MATTER AND ITS PROPERTIES

Matter is anything that has mass and occupies space. Mass refers to the amount of matter present in a sample. Different forms of energy, such as heat, light, and electricity, are not considered to be matter. Nearly all the changes that matter undergoes involve the release or absorption of energy.

Physical States of Matter Matter exists in three physical states: • Gas: It has no fixed volume or shape. It takes the volume and shape of its container, i.e., it can be compressed to fit a small container and it expands to fill a large one. For eg, oxygen, carbon dioxide and nitrogen are gases. • Liquid: It has definite volume but no specific shape. It assumes the shape of the portion of the container that it occupies. For eg, water, milk, oil and alcohol are liquids.

• **Solid:** It has both fixed volume and fixed shape. Neither liquids nor solids are compressible to any appreciable extent. For example, iron, wood, sugar and ice are solids.

The distances between the particles are minimum in solids and maximum in gases. The forces of attraction between particles are strongest in solids and weakest in gases. The movement of particles is minimum in solids and maximum in gases. Solids and liquids do 'not get compressed when pressure is applied. Gases, however, have high compressibility. By applying high pressure, they can be compressed into very small volumes. Thus, a large amount of a gas can be compressed and stored in a small metal cylinder. Cooking gas (Liquefied Petroleum Gas, LPG), oxygen gas supplied to hospitals in cylinders, and compressed natural gas (CNG) used as fuel for vehicles are all examples of compressed gases.

Apart from the above three basic states of matter, two other states exist, which have been recently discovered. • Plasma is the fourth state of matter. Inside the sun and the stars, the temperature is so high that the atoms break up to give a mixture of free electrons and ions. This mixture is called plasma, which makes the sun and other stars glow. When electricity is passed through gases (at very low pressures) in a glass tube, plasma is generated. Gases present in neon sign bulbs and fluorescent tubes get ionized to form plasma when electricity is passed through them. This plasma makes them glow. • Bose-Einstein Condensate (BEC), the fifth state of matter, was reached by three scientists, Cornell, Ketterle and Wieman of USA, when they cooled a gas of very low density to extremely low temperatures.

Properties of Matter Every substance has a unique set of properties or characteristics. that allow us to recognise it and to distinguish it from other substances. Properties. of matter can be grouped into two categories:

- Physical properties are those characteristics that can be 'observed without changing the basic identity of the substance, for example colour, odour, hardness, melting point, boiling point, and density.

Examples of physical properties: Mercury is a liquid at room temperature, potassium has a melting point of 63°C, and copper metal can be drawn into thin wires.

- Chemical properties describe the way a substance may change or react to form other substances. Examples of chemical properties: Iron metal rusts in moist atmosphere. nickel dissolves in acid to give a green solution, magnesium bums in presence of oxygen.

If a substance possesses a bad property, such as toxicity, it does not mean it cannot be used for the betterment of human society. Carbon monoxide is a gaseous air pollutant present in automobile exhaust and cigarette smoke, and is toxic to human beings Despite its toxicity, carbon monoxide plays a key role in the maintenance of a high standard of living. Its contribution lies in the isolation of iron from iron ores and in production of steel. Thus, carbon monoxide is both good and bad substance. A similar 'good-bad' dichotomy exists for most chemical substances. Changes that can occur in matter are classified into two categories: physical and chemical. • A physical change is a process in which a substance changes its physical appearance but not its chemical composition. No new substance is formed as a result of the physical change. Examples: grating of carrot, boiling of water. designing of wood into a table, forming of gold foil from a bar of gold, glowing of an electric bulb, breaking of a glass tumbler, melting of butter, making a salad from raw vegetables and fruits, formation of clouds, stretching of a rubber band, tearing of paper, breaking of a chalk piece, and rotation of a fan.

A chemical change is a process in which a substance undergoes a change in its chemical composition. It gets converted into one or more new substances that have properties and composition distinctly different from those of the original substance. Examples: burning of a match stick, souring of milk, digestion of food, explosion of a fire cracker, cooking of a vegetable, ripening of fruits, burning of fuels and growth of a plant.

Composition of Matter Matter is made of tiny particles (atoms or molecules) which are so small that we cannot .see them even with a high power microscope. These particles of matter are constantly moving. When a beam of sunlight enters a room, tiny dust particles can be seen moving rapidly in a very haphazard way. This happens because these dust particles are constantly hit by the particles of air which are moving very fast. The zigzag movement of the small particles suspended in a liquid or gas is called Brownian motion. An increase in temperature increases Brownian motion.

The spreading out and mixing of one substance with another due to the motion of its particles is called diffusion. Diffusion continues until a uniform mixture is formed. Diffusion is fastest in gases and slowest in solids. As the temperature of the diffusing substance is increased, the rate of diffusion also increases. Some of the real life situations involving diffusion are-• We can smell the food cooking in neighbour's kitchen, the fragrance of burning incense stick or the smell of perfume because of diffusion.

- The leakage of cooking gas can be easily detected due to diffusion of ethyl mercaptan (a strong smelling substance present in cooking gas) into the air.

- The spreading of ink or any colour in water is also an example of diffusion.

- Carbon dioxide and oxygen present in air diffuse into water in rivers and seas. This carbon dioxide is used by aquatic plants to prepare food by photosynthesis and the oxygen is used by aquatic animals for breathing.

- Spreading of virus on sneezing is also because of diffusion.

Osmosis can be considered to be a special kind of diffusion. In both diffusion as well as osmosis, particles move from a region of higher concentration to a region of lower concentration. However, diffusion can occur without a membrane or through a permeable membrane whereas osmosis occurs through a semi-permeable membrane (which allows only solvent molecules to pass through it). Preserving of pickles in salt, swelling up of raisins on keeping in water, and earthworm dying on coming in contact with salt - all display the phenomenon of osmosis.

In dialysis, a process similar to osmosis, a semi-permeable membrane allows the passage of solvent, dissolved ions and small molecules but blocks the passage of colloidal sized particles and large molecules. The kidneys, a complex dialyzing system, remove waste products from the blood, which are then eliminated in urine. If the kidneys fail, these waste products do not get removed and poison the body.

Change of State Of Matter The physical state of matter can be changed by changing the temperature or pressure. The process of changing

(i) a solid to a liquid by heating is called melting (or fusion)

(ii) a liquid to a gas by heating is called boiling (or vapourisation)

(iii) a gas to a liquid by cooling is called condensation

(iv) a liquid to a solid by cooling is called freezing

Concepts associated with Change of State Latent Heat: The heat energy required to change the state of a substance is called its latent heat. Latent heat does not increase the temperature of the substance but has to be supplied to bring about a change in state. The latent heat which is supplied is used up in overcoming the forces of attraction between particles of the substance undergoing the change of state. Thus, there is no rise in temperature during the melting of ice or boiling of water.

The heat required to convert a solid into its liquid state is called latent heat of fusion and the heat required to convert a liquid into its vapour state (or gas) is called latent heat of vapourisation. Ice at 0°C is more effective in cooling a substance than water at 0°C because ice takes its latent heat from the substance for melting and hence cools it more effectively. On the other hand, water at 0 cC does not take any such latent heat from the substance. An ice cube held in the hand feels very cold because it takes away latent heat from the hand for melting. When ice at 0°C melts, it requires latent heat of fusion to form water at 0°C. Likewise, when water at 0°C freezes to from ice at 0°C, it liberates an equal amount of heat. When water changes into steam, it absorbs latent heat, and when steam condenses to form water, it gives out an equal amount of latent heat.

Burns caused by steam are much more severe than those caused by boiling water, simply because steam contains more heat (in the form of latent heat) than boiling water. Due to the same reason, steam is better than boiling water for heating purposes.

Sublimation: The conversion of a solid directly into vapour on heating, and of vapour into solid on cooling, is known as sublimation. Ammonium chloride, iodine, camphor, naphthalene, and anthracene undergo sublimation. Naphthalene balls, used to protect woollen and silk clothes from insects, disappear with time due to sublimation.

Gases can be liquefied by applying pressure and lowering temperature. Similarly, decreasing the pressure and raising the temperature can also change the state of matter.- Solid carbon dioxide, also called dry ice, is stored under high pressure. On decreasing the pressure and increasing the temperature, it gets converted directly into carbon dioxide gas, i.e., it sublimes. Dry ice is an extremely cold, white solid, used to 'deep freeze' food and keep ice-cream cold. Dry ice is much more effective for-cooling than ordinary ice.

Evaporation: The process by which a liquid changes into vapour even below its boiling point is called evaporation. Evaporation can occur even at room temperature. Drying of wet clothes and recovery of salt from sea water occurs because of evaporation. Evaporation is facilitated by high temperature, large surface area of the liquid, low humidity of air, and high speed of wind. Evaporation causes cooling because when a liquid evaporates, it draws the latent heat of vaporisation from the surface it touches. Evaporation of ether or spirit from the back of our hand leaves it feeling cool. Evaporation of sweat from our body keeps us cool. Water kept in earthen pots during hot summer days becomes cool because of evaporation of water through the pores in the pot.
Pure Substances and Mixtures Matter can be classified on the basis of its chemical composition as a pure substance or a mixture.

A pure substance is made up of only one kind of particles (atoms or molecules). For example, pure water is water and nothing else. Pure copper contains only copper and nothing else. A pure substance always has a definite and constant composition and its properties are always the same under a given set of conditions. A mixture contains two or more kinds of particles, i.e., two or more pure substances mixed together, each of which retains its own identity. In some mixtures like soil, rocks, and wood, the components are readily distinguished. Such mixtures are heterogeneous. Salt solution, sugar solution, air, petrol and alloys like brass are uniform throughout and are known as homogeneous mixtures. Chocolate-chip cookies and fresh-fruit pudding are heterogeneous mixtures whereas soft drinks are homogeneous mixtures. Some more examples of mixtures: Milk, tea, coffee, gunpowder. sea water, ink, paint, dyes, kerosene oil, glass, coal, blood, soap solution, butter, cheese, face cream, etc.

Pure substances can be further classified as elements and compounds. Elements An element is a substance which cannot be broken down into simpler substances by chemical or physical means. It is made up of only one kind of atoms.

There are 117 elements known at present, out of which 88 occur naturally and 29 have been synthesized. Elements can be solids, liquids or gases. For example, sodium magnesium, iron, gold, carbon, and sulphur are solids, mercury is a liquid, and helium, argon, and neon are gases. Astatine is the rarest naturally occurring element in the earth's crust.

Some Important Elements and Their Symbols Element Symbol Element Symbol Aluminium Al Lithium Li Antimony Sb Magnesium Mg Argon Ar Manganese Mn Barium Ba Mercury Hg Beryllium Be Neon Ne Boron B Nickel Ni Bromine Br Nitrogen N Calcium Ca Oxygen 0 Carbon C Platinum Pt Chlorine CI Phosphorus Chromium Cr Potassium K Cobalt Co Radium Ra Copper Cu Silicon Si Fluorine F Silver Ag Germanium Ge Sodium Na Gold Au Sulphur S Helium He Thorium Th Hydrogen H Tin Sn Iodine I Tungsten W Iron Fe Uranium U Lead Pb Zinc Zn. In the universe, the composition of elements is: Hydrogen: 91 % Helium: 9% and all others < 0.1 %. In earth's crust, the composition is: Oxygen: 60.1% Silicon: 20.1 % Aluminium: 6.1% Hydrogen: 2.9% Calcium: 2.6%, Magnesium: 2.4%, Iron 2.2%, Sodium 2.1% and all others 1.5%. In human Body, the composition is: Hydrogen: 60.5%, Oxygen: 25.7%, Carbon: 10.7%, Nitrogen: 2.4% and all others: 0.7%. The super-heavy element 117 was discovered by a team of Russian and American scientists (April, 2010). It is made of atoms containing 117 protons, and is almost 40% heavier than lead. Six atoms of the element were produced by smashing together isotopes of calcium and a radioactive element, called Berkelium, in a particle accelerator near Moscow.

Metals, Non—Metals and Metalloids On the basis of their properties, elements can be categorised as metals, non-metals and metalloids.

Metals: An element that is malleable, ductile, and conducts electricity is called a metal. Gold, silver, iron, copper, tin, lead, sodium, and uranium are some examples of metals. Aluminium is the most abundant metal in the earth's crust. Other major metals in the earth's crust are iron, calcium, sodium, potassium and magnesium.

Important Properties of Metals

- Metals are malleable, i.e., they can be beaten into thin sheets. Gold and silver are the most malleable metals. Next in the list are aluminium and copper. Silver foils are used for decorating sweets. Aluminium foils are used for packing chocolates, biscuits, medicines, cigarettes, etc. Aluminium and copper sheets are uvci to make utensils. Iron sheets are used to make a large variety of products, like boxes, buckets, tanks, etc.

- Metals are ductile, i.e., they can be drawn into thin wires. Gold and silver exhibit highest ductility, followed by copper and aluminium. Copper and aluminium wires • are used in electrical wiring.

- Metals are good conductors of heat and electricity. Silver metal has been ranked as the best conductor of heat followed by copper and aluminium. That is why cooking utensils are usually made of copper or aluminium. Silver is the best conductor of electricity. Copper is the next best followed by gold, aluminium and tungsten. Electrical wires are, therefore, made of copper and aluminium. Iron and mercury have lower electrical conductivity.

• Metals are lustrous. Gold, silver and copper have a shining surface and can be polished. They are used for making jewellery and decoration pieces. On keeping in air for a long time, metals lose their shine due to the formation of a layer of oxide, sulphide or carbonate due to the action of various gases present in air.

• Metals are hard except sodium and potassium, which are soft metals and can be cut with a knife. • Metals are s-:lids at room temperature. Mercury is an exception. It is the only metal which is a liquid at room temperature.

• Metals generally have high melting and boiling points. El.‘ -eptions are sodium and potassium which have low melting points. Melting points of gallium and caesium are so low that they start melting in hand.

Non-Metals: An element which is neither malleable nor ductile and does not conduct electricity is a non metal. Carbon, sulphur, hydrogen, oxygen, chlorine, and iodine are some examples of non-metals. Diamond and graphite are also non-metals. They are the allotropic forms of carbon. Carbon is a very important non-meta i because carbon compounds like proteins, fats, carbohydrates, vitamins and enzymes, etc. are essential for the growth and development of living organisms. Oxygen is essential for breathing and combustion of fuels. Sulphur is present in hair, wool, onions and garlic. The major non-metals in the earth's crust in the decreasing order of their abundance are oxygen, silicon, phosphorus and sulphur. Important Properties of Non-Metals • Non-metals are brittle. They cannot be beaten into thin sheets or drawn into wires because of their brittleness.

• Non-metals are bad conductors of heat and electricity. Many non-metals are insulators. There are a few exceptions. For example, diamond is a good conductor of heat and graphite is a good conductor of electricity. Graphite is, therefore, used for making electrodes in dry cells.

• Non-metals are dull in appearance, i.e., they do not have lustre. Iodine is an exception. It has a shining surface like that of metals.

• Non-metals are quite soft. Carbon in the form of diamond is an exception. In fact, diamond is the hardest natural substance known.

- Non-metals can exist as solids (e.g., carbon, sulphur and phosphorus), liquids (e.g bromine) and gases (e.g., hydrogen, oxygen, nitrogen and chlorine).

- Non-metals have low melting and boiling points, except graphite which has a very high melting point.

- Non-metals have many different colours. Sulphur is yellow, phosphorus is white or red, graphite is black, chlorine is yellowish green, bromine is reddish-brown, hydrogen and oxygen are colour less.

