_2(\text{g})$

At the cathode: Whether hydrogen or a metal is produced at the cathode depends on the position of the metal in the metal reactivity series. The metal will be produced if the metal is less reactive than hydrogen. Hydrogen will be produced if the metal is more reactive than hydrogen

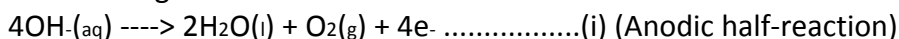
At the anode: Oxygen is produced (from hydroxide ions), unless halide ions (chloride, bromide or iodide ions) are present. In that case, the negatively charged halide ions lose electrons and form the corresponding halogen (chlorine, bromine or iodine).

Electrolysis

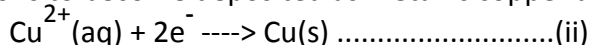
Electrolysis of Concentrated Copper (II) tetraoxosulphate (VI) Using Inert (Platinum or Carbon) electrodes: The electrolytic cell used here must be designed in a way that will enable the collection of gas at the anode and the removal of deposited metal at the cathode. (Please refer to your textbooks for a standard labelled diagram).



At the anode: despite the higher concentration of the SO_4^{2-} ions, the OH^- ions are still preferentially discharged because of the wide gap separating them in the electrochemical series. So, the positions of ions in the series overrides their concentration. Hence, expectedly, they undergo oxidation to form $2\text{H}_2\text{O}$ and O_2 gas.



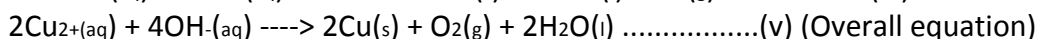
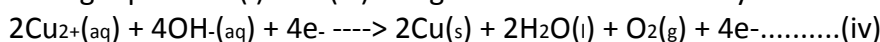
At the cathode, the Cu^{2+} is preferentially discharged over H^+ , because it is lower in the electrochemical series and also, of higher concentration. So, each Cu^{2+} undergoes reduction by gaining two electrons to become deposited as metallic copper atoms:



We will multiply equation (ii) by 2 to balance the number of moles of electrons transferred



Combining equations (i) and (iii) will give the overall electrolytic reaction:



From equation (v) above, it can be seen that for every 2 moles of copper metal deposited at the cathode, 1 volume of oxygen is liberated at the anode. The water molecule produced in the equation is a by-product.

Note: As the Cu^{2+} and OH^- are being removed from the solution in form of Cu metal and O_2 gas, the H^+ and SO_4^{2-} still remain in solution. These combine to form tetraoxosulphate (VI) acid, which makes the resulting solution after the electrolysis more acidic. The blue colour of the electrolyte also fades because of the removal of the Cu^{2+} from solution.

Summary:

Electrolyte - Concentrated copper (II) tetraoxosulphate (VI), CuSO_4

Ions Present - Cu^{2+} , SO_4^{2-} and H^+ , OH^-

Concentrations - High (Cu^{2+} , SO_4^{2-}), Low (H^+ , OH^-)

Nature of Electrodes - Inert

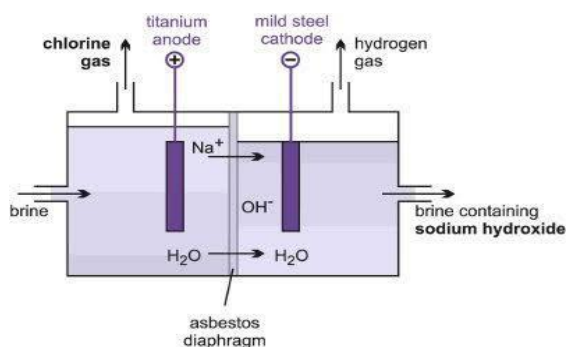
Product at the Cathode - Copper metal

Product at the Anode - Oxygen gas

Mole Ratio - 2:1

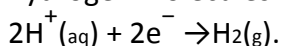
Effect on Electrolyte - The electrolyte becomes more acidic.

Electrolysis of concentrated sodium chloride solution (Brine): Brine is a solution of sodium chloride (NaCl) and water (H₂O). The electrolysis of brine is a large-scale process used to manufacture chlorine from salt. Two other useful chemicals are obtained during the process, sodium hydroxide (NaOH) and hydrogen (H₂). The chlorine and sodium hydroxide produced in the process must be separated because they react when they come into contact with each other.

