JK Chrome

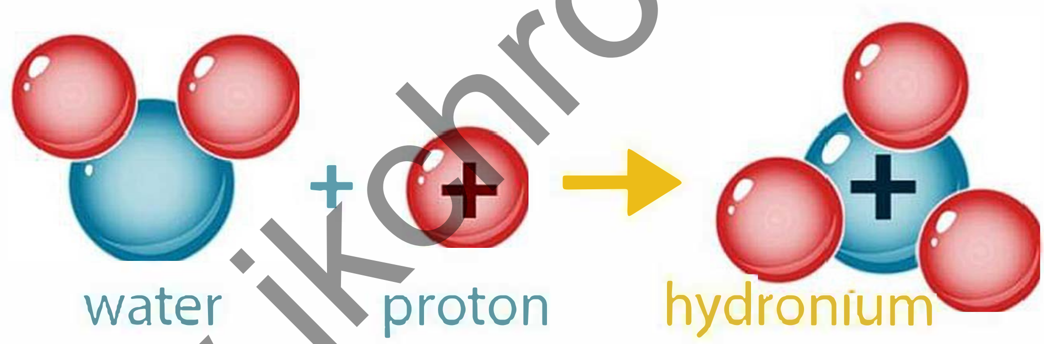
NCERT Summary

Summary of Chemistry- 1

Acid, Base and Salts

1. Acid

- The word 'acid' is derived from a Latin word, which means "sour". The sour taste of most of the fruits and vegetables is due to various types of acids present in them. The digestive fluids of most animals and humans also contain acids.
- An acid is a compound, which on dissolving in water yields **hydronium ions** (H_3O^+) as the only positive ions. The characteristic property of acid is due to the presence of these hydronium ions.



-
- Acids are compounds that contain Hydrogen (Hydrochloric, **HCl**; **Sulphuric, H_2SO_4**; **Nitric, HNO_3**). However, not all compounds that contain Hydrogen are acids (**Water, H_2O**; **Methane, CH_4**). Acids are usually compounds of non-metals with **Hydrogen** and sometimes **Oxygen.**
- <u>Acids can be classified in various ways, depending on the factors mentioned below:</u>
  (i) Classification Based on the Strength of the acid.
  (ii) Classification Based on the Basicity of the Acid.
  (iii) Classification Based on the Concentration of the acid.
  (iv) Classification Based on the presence of Oxygen.

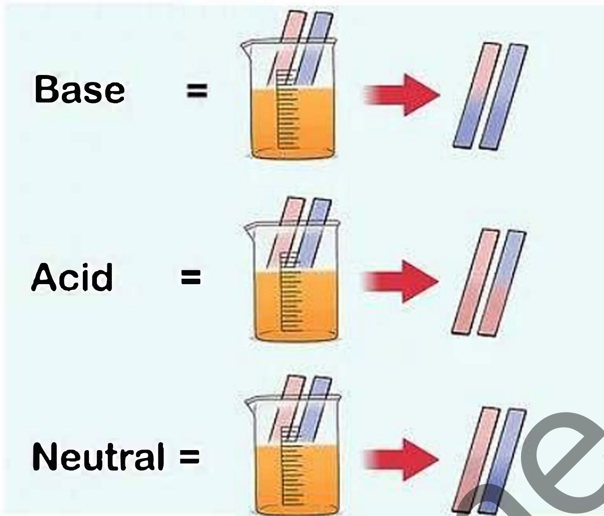
- The strength of an **acid** depends on the concentration of the **hydronium ions** present in a solution. The greater the number of hydronium ions present, greater is the **strength of acid**. **However**, some acids do not dissociate to any appreciable extent in water such as carbonic acid. **Therefore**, these acids will have a low concentration of **hydronium ions**.
- **Strong Acid:** An acid, which dissociates **completely** or almost completely in water, is classified as a strong acid. It must be noted that in these acids all the **hydrogen ions** (H^+) combine with water molecule and exist as **hydronium ions** (H_3O^+).
  Examples of strong acids are: Hydrochloric acid, Sulphuric acid, Nitric acid etc.
- **Weak Acid:** An acid that dissociates only **partially** when dissolved in water, is classified as a weak acid. Most of the molecules remain in solution in molecular form itself in **such acid**.
  Examples: Acetic acid, Formic acid, Carbonic acid, etc.

STRONG	· *High [ions] = strong electrolyte* · *High [ions] = greater / faster reaction rate (greater chance of collisions)* · *High [H^+] = low pH value*
WEAK	· *Low [ions] = weak electrolyte* · *Low [ions] = slower reaction rate (less chance of collisions)* · *Low [H+] = higher pH value*

Comparing strong and weak acids

- Acids are generally sour in taste. Special types of substances are used to test whether a substance is acidic or basic. These substances are known as indicators. The indicators change their color when added to a solution containing an acidic or a **basic substance**. **Turmeric**, **litmus**, china rose petals (Gudhal), etc., are some of the naturally occurring indicators.
- The most commonly used natural indicator is **litmus**. It is extracted from lichens. It has a mauve (purple) color in **distilled water**. When added to an acidic solution, it turns red and when added to a **basic solution**, it turns

blue. It is available in the form of a solution, or in the form of strips of paper, known as **litmus paper**. Generally, it is available as red and blue litmus paper.



Change in color of litmus paper

- The solutions which do not change the color of either red or **blue litmus** are known as **neutral solutions**. These substances are neither acidic nor basic.
- Acids are corrosive and can **burn flesh** and **dissolve metal**.

2. Bases and Alkalis

- A Base is a substance that gives OH ions when dissolved in water. Bases are usually **metal hydroxides** (MOH). **Examples** include Sodium Hydroxide, NaOH, Calcium Hydroxide, $Ca(OH)_2$. The solution of a base in water is called an **alkali**.
- Bases and acids neutralize each other, therefore another way to define a base is a compound that reacts with an acid to give salt and water only. Like acids, alkalis can be strong or weak. The **more hydroxide ions** they produce, **the stronger the alkali**.
- The acidic property of an acid is due to the presence of **hydrogen ions** (H^+) while that of a base or alkali, is due to the presence of hydroxyl (OH^-) ions in them. When an acid and base (alkali) combine, the positively charged hydrogen ion of the acid combines with the **negatively charged hydroxyl ion** of the base to form a molecule of water. Hence, the water molecule formed does not have any charge because the positive and negative charges of the **hydrogen ions and hydroxyl ions get neutralized**.

- The strength of a base depends on the concentration of the hydroxyl ions when it is dissolved in **water**.
  (i) Strong Base: A base that dissociates completely or almost completely in water is classified as a strong base. The greater the number of hydroxyl ions the base produces, the stronger is the base.
  Examples: Sodium hydroxide: NaOH, Potassium hydroxide: KOH, Calcium hydroxide: Ca $(OH)_2$.
  (ii) Weak Base: A base that dissociates in water only partially is known as a weak base.
  Examples: Magnesium hydroxide: $Mg(OH)_2$, Ammonium hydroxide: NH_4OH.
- Bases are bitter to taste. They are soapy and slippery to touch. Strong alkalis like sodium hydroxide and potassium hydroxide are highly corrosive or caustic in nature. Sodium hydroxide and potassium hydroxide are commonly called caustic soda and caustic potash respectively. Organic tissues like skin, etc. get completely corroded by these two alkalis. However, the other alkalis are only mildly corrosive.

3. PH

- A scale for measuring hydrogen ion concentration in a solution, called pH scale has been developed. The p in pH stands for 'potenz' in German, meaning power. On the pH scale we can measure pH from 0 (very acidic) to 14 (very alkaline). pH should be thought of simply as a number that indicates the acidic or basic nature of a solution. Higher the hydronium ion concentration, lower is the pH value. The pH of a **neutral solution** is 7.
- **Values less** than 7 on the pH scale represent an acidic solution. As the pH **value increases** from **7 to 14**, it represents an increase in OH^- ion concentration in the solution, that is, increase in the strength of alkali. Generally paper impregnated with the universal indicator is used for measuring pH.
- There are chemicals that change color at different pH values. These are called indicators. One of the most famous is Litmus. This substance turns red when the pH is less than 7 (acidic) and turns blue when the pH is greater than 7 (basic).