Metalloids: Elements which show some properties of metals and some of non-metals,

i.e., properties intermediate between those of metals and non metals, are called metalloids. For example, despite looking like metals, they are brittle like non-metals. Instead of being good conductors of electricity like metals or insulators like non-metals, they are semi-conductors. Boron, silicon and germanium are examples of metalloids.

Compounds A compound is a substance that can be broken down into two or more simpler substances by chemical means. It is made by chemical combination of two or more elements in fixed proportions by mass. Properties of a compound are different from those of its component elements. For example, water is a compound made up of two elements, hydrogen and oxygen. Other examples of compounds: Common salt (sodium chloride), sand (silicon dioxide), marble (calcium carbonate), chalk (calcium carbonate), limestone (calcium carbonate), quick lime (calcium oxide), slaked lime (calcium hydroxide), baking soda (sodium bicarbonate), washing soda (sodium carbonate), methane. hydrochloric acid, sodium hydroxide, sugar, starch, etc.

Differences between Mixtures and Compounds:

Mixture Compound

1. A mixture can be separated into its components by physical methods, like filtration, distillation, etc. A compound can be separated into its constituents only by chemical methods and not by physical methods.

2. A mixture exhibits the properties of its components. A compound shows properties which are entirely different from those of its components.

3. No energy changes are involved in the formation of a mixture. Energy is evolved or absorbed during formation of a compound.

4. Composition of a mixture is variable. Composition of a compound is fixed

5. A mixture does not have a fixed melting/boiling point. A compound has a fixed. melting/ boiling point.

Solutions, Suspensions, and Colloids The substance which dissolves in another substance to form a solution is called the solute. and the substance in which the solute dissolves is called the solvent. Solute particles can also be referred to as the 'dispersed particles' and solvent as the 'dispersion medium'. The size of solute particles is minimum in solutions and maximum in suspensions.

Solutions in which the solvent is water are called aqueous solutions and those in which the solvent is an organic liquid are called non-aqueous solutions.

Solutions A solution is a homogeneous mixture. Examples: Salt solution, sugar solution, soft drinks, vinegar, sea water. air, and metal alloys like brass.

Important Characteristics of a Solution

- A solution is a homogeneous mixture.
- The solute particles are extremely small in size (less than 1 nm in diameter). They cannot be seen even with a microscope.
- The solute cannot be separated from the solvent by filtration.
- The solute does not separate out on keeping.
- A solution does not scatter light because the particles are extremely small.

Types of Solutions

- **Solid in solid :** Metal alloys like brass (solution of zinc in copper), bronze (solution of tin in copper)
- **Solid in liquid :** Solution of sugar in water, copper sulphate in water Liquid in liquid: Vinegar (solution of acetic acid in water)
- **Gas in liquid:** Carbonated drinks like Coca-Cola, soda-water
- **Gas in Gas:** Air (solution of oxygen, carbon dioxide, argon, water vapour, etc., in nitroKien gas)

Suspensions A suspension is a heterogeneous mixture in which particles of a solid are dispersed in the liquid without dissolving in it. Examples: Sand particles in water, mud in water, chalk particles in water, milk of magnesia (magnesium hydroxide in water).

Important Characteristics of a Suspension

- A suspension is a heterogeneous mixture. Chemistry - 11
- The solute particles in a suspension are quite large (more than 100 nm in diameter).
- The particles in a suspension can be seen easily.
- The particles can be separated from the dispersion medium by filtration.
- The particles of a suspension settle down on keeping.
- As the particles are large, a suspension scatters the beam of light passing through it.

Colloids A colloid is a type of solution in which the particle size of the solute is bigger than that of a true solution but smaller than that of a suspension. Colloidal solutions are heterogeneous. Examples: Milk, blood, soap solution, starch solution, ink, jelly.

Important Characteristics of a Colloid

- A colloid is heterogeneous even though it appears to be homogeneous.
- The diameter of solute particles in a colloid is between 1 nm and 100 nm.
- The particles of colloids cannot be seen even with a microscope.
- A colloid can be separated by centrifugation but not by filtration.
- The particles of a colloidal solution do not settle down on keeping.
- A colloid scatters a beam of light passing through it. Scattering of light by colloidal particles is known as Tyndall Effect.

Types of Colloids

Colloids can be classified into the following groups on the basis of the physical state of the dispersed phase and the dispersion medium —

• Sol (tiny solid particles dispersed in a liquid). E.g. Soap solution, starch solution, ink, paint

• Solid sol (solid particles dispersed in a solid). E.g. Coloured gemstones like ruby, sapphire, emerald

• Aerosol (a solid or liquid dispersed in a gas) E.g. Smoke, automobile exhausts, fog, mist, clouds, hairspray

• Emulsion (small drops of a liquid dispersed in another liquid). E.g. Body lotion, milk, butter

• Foam (a gas dispersed in a liquid). E.g. Shaving cream soap bubbles, fire-extinguisher foam

• Solid foam (a gas dispersed in a solid). E.g. Sponge, bread, foam rubber • Gel (a network of solid particles dispersed in a liquid). E.g. Gelatine, jelly, hair gel Solubility The concentration of a solution is defined as the amount of solute present in a given amount of the solution. A solution in which some more solute can be dissolved without increasing its temperature is called an unsaturated solution, whereas a solution in which no more solute can be dissolved at that temperature is called a saturated solution.

The maximum quantity of a solute that can be dissolved in 100 grams of a solvent at a particular temperature is known as the solubility of the solute in that solvent at that temperature.

The solubility of a solid in a liquid generally increases on increasing the temperature. and decreases on decreasing the temperature. It remains unaffected by changes in pressure. The solubility of a gas in a liquid generally decreases on increasing the temperature, and increases on decreasing the temperature. In contrast, it increases on increasing the pressure, and decreases on decreasing the pressure. For example, when water is heated, air dissolved in water comes out in the form of tiny bubbles. This shows that solubility of air (gas) in water (liquid) decreases with increase in temperature. When a soda water bottle is opened, the pressure decreases and carbon dioxide gas dissolved in water escapes producing a fizz. This shows that solubility of a gas in a liquid decreases on decreasing the pressure.

Separation of Mixtures

Many procedures have been developed to separate mixtures into their components. The method which is used for this purpose depends upon the nature of the components present in the mixture.

1. A mixture of two solids can be separated by one of the following methods: (a) Use of suitable solvent A mixture of sugar and sand can be separated by adding water as the solvent which dissolves sugar but not sand. Filtration of the solution leaves sand on the filter paper. Evaporation of water from the filtrate gives sugar.

(b) Sublimation The process of sublimation is used to separate the component which sublimes on heating from the one which does not. Thus. naphthalene, which sublimes. car hi easily separated from sodium chloride by this method.

(c) Use of a magnet Iron is attracted by a magnet. Therefore, it can be separated from other compoi'nts of a mixture with the help of a magnet. In factories. scrap iron is separated from a heap of waste material with the help of electromagnets fitted to a crane.

2. A mixture of a solid and a liquid can be separated by one of the following at a methods: that (a) Filtration Filtration is used to separate insoluble substances from a liquid. e.g., a mixture of :ure, sand and water can be separated by filtration. Different kinds of filters can be issr.-cc s in e.g., filter paper, wire-mesh, cotton, muslin cloth or a layer of sand. Used tea leaves the are separated from prepared tea by filtration, using a tea strainer. Drinking water 3 on filtered using water filters. 'hen (b) Centrifugation

ows The method of centrifugation is used to separate suspended particles from a liqu. 'hen The mixture is separated by rotating it at high speed in a centrifuge. This process

Ivied used in dairies to separate cream from milk.

(c) Evaporation A solid substance dissolved in a solvent can be separated by the process of evaporation. The dissolved substance is left as a solid residue after the solvent has evaporated. The solvent itself cannot be recovered by this method. Common salt is obtained from sea water by evaporation. Sea water, trapped in shallow lakes called lagoons, is subjected to the heat of the sun. Water evaporates leaving behind salt as a solid. If any impurities are present in the dissolved solid, they would still be present after its recovery by evaporation.

(d) Crystallisation When a hot, concentrated solution of a substance is allowed to cool slowly, crystals. of pure solid are formed, while impurities remain dissolved in the solvent. This process is called crystallisation. The crystals can be separated by filtration.

An impure sample of a compound, like copper sulphate or alum, can be purified by crystallisation.

(e) Chromatography Two or more dissolved solids present in a solution in very small amounts can be separated and identified by chromatography.

ATOM AND ITS STRUCTURE

Matter is made up of small particles called atoms and molecules. Properties of matter depend on properties of atoms or molecules from which it is made. In 1808, John Dalton presented his atomic theory to explain the properties of matter. This theory became one of the foundations of modem chemistry.

Basic Terminology

Atom: An atom is the smallest particle of an element that can exist and take part in a chemical reaction. Atoms are so small that they cannot be seen even under the most powerful optical microscope. However, it has been possible to photograpl: images of atoms using the scanning tunneling microscope. Hydrogen atom is the smallest atom known. Its atomic radius is 0.037 nm. Atoms of noble gases (such as helium, neon, argon, krypton etc.) are chemically un reactive and exist in the free state, as single atoms. Atoms of most elements are very reactive and do not exist as single atoms. Instead, they exist as molecules or ions.

Molecule: A molecule is an electrically neutral group of two or more atoms chemically bonded together. It is the smallest particle of a substance (element or compound) that can exist in the free state, and has the properties of that substance.

Atomicity: The number of atoms present in one molecule of an element is called its atomicity. The atomicity of hydrogen (H2), nitrogen (N2), oxygen (02), and chlorine (Cl2) is 2, i.e., these molecules are diatomic, Ozone (03) is triatomic, phosphorus (P4) is tetra-atomic, and sulphur (SG) is octa-atomic. All these are homoatomic molecules, i.e., molecules containing same kind of atoms.

Heteronuclear molecules: The molecule of a compound consists of two or more different kinds of atoms chemically combined together. The molecule of ammonia (NH3) contains one atom of nitrogen (N) and three atoms of hydrogen (H). Water (H20), carbon dioxide (CO2), hydrogen chloride (HCI) are some examples of molecular compounds (compounds which consist of molecules). All these are heteroatomic molecules, i.e. molecules in which two or more kinds of atoms are present.

Chemical symbols: They are a shorthand notation for the names of elements. The symbol consists of either a single letter or two letters (the first one being a 'capital' letter and the second, a ‘small’ letter). This was proposed by J.J. Berzelius. Forexample, the symbol tor nitrogen is ‘N' and that tor chlorine is ‘Cl’.

Chemical formulae: They are used to denote compound composition in a concisemanner. They consist of the symbols of the elements present in the compound andnumerical subscripts (located to the right of each symbol) that indicate the number of atoms of each element present in a molecule of the compound. A molecule oi sulphur dioxide contains one atom oi sulphur and two atoms of oxygen. Therelore. the tormula of sulphur dioxide is S02. Similarly, ammonia is NH3, water is H20; methane is CH4, and so on.

Atomic_mass:molecular mass: The atomic mass of an element is the relative mass of its atom as compared with the mass of a Carbon-12 atom taken as 12 units. It indicates the number of times one atom of the substance is heavier than 1/12 (one-twelfth) of a Carbon-12 atom.

Molecular mass: The molecular mass of a substance is the relative mass of its molecule as compared with the mass of a Carbon-12 atom taken as 12 units all indicates the number of times one atom of the substance is heavier than 1/12 (one tweltth) of a Carbon-12 atom. It indicates the number of times one molecule of the substance is heavier than 1/12 (one-twelfth) ot a Carbon-12 atom. Atomic mass unit: Atomic mass unit (1 u) = 1/12 the mass of a Carbon-12 atom. 1u = 1.66 X 102" g. The atomic mass of sulphur is 32u, i.e., it is 32 times heavier than 1/12 of a Carbon-12 atom. Similarly, the atomic mass of oxygen is 16u.

Atomic Number: The number of protons (or the number of electrons) in one atom of an element is known as the atomic number of that element and is represented by the letter‘ Z‘. For example, the number ot protons (and electrons) in carbon is 6, so
the atomic number (Z) of carbon is 6.

Mass number: The total number of protons and neutrons present in one atom ot an element is kl'10WT‘i as its mass number and is denoted by the letter 'A‘. A carbon atom

has 6 protons and 6 neutrons, so the mass number (A) of carbon is 6 + 6 = 12. The atomic mass ot an atom is numerically equal to its mass number. For example,
it the mass number of an atom is 16, then its atomic mass will be 16u. Mass Number = Atomic Number + Number of neutrons.

Structure of Atom

Atoms are made up of three types of smaller particles called subatomic particles. They are electrons, protons and neutrons. The existence of electrons in an atom was shown by J.J. Thomson, that of protons by E. Goldstein, and of neutrons by James Chadwick. The electron is a negatively charged particle and the proton is a positively charged particle found in the atoms of all elements. The neutron, a neutral particle, is present in the atoms of all elements except hydrogen. Subatomic Relative Relative, Location in Particle Mass Charge the Atom _ Electron 1/1840 u -1 Outside the 7 – nucleus Proton ln the nucleus - Neutron 1 u 0 I ln the nucleus

Thomson's model of the Atom

According to Thomson s Model, an atom consists of a sphere of positive charge with negatively charged electrons embedded in it (just like seeds in a watermelon). These positive and negative charges are equal in magnitude. Therefore, the atom is electrically neutral.

Ftutherford's model of the atom

Rutherford's Nuclear Model of the atom can be described as:

1 An atom consists of a positively charged, dense, and very small region called the nucleus. Almost the entire mass of the atom is concentrated in the nucleus, which contains all the protons and the neutrons.

2 The electrons revolve round the nucleus in circular paths, called orbits, at very high speed. 4

3 The electrostatic forces of attraction between the positively charged nucleus and negatively charged electrons hold the atom together.

4 The number of protons and electrons in an atom is equal. Therefore, the atom is electrically neutral.

5 A major part of the atom is empty space. Bohr's model of the atom (Modern Atomic Theory)

6 The modern concept of the atom, given by Neils Bohr, can be described as: An atom is made up of electrons, protons, and neutrons. Electrons have negative charge, protons have positive charge, and neutrons have no charge. The atom is electrically neutral as the number of electrons is equal to the number of protons.

The protons and neutrons are located in the nucleus of the atom. The nucleus is positively charged due to the presence of protons. -

The electrons revolve around the nucleus in circular paths called energy levels or shells.

The energy levels are counted from the centre outwards and are represented either by the numbers 1, 2,3,4,5 and 6 or by the letters K, L, M, N, O'and P.

There is a maximum number of electrons which each energy level can hold. For example, K, the innermost shell, can hold a maximum of 2 electrons, L shell can hold 8 electrons, M shell can hold 18 electrons and N shell can hold 32 electrons.

Each shell is associated with a certain amount of energy. The shell nearest to the nucleus has minimum energy and the shell farthest from the nucleus has maximum energy.

As long as an electron keeps revolving in a particular shell, there is no change in its energy. The change in energy of an electron takes place when it moves from one shell to another. _

Arrangement of Electrons in the Atom
The arrangement of electrons in the various energy levels of an atom of an element is called the electronic configuration of the element. The maximum number ol electrons which can be accommodated in any energy level of the atom is given by '2n2, (where n is the number of that energy level). The outermost shell cannot accommodate more than 8 electrons, even if it has the capacity to accommodate more electrons. Electrons do not occupy a new shell unless all the inner shells are completely tilled with electrons. Thus, the electronic configuration ol magnesium (with atomic number 12) can be written as 2, 8, and 2.

Valence electrons
The electrons present in the outermost shell of an atom are known as valence electrons because they determine the valency (combining capacity) of the atom. Only the valence electrons are involved in chemical reactions. For example, a magnesium atom has 2 valence electrons.