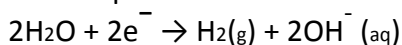


The negative cathode electrode reaction for the electrolysis of brine (sodium chloride solution):

The negative cathode attracts the Na⁺ (from sodium chloride) and H⁺ ions (from water). Only the hydrogen ions are discharged at the cathode. The more reactive a metal, the less readily its ion is reduced on the electrode surface. The hydrogen ions are reduced by electron (e⁻) gain to form hydrogen molecules at the negative electrode which attracts positive ions.



other equations:



The positive anode electrode reaction for the electrolysis of brine (sodium chloride solution). The positive anode attracts the negative hydroxide OH⁻ ions (from water) and chloride Cl⁻ ions (from sodium chloride). Only the chloride ion is discharged in appreciable quantities i.e. it is preferentially oxidized to chlorine. The chloride ions are oxidized by electron loss to give chlorine molecules at the positive electrode which attracts negative ions.



The hydroxide ion, with the unchanged sodium ion, forms



FARADAY'S LAWS OF ELECTROLYSIS

Michael Faraday who was the first person to state the quantitative results of electrolysis. These laws asserts that the amount of substances liberated at the electrodes during electrolysis depends on the three factors namely:

- a. The magnitude of the steady current passed.
- b. The time of flow of the steady current and
- c. The charge on the ions on the element liberated.

Later on, Faraday put forward two laws to describe these quantitative relationships and they are known as Faraday's laws.

FARADAY'S FIRST LAW OF ELECTROLYSIS

Faraday's first law of electrolysis states that the mass (m) of a substance liberated during electrolysis is directly proportional to the quantity (Q) of electricity passing through the electrolyte.

Mathematically, m varies directly with Q..... (i)

But $Q = \text{Current (I)} \times \text{time (t)}$

Therefore, m varies directly with current (I) and time (t)

$$M = EIt$$

Where E = proportionality constant.

FARADAY'S SECOND LAW OF ELECTROLYSIS

Faraday's second law of electrolysis states that when the same quantity of electricity is passed through different electrolyte in series, the relative amount (n) in moles of the element deposited are inversely proportional to the charges on the ions of the respective elements. From the Faraday's second law, the following can be deduced:

a. One Faraday of electricity is required to discharge one mole of a univalent ion like K^+ during electrolysis.

b. Two Faraday's of electricity are required to discharge one mole of a divalent ion like Zn^{2+} during electrolysis.

c. Three Faraday's of electricity are required to discharge one mole of a trivalent ion like Fe^{3+} during electrolysis.

Mathematically n varies inversely as $1/z$

$$nZ = a \text{ constant.}$$

WORKED EXAMPLES

During the electrolysis of silver trioxonitrate v solution, 9650 coulombs of electricity was passed. Calculate:

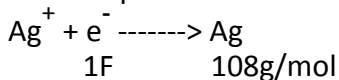
a. the amount of silver deposited in moles.

b. the amount of silver deposited in grams.

(Take 1Faraday = 96500 coulombs; $Ag = 108g/mol$)

Solution:

a. The equation of the reaction



1 mole of electron = 1 Faraday = 96500C

96500 will deposit 1 mole of Ag

9650C will deposit 0.1 mole of Ag

Therefore, the amount of silver deposited = 0.1mol.

b. Since 1 mole of silver ($Ag = 108g/mol$)

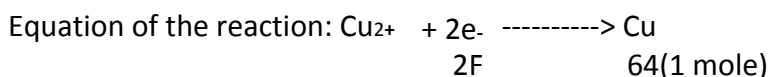
0.1 mol of Ag will be $\times 0.1$

$$= 10.8g$$

Therefore, mass of silver deposited = 10.8g.

When a solution of copper II salt was electrolysed, 3.20g of copper was deposited. Calculate the quantity of electricity required for the electrolysis. ($Cu = 64g/mol$; 1Faraday = 96500C)

Solution:



Amount of mole of copper deposited is

$$n = \text{mass (g)} / \text{molar mass}$$

$$n = 3.20 / 64$$

= 0.050mol

From the equation, 2 moles of electrons will deposit 1mole of Cu.

1 mole of electron = 1 Faraday = 96500C

2 moles of electrons = 2 Faraday = 2 × 96500 to deposit 1Cu

Hence, since 1mole of Cu requires 2 × 96500

0.05 mole of Cu will require 2 × 96500 × 0.5C

Q = 9650C.