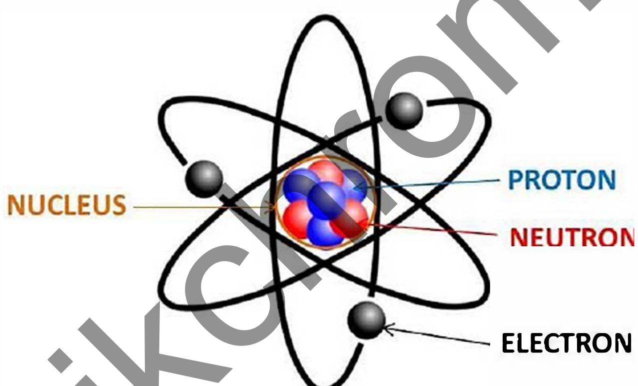
4. Salts

- A Salt results when an acid reacts with a base. Both are **neutralized**. The **H^+ and OH^-** ions combine to form water. The non-metallic ions of the acid and the metal ions of the base form the **salt**.

- Important salts used in everyday life and industrial applications are **Sodium chloride** ($NaCl$), **Sodium carbonate**, (Na_2CO_3), **Sodium Bicarbonate**, ($NaHCO_3$), **Sodium Hydroxide** ($NaOH$).
- The salt ions normally stay in the solution. The **salt crystallizes** out when the water is removed. Some salts are **insoluble**. They will precipitate out when the acid and base are added together.
- Salts of a strong acid and a strong base are neutral with pH value of 7. On the other hand, salts of a strong acid and weak base are acidic with pH values less than 7 and those of a strong base and weak acid are basic in nature, with pH values more than 7.

Atomic Structure

An atom is the smallest particle of the element that can exist independently and retain all its chemical properties. Atoms are made up of fundamental particles: **Electrons**, **Protons**, and **Neutrons**.



An atom

➢ Dalton's Atomic Theory

John Dalton provided a simple theory of matter to provide theoretical justification to the laws of chemical combinations in 1805.

<u>The basic postulates of the theory are:</u>

- All substances are made up of tiny, **indivisible particles** called **atoms**.
- Atoms of the same element are identical in shape, size, mass and other properties.
- Each element is composed of its own kind of atoms. Atoms of different elements are different in all respects.
- Atom is the smallest unit that takes part in chemical combinations.

- Atoms combine with each other in simple whole-number ratios to form compound atoms called **molecules**.
- Atoms cannot be created, divided, or destroyed during any chemical or physical change.

➢ Representation of an Atom by a Symbol

- Dalton was the first scientist to use the symbols for elements in a very specific sense. When he used a symbol for an element he also meant a definite quantity of that element, that is, one atom of that element.
- A symbol signifies a shorthand representation of an atom of an element. The symbol of any element is based on the English name or Latin name (written in English alphabets) and many of the symbols are the first one or two letters of the element's name in English. The first letter of a symbol is always written as a capital letter (uppercase) and the second letter as a small letter (lowercase).

  Examples:

  (i) Hydrogen- **H**

  (ii) Aluminum- **Al** and not AL

  (iii) Cobalt- **Co** and not CO.

  Symbols of some elements are formed from the first letter of the name and a letter, appearing later in the name.

  Examples:

  (i) Chlorine - **Cl**

  (ii) Zinc - **Zn**
- Other symbols have been taken from the names of elements in Latin, German, or Greek.

  Examples:

  (i) The symbol of iron is Fe from its Latin name **Ferrum.**

  (ii) Sodium is Na from **Natrium**.

  (iii) Potassium is K from **Kalium.**

  Therefore, each element has a name and a **unique chemical symbol**.

➢ Size of the Atom/ Elements

- Atoms are very small, they are smaller than anything that we can imagine or compare with. One hydrogen atom, the smallest atom known is approximately 5 x 10 mm in diameter. Atomic radius is measured in nanometres. 1 m = 10^9 nm.

➢ Atomic Mass

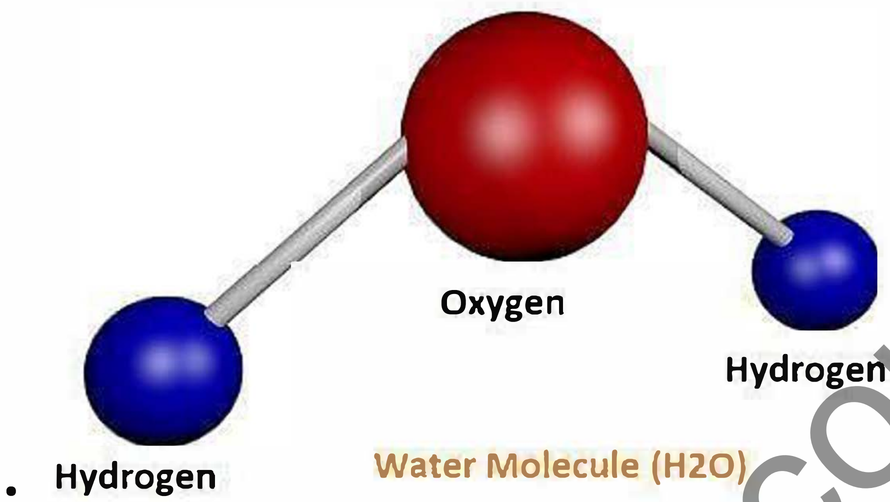
- The mass of a particular atom is taken as a standard unit and the masses of other atoms are related to this standard. Hydrogen is the lightest element and is the smallest atom was chosen and assumed to have a mass of 1. An atom of hydrogen was assigned an atomic mass equal to one atomic mass unit (**A.M.U**).
- The number does not signify the mass of an atom in grams. It is just a pure number. The masses of atoms of other elements were compared to that of hydrogen, in order to find their atomic mass relative to it. If one atom of Sulphur weighs as much as **32 atoms** of hydrogen, then the relative atomic mass of Sulphur is 32 **A.M.U**.
- This way of defining the mass of one atom of hydrogen has its difficulties. While the mass of one atom of hydrogen is considered as 1 atomic mass unit, hydrogen gas in its natural state has 3 isotopes of atomic mass 1, 2 and 3 respectively. Thus average mass works out to be 1.00 **A.M.U** rather than 1 **A.M.U.** This in turn complicates the atomic masses of all other elements.
- Later on, an atom of oxygen was preferred as standard by taking its mass as 16 units.
- However, in 1961 for a universally accepted atomic mass unit, carbon-12 isotope was chosen as the standard reference for measuring atomic masses.

One atomic mass unit is a mass unit equal to exactly one twelfth (1/12th) the mass of one atom of carbon-12.

- The relative atomic masses of all elements have been found with respect to an atom of carbon-12. It is equal to 1.66×10^{-24}g.