Noble gases (helium, neon, argon, krypton, xenon, and radon) do not react with other elements to form compounds. The electron arrangements in their atoms are very stable and do not allow the outermost electrons to take part in chemical reactions. Thus, they are also known as inert gases. All the noble gases have completely tilled outermost shells, which is a highly stable state. That is why they can exist in the tree state as individual atoms. Neon gas is used in advertising signs (called neon signs). It glows red when electricity is passed through it. Argon gas is filled in light bulbs to prevent tungsten\ filament from reacting.

The atoms combine with one another to achieve the inert gas electronic configuration and become more stable. This can be done by:

- Losing one or more electrons to another atom
- Gaining one or more electrons from another atom
~ Sharing one or more electrons with another atom

Valency of Elements

Valency of an element is defined as the capacity of its atoms to form chemical bonds. The valency of an element is either equal to the number of valence electrons in its atom or equal to the number of electrons required to complete eight electrons in the valence shell.

Valency of metal = Number of valence electrons in its atom Valency of a non-metal = Number of valenceelectrons in its atom There are two types of valency:

- **Electrovalency:** ln the formation of an electrovalent compound (or ionic compound), the number of electrons lost or gained by one atom of an element to achieve the nearest inert gas electronic configuration is known as its electrovalency.
- **Covalency:** ln the formulation of a covalent compound (or molecular compound), the number of electrons shared by one atom of an element to achieve the nearest inert gas electronic configuration is known as its covalency.

Isotopes

isotopes are atoms of the same element having the same atomic number but different atomic masses. The difference in the masses of isotopes of an element is due to the different number of neutrons in their nuclei. For example, the element hydrogen has three isotopes which are shown in the table below. All these three isotopes have the same atomic number of 1 but different mass numbers of 1, 2 and 3.

The three isotopes of carbon are‘§C,‘ZC, ‘QC. Since the isotopes of an element contain the same number of electrons, they have identical electronic configurations. Thus, all the isotopes of an element show identical chemical properties. Since the masses of the isotopes of an element are slightly different, therefore, their physical properties (like density, melting point, boiling point, etc.) are slightly different.

Radioactive isotopes V

Some isotopes are unstable due to the presence of extra neutrons in their nuclei. The isotopes which are unstable and emit various types of radiations are called radioactive isotopes. The radiations are emitted in the form of alpha particles, beta particles and gamma rays. Examples of radioactive isotopes: Carbon-14, Sodium=24, Cabalt-60, Arsenic-74, iodine-131, and Uranium-235. They emit high energy radiations which are harmful to human beings. Therefore, these radioactive isotopes should be used very carefully. ‘

Applications of Radioactive Isotopes -

- They are used as fuel in nuclear reactors of nuclear power plants for generating electricity. Uranium-235 is used for this purpose. Radioactive isotopes like Uranium- 235 and Plutonium-239 are also used for making nuclear bombs. '

- They are used in medicine to detect the presence of tumors and blood clots in the body. A small amount of the radioactive compound (called tracer) is either injected into the body or is given orally. It accumulates in the area of the tumor or blood clot.

The exact position of the accumulated tracer can be determined with the help of the instrument, the Geiger Counter. Arsenic-74 is used to detect the presence of tumors and Sodium-24 is used for blood clots.

- They are used in the treatment of cancer (radiotherapy). High energy gamma radiations emitted by Cobalt-60 are used to bum cancerous cells.

- They are used to determine the activity of the thyroid gland. This helps in the treatment of diseases like goitre.

- They are used to detect leakages in underground oil pipelines, gas pipelines and water pipes. A solution of the radioactive substance is introduced in the pipeline.

This solution leaks out from any crack that might be present and is detected with the help of the Geiger Counter.

lsobars

Atoms of different elements having different atomic numbers but same mass number (atomic mass) are called isobars. lsobars have different number of protons but the total of the protons and neutrons in their_nucle.i is the same. For example, Argon (‘jg/tr) and Calcium ($801) are isobars. -

Ions

A positively or negatively charged atom (or group of atoms), formed by the loss or gain electrons by the atom, is known as an ion. lons contain an unequal number of electrons and protons and are of two types:

Cation: A positively charged ion is known as a cation. lt is formed by the loss of one or more electrons by an atom. Examples: Sodium ion, Na‘, Calcium ion, Ca2*, Aluminum ion, AP‘. All metal atoms form cations as they can lose electrons easily. Lithium ion batteries are_used in mobile phones.

Anion: A negatively charged ion is known as an anioh. It is formed by the gain ol one or more electrons by an atom. Examples: Chloride ion, Cl‘. and Oxide ion, O2‘. The ions of all non-metals are anions (except hydrogen ion and ammonium ion, which are cations).

Ionic Compounds -

The compounds which are made up of ions are called ionic compounds. Sodium chloride (common salt), copper sulphate, and potassium nitrate are examples of ionic compounds. These compounds are formed by the combination between metals and non- metals. The valency ol an ion is equal to the charge on the ion. While writing the formula of an ionic compound, the number of cations and anions is adjusted so that the total number of positive charges is equal to the total number of negative charges. Thus the formula tor Magnesium chloride is MgCl2. From the above table, since Mg ion has charge +2 and Cl ion has charge -1, two Cl ions are needed with one Mg ion, thus giving it the formula MgCl2

Gram Atomic Mass and Gram Molecular Mass

The amount of a substance for which mass in grams is numerically equal to its atomic mass is called gram atomic mass of that substance. For example, the atomic mass of carbon is 12u, so its gram atomic mass is 12 grams. The gram atomic mass ola substance represents the mass of 1 mole. of atoms (6.023 x 1023 atoms) of that substance.

The molar mass of a substance is the mass of 1 mole of that substance‘. The unit of molar mass is gramstper mole. The molar mass of an element has 6.023 X 102“ atoms of the element in it. The molar mass of an element is equal to the gram atomic mass oi the element expressed in g/mol.

The amount of a substance whose massin grams is numerically equal to its molecular mass is called gram molecular mass of that substance. The molecular mass of water (H20) is 18u, so its gram molecular mass is 18 grams. The gram molecular mass of a substance represents the mass of 1 mole of molecules (6.023 x 1023molecules) of that substance.

The mole concept

Mole is a link between the mass of atoms (or molecules) and the number of atoms (or molecules). A group of 6.023 x 1023 particles (atoms or molecules) of a substance is called a mole of that substance.

For example,

1 mole of nitrogen atoms (N) = 6.023 x 1023 nitrogen atoms. 1 mole of nitrogen molecules (N2) = 6.023x 1023 nitrogen molecules The number, 6.023 x 1023, which represents a mole, is known as Avogadro's Number. Number of moles of atoms ml‘? Mass of element in grams.

CHEMICAL REACTIONS

ln a chemical reaction, the reactants (substances that participate in a chemical reaction) react to form the products (new substances that are produced as a result of the reaction). A rearrangement of atoms takes place during the process leading to formation of products with new properties. Souring of milk, formation of curd, cooking of food, fermentation of grapes, digestion of food,~process of respiration, buming of fuels, rusting of iron, ripening of fruits are all examples of chemical reactions.

Characteristics of Chemical'Reactions

Chemical reactions are often accompanied. by some features which can be observed easily. These important characteristics of chemical reactions are: ' Evolution of gas - The reaction between sodium carbonate and dilute hydrochloric acid is characterised by the evolution of carbon dioxide gas. Formation of a precipitate - The reaction between sulphuric acid and barium chloride is accompanied by the formation of a white precipitate of barium sulphate.

Change in colour - When sulphur dioxide gas is passed through an acidified solution of potassium dichromate, the colour changes from orange to green. Change in temperature- The reaction between quicklime (calcium oxide) and water to form slaked lime (calcium hydroxide) is accompanied by a rise in temperature. Such heat producing reactions are called exothermic reactions. A lot of heat is released when carbon bums in air to form carbon dioxide. The reaction between barium hydroxide and ammonium chloride to give barium chloride, water and ammonia is accompanied by a fall in temperature. Such heat absorbing reactions are called endothermic reactions.

Change in state-When wax (solid) is bumt in the form of a candle, water (liquid) and carbon dioxide (gas) are produced. Some chemical reactions may show two or more characteristics.

Chemical Equations

The representation of a chemical reaction with the help of symbols and formulae of the substances involved in it is known as a chemical equation. The chemical equation is a short-hand method of representing a chemical reaction in which the reactants are written on the left hand side, separated by a plus sign (+), and the products are written on the right hand side, separated by a plus sign (+). The arrow sign (->), pointing towards the right, is put between the reactants and products. Matter can neither be created nor destroyed in a chemical reaction. Thus, the number of atoms of different elements in reactants must be equal to the number of same type of atoms in products. The process of making the number of atoms equal on both sides of an equation is called Balancing of equation.

The reaction of hydrogen with oxygen to form water can be written in an equation form

as:
H2 + 02 -> H2_0
But in the above reaction,_there are 2 atoms of Hand 2 atoms of O on the left hand side and 2 atoms of H and 1 atom of O on the right hand side. Thus the number of atoms of each element is not the same on both the sides. The balanced equation can be written

The combination or nitrogen and oxygen to form nitrogen monoxide, which takes place inside the engines of motor vehicles is an endothermic reaction. Nz(_g) + 02(_q) + Heat —> 2N0(g) 4. All decomposition reactions are endothermic in nature. An example is: CaC03(s) + Heat —» Ca0(s) + C02(g) Photosynthesis is an endothermic reaction because sunlight is absorbed during the process. The electrolysis of water to form hydrogen and oxygen is also endothermic because electrical energy is absorbed.

Types of Chemical Reactions
Sonfe of the important types of chemical reactions are - Combination Reactions ' The reactions in which two or more substances combine to form a single substance are called combination reactions. For example,
21'/2(.9)+ 01(9) —> ZHz0(l)

Quicklime, used for white-wash of houses, is added to water to form slaked lime, which is applied to the walls with a brush.
Ca0(s) + H2O(l) —> Ca(0H)2 (5)
This slaked lime slowly reacts with carbon dioxide present in air to form a shining layer of calcium carbonate on the walls. V Ca(0H)z(rlq) + c02(g) e 01003 (S) + H20(I)

Decomposition Reactions
The reactions in which a compound breaks down into two or more simpler substances are known as decomposition reactions. Decomposition can be effected by application of heat, light, or electricity. For example, .
CaC03 (s) "ii (.‘a0(s) + C02(g) CaO is Lime which has many uses in industry. lt is used on a large scale in the manufacture of glass and cement. ‘

electricity
' 211200) mt -2512(9) + 02 (Q)
This is called electrolysis of water. Decomposition of silver chloride or bromide is used in black and white photography. Decomposition by means of electricity is used to extract metals from their compounds. When molten metal chloride or oxide is decomposed by passing electricity, then metal is produced at the cathode. Decomposition of food into simpler substances takes place during the process of digestio'n_in the body. For example, starch present in wheat and rice decomposes to give glucose whereas proteins give amino acids.

Displacement Reaction

The reactions in which one element replaces another element in a compound are known as displacement reactions. A more reactive element displaces a less reactive element from its compound. For example, _
Cu_S‘04(aq) + Fe(s) —> FeS0,,(aq) + Cu(s) '

Double Displacementliteactions ‘

The reactions in which‘ two compounds exchange ions to form two new compounds are called double displacement‘ reactions. For example,
BaCl2(aq) + Na2S04(aq) ——> Ba5O.,,(s) + 2NaCl(aq)

Oxidation and Reduction Reactions

The addition of oxygen to a substance or removal of hydrogen from a substance is called oxidation. The removal of oxygen from a substance or addition of hydrogen to a substance is called reduction. Oxidation and reduction reactions take place side by side and are called redox reactions.

The substance which gives oxygen lor oxidation, or removes hydrogen (i.e., brings about oxidation), is called an oxidising agent. The substance which gives hydrogen for reduction, or removes oxygen (i.e., brings about reduction), is called a reducing agent.
Examples;
Z110 + C $211+ CO
ln this reaction, zinc oxide is reduced to zinc and carbon is oxidised to carbon monoxide. Here, zinc oxide is the oxidising agent and carbon is the reducing agent. This reaction is used in the extraction of zinc metal. Carbon is used in the form oi coke.

A common example of reduction is hydrogenation oi vegetable oil (liquid) which leads to the production oi vanaspati ghee (solid fat). When food materials prepared in oils and fats are kept for a long time they get an unpleasant smell and taste. Such food materials are said to have become stale or rancid. This happens because oils and fats present in food materials undergo oxidation by atmospheric oxygen, and their oxidation products have unpleasant smell and taste.

This condition produced by aerial oxidation of oils and it is called Rancidity. Rancid food materials are unfit for eating.

Another common effect of oxidation reactions obsen/ed in daily life is the Corrosion of metals. Corrosion is the process in which metals are destroyed gradually by the action of air, moisture, or a chemical on their surface. It is mainly caused by aerial oxidation.

Rusting of iron metal is a common example. Iron is oxidised by oxygen present in the air in the presence of moisture to form hydrated ferric oxide (rust) which is reddish brown in colour. Corrosion weakens iron and steel objects, like bodies oi vehicles, bridges, ships, etc. Rust flakes off and exposes a fresh surface of iron, thus continuing the process.

The green copper hydroxide-copper carbonate coating associated with copper corrosion is a tough iilm that adheres to the copper surface (statues, buildings, utensils, etc.). Copper corrosion requires the presence of oxygen, water, and carbon dioxide. All these substances are normally present in air. The corroded copper objects can be cleaned with dilute acid solution.

Silver tarnishes quickly in the presence of sulphur-containing air pollutants, such as hydrogen sulphide, and sulphur containing foods, such as eggs and mustard. This silvenrvare tarnish is a thin layer of black silver sulphide. The bright surface of aluminium objects changes to a dull silver-white as a thin film of aluminium oxide forms through atmospheric oxidation. This layer of aluminium oxide protects aluminium objects from further corrosion. This layer can be made thicker, for greater protection, by electrolysis. This process is called anodizing. Aluminium objects, like pressure cookers, cooking utensils, saucepans, etc., are anodized.

ACIDS, BASES AND SALTS

On the basis of their chemical properties, compounds can be classified as acids, bases, and salts.

• Indicator

An indicator is a dye which gives different colours in acid and base. Three common indicators used to test acids and bases are Litmus, Methyl Orange, and Phenolphthalein. Litmus can be used in the form of litmus solution or in the form of litmus paper. It is of two types - blue litmus and red litmus. An acid turns blue litmus red and a base turns red litmus blue. (A water soluble base is called an alkali).

Litmus is a natural indicator.

The neutral colour of litmus is purple. Methyl orange and phenolphthalein are synthetic indicators. The neutral colour of methyl orange is orange, whereas that of phenolphthalein is colourless. Methyl orange gives red colour in an acid solution and yellow colour in a basic solution. Phenolphthalein remains colourless in an acid solution and gives pink colour in a basic solution.

Turmeric is also a natural indicator, and contains a yellow dye. It turns red in presence of a base. That is why yellow stains of turmeric on a cloth turn reddish-brown in contact with soap, which is basic in nature. Extract of red cabbage is a natural indicator, and is red in colour. It remains red in acidic solutions but turns green in the presence of a base. Substances which change their smell (odour) in acidic and basic medium are called olfactory indicators. Examples: Onion and vanilla extracts. The smell of onion cannot be detected when a base is added to onion extract. However, acids do not destroy the smell of onions. Similarly, the pleasant smell of vanilla is destroyed in presence of a base but not in presence of an acid.