USES OF ELECTROLYSIS

There are several uses of electrolysis; they include:

Purification of Copper: Purification of copper is carried out using CuSO₄ solution as electrolyte, the impure copper as the anode and the cathode a strip of pure copper. During the process, the anode (impure copper) decomposes and goes into solution as Cu²⁺, i.e. Anode reaction: Cu(s) → Cu²⁺(aq) + 2e⁻(aq) - oxidation reaction. While at the cathode, pure copper is deposited i.e. Cathode reaction:

Cu²⁺(aq) + 2e⁻(aq) → Cu(s) - reduction reaction

The impurities, which include silver (Ag) and gold (Au) are not discharged in the process, but collect in a sludge at the bottom of the cell and are recovered from it.

Production of Aluminium: In the production of aluminium, pure aluminium oxide, Al₂O₃ (alumina) is obtained from the chief raw material – bauxite, Al₂O₃.2H₂O. The purified Al₂O₃ is then electrolyzed in solution in molten cryolite (Na₃AlF₆ – sodium hexafluoroaluminate (III)) to obtain pure aluminium. Cryolite is unchanged in the process and can therefore be used indefinitely.

Cathodic reaction: 2Al³⁺(aq) + 6e⁻(aq) → 2Al(s)

Anodic reaction: 3O²⁻(aq) → ³/2 O₂(g) + 6e⁻(aq)

Note: The carbon anodes are constantly attacked by the oxygen produced at the anode. Hence, the anodes are usually changed.

The cryolite serves to dissolve the Al₂O₃, thereby enabling it to conduct electricity and decompose. Alumina, Al₂O₃ is not dissolved in water because it reacts vigorously with water.

Production of Na and Cl₂: We have already discussed the electrolysis of fused NaCl (without water). Sodium and chlorine are produced commercially by the electrolysis of NaCl in the molten condition (Down's process). Due to high melting point of sodium chloride (about 800oC), calcium chloride is added to it to lower it to about 600oC.

Cathodic reaction: 2Na⁺(aq) + 2e⁻(aq) → 2Na(s) – reduction.

Anodic reaction: 2Cl⁻(aq) → Cl₂(g) + 2e⁻(aq) – oxidation

Chlorine can also be produced through the electrolysis of conc. sodium chloride solution (Brine).

Production of NaOH: The electrolysis of conc. sodium chloride solution using carbon electrodes results in the solution being highly concentrated of sodium hydroxide. Sodium hydroxide may be prepared commercially by this method. This process has earlier been treated here. Also, using mercury cathode, Na⁺ is discharged, and then reduces to the metal. i.e. Na⁺(aq) + e⁻(aq) → Na(s). Then Na(s) combines with the mercury to form a mixture - sodium amalgam Na/Hg. The sodium amalgam is run into water, resulting in the reaction of sodium with water to form NaOH solution, while the mercury is dissociated from it.

ORGANIC CHEMISTRY

This is the study of the Chemistry of all the compounds of carbon. However, certain compounds of carbon such as the oxides, the trioxocarbonate (IV), the metallic carbides and the cyano salts are excluded from this definition. The bodies of plants and animals are mostly made of organic compounds, which contains carbon together with one or more other elements, such as hydrogen, oxygen, chlorine, nitrogen and sulphur. Consequently, carbon is able to form a very great number of compounds.

The presence of numerous organic compounds is due to the following properties of carbon:

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

The ease with which carbon combined with hydrogen, oxygen, nitrogen and the halogens.

The ability of carbon atoms to form single, double or triple covalent bonds.

Different arrangement of the same atoms within a molecule produces a variety of compounds.

Reasons for the Special Properties of Carbon

The special properties of carbon stem from the fact that it is a relatively small atom with four valence electrons. Carbon completes its valence shell octet by sharing electrons with other atoms. This implies that the chemistry of carbon compounds will be largely the chemistry of covalent compounds. The major difference in the chemical and physical properties of organic compounds are due to the nature of the other elements bonded to carbon.

Characteristics of Organic Compounds

Organic compounds are mostly covalent. They are stable because of the strong carbon-carbon bonds. Since they have a covalent nature, they do not ionize in solution and are non-conductors of electricity.