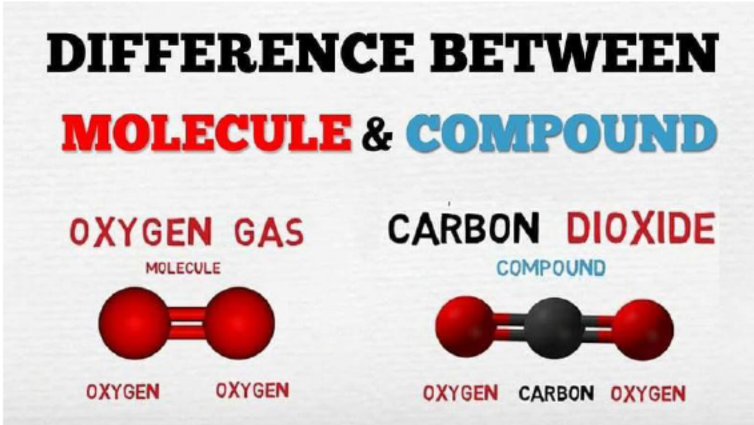
➢ Molecule

- A molecule is in general, **a group of two or more atoms** that are chemically bonded together, that is, tightly held together by attractive forces.
- A molecule can be defined as the smallest particle of an element or a compound that is capable of independent existence and shows all the properties of that substance.
- Atoms of the same element or of different elements can join together to form molecules.
-
-
-



Water Molecule (H2O)

- The molecules of an element are constituted by the same type of atoms. Molecules of many elements, such as Argon (Ar), helium (He) etc. are made up of only one atom of that element. But this is not the case with most of the nonmetals.
  Example: A molecule of oxygen consists of two atoms of oxygen and hence it is known as a diatomic molecule, O_2. If 3 atoms of oxygen unite into a molecule, instead of the usual 2, we get ozone. The number of atoms constituting a molecule is known as its **atomicity**.
- Atoms of different elements join together in definite proportions to form molecules of **compounds**. Compounds composed of metals and nonmetals contain charged species. The charged species are known as **ions**.
- An ion is a charged particle and can be **negatively** or **positively charged**. A negatively charged ion is called an 'anion' and the positively charged ion, a 'cation'. Take, for example, **sodium chloride** (NaCl). Its constituent particles are positively charged sodium ions (Na^+) and negatively charged chloride ions (Cl^-). Ions may consist of a single charged atom or a group of atoms that have a net charge on them.
- A group of atoms carrying a charge is known as a **polyatomic ion**.



➢ **Chemical Formulae**

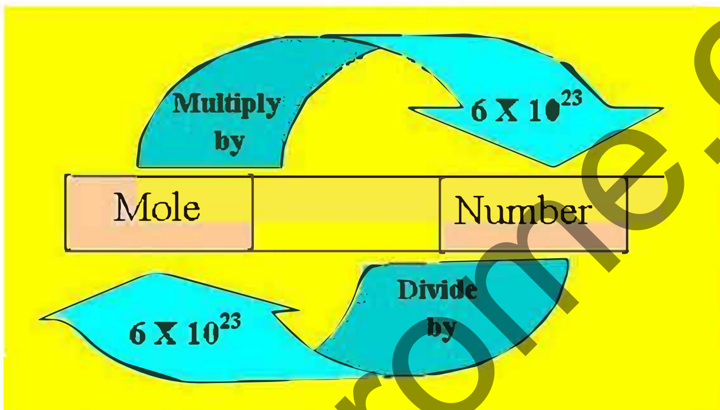
- The chemical formula of a compound is a symbolic representation of its composition. The chemical formulae of different compounds can be written easily.
- The combining power (or capacity) of an element is known as its **valency**. Valency can be used to find out how the atoms of an element will combine with the atom(s) of another element to form a chemical compound. The valency of the atom of an element can be thought of as hands or arms of that atom.
- The simplest compounds, which are made up of two different elements are called **binary compounds**. While writing the Chemical formula for compounds, we write the constituent elements and their valencies. Then we must crossover the valencies of the combining atoms.
- The formulae of ionic compounds are simply the whole number ratio of the positive to negative ions in the structure.

➢ **Molecular Mass**

- The molecular mass of a substance is the sum of the atomic masses of all the atoms in a molecule of the substance. It is therefore the relative mass of a molecule expressed in **atomic mass units** (u).
- The **formula unit mass** of a substance is a sum of the atomic masses of all atoms in a formula unit of a compound. Formula unit mass is calculated in the same manner as we calculate the molecular mass. The only difference is that we use the word formula unit for those substances whose constituent particles are ions.
- Scientists use the relative atomic mass scale to compare the masses of different atoms of elements. **Atoms of carbon-12 isotopes** are assigned a relative atomic mass of 12 and the relative masses of all other atoms are obtained by comparison with the mass of a carbon-12 atom.

➢ Mole Concept

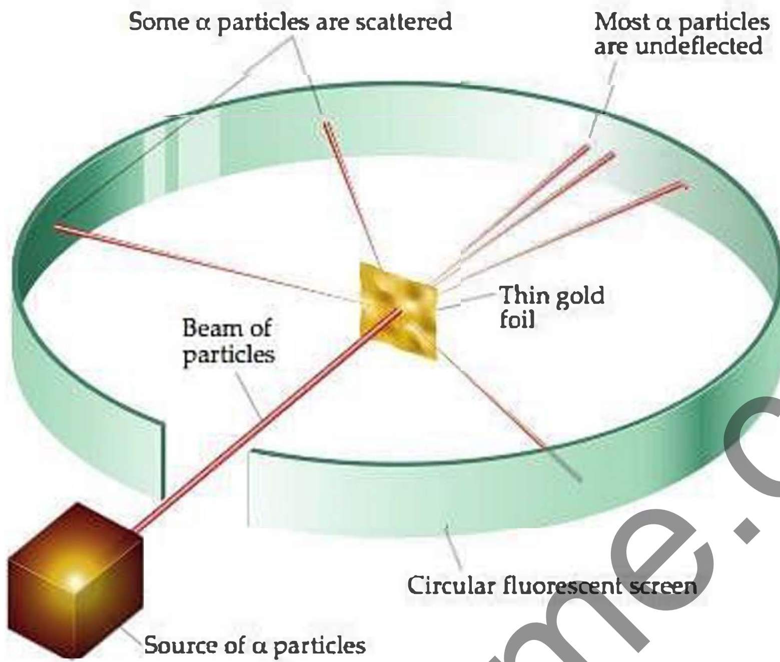
- Since it is not possible to calculate the weight of particles individually, a collection of such particles called mole is taken for all practical purposes. It was discovered that the number of atoms present in 12g of carbon of 12C isotope is 6.023×10^{23} atoms. This is referred to as **Avogadro number** after the discoverer Avogadro.
- A mole of a gas is the amount of a substance containing **6.023×10^{23} particles.** It is a basic unit of the amount or quantity of a substance. The substance may be atoms, molecules, ions or group of ions.



- Mass of 1 mole of a substance is called its molar mass. One mole of any gas at STP will have a volume of 22.4 L. This is called the **molar volume.**
- Credit for the discovery of electron and proton goes to J.J. Thomson and E. Goldstein, respectively. J.J. Thomson proposed that electrons are embedded in a positive sphere.

➢ Rutherford's Model of the Atom

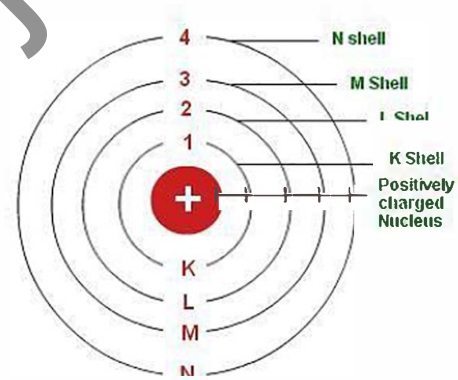
Rutherford's alpha-particle scattering experiment led to the discovery of the atomic nucleus. Rutherford's model of the atom proposed that a very tiny nucleus is present inside the atom and electrons revolve around this nucleus. The stability of the atom could not be explained by this model.



Rutherford's Alpha-particle Scattering Experiment

➢ Neils Bohr's Model

- Neils Bohr's model of the atom was more successful. He proposed that electrons are distributed in different shells with discrete energy around the nucleus. If the atomic shells are complete, then the atom will be stable and less reactive.