Acids Acids are substances which turn blue litmus red. They have a sour taste. The sour taste of lemon, orange, tamarind, raw mango and raw grapes is due to the presence of acids in them. Citrus fruits like lemons and oranges contain citric acid, vinegar contains acetic acid, sour milk and curd contain lactic acid, tamarind and raw grapes contain tartaric acid, and tomatoes contain oxalic acid. Formic acid is present in ant sting and nettle leaf sting. All these are organic acids and are weak acids. Hydrochloric acid, sulphuric acid, and nitric acid are called mineral acids because they are prepared from minerals of thc earth. These three acids are strong acids. Carbonic acid is a weak mineral acid. Acetic acid, in the form of vinegar, is used in making pickles and tomato ketchup, tartan acid is used in baking powder, and carbonic acid is used in soda water and fizzy sof! drinks.

A concentrated acid contains minimum possible amount of water, whereas a dilutE acid contains much more water. The process of diluting a concentrated acid with wate,' is highly exothermic (heat producing). Therefore, dilution should be carried out by slowly adding concentrated acid to water and not by adding water to acid. If water is added hif the acid, the large amount of heat produced converts water to steam which can splash' the acid on the body or clothes and cause acid bums. Acid solutions conduct electricity. Acids react with metals to form hydrogen gas, which burns making a 'pop' sound. Sour foodstuffs, such as curd, lemon juice, etc., should no be kept in metal vessels because the acids present in these foodstuffs can react with the metal to form poisonous compounds which can cause food poisoning.

Acids react with bases (alkalis) to form salt and water. This is known as neutralisatior. reaction. They also react with metal oxides to form salt and water. Mineral acids are corrosive in nature. They cause severe burns on the skin, make holes in clothes, burr wood, and corrode metal structures and stonework. That is why acids are stored it containers made of glass or ceramic and not in metal containers.

All acids produce hydrogen ions (1-1+ ions) when dissolved in water: II Cl(aq) —) 1-1+ (aq) + (a(?) 112SO4(aq) —) 2H+ (aq) + S O4 (aq) Though all acids contain hydrogen, all hydrogen containing compounds are not acids Acids produce 1-1'(aq) ions only in the presence of water. So, an acidic substance will no furnish H+ (aq) ions in the absence of water and will, therefore, not show acidic. behaviour.

Strong and Weak Acids An acid which is completely ionized in water to produce a large amount of H+ ions is called a strong acid. Examples: HCI, 1-12SO4, HNO3. These acids have high reactivity and high electrical conductivity. Thus, they are strong electrolytes. An acid which is partially ionized in water to produce a small amount of Fl+ ions is called a weak acid. Examples: CH3COOH, and H2003. They have low reactivity and i01N electrical conductivity. Thus, they are weak electrolytes.

Some Common Uses of Acids

- Sulphuric acid is used in the manufacture of fertilizers, paints, dyes, plastics, synthetic fibres, detergents, car batteries, etc.

- Nitric acid is used for making fertilizers, dyes, plastics, and explosives like Trinitro Toluene (TNT).

- Hydrochloric acid is used in dyes, textiles, and leather industry. It is used for water removing deposits from inside boilers.

It is used for making plastics like Polyvinyl slowl Chloride (PVC). It is used in medicines and cosmetics. ded tt, splay' Antacids and Acid Inhibitors Gastric juice is an acidic digestive fluid secreted by glands in the mucous membrane that wh id lines the stomach. It contains hydrochloric acid (Ha), Overeating and emotional factors ild nc can cause the stomach to produce too much HCI. This leads to hyperacidity, commonly ith the known as 'acid indigestion' or 'heartburn'.

Two approaches are used to combat the problem of excess stomach acid: • Removal of excess acid through neutralisation, which involves the use of antacids like Digene and Gelusil [Mg(OH)2. Al(OH)31, Milk of Magnesia [Mg(OH)2], and Turns [CaCO3]. These are basic substances capable of neutralising the HCI present in gastric juice. Neutralisation involving sodium bicarbonate and calcium carbonate produces carbon dioxide, which causes a person to belch often. • Decrease in the production of stomach acid, which involves the use of acid inhibitors like Pepcid, Tagamet, and Zantac. These substances inhibit the production of gastric acid by blocking the action of histamine, a gastric acid secretion regulator.

Bases

Bases are substances which turn red litmus blue. They have a bitter taste and are soapy to touch. They neutralise acids. All metal oxides and metal hydroxides are bases. For example, Na2O, CaO, NaOH, KOH, Ca(OH)2, Mg(OH)2, Ba(OH)2 are bases. NH4OH, Na2CO3, CaCO3 and NaHCO3 are also considered as bases because they neutralise acids. Water soluble bases are called alkalis. For example, NaOH, KOH, NH4OH, Mg(OH)2, and Ca(OH)2. All bases produce hydroxide ions (OH- ions) when dissolved in water. For example, KOH(aq) -4 10-(aq) + 011-(aq) Mg(011)2(aq) Mg2+(aq) + 20 H-(aq)

Strong and Weak Base A base which is completely ionized in water to produce a large amount of OH- ions is called a strong base. Examples: NaOH and KOH. A base which is partially ionized in water to produce a small amount of OH- ions is called a weak base. Examples: NH4OH, Mg(OH)2, and Ca(OH)2.

Some Common Uses of Bases

- Sodium hydroxide is used in the manufacture of soap, paper, and rayon (synth-3!c fibre). It is also used in oil refining and making dyes and bleaches.
- Potassium hydroxide is used in the manufacture of shampoos and shaving creams
- Magnesium hydroxide is used as an 'antacid'.
- Calcium hydroxide is used in the manufacture of bleaching powder.

The pH Scale

The concentrations of H+ and OH- ions are equal in pure water. Acidic solutions have excess of H+ ions, whereas basic solutions have excess of OH- ions. The strengths of acid solutions and basic solutions can be represented by means of a scale, known as the pH scale, which was devised by Sorenson. This is done by making use of Id+ ion concentrations in these solutions. The pH of a solution is inversely proporti::)nal to the concentration of H+ ions in it. A solution with high concentration of H.' ions has a low pH value, and vice versa. The letter 'p' in the term 'pH' stands for th. German word 'potenz' (which means power) and 'H' stands for 11+ ion concentration. The pH scale has values from 0 to 14. pH value is a number and has no units.

Neutral substances have a pH of exactly 7. For example, pure water, salt solution and sugar solution have a pH value of 7, i.e., they are neutral. Acids have a pH value less than

7. The lower the pH value, the stronger is the acid. Bases have a pH of more than 7. The higher the pH value, the stronger is the base. pH values of some common substances is shown in the table below.

A universal indicator is used to obtain an idea about how acidic or basic a substance is. It is a mixture of different indicators which give different colours at different pH values on the affected area gives relief. When a wasp stings, it injects an alkaline liquid into the skin. Therefore, rubbing a mild acid, like vinegar, on that area gives relief. An ant's sting injects methanoic acid into the skin, which can be neutralised by rubbing baking soda solution. Some plants also give painful stings. The stinging hair of nettle plant leaves inject methanoic acid into the skin which causes burning pain. It can be relieved with the help of baking soda, or by rubbing the leaf of a 'dock' plant (which contains some basic chemical).

- The bacteria present in our mouth break down the sugar to form acids. Tooth decay starts when.. the pH of acid formed in the mouth falls below 5.5. Using the toothpastes,which are basic, for cleaning the teeth can neutralise the excess acid in the mouth and prevent tooth decay.

Salts Salts are formed when acids react with bases. Salts are ionic compounds and solutions of salts conduct electricity.

The aqueous solutions of most salts are neutral (pH = 7), but some salts produce acidic or basic solutions when dissolved in water due to their hydrolysis. Hydrolysis is degradation of a compound by the action of water.

The salts of strong acids and strong bases give neutral solutions (pH = 7). Examples: Sodium Chloride and Potassium Sulphate. The salts of strong acids and weak bases give acidic solutions (pH < 7). Example: Ammonium Chloride. The salts of weak acids and strong bases give basic solutions (pH > 7). Example: Sodium carbonate.

Some Salts Used in Everyday Life Common Salt Common salt (sodium chloride or NaCI) is obtained from sea water by the process of evaporation. Rock salt (large crystals of common salt) is mined from underground deposits just like coal. Rock salt was formed when the seas dried up due to evaporation thousands of years ago.

Common salt is used:

- For making useful chemicals like sodium hydroxide, sodium carbonate, sodium bicarbonate, hydrochloric acid, hydrogen, chlorine, and sodium metal.

- To improve the flavour of food. It is required for the proper functioning of the nervous system, movement of muscles, and generation of hydrochloric acid in the stomach for digestion of food.

- As a preservative in pickles, and for preserving meat and fish. Chemistry - 35 -In cold countries to melt ice which gets deposited on the roads ree useful products are obtained by the electrolysis of sodium chloride solution (also ailed brine): Sodium hydroxide, chlorine, and hydrogen. The process of electrolysis of odium chloride solution is called chior-alkali process. hlorine is a disinfectant and is used to sterilize drinking water supply and the water in wimming pools. It is used in the manufacture of bleaching powder and hydrochloric cid. It is used to make plastics, such as polyvinyl chloride (PVC), pesticides, hlorofluorocarbons (CFCs), chloroform, carbon tetrachloride; paints, dyes, and solvents r dry cleaning (like trichloroethane). ydrogen is used in the manufacture of ghee or margarine, hydrochloric acid, ammonia, nd methanol. Liquid hydrogen is used as a fuel for rockets odium hydroxide and chlorine combine to form sodium hypochlorite (NaCIO) which is bleaching agent ashing Soda lashing soda is chemically sodium carbonate containing 10 molecules of water of rystallisation (Na9CO3.10H20). Anhydrous sodium carbonate (Na2CO3) is known as oda ash'. Washing soda has detergent (or cleansing) properties. It attacks dirt and rease to form water soluble products, which are washed away with water. It is also ised for removing permanent hardness of water. it is used in the manufacture of glass. nap, paper, and compounds such as borax.

Laking Soda iaking soda is chemically sodium hydrogen carbonate or sodium bicarbonate. It is ised as an antacid. it is sometimes added for faster cooking of food. Baking powder. ised for making cakes, bread, etc., is a mixture of baking soda and a mild acid, like tar-aric acid or citric acid. As long as baking powder is dry, baking soda, NaHCO3, and artaric acid do not react. When it mixes with water present in the dough (for bread or ake), reaction occurs between NaHCO3 and the acid to produce carbon dioxide gas, *Mich makes the cake or bread soft and spongy. Vithout the baking powder the cake obtained is hard and small in size. If baking soda is ised instead of baking powder, then Na2CO3 formed during baking will give a bitter taste a the cake. Tartaric acid present in baking powder neutralises Na,-,CO3 to give sodium artarate which has a pleasant taste.

Baking soda is used in fire extinguishers. When the knob of the fire extinguisher is pressed, sulphuric acid gets mixed with NaHCO3 to produce carbon dioxide gas, which forces a stream of liquid to fall on the burning substance. Carbon dioxide itself forms a blanket around the burning substance and cuts off its supply of air, thus extinguishing the fire.

Bleaching Powder Bleaching powder is chemically calcium oxychloride, $CaOCl_2$. It is also called chloride of lime. The real bleaching agent present in bleaching powder is chlorine. Bleaching agent is a substance which removes colour from coloured substances and makes them colourless. Bleaching powder is used for bleaching cotton and linen (textile industry), and wood pulp (paper industry). It is used for disinfecting drinking water supply, and for making wool unshrinkable. It is also used as an oxidising agent.

Plaster of Paris Plaster of Paris (P.O.P.) is calcium sulphate hemihydrate (half hydrate), $CaSO_4.1/2H_2O$. It was initially made by heating gypsum ($CaSO_4.2H_20$), which was mainly found in Paris. It is a white powder, which sets into a hard mass on wetting with water due to its conversion to gypsum. Plaster of Paris is used for setting fractured bones in the right position. It is used for making casts in dentistry. It is also used as a fire-proofing material. It is also used for making walls and ceilings smooth before painting, and for making toys, decorative materials, chalks, and casts for statues.

Water of Crystallisation Some salts contain a few water molecules as a part of their crystal structure. This water is known as water of crystallisation. Salts which contain water of crystallisation are called hydrated salts. For example, $CuSO_4.5H_20$, $FeSO_4.7H_20$, $CaSO_4.2H_20$, and

$Na_2CO_3.10H_2O$.

The shape of the crystals, and, in some cases, their colour, is due to the presence of water of crystallisation. Hydrated salts lose their water of crystallisation on strong heating to give anhydrous salts. On strong heating, blue copper sulphate crystals ($CuSO_4.5H_20$) lose their water of crystallisation to give anhydrous copper sulphate ($CuSO_4$). When water is added to anhydrous copper sulphate, it gets hydrated and turns blue.

METALS AND NON-METALS

Like their physical properties, the chemical properties of metals and non-metals are different. Chemical Properties of Metals Reactions of Metals with Oxygen Metals react with oxygen to .form metal oxides, which are basic in nature. Some metal oxides react with water to form alkalis. For example, $4Na + 0_2$ $2Na_20$ - $Na_20 + H_2O$ $2NaOH$ Sodium, potassium, and lithium metals are very reactive. They react vigorously with oxygen present in the air. That is why they are stored under kerosene oil to-protect them from oxygen, moisture, and carbon dioxide in the air.

Metal oxides which show basic as well as acidic behaviour are known as amphoteric oxides. Examples: Aluminium oxide and zinc oxide. They react with both acids and bases to form salt and water. Silver and gold do not react with oxygen even at high temperatures.

Reaction of Metals with Water When a metal reacts with water (cold or hot), it forms metal hydroxide and hydrogen gas. When a metal reacts with steam, the products are metal oxide and hydrogen gas. Sodium and potassium react vigorously with water, producing a lot of heat. Lead, copper, silver, and gold do not react with water or steam. Only those metals displace hydrogen from water which are above hydrogen in the reactivity series shown in the table below.

Reactions of Metals with Dilute Acids Metals react with dilute acids to form salt and hydrogen gas. Metals like copper, silver, and gold, which are less reactive than hydrogen, do not react with dilute acids. Metals which are above hydrogen in the reactivity series react with dilute acids. Aqua-regia, a mixture of one part of concentrated nitric acid and 3 parts of concentrated hydrochloric acid, is a highly corrosive, fuming liquid. It can dissolve all metals, including gold and platinum. However, concentrated nitric acid and hydrochloric acid separately cannot dissolve gold and platinum.

The Reactivity (or Activity) Series of Metals The arrangement of metals in order of decreasing reactivities is called reactivity series of metals. The most reactive metal (potassium) is placed at the top, whereas the least reactive (gold) at the bottom of the series (see the table below).

Potassium K Most reactive Sodium Na metal These metals are Calcium Ca more reactive Magnesium Mg Aluminium Al than hydrogen Zinc Zn De'c't casino Iron Fe chcinic al Tin Sn reac:h•ity Pb Lead These metals are Hydrogen (H) Copper Cu less reactive than 11)Mercury Hg Silver Gold Ag Au (Least reactive metal)

Reactivity Series of Metals Less reactive metals (like silver and gold) are usually found in free state in nature. Metals which are more reactive than hydrogen can displace hydrogen from its compounds, like water and acids, to form hydrogen gas, whereas metals less reactive than hydrogen cannot do so.

Reaction of Metals with Salt Solutions A more reactive metal displaces a less reactive metal from its salt solution. For example, CuSO4(aq) + Fe(s) FeSO4(aq) + Cu(s) When an iron rod is placed in copper sulphate solution, then the blue colour of copper sulphate solution fades slowly and a reddish-brown layer of copper gets deposited on the iron rod.