Most organic compounds are non-polar, unless the compounds consist of very electronegative elements like chlorine or the hydroxyl group. Non-polar substances are held together only by weak intermolecular forces such as the van-der-waals forces.

Organic compounds are generally soluble in non-polar solvents like benzene and ether.

They are generally insoluble in water except in cases where the compound contains the hydroxyl group.

Organic compounds generally have low melting and boiling point compared to the inorganic compounds.

Most organic compounds are thermally unstable, decomposing into simpler molecules when heated to temperature above 500°C.

They are inflammable and burn exothermically in a plentiful supply of air to yield carbon (IV) oxide and water.

Reactions involving organic compounds tend to be much slower than the ionic reaction in inorganic chemistry.

Terms Used in Organic Chemistry

HOMOLOGOUS SERIES: A homologous series, is a family of organic which follows a regular structural pattern in which each successive member differs in its molecular formula by $-CH_2-$ group. The simplest series is the Alkanes. Alkanes are a series of Hydrocarbons with a general molecular formula of C_nH_{2n+2} , where n is a whole number with a value of one or more. Each individual member is referred to as a homologue. Other homologous series includes alkenes (C_nH_{2n}), alkynes (C_nH_{2n-2}), alkanols (C_nH_{2n+1}) and the alkanic acid otherwise called carboxylic acid ($C_nH_{2n+1}COOH$).

Characteristics of Homologous Series

All members of the series share a general molecular formula eg C_nH_{2n+2} for the Alkanes, C_nH_{2n} for the alkenes, C_nH_{2n-2} for the alkynes and so on.

Each successive member in a series differ in molecular formula by the addition of a $-CH_2-$ group.

Each successive member differs in molecular mass by an increase of 14 ($C = 12, H = 1$).

Chemical properties of the members are similar but with gradual variation along the series.

The physical properties change gradually as the number of the carbon atoms per molecules increases example the boiling points of the alkanes increase down the series. Similarly, the melting points and densities also increase, while their solubility in water decreases down the series.

All members are prepared by the same general method.

ALKYL GROUP: This includes all univalent group derived from alkanes by the loss of a hydrogen atom example methyl group (CH_3 obtained from methane CH_4 , by the loss of a hydrogen atom. ALKYL group has a general formula of C_nH_{2n+1} and is named after the parent alkane by replacing the ending "ane" by "yl". Alkyl group is given the general symbol of "R".

FUNCTIONAL GROUP: A functional group is an atom, a radical or a bond common to a homologous series and which determines the main chemical properties of the series. Each functional group has its own characteristic properties. When two or more functional groups occur in one molecule, the properties of one are influenced by the presence of the others.

FORMULAE OF ORGANIC COMPOUNDS

1. **EMPIRICAL FORMULA:** This is the simplest formula of a compound. It indicates the relative number of each kind of atom present in a molecule of a substance. It is found by determining the percentage composition of the substance by quantitative analysis.

2. **MOLECULAR FORMULA:** This is a more useful formula than the empirical formula. It indicates the actual number of each kind of atoms in a molecule of a substance. The molecular formula is deduced from the relative molecular mass and the empirical formula of the substance.

Molecular formula = Empirical formula \times n.

STRUCTURAL FORMULA: In inorganic chemistry, a molecular formula is informative enough to distinguish one substance from another. This is not the case in organic chemistry where the molecular formula may represent more than one substance. A more informative formula called the structural formula, is often used to represent a particular organic substance; such a formula indicates how the atoms are arranged within the molecule of a substance.

THE IUPAC NOMENCLATURE FOR ALIPHATIC COMPOUNDS

IUPAC stands for the International Union of Pure and Applied Chemistry. They are the most universally accepted system and method of naming organic compounds. They have some basic principles in naming even the most complicated compounds or molecules and they are:

a. The longest continuous chain of carbon atoms is selected and named as the parent chain.

b. If there's a branch chain, the chain is numbered and the one with the lowest value is taken as the number of the substituent branch chain.

Eg: $CH_3CH_2CH_2CHClCH_3$ named as 2 Chloropentane.

c. The name of the substituent prefix the name of the parent chain alphabetically and the position of substitution preceded the whole.

d. The numbers assigned to the functional groups are chosen so as to be as small as possible. The functional group numbers are given precedence over those assigned to other substituents as in the following examples;

i. $\text{CH}_3\text{CH}_2\text{OH}$ (Ethanol). Parent chain is ethane.