Neil's Bohr's Model of the Atom

➢ J. Chadwick Discovery

- J. Chadwick discovered presence of neutrons in the nucleus of an atom.
  So, the three sub-atomic particles of an atom are:
  (i) Electrons
  (ii) Protons
  (iii) Neutrons
  Electrons are negatively charged, protons are positively charged and neutrons have no charges.
- The discovery of the electron, proton, and neutron was the starting point of new avenues of research in science, which gave physicists an insight into the structure and nature of the atoms of matter. An atom is made up of three elementary particles, namely electrons, protons, and neutrons.
- Electrons have a negative charge, protons have a positive charge and neutrons have no charge. Neutrons are neutral. Due to the presence of equal number of negative electrons and positive protons the atom as a whole is electrically neutral.
- Based on the above findings, one can say that the atom has two major divisions:
  (i) The **first** is the centre of an atom, called its **nucleus**. The protons and neutrons are located in the small nucleus at the centre of the atom. Due to the presence of protons the nucleus is positively charged.
  (ii) The **second** are electrons, which revolve around the nucleus in different shells (or orbits). Shells of an atom are designated as K, L, M, N,…. The space around the nucleus in which the electrons revolve determines the size of the atom.
- The maximum number of electrons present in a shell is given by the formula $\mathbf{2n^2}$, where 'n' is the orbit number or energy level index, 1,2,3,…so on.
- Hence, the maximum number of electrons in different shells are as follows:
  (i) First orbit or K-shell will be = 2.12 = 2
  (ii) Second orbit or L-shell will be = 2.22 = 8
  (iii) Third orbit or M-shell will be = 2.32 = 18
  (iv) Fourth orbit or N-shell will be = 2.42= 32, and so on.
- The maximum number of electrons that can be accommodated in the outermost orbit is 8. Electrons are not accommodated in a given shell unless the inner shells are filled. That is, the shells are filled in a step-wise manner.

➢ Valency

- The electrons present in the outermost shell of an atom are known as the **valence electrons**. It is the decisive shell during a **chemical reaction**. The electrons of only this outermost shell are involved during chemical combinations, electrons are either given out from the outermost shell, or accepted into the outermost shell, or shared with the electrons in the outermost shell of another element.
- Elements having same number of valence electrons in their atoms possess similar chemical properties. The number of the valence shell in an atom determines its position in the Periodic Table i.e. the period to which the element belongs. Elements having 1, 2 or 3 electrons in the valence shell are metals. Exception is H and He. Elements having 4 to 7 electrons in their valence shell are non-metals.
- Valency is the combining capacity of an element. It is the number of electrons in an atom that actually take part in bond formation. For example, carbon atom with an atomic number 6 has 4 valence electrons.
- **Calculation of Valency:** The number of valence electrons is the valency of the element. The valency of an element can also be calculated by finding the number of electrons required to complete octet. If the outermost shell of an atom is completely filled, its valency = 0. The outermost shells of the noble gases helium, neon, argon, krypton etc. are completely filled. Hence their valency is zero. Such elements are very un-reactive and inert by nature.

➢ Atomic Number

- The nuclei of atoms is made up of protons and neutrons. These two components of the nucleus are referred to as nucleons. The electrons occupy the space outside the nucleus.
- Since an atom is electrically neutral, the number of protons in the nucleus is exactly equal to the number of electrons. This number is the atomic number given by the symbol Z.

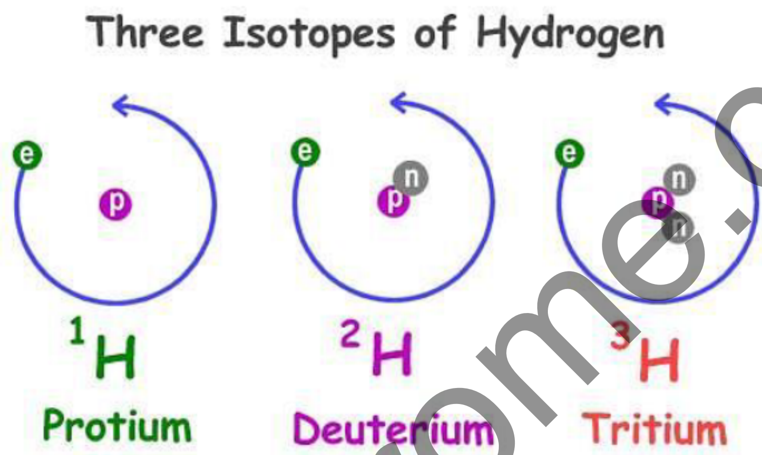
➢ Mass Number

- The total number of protons and neutrons present in one atom of an element is known as its mass number.

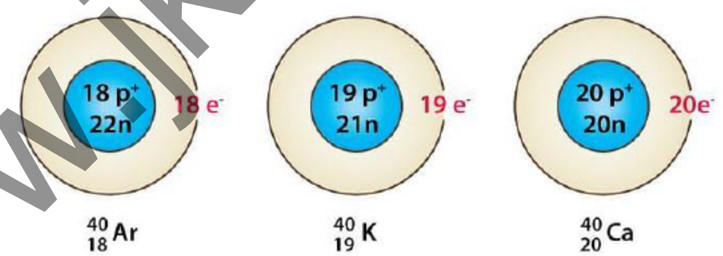
Mass number = Number of protons + Number of neutrons

- **Isotopes:** Isotopes are atoms of the same element, which have different mass numbers. It is interesting to note that atoms of a given atomic number can have different numbers of neutrons. For example, take the case of hydrogen atom, it has three atomic species, namely protium (11 H), deuterium (21 H or D) and tritium (31 H or T). The atomic number of each one is 1, but the mass number is 1, 2 and 3, respectively.

- All isotopes of an element have the same number of valence electrons thus have identical chemical properties.
- The physical properties of the isotopes are different due to the difference in the number of neutrons in their nuclei. The densities, melting points and boiling points, etc., are slightly different.

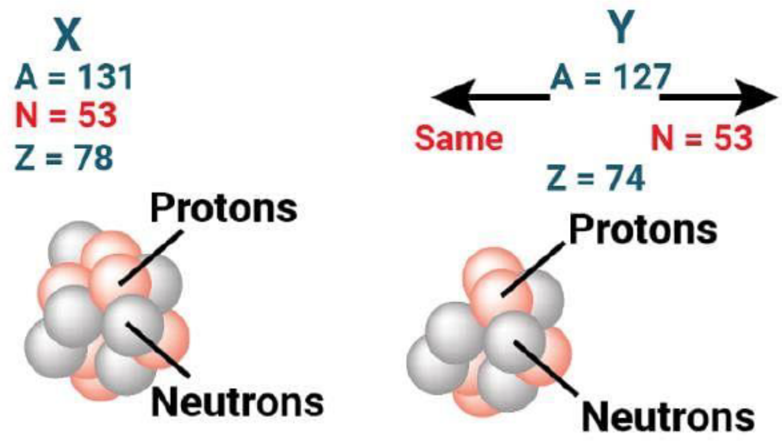


- **Isobars:** Atoms of different elements with different atomic numbers, which have the same mass number, are known as isobars. These have different number of protons but equal sum of number of protons and neutrons.