This happens because iron is more reactive than copper. If, on the other hand, a copper rod is placed in FeSO4 solution, then no reaction occurs because of the lower reactivity of copper as compared to iron.

Reaction of Metals with Chlorine Metals react with chlorine to form metal chlorides which are ionic compounds. For example,

2Na + C12 2NaC1 These metal chlorides are electrolytes, i.e., they conduct electricity in solution or in molten state.

Reaction of Metals with Hydrogen

Most of the metals do not react with hydrogen. Only reactive metals like sodium, r potassium, calcium, and magnesium react with hydrogen to form metal hydrides. Ca + 112 -4 CaH2 Metal hydrides are ionic compounds in which hydrogen is present in the form of hydride ion (H), an anion.

I Chemical Properties of Non-Metals Reaction of Non-metals with Oxygen Non-metals combine with oxygen to form acidic oxides (like carbon dioxide and sulphur dioxide) or neutral oxides (like wafer and carbon monoxide). Non-metal oxides are covalent in nature. Acidic oxides of non-metals dissolve in water to form acids. For example,

S + 02 -4 SO2 S02 + 1120 -4 112.503 Neutral oxides of non-metals do not produce an acid with water.

Reaction of Non-Metals with Water Non-metals do not react with water to produce hydrogen gas.

Reaction of Non-Metals with Dilute Acids Non-metals do not react with dilute acids. No hydrogen gas is evolved when a dilute acid s added to a non-metal. Reaction of Non-Metals with Salt Solutions \ more reactive non-metal displaces a less reactive non-metal from its salt solution. For !xample,

2K/ + C/2 —> 2KCI +

leaction of Non-Metals with Chlorine Jon-metals react with chlorine to form covalent chlorides which do not conduct lectricity. Nonmetal chlorides are usually liquids or oases. For example, 112 + Cl2 2HCI leaction of Non-Metals with Hydrogen Ion-metals react with hydrogen to form covalent hydrides. For example, "2 + 3112 -4 2N H3 Ion-metal hydrides are liquids or gases. They do not conduct electricity.

Uses of Metals

- Aluminium, copper, and iron are used to make utensils and industrial equipment.
- Copper and aluminium are used to make electrical wires.
- Zinc is used for galvanising iron to protect it from rusting.
- Chromium and nickel are used in the manufacture of stainless steel, and for electroplating iron and steel objects.
- Mercury is used in thermometers.
- Aluminium foils are used in packaging of medicines, cigarettes, and food materials.
- Silver foils are used to decorate-sweets.
- Gold and silver are used to make ornaments.
- Lead is used in car batteries. • Zirconium is used in making bullet-proof alloy steels.
- Sodium, zirconium, and titanium are used in atomic energy and space science projects.
- Many metals are used as catalysts in chemical reactions.

Uses of Non-Metals

- Hydrogen is used in the manufacture of Vanaspati ghee.
- Hydrogen is used in the manufacture of ammonia. Compounds obtained from ammonia are used as fertilizers.
- Liquid hydrogen is used as rocket fuel.
- Carbon (graphite) is used for making the electrodes of dry cells.
- Nitrogen is used as a refrigerant to preserve food materials. It is also used to provide an inert atmosphere. It is filled in electric bulbs.
- Nitrogen is used in the manufacture of ammonia, nitric acid, and fertilizers (like urea, ammonium nitrate, ammonium sulphate, ammonium phosphate, calcium ammonium

nitrate (CAN), etc.) Liquid ammonia is used as a refrigerant in ice factories and cold storages.

• Trinitro toluene (TNT) and nitroglycerine (compounds of nitrogen) are used as explosives.

Sulphur is used in the manufacture of sulphuric acid.

• Sulphur is used in the vulcanisation of rubber.

• Sulphur is used as a fungicide, and for making gun powder.

Types of Chemical Bonds There are two types of chemical bonds — Ionic and Covalent.

Ionic Bond The chemical bond formed by the transfer of electrons from one atom to another is known as an ionic bond. It is formed when one atom donates electrons and the other accepts electrons, so that both achieve the inert gas electron configuration. Ionic bonds are formed between metals and non-metals. The compounds containing ionic bonds are called ionic compounds. Ionic compounds are made up of ions. They are also called electrovalent compounds. Examples: Sodium chloride, potassium nitrate, copper sulphate, calcium oxide, sodium hydroxide, ammonium sulphate, magnesium chloride, etc.

Covalent Bond The chemical bond formed by the sharing of electrons between two atoms is known as a covalent bond. It is formed when both the reacting atoms need electrons to achieve the inert gas electron configuration. When a non-metal combines with another non-metal, a covalent bond is formed. It can also be formed between two atoms of the same non-metal. The shared electrons are counted with both the atoms. The compounds containing covalent bonds are called covalent compounds. Examples: Methane (CH4), ethane (C2H6), ethene (C2H4), ethyne (C2H2), water (H20), ammonia (NH3), ethanol (C2H5OH), hydrogen chloride gas (HCI), carbon dioxide (CO2), carbon tetrachloride (C014), glucose (C61-11206), cane sugar (C121-122011) urea [CO(NH2)2], hydrogen gas (H2), oxygen gas (02), chlorine gas (C12), etc.

Covalent bonds are of three types:

• Single Bond is formed by the sharing of one pair of electrons between two atoms, as in hydrogen molecule (H-H). hydrogen chloride molecule (H-CI).

- Double Bond is formed by the sharing of two pairs of electrons between two atoms, as in oxygen molecule (0=0), carbon dioxide molecule (0=C=0), and ethene molecule H2C=CH2

- Triple Bond is formed by the sharing of three pairs of electrons between two atoms, as in nitrogen (N N) molecule and ethyne (acetylene) molecule (H-C E C-H).

Properties of Ionic Compounds

- Ionic compounds are usually crystalline solids.

- They have high melting and boiling points, i.e., they are non-volatile.

- They are usually soluble in water, but insoluble in organic solvents like alcohol. acetone, benzene, ether, etc.

- They conduct electricity when they are dissolved in water or melted.

Properties of Covalent Compounds

- Covalent compounds are usually liquids or gases. Only some of them are solids. Examples of covalent solids are Glucose, Urea, etc.

- They usually have low melting points and boiling points, i.e., they are volatile.

- They are usually insoluble in water (except glucose, sugar, urea, etc.), but soluble in organic solvents.

- They do not conduct electricity.

Occurrence of Metals

The main source of metals is the earth's crust. Most metals are quite reactive. Therefore, they do not occur as free elements in nature.: The less reactive metals like copper. silver, and gold are found in the free state (native state) as well as in the combined state (in the form of compoUnds). All the metals placed above copper in the reactivity series are found in nature only in the form of their compounds. Silver, gold, platinum. ruthenium. and iridium are known as noble metals because of their lack of reactivity. They are found in the native state.

Minerals and Ores

Minerals are the natural materials in which the metals or their compounds are found in the earth. Those minerals from which metals can be extracted conveniently and profitably are called ores. Thus, all ores are minerals, but all minerals are not ores. Commercially, the most important sources of metals are oxide, sulphide, and carbonate minerals. The table below shows the ores of some metals Ores of Some Common Metals

Metal Ore Sodium (Na) NaCI (rock salt), NaNO3 (Chile salt peter), Na3AIF6 (cryolite) Calcium (Ca) CaSO4.2H20 (gypsum) CaSO4 (anhydrite), CaF2 (fluorite) CaCO3 (limestone, marble and chalk) Magnesium (mg) MgCO3.CaCO3 (dolomite) KCI.MgC12.6H20 (carnallite) Aluminium (Al) Al203.2H20 (bauxite)Na3AIF6 (cryolite) Zinc (Zn) ZnS (zinc blende) ZnCO3 (calarnite) Iron (Fe) Fe203 (haematite) Fe304 (magnetite) FeS2 (iron pyrites) Lead (Ph) PbS (galena) Copper (Cu) CuFeS2 (copper pyrites) CuCO3.Cu(OH)2 (malachite) Mercury (Hg) HgS (Cinnabar) Silver (Ag) Ag2S (Argentite) AgCI (horn silver) Gold (Au) Native (as free metal)

Extraction of metals

The various processes involved in the extraction of metals from their ores, and refining are known as Metallurgy. The process used depends on the metal. The three major steps involved in the extraction of a metal from its ore are: 1. Concentration of Ore This step involves the removal of unwanted impurities (called gangue), like sand, limestone, mica, stones, etc. from the ore. 2. Conversion of Concentrated Ore into Metal Different methods are used for extracting metals, depending on their reactivity. The highly reactive metals, like potassium, sodium, calcium. magnesium, and aluminum, are extracted by the electrolytic reduction of their molten chlorides or oxides. During electrolysis, the metal is produced at the cathode (negative electrode), and chlorine or oxygen at the anode (positive electrode). For example, electrolysis 2NaC1 > 2Na + C12 electrolysis Al203 > 4A1+ 302 The moderately reactive metals, such as manganese, zinc, iron, tin, lead, and copper, are extracted by the reduction of their oxides with carbon, aluminium, sodium, or calcium. It is easier to obtain metals from their oxides (by reduction) than from carbonates or sulphides. The concentrated ores are, therefore. first converted into metal oxides. Calcination is the process in which a carbonate ore is heated strongly in the absence of air to convert it into metal oxide. For example, Calcination Z11CO3 > Z710

Roasting is the process in which a sulphide ore is strongly heated in the presence of air to convert it into metal oxide. For example, Roasting 2ZnS + 302 2ZnO + 2502 Oxides of zinc, iron, nickel, tin, lead, and copper are reduced by carbon (in the form of coke), whereas oxides of manganese and chromium are reduced by aluminium powder.

Z710 C --> Z71 + CO 3M7102 + 4A1 3Mn + 2A1,03 + Heat The reduction of a metal oxide by aluminium powder is a highly exothermic reaction and is called thermite reaction. This property is used in joining the broken pieces of heavy iron objects, like railway tracks or cracked machine parts. This is done by ig-niting a mixture of iron (III) oxide and aluminium powder with a burning magnesium ribbon. Due to the evolution of heat, iron metal is produced in the molten state, which is poured between the broken iron pieces to weld them. This is called aluminothermy or thermite welding.

The less reactive metals, like mercury and copper, are extracted by the reduction of their oxides by heat alone. The sulphide ores of mercury and copper are roasted in air when their oxides are formed. On strong heating, the oxides get reduced to metals. For example,

Roasting 2HgS + 302 2Hg0 2S02 Heat 2Hg0 + °2

3. Refining of Metals

The process of purifying impure metals is called refining of metals. Different methods are used for refining different metals. The most widely used method is electrolytic refining:In this method, a thick block of impure metal is made the anode, a thin strip or pure metal is made the cathode, and a water soluble salt (of the metal to be refined) is taken as the electrolyte. On passing electric current, impure metal dissolves from the anode and goes into the electrolyte solution. Pure metal from the electrolyte deposits on the cathode. The soluble impurities-go into the solution whereas the insoluble impurities settle down at the bottom of the anode as anode mud. If an ore gives carbon dioxide on heating, or on treatment with a dilute acid, then it is a carbonate ore. If an ore gives sulphur dioxide on heating in air, or gives hydrogen sulphide gas on treatment with a dilute acid, then it is a sulphide ore.

Prevention of Rusting Of Iron

Rusting of iron can be prevented if damp air is not allowed to come in contact with iron objects. This can be done by: • Painting the iron surface

- Applying grease or oil

- Galvanisation, i.e., depositing a thin layer of zinc metal on iron objects. Iron sheets used for making buckets, drums, dust-bins, and sheds and iron pipes used for water supply are galvanised to prevent rusting. Zinc reacts with air to form a thin coating of zinc oxide.

- Tin-plating and chromium-plating as tin and chromium are resistant to corrosion. Steel tiffin boxes are plated with nickel or tin. Chromium plating is done on taps, bicycle handles, and car bumpers made of iron and steel. • Alloying it to make stainless steel. Stainless steel is obtained when iron is alloyed with chromium and nickel. Cooking utensils, knives, scissors, and surgical instruments, etc., are made of stainless steel.

Alloys An alloy is a homogeneous mixture of two or more metals or a metal and small amount of non-metals. The properties of an alloy are different from the properties of the constituent metals. Alloys are stronger and/or harder, and have lower melting points than the constituent metals. They are more resistant to corrosion, and have lower electrical conductivity than pure metals.

Some of the common alloys are:

- Duralium (or Duralumin), an alloy of aluminium with copper, magnesium and manganese, is used for making aircraft bodies and parts, space satellites, and kitchenware.

- Magnalium, an alloy of aluminium with magnesium, is used to make balance beams and light instruments.

- Steel, an alloy of iron with carbon, is used for making nails, screws, bridges, railway lines, ships, vehicles, buildings, etc.

- Stainless steel, an alloy of iron with chromium and nickel, is used for making cook-ing utensils, knives, scissors, tools, surgical instruments. etc.

- Brass, an alloy of copper (80%) and zinc (20%), is golden in colour. It is used for making utensils, nuts, bolts, screws, wires, tubes, ornaments, instruments, fancy lamps, and flower vases.

- Bronze, an alloy of copper (90%) and tin (10%), is used for making coins, statues, medals, utensils, and propellers of ships.

- Solder, an alloy of lead (50%) and tin (50%), has a low melting point. It is used for welding (soldering) electrical wires together.

- Amalgam is an alloy of mercury with one or more other metals. An amalgam consisting of mercury, silver, tin, and zinc is used by dentists for fillings in teeth.

Alloys of gold with small amounts of silver and copper are used for making jewellery. Pure gold (known as 24 carat gold) is very soft due to which it is not suitable for making jewellery. Ornaments are usually made of 22 carat gold (i.e., 22 parts of pure gold alloyed with 2 parts of either silver or copper).

PERIODIC CLASSIFICATION OF ELEMENTS

The 115 elements known at present have been divided into groups such that elements in the same group have similar properties. This helps in the study of the properties of all the elements.

Some Earlier Attempts Dobereiner's Law of Triads When elements are arranged in the order of increasing atomic masses, groups of three elements (known as triads), having similar chemical properties are obtained. The atomic mass of the middle element of the triad is equal to the average of the atomic masses of the other two elements. Examples: Lithium, Sodium, and Potassium; Calcium, Strontium. and Barium; Chlorine, Bromine, and Iodine.

Newland's Law of Octaves When elements are arranged in the order of increasing atomic masses, the properties of the eighth element (starting from a given element) are a repetition of the properties of the first element.

The Periodic Table The periodic table is a chart of elements in which the elements having similar properties occur in the same vertical column or group. In this table, the elements having similar properties are repeated after certain intervals or periods. A periodic table consists of horizontal rows of elements called periods, and vertical columns, called groups.

Mendeleev's Periodic Table Mendeleev s Periodic Law states 'The properties of elements are periodic function of their atomic masses.' There were seven periods and eight groups in the original periodic table of Mendeleev.

Mendeleev's periodic table could:

- Predict the existence of some elements
- Predict the properties of several elements
- Accommodate noble gases when they were discovered

However, it could not: • Explain the position of isotopes • Explain the wrong order of atomic masses of some elements • Assign correct position to hydrogen

Modern Periodic Law In 1913, Henry Moseley suggested that atomic number of elements is a better basis for the classification of elements.

The Modern Periodic Law states 'The properties of elements are a periodic function of their atomic numbers.' When elements are arranged according to increasing atomic numbers, there is a periodicity in the electronic configurations of elements, which leads to the periodicity in their chemical properties.