$\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_2\text{OH}$ (2 methyl butan-1-ol). Parent chain is butane.

$\text{CH}_3\text{C}(\text{CH}_3)(\text{OH})\text{CH}_3$ (2 methyl propan-2-ol)

HYDROCARBONS: Hydrocarbons is the branch of organic chemistry that deals with the compounds of hydrogen and carbon only. The carbon atom has four electrons in its outer shell and use these electrons when bonded to different atoms, by sharing electrons to form covalent bonds. Carbon atoms can combine with one another to form chains and rings of different sizes. They can be in straight chains, rings and branched chains. The carbon atom can also be bonded with hydrogen, oxygen, nitrogen, chlorine, bromine, iodine etc.

ISOMERISM: Isomerism is the occurrence of two or more compounds with the same molecular formula but different structural formula. Isomerism is a very common feature in organic chemistry. As the number of carbon atoms in a molecule increases, the number of isomers also increases.

TYPES OF ISOMERISM

There are two main types of isomerism.

- Structural isomerism
- Stereo isomerism.

Structural Isomerism

Under structural isomerism, we have;

a. **Straight or branched chain isomers:**

$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ (straight chained butane).

$\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3$ (a branched chain known as 2-methyl propane).

Positional Isomers:

The positions vary on the same carbon-carbon chain.

$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ (Butan-1-ol, $\text{C}_4\text{H}_9\text{OH}$).

$\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$ (Butan-2-ol, $\text{C}_4\text{H}_9\text{OH}$)

Stereo Isomerism

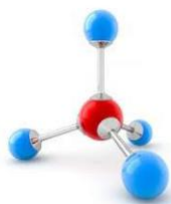
Examples of stereo isomerism: The Cis and Trans isomerism. Stereo isomerism is also known as geometric isomerism. Stereo isomerism (geometric isomerism) is the existence of compounds with the same molecular formula, but are not identical because of different spatial arrangements of the component atoms. For example, there are two geometric isomers for but-2-ene, that differ in the arrangement of the groups attached to the double bond. In one isomer, both methyl groups are on the same side of the double bond (Cis but-2-ene) and in the other, they are on opposite side (Trans but-2-ene). The separate existence of these compounds is due to the fact that the double bond is rigid and the parts of the molecule are not free to rotate in respect to each other about this bond.

ALKANES

In organic chemistry, an alkane, or paraffin, is an acyclic saturated hydrocarbon. In other words, an alkane consists of hydrogen and carbon atoms arranged in a structure in which all the carbon–carbon bonds are single. Alkanes have the general chemical formula C_nH_{2n+2} . The alkanes range in complexity from the simplest case of methane (CH_4), where $n = 1$ (sometimes called the parent molecule), to arbitrarily large and complex molecules, like pentacontane ($C_{50}H_{102}$) or 6-ethyl-2-methyl-5-(1-methylethyl) octane, an isomer of tetradecane ($C_{14}H_{30}$). IUPAC defines alkanes as "acyclic branched or unbranched hydrocarbons having the general formula C_nH_{2n+2} , and therefore consisting entirely of hydrogen atoms and saturated carbon atoms". However, some sources use the term to denote any saturated hydrocarbon, including those that are either monocyclic (i.e. the cycloalkanes) or polycyclic, despite their having a distinct general formula (i.e. cycloalkanes are C_nH_{2n}).

In an alkane, each carbon atom is sp^3 -hybridized with 4 sigma bonds (either C–C or C–H), and each hydrogen atom is joined to one of the carbon atoms (in a C–H bond). The longest series of linked carbon atoms in a molecule is known as its carbon skeleton or carbon backbone. The number of carbon atoms may be considered as the size of the alkane. One group of the higher alkanes are waxes, solids at standard ambient temperature and pressure (SATP), for which the number of carbon atoms in the carbon backbone is greater than about 17. With their repeated $-CH_2$ units, the alkanes constitute a homologous series of organic compounds in which the members differ in molecular mass by multiples of 14.03 u (the total mass of each such methylene-bridge unit, which comprises a single carbon atom of mass 12.01 u and two hydrogen atoms of mass ~ 1.01 u each).