Isobars

- **Isotones:** The atoms of different elements, which have the same number of neutrons but different atomic numbers, are called **isotones.**

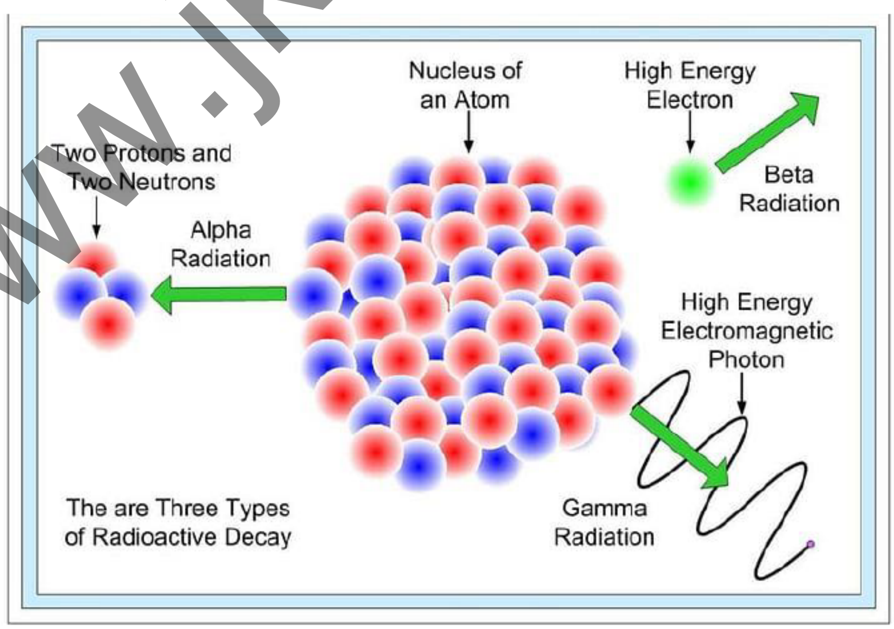


Isotones

➢ Radioactivity

- Radioactivity is a nuclear phenomenon. It is the spontaneous emission of radiation from the nucleus.
- In 1899, the study of radioactivity was taken up by **Ernest Rutherford**. He placed a little radium at the bottom of a small lead box and subjected the rays that emerged from it to the action of a very strong magnetic field at right angles to their direction. He found that the rays separated into three distinct constituents.

Rutherford called the three types of radiation **alpha** (α), **beta** (β), and **gamma** (γ) rays.



Three types of Radioactive Decay

- The **α-rays** were deflected in a direction opposite to that of **β-rays** and **α-rays** carried a positive charge, **β-rays** carried a negative charge and those which passed undeviated were neutral or uncharged were **γ-rays**.

CHEMICAL BONDING

- Atoms are made up of three smaller particles called protons, neutrons and electrons. The protons and neutrons are found in the nucleus of the atom. Protons have a single positive charge. This is called the Atomic Number of an atom. The Atomic Number tells us the number of electrons that the atom contains. It is these electrons that determine the chemical properties of the atom and the way it combines with other atoms to form specific compounds. Electrons have a single negative charge. Normally, atoms are electrically neutral so that the number of electrons is equal to the number of protons.
- Electrons orbit around the nucleus. Electrons cannot orbit the nucleus of an atom in any orbit. The electrons are restricted to specific paths called orbitals or shells. Each shell can only hold a certain number of electrons. When a shell is full, no more electrons can go into that shell. The key to the properties of atoms is the electrons in the outer shell. A complete outer shell of electrons is a very stable condition for an atom.
- **Valency:** Hydrogen is the simplest element. It has one electron. Its outer shell only holds two electrons. Valency can be simply defined as the number of Hydrogen atoms that an element can combine with. The atoms with full electron shells (Helium, Neon, Argon) are chemically inert forming few compounds. The atoms don't even interact with each other very much. These elements are gases with very low boiling points. The atoms with a single outer electron or a single missing electron are all highly reactive. Sodium is more reactive than Magnesium. Chlorine is more reactive than Oxygen. Generally speaking, the closer an atom is to having a full electron shell, the more reactive it is. Atoms with one outer electron are more reactive than those with two outer electrons, etc. Atoms that are one electron short of a full shell are more reactive than those that are two short.
- Chemical bonds are what hold atoms together to form the more complicated aggregates that we know as molecules and extended solids. The forces that hold bonded atoms together are basically just the same kinds of electrostatic attractions that bind the electrons of an atom to its

positively charged nucleus. chemical bonding occurs when one or more electrons are simultaneously attracted to two nuclei.

- Mainly 3 Types of bonds can be present in Chemical Compounds.

1. Electrovalent or Ionic Bond: It is formed by Transferring of Electrons between 2 Atoms. These types of bonds are mainly formed between Metals and Non - Metals. These compounds exist in solid form. These compounds have high boiling Point, Melting Point and thermal stability.

2. Covalent Bond: It is formed by equal sharing of Electrons between 2 Atoms. This type of bond is mainly formed between non - metals. These compounds may be solid, liquid or gas. These compounds have low boiling Point, Melting Point and thermal stability in comparison to Ionic Bond.

3. Co - Ordinate or Dative Bond: It is formed by unequal sharing of Electrons between 2 Atoms. This bond is also called as Semi - Polar bond since; it involves Electro valency and Covalency both. These compounds may be solid, liquid or gas. These compounds are insoluble in H_2O. These compounds do not conduct Electricity. These compounds have high B.P. than Covalent Compounds but less than Electrovalent Compounds.

CHEMICAL REACTIONS AND EQUATIONS

- Atoms and Molecules, Elements and Compounds: There are about a hundred different types of atoms in the Universe. Substances made up of a single type of atom are called Elements. Some elements are made up of single atoms: Carbon(C), Helium(He), Sodium(Na), Iron(Fe) etc. He, Fe, and Na are the Chemical Symbols of the elements.
- Some elements are made up of groups of atoms: Oxygen(O_2), Ozone(O_3), Chlorine(Cl_3) etc. These groups of atoms are called molecules.
- Molecules can also be made up of combinations of different types of atoms. These substances are called compounds: Common Salt(NaCl), Methane(CH_4), Ammonia(NH_3) etc. O_2, CH_4, NH_3 are the Chemical Formulas of Oxygen, Methane and Ammonia respectively. CH_4 means that a single molecule of methane contains one atom of Carbon and four atoms of Hydrogen. This chemical formula could have been written but the C_1H_4 is never written. Similarly, a molecule of Ammonia (NH_3) contains one atom of Nitrogen and three atoms of Hydrogen.

- A change in which one or more new substances are formed is called a chemical change. A chemical change is also called a chemical reaction. The change may conveniently be represented by a chemical equation.
- Chemical reactions occur when different atoms and molecules combine together and spit apart. For example, if Carbon (C) is burnt in Oxygen (O_2) to form Carbon Dioxide, a Chemical Reaction occurs. This reaction can be written: $C + O_2 \rightarrow CO_2$. This is called a Chemical Equation. The substances on the left hand side of the equation are called the Reactants. The substances on the right hand side are called the Products.
- There is one very important rule with chemical equations: The number of individual atoms on each side of the equation must be the same. On the left had side, there is an atom of Carbon and a molecule of Oxygen (containing two atoms). On the right hand side there is a molecule of carbon dioxide (containing one atom of carbon and two atoms of Oxygen). The number of atoms on the left hand side is equal to the number of atoms on the right hand side. All that has changed is the arrangement of the atoms. In a chemical reaction atoms are re-arranged; no atoms are destroyed or created.
- Hydrogen gas is mixed with Oxygen gas. If the mixture is sparked, it explodes to form water. This chemical reaction can be expressed as: $H_2 + O_2 \rightarrow H_2O$. On the left had side, there is a molecule of Hydrogen (containing two atoms) and a molecule of Oxygen (also containing two atoms). On the right hand side there is a molecule of water (containing two atoms of Hydrogen and one atom of Oxygen). The left hand side has one extra atom of Oxygen. This is not allowed by the Law of Conservation of Matter. Both sides must contain the same number o atoms. To make the equation conform, we must balance the equation. It is not possible to change the chemical formulas of the reactants or products. Water will always be H_2O. Balancing the equation is achieved by changing the number of molecules involved. The balanced form of the above equation is: $2H_2 + O_2 \rightarrow 2H_2O$. Now, on the left had side, there are two molecules of Hydrogen (each containing two atoms making four atoms) and a molecule of Oxygen (containing two atoms). On the right hand side there are two molecule of water (each containing two atoms of Hydrogen and one atom of Oxygen making a total of four atoms of Hydrogen and two of Oxygen). The equation is now balanced. In summary, when Hydrogen reacts with Oxygen, two molecules of Hydrogen react with one molecule of Oxygen to give two molecules of water.
- The reaction goes in both directions. While the Nitrogen and Hydrogen are combining to form Ammonia, Ammonia splits to form Hydrogen and Nitrogen. A mixture of all three substances results. This type of reaction

is called an Equilibrium and is represented by arrows going in both directions. $N_2 + 3H_2 \rightarrow 2NH_3$.