IModern Periodic Table The modem periodic table was prepared by Neils Bohr. The arrangement of elements in the modem (long form) periodic table is based on their electronic configurations. There are seven periods (horizontal rows) in the periodic table. The elements in a t period have consecutive atomic numbers. The following figure shows the modern periodic table.

The first period starts with hydrogen and ends with the noble gas, helium. All other periods start with alkali metals like Lithium, Sodium, Potassium, etc., and end with noble tgases like Neon, Argon, Krypton, etc. The first element of every period has 1 valence ;electron and the last element of every period has 8 valence electrons (except the first (period in which the last element helium has 2 valence electrons). Since the electronic configurations of elements in a period are different, they show different properties.

There are eighteen groups (vertical columns) in the periodic table (numbered 1 to 18). The elements in a group do not have consecutive atomic numbers. All the elements in a group have similar electronic configurations and show similar properties. The valence shells of all the noble gases are completely filled with electrons.

Hydrogen element has been placed at the top of group 1, above the alkali metals, because the electronic configuration of hydrogen is similar to that of alkali metals (1 valence electron). Group 3 to group 12 elements are called transition elements. The elements with atomic numbers 57 to 71 are called lanthanide series (because their first element is Lanthanum). The elements with atomic numbers 89 to 103 are called actinide series (because their first element is Actinium). These are two series of ele-ments having similar properties.

In the periodic table, metals and non-metals have been separated by some elements. called metalloids, which are placed diagonally. These metalloids are Boron, Silicon, Germanium, Arsenic, Antimony, Tellurium, and Polonium. Metalloids have properties which are intermediate between those of metals and non-metals. The metals lie on the left side and non-metals on the right side of the metalloids. The metalloid, Silicon, is a semiconductor. It is used to make silicon 'chips', which are used to integrate thousands of transistors into a tiny space. It has been possible to make extremely small circuits, like those used in laptop computers, with the help of silicon chips.

Characteristics of Periods Valence Electrons On moving from left to right in a period, the number of valence electrons in elements of the period increases from 1 to 8. The elements in a period have consecutive atomic numbers

Metallic Character On moving from left to right in a period, the metallic character of elements decreases but the non-metallic character increases. Metals lose electrons and form positive ions, so metals are called electropositive elements. Nonmetals accept electrons and form negative ions, so non-metals are called electronegative elements. Thus, on moving from left to right in a period, the electropositive character of elements decreases, but the electronegative character increases (Sodium is most electropositive and Chlorine is most electronegative in the third period).

Chemical -Reactivity On moving from left to right in a period, the chemical reactivity of elements first decreases and then increases. -Its, • °n'i Period 3: ties the Na Mg Al Si P S CI

Chemical Reactivity • Chemical Reactivity ids decreases increases like Nature of Oxides On moving from left to right in a period, the basic nature of oxides decreases and the acidic nature of oxides increases. Chemical Reactivity Chemical Reactivity decreases increases

Characteristics of Groups Valence Electrons All the elements of a group have the same number of valence electrons. Elements in a group do not have consecutive atomic numbers. The group number of elements having up to two valence electrons is equal to the number of valence electrons. Example: if number of valence electrons is 2 then the element belongs to Group 2. The group number of elements having more than two valence electrons is equal to the number of valence electrons plus 10. Example: If the number of valence electrons is 6, then the element belongs to Group 16. There is one exception to this rule. Helium has 2 valence electrons but it belongs to Group 18.

Size of Atoms On going down from top to bottom in a group, the size of atoms increases. Example: In Group 17 of halogens, Fluorine atom is the smallest whereas Iodine atom is the largest in size.

Metallic Character On going down in a group, the metallic character of elements increases. Also, the electropositive character of elements (i.e., tendency to lose electrons) increases, whereas the electronegative character (i.e., tendency to gain electrons) decreases. In Group 1, Lithium is the least metallic (least electropositive) element and Francium is the most metallic (most electropositive) element. In Group 17, out of Fluorine, Chlorine, Bromine, and Iodine, Fluorine is the most electronegative element whereas Iodine is the least electronegative element. Of all the elements, Francium is the most electropositive element and Fluorine is the most electronegative element.

Chemical Reactivity On going down in a group of metals, the tendency of the atoms to lose electrons increases, and so their chemical reactivity also increases. On going down in a group of non-metals, the tendency of the atoms to gain electrons decreases, due to which their reactivity also decreases. Thus, in Group 1. Lithium is the least reactive and Francium is the most reactive, whereas in Group 17, out of the four common halogens, Fluorine is the most reactive and Iodine the least reactive.

Nature of Oxides The nature of oxides of all the elements of a group is the same. Example: All elements of Group 1 form basic oxides, whereas all elements of Group 17 form acidic oxides.

Merits of the Modern Periodic Table

- It is based on the atomic numbers of elements.
- It explains why elements in a group show similar properties but elements in different groups show different properties.
- It explains the reasons for the periodicity in properties of elements.
- It tells why the properties of elements are repeated after 2, 8, 18 and 32 elements.
- There are no anomalies in the arrangement of elements in the periodic table.
- The type of compounds formed by an element can be predicted by knowing its t position in the periodic table.

Some Points to Remember

- The period number of an element is equal to the number of electron shells in its atom.
- Elements having the same valence shell belong to the same period.

- The group number of an element o having up to 2 valence electrons is equal to the number of valence electrons. o having more than 2 valence electrons is equal to the number of valence electrons plus 10.

- Elements having the same number of valence electrons belong to the same group.

- When an element from groups 1, 2 or 13 combines with an element from groups 14, 15, 16 or 17, an ionic bond is formed.

- When two elements from groups 14, 15, 16, and 17 combine together, covalent bonds are formed.

Isotopes of Hydrogen The three isotopes of hydrogen are Protium (or ordinary hydrogen, H), Deuterium (or heavy hydrogen, D), and Tritium (T). Tritium is used to make thermonuclear devices. It is also used as a radioactive tracer.

Hard and Soft Water Water that produces lather with soap readily is called soft water. Examples: Rain water, distilled water, and demineralised water.

Water which does not produce lather with soap readily is called hard water. Examples: Sea water, river water, spring water, lake water, and well water. Hardness of water is due to the presence of bicarbonates, chlorides and sulphates of calcium and magnesium in it. Temporary (or carbonate) hardness is due to the presence of bicarbonates and can be easily removed by boiling and filtering the water. Permanent (or non-carbonate) hardness is due to the presence of soluble chlorides and sulphates. It cannot be removed simply by boiling the water. Other methods have to be employed for this purpose. Removal of hardness from hard water is called softening of water.

Heavy Water Chemically heavy water is Deuterium Oxide (D20). Ordinary water contains traces (1 part in 6000 parts) of D20. Heavy water is used as a moderator to control nuclear reactions, and as a trace compound to study many reactions.

Uses of Alkali Metals Lithium: Lithium-aluminium alloy is used for aircraft construction, lithium-magnesium alloy for aerospace components, lithium carbonate for making strong and weather-proof glass, lithium chloride in air-conditioning plants to regulate, humidity, lithium bromide as a sedative, lithium bicarbonate and lithium salicylate for the treatment of rheumatism, and lithium metal to make electrochemical cells.

Sodium: About 60% of world production of sodium is used to make Tetraethyl lead and Tetramethyl lead which are used as anti-knocking agents for gasoline (petrol). Liquid sodium is used as a coolant in nuclear reactors. Sodium is used in sodium vapour lamps, for the production of artificial rubber, dyes, drugs, etc., and for filling exhaust valves of aeroplane engines.

Potassium: Potassium chloride is used as a fertiliser. Caesium: Caesium is used in photoelectric cells.

Biological Importance of Sodium and Potassium In the human body, sodium ions are primarily found outside the cells in blood plasma and other fluids, whereas potassium ions are present inside the cells. These ions help in transmission of nerve signals, in regulating the flow of water across cell membranes and in the transport of sugars and amino acids into the cells. Since potassium ions are the most abundant cations within the cell fluids, they activate many enzymes and participate in the oxidation of glucose.

Biological Importance of Magnesium and Calcium Magnesium ions are concentrated inside the animal cells and calcium ions are concentrated in the body fluids outside the cells. Both these ions catalyse a number of enzymatic reactions and help in the storage of energy. Magnesium ions are present in chlorophyll required by plants for photosynthesis. Calcium ions are present in bones and teeth. They are important for blood clotting, muscle contraction, and regular heart beat.

Uses of Alkaline Earth Metals • Beryllium is used for making windows of X-ray tubes. • Radium salts are used in radiotherapy. Example: Treatment of cancer. • Calcium oxide (quick lime) is used in the purification of sugar, as a constituent of mortar, in the preparation of cement and glass, and as a basic lining in furnaces. • Calcium hydroxide (slaked lime) is used as a building material in the form of mortar (which also contains sand), in whitewash, and in the manufacture of bleaching pow-der. • Calcium carbonate is used in the manufacture of high quality paper, in toothpaste, in chewing gum, and as filler in cosmetics.

Cement

Cement is a mixture of calcium silicates and aluminates along with small amounts of gypsum. It sets into a hard stone like mass when treated with water. The main components of cement are tricalcium silicate (3Ca0. Si02), dicalcium silicate (2CaO.Si02). and tricalcium aluminate (3Ca0. Al203). Tricalcium. silicate, which constitutes 50% of the cement, has the property of setting quickly and acquiring considerable strength within a few days..

Portland cement is a mixture of lime. magnesium oxide, silica, ferric oxide, alumina, and sulphur trioxide. The essential raw materials required for the manufacture of cement are limestone, clay, and gypsum. Sometimes, fly ash (which mainly consists of calcium silicate) is added to cement to reduce its cost without affecting the quality. Hydraulic cements are materials that set and harden after combining with water. Most construction cements are hydraulic and are based upon Portland cement. Non-hydraulic cements include materials like lime and gypsum plasters, which must be kept dry in order to gain strength.

Glass Silicon dioxide (silica) occurs in large amounts in rocks, sand, and in larger crystals (quartz). Quartz melts at 1600-1700°C, forming a tacky liquid. When the liquid is cooled rapidly, an amorphous solid, known as quartz glass or silica glass, results. Different substances can be added to silica to cause it to melt at a lower temperature. Glass can be generally divided into two groups: oxide glass and non-oxide glass. The ingredients of oxide glasses include oxides (chemical compounds that include oxygen). Non-oxide glasses are made from compounds that contain no oxides, and which often instead contain sulfides or metals. Oxide glasses are much more widely used commercially. The common types of glass discussed below are all oxide glasses.

Soda-lime glass is the kind of glass used for flat glass, most containers and electric light bulbs, and many other industrial and art objects. More than 90 percent of all glass is soda-lime glass. It has been made of almost the same materials for hundreds of years. The composition is about 72 percent silica (from sand), about 13 percent sodium oxide (from soda ash), about 11 percent calcium oxide (from limestone), and about 4 percent minor ingredients. Soda-lime glass is inexpensive, easy to melt and shape, and reasonably strong. All glass container manufacturers use the same basic soda-lime composition, making the containers easy to recycle. Manufacturers sort the glass by color and then later reuse it in the production of new containers.

Soda-lead glass, commonly called crystal or lead glass, is made by substituting lead oxide for calcium oxide and often for part of the silica used in soda-lime glass: Soda-lead glass is easy to melt. It is much more expensive than soda-lime glass. Soda-lead glass has such beautiful optical properties that it is widely used for the finest tableware and art objects. In addition, lead oxide improves the electrical properties of glass.

Borosilicate glass is heat-shock resistant and better known by such trade names as Pyrex and Kimax. It contains about 80 percent silica, 4 percent sodium oxide, 2 percent alumina, and 13 percent boric oxide. Such glass is about three times as heat-shock resistant as soda-lime glass and is excellent for chemical and electrical uses. This glass makes possible such products as ovenware and beakers, test tubes, and other laboratory equipment.

Fused silica glass glass is a highly heat-shock resistant glass that consists entirely of silica. It can be heated to extremely high temperatures and then plunged into ice-cold water without cracking. Fused silica is expensive because exceptionally high temperatures must be maintained during production. It is used in laboratory glassware and optical fibers.

96 percent silica glass resists heat almost as wQII as fused silica, but it is less expensive to produce. It consists of a special borosilicate composition that has been made porous by chemical treatment. The pores shrink when the glass is heated, leaving a smooth, transparent surface. The glass is sold under the trade name Vycor.

Colored glass gets its coloring from certain oxides that are added to the glass. For example, 1 part of nickel oxide in 50,000 produces a tint that may range from yellow to purple, depending on the base glass. One part of cobalt oxide in 10,000 gives an intense blue. Red glasses are made with gold. copper, or selenium oxides. Other colors can be produced in glass with other chemicals.

Photochromic glass contains a dispersion of silver chloride or silver bromide. The glass darkens when exposed to sunlight because silver halide decomposes in light to form silver and halogen atoms (the finely divided silver is black). These recombine in the dark to form silver halide.

Ceramics The three basic ingredients of common pottery are silicate minerals: clay, sand, and feldspar. Clay minerals and mica are aluminosilicates. Feldspars are aluminosilicates containing potassium, sodium, and other ions in addition to silicon and oxygen. Examples: K20.Al203.6 Si02. Feldspars are the most abundant rock forming silicates in the earth's crust.

Nearly pure alumina and zirconia are now used as bases for ceramic materials. which are excellent electrical or thermal insulators. Magnetic ceramics, which contain iron compounds, are used as memory elements in computers. Glass ceramics are used for cooking utensils and kitchen ware. They include materials marketed under the name' Pyroceram' .

Asbestos Asbestos is a general term applied to a group of fibrous silicate minerals. Asbestos has been widely used as themal insulation material. Zeolites Zeolites are aluminosilicates which are used as catalysts in petrochemical industries for cracking of hydrocarbons. They are used to convert alcohols into gasoline. Hydrated zeolites. called permutit, are used as ion exchangers in softening of hard water.

Uses of Boron and Aluminium • Boron fibres are used to make bullet-proof vests and light composite material for aircrafts. • Metal borides are used in nuclear industry as protective shields. • Borax and boric acid are used in the manufacture of heat, resistant glass (i.e., Pyrex), glass-wool and fibre glass. They have antiseptic properties and are also used in the manufacture of enamels and glazes for earthenware like tiles, pottery, etc. • Aluminium is used for making transmission cables. • Aluminium powder mixed with linseed oil shines like silver and is called silver paint. This paint is used to protect iron and zinc. • Aluminium powder is used in flash light bulbs for indoor photography. • Potash alum, K2SO4. Al2(SO4)3.24H20, is used for purification of water, as styptic for stopping bleeding, in foam jype fire extinguishers, as mordant for dyeing, and for tanning of leather, in calicoprinting and sizing of paper.

Allotropic Forms of Phosphorus, Oxygen and Sulphur Three important allotropeg of phosphorus are:

• White Phosphorus (most reactive) • Red Phosphorus • Black phosphorus (least reactive)

Oxygen exists in two non-metallic forms:

• Dioxygen (02) • Ozone (03) Ozone is used as a disinfectant, and as a germicide for sterilizing water. It is used for purifying air in crowded places such as cinema halls, underground railway stations, tunnels, mines, etc. It is used for bleaching fabrics, oil, starch, etc. It is used in the manufacture of artificial silk. The important allotropes of sulphur are: • Rhombic Sulphur (or a-sulphur) • Monoclinic Sulphur (or 13-sulphur) • Plastic Sulphur (or x-sulphur) Plastic sulphur is regarded as a super-cooled liquid.