METHANE



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Methane is a colourless, odourless gas that occurs abundantly in nature and as a product of certain human activities. Methane is the simplest member of the paraffin series of hydrocarbons and is among the most potent of the greenhouse gases. Its chemical formula is CH_4 . Methane is produced by methanogenic bacteria and some long-chain alkanes function as pheromones in certain animal species or as protective waxes in plants and fungi. Nevertheless, most alkanes do not have much biological activity. They can be viewed as molecular trees upon which can be hung the more active/reactive functional groups of biological molecules.

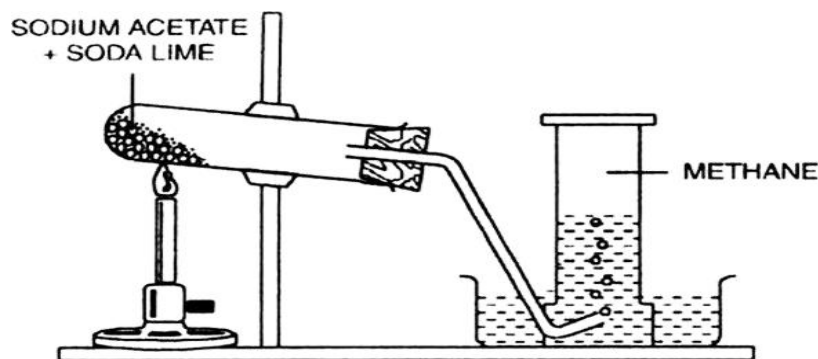
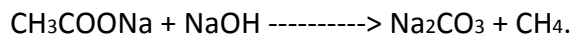
Sources of Methane:

In nature, methane is produced by the anaerobic bacterial decomposition of vegetable matter under water (where it is sometimes called marsh gas or swamp gas). Wetlands are the major natural source of methane produced in this way. Other important natural sources of methane include termites (as a result of digestive processes), volcanoes, vents in the ocean floor, and methane hydrate deposits that occur along continental margins and beneath Antarctic ice and Arctic permafrost. Methane also is the chief constituent of natural gas, which contains from 50 to 90 percent methane (depending on the source), and occurs as a component of firedamp (flammable gas) along coal seams.

Preparation of Methane

In the laboratory, methane is formed by heating sodium ethanoate with a mixture of sodium hydroxide and calcium oxide, called soda lime, on heating in the presence of a catalyst, calcium oxide, the $-COONa$

group from sodium ethanoate is replaced by the hydrogen atom from sodium hydroxide, forming methane and sodium hydroxide gets converted into sodium carbonate.



Physical Properties of Methane

Methane is a colourless, odourless and non-poisonous gas.

Methane is lighter than air, having a specific gravity of 0.554.

It is only slightly soluble in water.

It burns readily in air, forming carbon dioxide and water vapour.

The flame is pale, slightly luminous, and very hot.

The boiling point of methane is $-162\text{ }^\circ\text{C}$ ($-259.6\text{ }^\circ\text{F}$) and the melting point is $-182.5\text{ }^\circ\text{C}$ ($-296.5\text{ }^\circ\text{F}$).

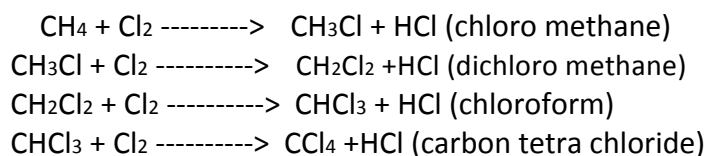
Chemical Properties of Methane

Combustion Reaction: Combustion of methane is an exothermic reaction in which a large amount of energy is liberated. Due to this property, methane is used as a domestic and industrial fuel.

Halogenation: Replacement of halogen atom with H-atom of an organic compound is called Halogenation. It is a substitution reaction. This reaction occurs in the presence of sun light. It is a free

radical mechanism reaction. The reaction will continue till the replacement of all four hydrogen atoms of methane with chlorine.

Chlorination:



Since it is a chain reaction, therefore, it gives a mixture of different compounds.

Uses of Methane

It is used as domestic and industrial fuel.

Shoe polish.

Printing ink.

Tyre manufacturing.

Manufacture of methyl alcohol.

First Ten Members of the Alkane Family

Methane CH_4

Ethane C_2H_6

Propane C_3H_8

Butane C_4H_{10}

Pentane C_5H_{12}

Hexane C_6H_{14}

Heptane C_7H_{16}

8. Octane C_8H_{18}

Nonane C_9H_{20}

Decane $\text{C}_{10}\text{H}_{22}$