- It is possible to push the reaction in one direction by adding a Catalyst. A catalyst is a substance that helps a reaction without being used up. If Ammonia is removed from the equilibrium mixture, the reaction will move to produce more Ammonia so that equilibrium is attained.
- The total mass of the elements present in the products of a chemical reaction has to be equal to the total mass of the elements present in the reactants. In other words, the number of atoms of each element remains the same, before and after a chemical reaction.
- During a chemical reaction atoms of one element do not change into those of another element. Nor do atoms disappear from the mixture or appear from elsewhere. Actually, chemical reactions involve the breaking and making of bonds between atoms to produce new substances.
- In a combination reaction two or more substances combine to form a new single substance.
- Decomposition reactions are opposite to combination reactions. In a decomposition reaction, a single substance decomposes to give two or more substances.
- Reactions in which heat is given out along with the products are called exothermic reactions.
- Reactions in which energy is absorbed are known as endothermic reactions.
- When an element displaces another element from its compound, a displacement reaction occurs.
- Two different atoms or groups of atoms (ions) are exchanged in double displacement reactions.
- Precipitation reactions produce insoluble salts.
- Reactions also involve the gain or loss of oxygen or hydrogen by substances. Oxidation is the gain of oxygen or loss of hydrogen. Reduction is the loss of oxygen or gain of hydrogen. The substance that brings about oxidation and is itself reduced is termed as oxidizing agent and the substance that brings about reduction and is itself oxidized is referred to as reducing agent. There are a number of oxidation reduction reactions that are of industrial use. The production of metals from their ores invariably involves these two processes.

MATTER AND ITS NATURE

A. Matter and Its Nature

- Anything that possesses mass, occupies space, offers resistance and can be perceived through one or more of our sense is called matter.

- Matter is made up of particles. Particles of matter have space between them and are continuously moving and attract each other.
- Matter can exist in three states-
  I. Solid
  II. Liquid
  III. Gas
- Solid has a definite shape, distinct boundaries and fixed volumes, Solids have a tendency to maintain their shape when subjected to outside force. Solids may break under force but it is difficult to change their shape, so they are rigid.
- Liquids have no fixed shape but have a fixed volume. They take up the shape of the container in which they are kept. Liquids flow and change shape, so they are not rigid but can be called fluid.
- A gas has no definite volume or shape. gases are highly compressible as compared to solids and liquids. The liquefied petroleum gas (LPG) cylinder that we get in our home for cooking or the oxygen supplied to hospitals in cylinders is compressed gas. Compressed natural gas (CNG) is used as fuel these days in vehicles.
- The forces of attraction between the particles(inter-molecular force) are maximum in solids, intermediate in liquids and minimum in gases. The spaces in between the constituent particles and kinetic energy of the particles are minimum in the case of solids, intermediate in liquids and maximum in gases.
- The arrangement of particles is most ordered in the case of solids, in the case of liquids layers of particles can slip and slide over each other while for gases, there is no order, particles just move about randomly.
- In spite of above differences all kinds of matter have a common property, the property of having a mass.
- The states of matter are interconvertible. The state of matter can be changed by changing temperature or pressure.
- On increasing the temperature of solids, the kinetic energy of the particles increases. Due to the increase in kinetic energy, the particles start vibrating with greater speed. The energy supplied by heat overcomes the forces of attraction between the particles. The particles leave their fixed positions and start moving more freely. A stage is reached when the solid melts and is converted to a liquid. The temperature at which a solid melts to become a liquid at the atmospheric pressure is called its melting point.
- The process of melting, that is, change of solid state into liquid state is also known as fusion.
- During the melting, the temperature of the system does not change after the melting point is reached, till all the ice melts. This happens even

though we continue to heat the beaker, that is, we continue to supply heat. This heat gets used up in changing the state by overcoming the forces of attraction between the particles. As this heat energy is absorbed by ice without showing any rise in temperature, it is considered that it gets hidden into the contents of the beaker and is known as the latent heat.

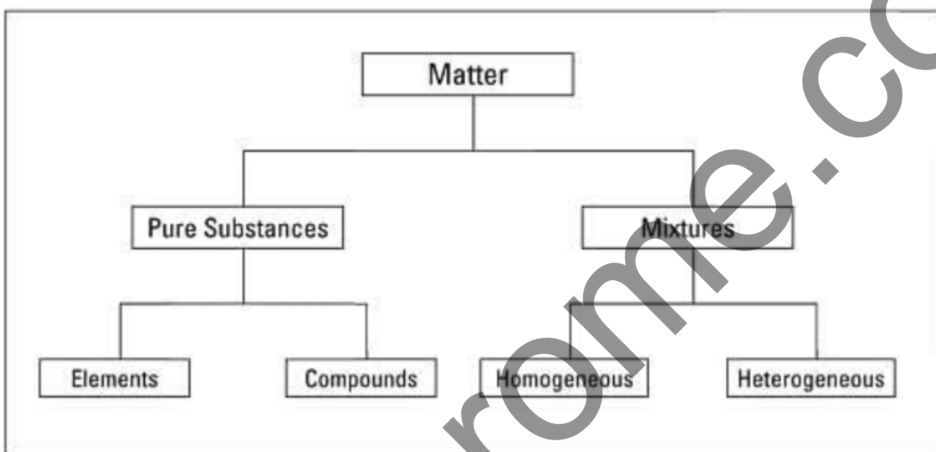
- The amount of heat energy that is required to change 1 kg of a solid into liquid at atmospheric pressure at its melting point is known as the latent heat of fusion.
- The temperature at which a liquid starts boiling at the atmospheric pressure is known as its boiling point.
- Latent heat of vaporisation is the heat energy required to change 1 kg of a liquid to gas at atmospheric pressure at its boiling point.
- Sublimation is the change of gaseous state directly to solid state without going through liquid state, and vice versa.
- Evaporation is a surface phenomenon. Particles from the surface gain enough energy to overcome the forces of attraction present in the liquid and change into the vapour state. The rate of evaporation depends upon the surface area exposed to the atmosphere, the temperature, the humidity and the wind speed. Evaporation causes cooling.
- During summer, we perspire more because of the mechanism of our body which keeps us cool. We know that during evaporation, the particles at the surface of the liquid gain energy from the surroundings or body surface and change into vapour. The heat energy equal to the latent heat of vaporisation is absorbed from the body leaving the body cool.
- Let us take some ice-cold water in a tumbler. Soon we will see water droplets on the outer surface of the tumbler. The water vapour present in air, on coming in contact with the cold glass of water, loses energy and gets converted to liquid state, which we see as water droplets.
- Properties such as shape, size, colour and state of a substance are called its physical properties. A change , which does not involve any alteration in composition of the substance is called a physical change. A physical change is generally reversible. In such a change no new substance is formed.
- Some substances can be obtained in pure state from their solutions by crystallisation.
- A change that alters the composition of a substance or substances taking part in the change is termed a chemical change. A chemical change is also called a chemical reaction. All new substances are formed as a result of chemical changes.