Uses of Compounds of Sulphur

• Sodium metabisulphite is used as a preservative for jams, jellies, and squashes. • Sulphur dioxide is used as a bleaching agent, disinfectant, and refrigerant. • Sulphuric acid is called the king of chemicals. It is used to manufacture fertilizers, dyes, drugs, paints, detergents, and explosives. It is used in metallurgy. It is used as an electrolyte in lead storage batteries.

Uses of Halogens

• Halogen acids are corrosive. HF attacks glass and is, therefore, used for etching glass and manufacture of glass shell for television tubes. Due to its high reactivity and special properties, fluorine is called a super halogen. • Chlorine is a powerful bleaching agent. It is also used to make bleaching powder. It is used to sterilise drinking water. It is used in the manufacture of DDT, refrigerants (CCl2F2, Freon), and in the preparation of poisonous gases like tear gas (CCI3NO2), mustard gas, and phosgene.

Uses of Noble Gases

• Helium is used .to fill balloons which are employed for meterological observations. Oxygen-helium mixture is used for artificial respiration in deep sea diving. Helium has the unusual property of diffusing through materials like rubber, glass, or plastics. • Neon is used in beacon light as safety signal for air navigators. It is used in fluorescent lamps and discharge tubes for advertising purposes. • Argon is used to provide 'an inert atmosphere, to fill incandescent and fluorescent lamps, and also in neon signs for obtaining lights of different colours. • Krypton and Xenon are used in -gas filled lamps. Their mixture is used for high speed photography. • Being radioactive, radon is used in treatment of cancer and x-ray photography for the detection of flaws in metals and other solids.

Transition Elements (Transition Metals)

The elements which lie in between's' and 'p' block elements in the periodic table are called transition elements. Their properties are intermediate between those of the's' and 'p' block elements. They show variable oxidation states (The highest oxidation state is +8 shown by ruthenium and osmium). A number of transition metals and their compounds show catalytic properties (For example: Cobalt, nickel, platinum, iron, vanadium pentaoxide etc.). Most of the transition elements form coloured compounds as shown in the table below. Colours of Some of the Hydrated Transition Metal ions

Their compounds are generally paramagnetic in nature. They have a great tendency to form complexes. Some examples of complexes are [Cu(NH3)42+, [PtC14]2-, and [Ni(CN)42. Transition metals form alloys.

The most abundant transition metal is iron. The first synthetic element, i.e., element mpde artificially, was Technetium. Alnico, an alloy of aluminium, nickel. cobalt and iron, is used to make permanent magnets. The most commonly occurring lanthanoid is Cerium. The most common mineral containing lanthanoids is Monazite sand.

CARBON AND ITS COMPOUNDS

The element carbon is a non-metal. Earth's crust contains only 0.02% carbon in the form of minerals (like coal, petroleum, carbonates, etc.). The atmosphere has only 0.03% of carbon dioxide gas. All living things (plants and animals) made up of compounds of carbon are called organic compounds.

The atomic number of carbon is 6 (electronic configuration: 2, 4). Carbon is tetravalent, i.e., its valency is 4. It forms covalent bonds by sharing of electrons. Carbon has the unique property of self combination (known as catenation) to form long chains, which gives rise to an extremely large number of carbon compounds (organic compounds).

Allotropes of Carbon Allotropes are the various physical forms in which an element can exist. In the free state, carbon occurs in nature mainly in two forms: Diamond (a colourless. transparent substance) and Graphite (a grayish-black opaque substance). Another naturally occurring form of carbon, called Buckminsterfullerene, has been recently discovered. These three are called allotropes of carbon. Diamond and graphite have entirely different physical properties. Example: Diamond is extremely hard whereas graphite is soft; diamond is a nonconductor of electricity whereas graphite is a good conductor of electricity. Their chemical properties are the same. Example: Both form carbon dioxide on burning in oxygen. The difference in their physical properties arises because of the different arrangements of carbon atoms in them. The compact and rigid structure of diamond makes it a very hard substance, due to which it is used for making rock borers for drilling oil wells, and for making glass cutters.

A sharp, diamond edged knife (called keratome) is used by eye-surgeons to remove cataract from the eye. Diamonds can be made artificially by subjecting pure carbon to very high pressure and temperature. Diamonds are used for making jewellery. There are 'no free electrons' in diamond. Therefore, it does not conduct electricity. Graphite consists of sheets (or layers) of carbon atoms, due to which it is a comparatively soft substance. It contains 'free electrons' because of which it conducts electricity. Therefore, graphite is used for making electrodes in dry cells. The carbon brushes of electric motors are also made of graphite. Powdered graphite is used as a lubricant for machine parts especially those which operate at very high temperatures. Mixed with clay, graphite is used for making the cores of pencils, called pencil leads. The tiles on the nose cone of space shuttle contain graphite because it does not melt easily. The third allotrope of carbon, Buckminsterfullerene (also called fullerene), contains clusters of 60 carbon atoms joined together to form spherical molecules. Its formula is C60. It is a football shaped molecule with 60 carbon atoms arranged as 20 hexagons and 12 pentagons which are interlocked. It has been named after the American architect. Buckminster Fuller, because its structure resembles the framework of dome-shaped halls designed by Fuller. Buckminsterfullerene is a dark solid, which is neither very hard nor soft. It burns in oxygen to produce only carbon dioxide. It is a much smaller molecule compared to diamond and graphite, which are giant molecules. The figure below shows the structure of all the above allotropes of carbon.

Charcoal is of four types:

a. Wood Charcoal obtained by strong heating of wood in a limited supply of air: b. Animal Charcoal obtained by heating of bones in the absence of air. 3. Sugar charcoal is obtained by the action of sulphuric acid on cane sugar. 4. Activated charcoal is prepared by heating charcoal at 1273K in a current of super heated steam. It is highly porous and is an excellent adsorbent. 5. Carbon black (or lamp black) is the soot obtained when natural gas, kerosene, petroleum, etc., are burnt in a limited supply of air. It contains 98-99% carbon.

Apart from the above, two new forms of carbon recently discovered are as follows:

Carbon Nano Tubes: A Carbon Nanotube is a tube-shaped material, made of carbon, having a diameter measuring on the nanometer scale. The graphite layer appears somewhat like a rolled-up chicken wire with a continuous unbroken hexagonal mesh and carbon molecules at the apexes of the hexagons as shown in the adjoining figure. They have a long, hollow structure with the walls formed by one-atom-thick sheets of carbon, called graphene. These cylindrical carbon molecules have unusual for nanotechnology, electronics, optics and other fields of materials science and technology. In particular, owing to their extraordinary thermal conductivity and mechanical and electrical properties, carbon nanotubes find applications as additives to various structural materials.

Graphene: Graphene is a substance made of pure carbon, with atoms arranged in a regular hexagonal pattern similar to graphite, but in a one-atom thick sheet as shown in the adjoining figure. Graphene is the basic structural element of some carbon allotropes including graphite, charcoal, carbon nanotubes and fullerenes. The Nobel Prize in Physics for 2010 was awarded to Andre Geim and Konstantin Novoselov at University of Manchestor for "groundbreaking experiments regarding the two-dimensional material grapheme". Since it is practically transparent and a good conductor, graphene is suitable for producing transparent touch screens, light panels, and maybe even solar cells. When mixed into plastics, graphene can turn them into conductors of electricity while making them more mechanically robust. This resilience can be utilised in new super strong materials, which are also thin, elastic and lightweight. In the future, satellites, airplanes, and cars could be manufactured out of the new composite materials.

Organic Compounds

Compounds of carbon and hydrogen (hydrocarbons) and their derivatives (containing oxygen or other elements) are known as organic compounds. Examples: Methane ($CH4$), Ethane ($C2H6$), Ethene ($C2H4$), Acetylene ($C2H2$), Ethyl alcohol ($C2H5OH$), Acetaldehyde ($CH3CHO$), Acetic acid ($CH3COOH$), Chloroform ($CHCI3$), and Urea [$CO(NH2)2$]. Organic compounds are covalent compounds having low melting and boiling points. Most of them do not conduct electricity.

Organic compounds occur in all living things like plants and animals. The oxides of carbon, carbonates, hydrogen carbonates, and carbides are inorganic compounds. More than 5 million carbon compounds are known at present. The reasons for the existence of a large number of organic compounds are • Catenation (Self Linking): Carbon atoms can link with one another by means of covalent bonds to form long chains or rings of carbon atoms, so that a large number of organic compounds are formed. This property of self-linking is called catenation.

• **Tetravalency:** The valency of carbon is 4 (tetravalency). Due to this large valency, a carbon atom can form covalent bonds with a number of carbon atoms as well as other atoms like hydrogen, oxygen, nitrogen, sulphur, chlorine, etc., to form a large number of organic compounds.

Types of Organic Compounds Hydrocarbons

A compound made up of only carbon and hydrogen is called a hydrocarbon. Example: Methane. ethane, ethane (ethylene), and ethyne (acetylene). Petroleum, which is obtained from underground oil deposits by drilling oil wells, is an important natural source of hydrocarbons. Petroleum in oil fields is covered with natural gas, which also contains hydrocarbons.

Types of hydrocarbons

• Saturated Hydrocarbons (Alkanes) An alkane is a hydrocarbon in which the carbon atoms are connected only by single bonds. The names of alkanes end with 'ane' and their general formula is $C,H2n+2$ where n is the number of carbon atoms in one molecule of the alkane. Examples: Methane ($CH4$), ethane ($C2H6$), propane ($C3H8$), butane ($C41$-110), and pentane ($C6H12$).

• Unsaturated Hydrocarbons (Alkenes and Alkynes) A hydrocarbon in which the two carbon atoms are connected by a double bond or a triple bond is called an unsaturated hydrocarbon. The unsaturated hydrocarbons are obtained mostly from petroleum by a process called cracking.

Alkenes contain a double bond between two carbon atoms which is formed by the sharing of two electron pairs (i.e., four electrons). The names of alkenes end with tene` and their general formula is Ci,H2n. Examples: Ethene (C2H4), propene (C2H6), and butene (C4H8). Ethene is used for ripening many raw fruits. Polymerisation of ethene gives polythene.

Alkynes contain a triple bond between two carbon atoms which is formed by the sharing of three electron pairs (or six electrons). The names of alkynes end with 'yne' and their general formula is C,1-12„.2. Examples: Ethyne (C2H2), propyne (C3H4), and butyne (C4H6). Ethyne (Acetylene) forms a polymer called polyacetylene.

• Cyclic Hydrocarbons The hydrocarbons in which the carbon atoms are arranged in the form of a ring are called cyclic hydrocarbons. They may be saturated or unsaturated. Saturated cyclic hydrocarbons are called cycloalkanes. The general formula of cycloalkanes is C,H2n, which is the same as that of alkenes. Examples: Cyclopropane (C3H6), cyclobutane (C4H8), cyclopentane (C5H10), and cyclohexane (C6H12). An important example of an unsaturated cyclic hydrocarbon is benzene (C6H6). It contains 3 carbon-carbon double bonds and 3 carbon-carbon single bonds. Compounds containing benzene rings are called aromatic compounds.

The systematic names of hydrocarbons were given by International Union of Pure and Applied Chemistry (IUPAC) in 1958, so they are called IUPAC names.

Isomers The organic compounds having the same molecular formula but different structures are known as isomers. For example, both n-butane and iso-H HHH butane have the same molecular formula (C4Hio) but they butane H-1 — — c I —c I —H I I H I I have different structures. LPG cylinders (cooking gas H HH cylinders) contain a mixture of n-butane and iso-butane, H H H I —c I I along with small amounts of propane and ethane. Isomerism iso-butane H_T -C-H is possible only with hydrocarbons having 4 or more carbon H-I-H atoms. Methane, ethane, and propane do not have isomers. if Butane, Pentane, and Hexane have 2, 3, and 5 isomers, respectively.

Coal and Petroleum Most of the fuels are obtained from coal, petroleum, and natural gas. Energy is released mainly in the form of heat (and some light) when a fuel is burnt. This energy can be used to cook food, run generators in thermal power stations, machines in factories, and engines of vehicles. Fuels such as coal, coke, and charcoal contain free carbon whereas fuels such as petrol, LPG, kerosene, and natural gas are all carbon compounds. When carbon burns in oxygen (of air), it forms carbon dioxide and releases a large amount of heat.

Coal, petroleum, and natural gas are known as fossil fuels because they were formed by the decomposition of the remains of plants and animals, which got buried under the surface or the earth millions of years ago, under high temperature and pressure.

Coal is a complex mixture of compounds of carbon, hydrogen and oxygen, and some free carbon. Small amounts of nitrogen and sulphur compounds are also present in coal. Petroleum (or rock oil) is a dark coloured, viscous, foul smelling crude oil. It is a complex mixture of hydrocarbons (some nitrogen and sulphur containing compounds are also present). Petrol, diesel, LPG, and kerosene are obtained from petroleum.

Due to the presence of nitrogen and sulphur compounds in them, combustion of coal and petroleum fuels leads to the formation of oxides of nitrogen and sulphur, which are major air pollutants. When the supply of oxygen is sufficient, the fuel burns completely, producing a blue flame (non-luminous flame). In a gas stove, cooking gas (LPG) burns with a blue flame because the stove has holes (inlets) for air, which allows complete combustion of cooking gas.

When the supply of oxygen is insufficient, then the fuel burns incompletely, producing a yellow flame (luminous flame). The yellow colour of the flame is due to the glow of hot, unburnt carbon particles produced by incomplete combustion of the fuel. Since incomplete combustion of wax takes place in a candle, it burns with a yellow flame. Fuels which do not vaporise on heating, burn without producing a flame. Thus, coal and charcoal burn without producing a flame. They just glow red and give out heat. The largest supply of fossil fuels is in the form of coal. Most of the coal is burned to make electricity. Coal can be converted into a relatively clean-burning fuel by a process known as gasification.

Refining of Petroleum Crude petroleum has to be refined before being put to commercial use. Two important operations are involved in refining of petroleum: Fractional distillation and Cracking. Fractional distillation leads to the separation of crude petroleum into a number of fractions, each passing over a definite temperature range. Each fraction is a mixture of different hydrocarbons which can be used for a definite purpose as stated in the table below.

Fraction Uses 1 Gaseous hydrocarbons Industrial and domestic fuel 2 Petroleum ether Solvent in perfumery, for dry cleaning of clothes 3 Gasoline Fuel 4 Kerosene Fuel in lamps, burners, etc. 5 Diesel oil or Gas oil Fuel for diesel engines, for industrial heating 6 Lubricating oils and Greases Lubricants 7 Paraffin wax Candles, polishes, waxed paper, ointments and cosmetics 8 Asphalt and coke Roofing, road building. cables, battery 'boxes and electrodes

Cracking is a process by means of which higher hydrocarbons are degraded to give smaller hydrocarbons. High-boiling fractions can be converted into gasoline by cracking. The quality of petrol used in car engines is denoted by their anti-knock properties. The anti-knock property of gasoline (petrol) is expressed in terms of the Octane number and that of diesel in terms of the Cetane Number. The higher the Octane or Cetane Number, the better is the fuel. The Octane Number can be increased by adding tetraethyl lead (TEL) to gasoline. Gasoline treated in this way is called ethyl gasoline or leaded gasoline.

Compressed Natural Gas (CNG) Compressed natural gas (CNG) is a fossil fuel substitute for gasoline (petrol), Diesel fuel, or propane/LPG. Although its combustion does produce greenhouse gases, it is a more environmentally clean alternative to those fuels, and it is much safer than other fuels in the event of a spill (natural gas is lighter than air, and disperses quickly when released). CNG may also be mixed with biogas, produced from landfills or wastewater, which doesn't increase the concentration of carbon in the atmosphere. CNG is made by compressing natural gas (which is mainly composed of methane [CH4J), to less than 1% of the volume it occupies at standard atmospheric pressure.