- Burning of coal, wood or leaves is a chemical change. Explosion of a firework is a chemical change. If you leave a piece of iron in the open for some time, it acquires a film of brownish substance. This substance is called rust and the process is called rusting. The process of rusting can be represented by the following equation: Iron (Fe) + Oxygen (O_2, from the air)water (H_2O) ’! rust (iron oxide- Fe_2O_3) For rusting, the presence of both oxygen and water (or water vapour) is essential. It is a chemical change.
- Prevent iron articles from coming in contact with oxygen, or water, or both. One simple way is to apply a coat of paint or grease. Another way is to deposit a layer of a metal like chromium or zinc on iron. This process of depositing a layer of zinc on iron is called galvanisation.
- Stainless steel is made by mixing iron with carbon and metals like chromium, nickel and manganese. It does not rust.
- Changes attended with absorption of heat are called endothermic changes, while those which occur with evolution of heat are called exothermic changes. The reactions in which heat is absorbed are known as endothermic reactions, while chemical reactions which evolve heat are called exothermic. The compounds formed from their elements with absorption of heat are called endothermic compounds, whilst those formed from their elements with evolution of heat are called exothermic compounds.

UPSC
NCERT Summary
Gist of Chemistry – 3

---

2. Classifications



(a) Pure Substance and Mixture

- **A pure substance** is one that contains one kind of materials throughout its body. A substance cannot be separated into other kinds of matter by any physical process.
- **Mixtures** are constituted by more than one kind of pure form of matter, known as a substance. Mixtures can be separated into pure substances using appropriate separation techniques like **filtration**, **sublimation**, **decantation**, **chromatography**, **crystallization**, etc.

(b) Homogeneous and Heterogeneous Substance

- A substance is said to be **homogeneous** if it has one and the same composition and properties in all its parts. On the other hand, if the composition and properties are not identical throughout the body the substance is **heterogeneous**. A pure substance must be homogeneous.

(c) Elements and Compounds

Pure substance are classified into elements and compounds:

- **Elements:** An element is a form of matter that cannot be broken down by chemical reactions into simpler substances. **Robert Boyle** was the first scientist to use the term element in 1661. Elements can be normally divided into metals, non-metals and metalloids.
- **Compound:** A compound is a substance composed of two or more different types of elements, chemically combined in a fixed proportion. Properties of a compound are different from its constituent elements.

Symbols: The symbol is an abbreviation for the full name of an element. In many cases the initial capital letter of the common name of element is used as abbreviation for it.
» H stands for Hydrogen, N for Nitrogen, etc. Two letters are used in cases of two or more elements having the same initial letter. A second prominent letter (small) from its name is added to the initial letter.
» Al stands for Aluminium, Cl stands for chlorine, etc. In some cases the symbols are derived by taking letter or letters from the Latin name of the element. Cu stands for Copper (Latin name Cuprum), Au stands for Gold (Latin name Aurum), etc.

➢ Representation Using Symbols

- **The symbol** represents one atom and naturally stands for a perfectly definite amount of the element concerned. Every substance is an aggregate of its molecules, and the symbolic representation of a molecule of the substance is called its **formula**.
- The number of atoms per molecule of the element is known as the **atomicity of the molecule**. If the molecule of an element contains one atom, then the molecule is represented by the symbol only, i.e., in such a case symbol also represents the formula.
- **Valency:** The number of chemical substances, except the element themselves, are composed of two or more of these elementary materials combined together.

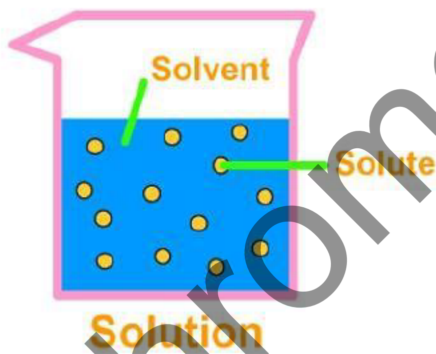
The valency of an element is the combining capacity of an atom of the element and is measured by the number of hydrogen atoms with which it can be combined.

- **Hydrogen is chosen as the standard of reference** because the combining capacity of hydrogen is least. Though the combining capacity of an atom of the element is by and large fixed, valency may vary, some elements exhibit different **valencies**. The highest valency known being 0, the valencies range between 0 and eight. Helium, argon, etc., the so-called inert gases have no combining capacity and hence they are regarded as zero-valent element. A valency is always a whole number.

- **Compounds** too like elements are represented by **molecular formula**. To build up the formula of a compound the symbols of the **constituent elements** are written side by side and the number of atoms of each is indicated by putting numerals to the lower right of the symbols. But the subscript one is not written in formula.

3. Solution

- A solution is a homogeneous mixture of two or more substances. The major component of a solution is called the **solvent**, and the minor, the **solute**. **Lemonade**, **soda water** etc. are all examples of solutions. We can also have **solid solutions** (alloys) and **gaseous solutions** (air).



- The particles of a solution are smaller than 1 nm (10^{-9} metre) in diameter. So, they cannot be seen by naked eyes. The solute particles cannot be separated from the mixture by the process of filtration. The **solute particles** do not settle down when **left undisturbed**, that is, a solution is stable.
- The concentration of a solution is the amount of **solute present** per unit volume or per unit **mass** of the solution/ solvent.
- Materials that are insoluble in a solvent and have particles that are visible to naked eyes form a suspension. A suspension is a **heterogeneous mixture**.

4. Alloys

- Alloys are **homogeneous mixtures** of metals and cannot be separated into their components by **physical methods**. But still, an alloy is considered as a mixture because it shows the properties of its constituents and can have variable composition.
  Example: Brass is a mixture of approximately 30% zinc and 70% copper.

- **Non-homogeneous systems**, in which solids are dispersed in liquids, are called suspensions. A suspension is a **heterogeneous mixture** in which the solute particles do not dissolve but remain suspended throughout the bulk of the medium. Particles of a suspension are visible to the naked eye.
- **Colloids** are **heterogeneous mixtures** in which the particle size is too small to be seen with the naked eye, but is big enough to scatter light. Colloids are **useful in industry and daily life**. The particles are called the dispersed phase and the medium in which they are distributed is called the dispersion medium.

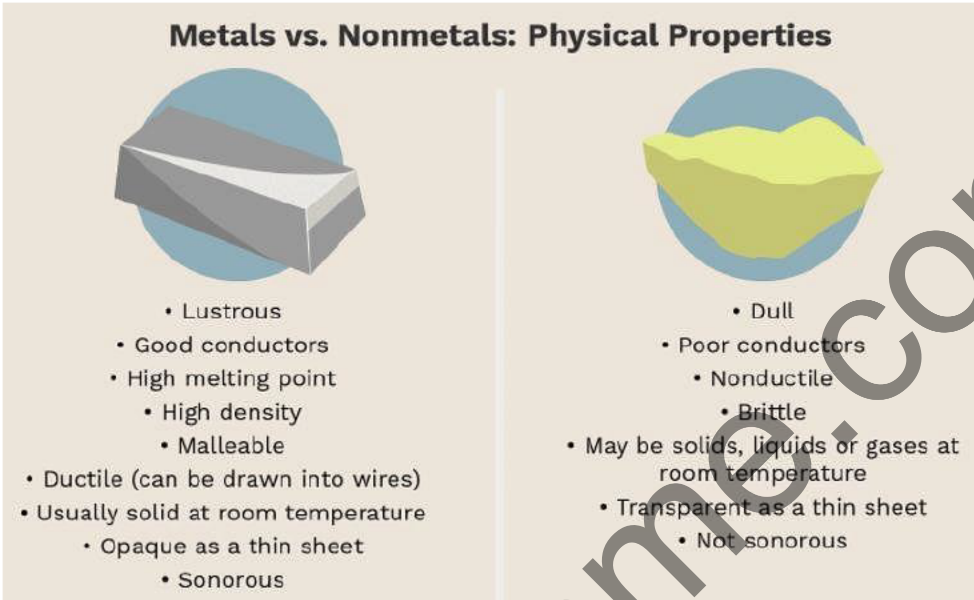
5. Metals and Non-Metals

Elements can be normally divided into **metals**, **non-metals and metalloids**.