Biofuels A biofuel is a type of fuel whose energy is derived from biological carbon fixation. Biofuels include fuels derived from biomass conversion, as well as solid biomass, liquid fuels and various biogases. Biofuels are gaining increased public and scientific attention, driven by factors such as oil price hikes and the need for increased energy security. Bioethanol is an alcohol made by fermentation, mostly from carbohydrates produced in sugar or starch crops such as corn or sugarcane. Cellulosic biomass, derived from non-food sources, such as trees and grasses, is also being dew-'Thoed as a feedstock for ethanol production. Ethanol can be used as a fuel for vehicles pure form, but it is usually used as a gasoline additive to increase octane and improve vehicle emissions.

Biodiesel is made from vegetable oils and animal fats. Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates. carbon monoxide, and hydrocarbons from diesel-powered vehicles.. Biodiesel is produced from oils or fats using transesterification, i.e., by chemically reacting lipids (e.g., vegetable oil, animal fat (tallow)) with an alcohol producing fatty acid esters.

Petrochemicals Petroleum and natural gas are excellent sources for the manufacture of a large number of compounds called petrochemicals. The important petrochemicals, which serve as building blocks for products like plastics, synthetic fibres, rubber, detergents, pesticides, dyes, drugs, etc., are obtained directly or indirectly from petroleum.

Soaps and Detergents Soap A soap is the sodium or potassium salt of a long chain carboxylic acid (fatty acid) which has cleansing properties in water. A soap has a large non-ionic hydrocarbon group and an ionic group, C00-11a+. Examples: Sodium stearate (CI7H35COONa) and sodium palmitate (C15H31COONa). A soap is the salt of a strong base and a weak acid, so a solution of soap in water is basic in nature. Soaps are biodegradable. Sodium soaps are hard in consistency and are called hard soaps. Potassium soaps are soft in consistency and are called soft soaps. Shampoos and shaving creams contain potassium soaps. Soap is manufactured by the hydrolysis of oils and fats with sodium or potassium hydroxide. Animal fats or vegetable oils like castor oil, cotton seed oil, soyabeen oil, linseed oil, coconut oil, palm oil and olive oil are used for making soaps. Sometimes, common salt (sodium chloride) is added to precipitate out all the soap from the solution. ThisIS- known as 'salting out'. On adding common salt, the solubility of soap in water decreases due to which it separates out easily.

Cleansing Action of Soap Soaps are molecules in which the two ends have differing properties, one is hydrophilic,that is, it dissolves in water, while the other end is hydrophobic, that is, it dissolves in hydrocarbons. When soap is at the surface of water, the hydrophobic 'tail' of soap will not be soluble in water and the soap will align along the surface of water with the ionic end in water and the hydrocarbon 'tail' protruding out of water. Inside water, these molecules have a unique orientation that keeps the hydrocarbon portion out of the water. This is achieved by forming clusters of molecules in which the hydrophobic tails are in the interior of the cluster and the ionic ends are on the surface of the cluster. This formation is called a micelle. Soap in the form of a micelle is able to clean, since the oily dirt will be collected in the centre of the micelle, due to the presence of hydrophobic tails. The micelles stay in solution as a Soap molecules Soap molecules colloid and will not come together Dirt particie i' -to precipitate because of ion-ion (011or Draftee) repulsion. Thus, the dirt suspended in the micelles is also Water

Soap is not suitable for washing clothes with hard water. The calcium and magnesium ions present in hard water form insoluble calcium and magnesium salts of fatty acids with soaps. This insoluble precipitate, known as scum, makes cleaning of clothes difficult and also harms the fabric.

Detergents A detergent (also called synthetic detergent) is the sodium salt of a long chain benzene sulphonic acid or the sodium salt of a long chain alkyl hydrogen sulphate. which has cleansing properties in water. Detergents are also called soap-less soap. They are better cleansing agents than soaps because they do not form insoluble calcium and magnesium salts with -hard water. They can, therefore, be used for washing even with hard water.

The cleansing action of a detergent is similar to that of soap. Detergents are usually used to make washing powders and shampoos. Some of the detergents (which have branched chains) are not biodegradable. They are called hard detergents. Biode-gradable detergents are called soft detergents. Non-biodegradable detergents cannot be decomposed by micro-organisms like bacteria in sewage discharge. Therefore, they cause water-pollution. Detergents have a stronger cleansing action than soaps. Deter-gents are also more soluble than soaps.

Synthetic detergents are of three types: Sodium alkyl sulphates and sodium alkylbenzene sulphonates are called anionic detergents. Alkyl benzene sulphonates with straight chain alkyl groups are called LAS detergents (Linear Alkyl Sulphonates) while those having branched chains are called ABS detergents (Alkyl Benzene Sulphonates). • Quaternary ammonium salts containing one or more long chain alkyl groups are called cationic detergents (or invert soaps). They are extensively used as germicides. Example: cetyltrimethylammonium bromide (used in hair conditioners).

ENVIRONMENTAL CHEMISTRY

Environmental chemistry deals with the study of the origin, transport, reactions, effects and fates of chemical species in the environment.

Atmospheric Pollution The atmosphere that surrounds the earth is not of the same thickness at all heights. There are concentric layers of air or regions and each layer has different density. The lowest region of atmosphere in which the human beings along with other organisms live is called troposphere. It extends up to the height of about 10 km from sea level. Above the troposphere, between 10 and 50 km above sea level lies stratosphere. Troposphere is a turbulent, dusty zone containing air, much water vapour and clouds. This is the region of strong air movement and cloud formation. The stratosphere, on the other hand, • contains dinitrogen, dioxygen, ozone and little water vapour. Atmospheric pollution is generally studied as tropospheric and stratospheric pollution. The presence of ozone in the stratosphere prevents about 99.5 per cent of the sun's harmful ultraviolet (UV) radiations from reaching the earth's surface and thereby protecting humans and other animals from its effect.

Tropospheric Pollution

Tropospheric pollution occurs due to the presence of undesirable solid or gaseous particles in the air. The following are the major gaseous and particulate pollutants present in the troposphere: • Gaseous air pollutants: These are oxides of sulphur, nitrogen and carbon, hydrogen sulphide, hydrocarbons, ozone and other oxidants. • Particulate pollutants: These are dust, mist, fumes, smoke, smog etc.

1**. Gaseous Air Pollutants (a) Oxides of Sulphur:** Oxides of sulphur are produced when sulphur containing fossil fuel is burnt. The most common species, sulphur dioxide, is a gas that is poisonous to both animals and plants. It has been reported that even a low concentration of sulphur dioxide causes respiratory diseases e.g., asthma, bronchitis, emphysema in human beings. Sulphur dioxide causes irritation to the eyes, resulting in tears and redness. High concentration of SO2 leads to stiffness of flower buds which eventually fall off from plants. Uncatalysed oxidation of sulphur dioxide is slow. However, the presence of particulate matter in polluted air catalyses the oxidation of sulphur dioxide to sulphur trioxide.

(b) Oxides of Nitrogen: Dinitrogen and dioxygen are the main constituents of air. These gases do not react with each other at a normal temperature. At high altitudes when lightning strikes, they combine to form oxides of nitrogen. NO2 is oxidised to nitrate ion, NO3- which is washed into soil, where it serves as a fertilizer. In an automobile engine, (at high temperature) when fossil fuel is burnt, dinitrogen and dioxygen combine to yield significant quantities of nitric oxide (NO) and nitrogen dioxide (NO2). The irritant red haze in the traffic and congested places is due to oxide's of nitrogen. Higher concentrations of NO2 damage the leaves of plants and retard. the rate of photosynthesis. Nitrogen dioxide is a lung irritant that can lead to an acute respiratory disease in children. It is toxic to living tissues also. Nitrogen dioxide is also harmful to various textile fibres and metals.

(c) Hydrocarbons: Hydrocarbons are composed of hydrogen and carbon only and are formed by incomplete combustion of fuel used in automobiles. Hydrocarbons are carcinogenic, i.e., they cause cancer. They harm plants by causing ageing, breakdown of tissues and shedding of leaves, flowers and twigs.

(d) Oxides of Carbon (i) Carbon monoxide: Carbon monoxide (CO) is one of the most serious air pollutants. It is a colourless and odourless gas, highly poisonous to living beings because of its ability to block the delivery of oxygen to the organs and tissues. It is produced as a result of incomplete combustion of carbon. Carbon monoxide is mainly released into the air by automobile exhaust. Other sources, which produce CO, involve incomplete combustion of coal, firewood, petrol, etc. The number of vehicles has been increasing over the years all over the world. Many vehicles are poorly maintained and several have inadequate pollution control equipments resulting in the release of greater amount of carbon monoxide and other polluting gases.

Carbon monoxide binds to haemoglobin to form carboxyhaemoglobin, which is about 300 times more stable than the oxygen-haemoglobin complex. In blood, when the concentration of carboxyhaemoglobin reaches about 3-4 per cent, the oxygen carrying capacity of blood is greatly reduced. This oxygen deficiency, results into headache, weak eyesight, nervousness and cardiovascular disorder. This is the reason why people are advised not to smoke. In pregnant women who have the habit of smoking the increased CO level in blood may induce premature birth, spontaneous abortions and deformed babies. (ii) Carbon dioxide: Carbon dioxide (CO2) is released into the atmosphere by respiration, burning of fossil fuels for energy, and by decomposition of limestone during the manufacture of cement. It is also emitted during volcanic eruptions. Carbon dioxide gas is confined to troposphere only. Normally it forms about 0.03 per cent by volume of the atmosphere. With the increased use of fossil fuels, a large amount of carbon dioxide gets released into the atmosphere. Excess of CO2 in the air is removed by green plants and this maintains an appropriate level of CO2 in the atmosphere. Green plants require CO2 for photosynthesis and they, in turn, emit oxygen, thus maintaining the delicate balance. Deforestation and burning of fossil fuel increases the CO2 level and disturb the balance in the atmosphere. The increased amount of CO2 in the air is mainly responsible for global warming.

2. Particulate Air Pollutants Particulates pollutants are the minute solid particles or liquid droplets in air. These are present in vehicle emissions, smoke particles from fires, dust particles and ash from industries. Particulates in the atmosphere may be viable or non-viable. The viable particulates e.g., bacteria, fungi, moulds, algae etc., are minute living

organisms that are dispersed in the atmosphere. Human beings are allergic to some of the fungi found in air. They can also cause plant diseases. Non-viable particulates may be classified according to their nature and size as follows: • Smoke particulates consist of solid or mixture of solid and liquid particles formed during combustion of organic matter. Examples are cigarette smoke, smoke from burning of fossil fuel, garbage and dry leaves, oil smoke etc.

• Dust is composed of fine solid particles (over 1 pm in diameter), produced during crushing, grinding and attribution of solid materials. Sand from sand blasting, saw dust from wood works, pulverized coal, cement and fly ash from factories, dust. storms etc., are some typical examples of this type of particulate emission. • Mists are produced by particles of spray liquids and by condensation of vapours in air. Examples are sulphuric acid mist and herbicides and insecticides that miss their targets and travel through air and form mists. • Fumes are generally obtained by the condensation of vapours during sublimation, distillation, boiling and several other chemical reactions. Generally, organic solvents, metals and metallic oxides form fume particles.

The effect of particulate pollutants are largely dependent on the particle size. Air-borne particles such as dust, fumes, mist etc., are dangerous for human health. Particulate pollutants bigger than 5 microns are likely to lodge in the nasal passage, whereas particles of about 10 micron enter into lungs easily.

Lead used to be a major air pollutant emitted by vehicles. Leaded petrol used to be the primary source of air-borne lead emission in Indian cities. This problem has now been overcome by using unleaded petrol in most of the cities in India. Lead interferes with the development and maturation of red blood cells.

Smog The word smog is derived from smoke and fog. This is the most common example of air pollution that occurs in many cities throughout the world. There are two types of smog: • Classical smog occurs in cool humid climate. It is a mixture of smoke, fog and sulphur dioxide. Chemically it is a reducing mixture and so it is also called as reducing smog.

• Photochemical smog occurs in warm, dry and sunny climate. The main components of the photochemical smog result from the action of sunlight on unsaturated hydrocarbons and nitrogen oxides produced by automobiles and factories. Photochemical smog has high concentration of oxidising agents and is, therefore, called as oxidising smog.

Formation of photochemical smog When fossil fuels are burnt, a variety of pollutants are emitted into the earth's troposphere. Two of the pollutants that are emitted are hydrocarbons (unburnt fuels) and nitric oxide (NO). When these pollutants build up to sufficiently high levels, a chain reaction occurs from their interaction with sunlight in which NO is converted into nitrogen dioxide (NO2). This NO2 in turn absorbs energy from sunlight and breaks up into nitric. oxide and free oxygen atom.

NO2 (g) NO(g) + 0(g) Oxygen atoms are very reactive and combine with the 02 in air to produce ozone. The ozone formed, reacts rapidly with the NO (g) formed initially to regenerate NO2. NO2 is a brown gas and at sufficiently high levels can contribute to haze. Ozone is a toxic gas and both NO2 and 03 are strong oxidising agents and can react with the unburnt hydrocarbons in the polluted air to produce chemicals such as formaldehyde, acrolein and peroxyacetyl nitrate (PAN). Effects of photochemical smog The common components of photochemical smog are 'ozone, nitric oxide, acrolein, formaldehyde and peroxyacetyl nitrate (PAN). Photochemical smog causes serious health problems. Both ozone and PAN act as powerful eye irritants. Ozone and nitric oxide irritate the nose and throat and their high concentration causes headache, chest pain, dryness of the throat, cough and difficulty in breathing. Photochemical smog leads to cracking of rubber and extensive damage to plant life. It also causes corrosion of metals, stones, building materials, rubber and painted surfaces.

How can photochemical smog be controlled? Many techniques are used .to control or reduce the formation of photochemical smog. If we control the primary precursors of photochemical smog, such as NO2 and hydrocarbons, the secondary precursors such as ozone and PAN, the photochemical smog will automatically be reduced. Usually catalytic converters are used in the automobiles, which prevent the release of nitrogen oxide and hydrocarbons to the atmosphere. Certain plants e.g., Pinus, Juniparus, Quercus, Pyrus and Vitis can metabolise nitrogen oxide and therefore, their plantation could help in this matter.

Stratospheric Pollution Formation and Breakdown of Ozone The upper stratosphere consists of considerable amount of ozone (03), which protects us from the harmful ultraviolet (UV) radiations (A 255 nm) coming from the sun. These radiations cause skin cancer (melanoma) in humans. Therefore, it is important to maintain the ozone shield. Ozone in the stratosphere is a product of UV radiations acting on dioxygen (02) molecules. The UV radiations split apart molecular oxygen into free oxygen (0) atoms. These oxygen atoms combine with the molecular oxygen to form ozone.

Ozone is thermodynamically unstable and decomposes to molecular oxygen. Thus, a dynamic equilibrium exists between the production and decomposition of ozone molecules. In recent years, there have been reports of the depletion of this protective ozone layer because of the presence of certain chemicals in the stratosphere. The main reason of ozone layer depletion is believed to be the release of chlorofluorocarbon compounds (CFCs), also known as freons. These compounds are nonreactive, non flammable, non toxic organic molecules and therefore used in refrigerators, air conditioners, in the production of plastic foam and by the electronic industry for cleaning computer parts etc. Once CFCs are released in the atmosphere, they mix with the normal atmospheric gases and eventually reach.