Metals usually show some or all of the following properties:

- They have a lustre (shine).
  Exception: Mercury, though a metal is liquid.
- They have **silvery-grey** or **golden yellow colour**.
- They conduct heat and electricity. Silver is the best while copper stands second.
- They are ductile (can be drawn into wires). **Gold is the most ductile metal**.
- They are malleable (can be hammered into thin sheets).
  Exception: Metals like antimony and bismuth are brittle.
- They are sonorous (make a ringing sound when hit).
- Metals have high melting points.
  Exception: Gallium and Caesium have very low melting points.
- Metals can form positive ions by losing electrons to non-metals. In electrolysis, metals get deposited at the negative electrode(cathode).
- Metals combine with oxygen to form basic oxides. **Aluminium** oxide and zinc oxide show the properties of both basic as well as **acidic oxides**. These oxides are known as **amphoteric oxides**.
- Different metals show different reactivities towards oxygen. Metals such as potassium and sodium react so vigorously that they catch fire if kept in the open. Hence, to protect them and to prevent accidental fires, they are kept immersed in kerosene oil.
- Different metals have different reactivities with water and dilute acids. Metals above hydrogen in the Activity series can displace hydrogen from dilute acids and form salts.
- **Metals occur** in nature as free elements or in the form of their compounds. The extraction of metals from their ores and then refining them for use is known as **metallurgy**.

- The surface of some metals, such as iron, is corroded when they are exposed to moist air for a long period of time. This **phenomenon** is known as **corrosion**.



Organic Chemistry

- Organic chemistry is that branch of chemistry which deals with the study of compounds of carbon with hydrogen (hydrocarbons), and their derivatives. Presently about five million organic compounds are known.
- Organic compounds were found to contain mainly **hydrogen and carbon**. Therefore, organic chemistry is defined as the study of hydrocarbons and their derivatives. Most atoms are only capable of forming small molecules. However one or two can form **larger molecules**.
- By far and away the best atom for making large molecules with is Carbon. Carbon can make molecules that have tens, hundreds, thousands even millions of atoms! The huge number of possible combinations means that there are more carbon compounds that those of all the other elements put together!
- A single carbon atom is capable of combining with up to four other atoms. We say it has a valency of 4. Sometimes a carbon atom will combine with fewer atoms. The Carbon atom is one of the few that will combine with itself. In other words, **carbon combines** with other carbon atoms. This means that Carbon atoms can form chains and rings onto which other atoms can be attached. This leads to a huge number of different compounds.

- Organic Chemistry is essentially the chemistry of Carbon. Carbon compounds are classified according to how the Carbon atoms are arranged and what other groups of atoms are attached.

➢ Hydrocarbons

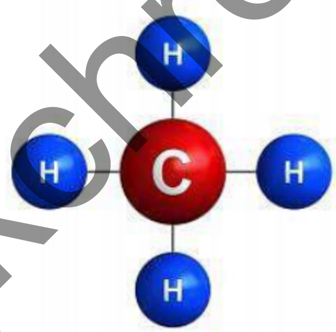
The simplest **Organic compounds** are made up of only Carbon and Hydrogen atoms only. Even these run into thousands! Compounds of Carbon and Hydrogen only are called **Hydrocarbons**.

1. Alkanes

In the alkanes, all four of the Carbon valency bonds are taken up with links to different atoms. These types of bonds are called single bonds and are generally stable and resistant to attack by other chemicals. Alkanes contain the maximum number of **Hydrogen atoms possible**. They are said to be saturated.

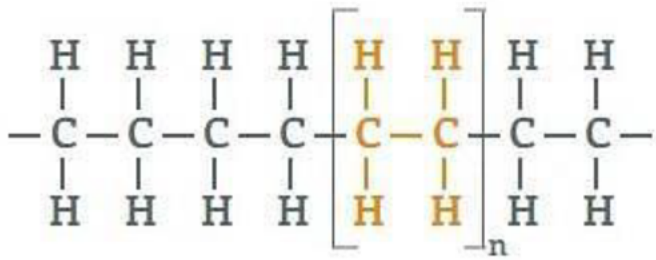
The simplest Hydrocarbon is:

- **Methane:** CH_4, this is the **simplest member** of a series of hydrocarbons. Each successive member of the series has one more **carbon atom** than the **preceding member**.



Methane CH_4

- **Ethane:** C_2H_6
- **Propane (heating fuel):** C_3H_8
- **Butane (lighter / camping fuel):** C_4H_{10}
- **Pentane:** C_5H_{12}
- **Hexane:** C_6H_{14}
- **Polythene** is a very large alkane with millions of atoms in a single molecule. Apart from being flammable, alkanes are stable compounds found underground.



Molecular Structure of Polyethylene

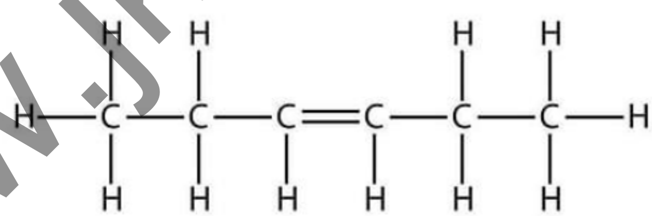
2. Alkenes

Another series of compounds is called the **alkenes**. These have a general formula: $\mathbf{C_nH_{2n}}$. These compounds are named in a similar manner to the alkanes except that the suffix is one. Alkenes have fewer hydrogen atoms than the alkanes. The extra valencies leftover occur as double bonds between a pair of **carbon atoms**. The double bonds are more reactive than single bonds making the **alkenes chemically** more reactive.

<u>The simplest alkenes are listed below:</u>

- **Ethene (used as an industrial starter chemical):** C_2H_4
- **Propene:** C_3H_6
- **Butene:** C_4H_8
- **Pentene:** C_5H_{10}

Hexene: C_6H_{12}



The Structural Formula for Hexene

3. Alkynes

A third series are the alkynes.

These have the following formula: $\mathbf{C_nH_{2n-2}}$

These highly reactive substances have many **industrial uses**. Again the naming of these compounds is similar to the alkanes except that the suffix is -yne. Alkynes have two carbon atoms joined by a triple bond. This is highly reactive making these compounds unstable.

<u>Examples of alkynes are:</u>

- **Ethyne -** Better known as acetylene which is used for welding underwater: **C_2H_2**

Structural Formula for Ethyne

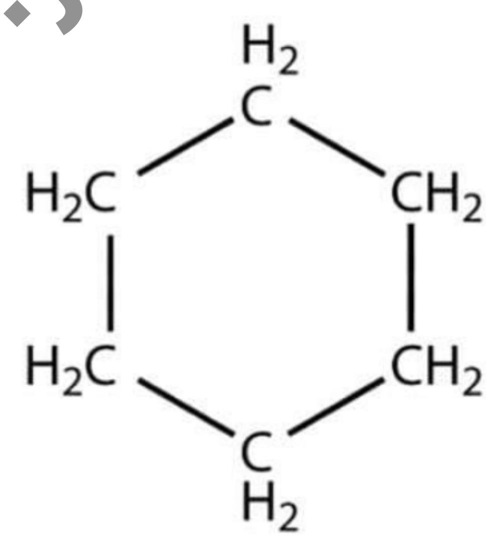
- **Propyne:** C_3H_4
- **Butyne**: C_4H_6
- **Pentyne**: C_5H_8
- **Hexyne:** C_6H_{10}

4. Carbon Rings

Alkanes, alkenes and alkynes all contain carbon atoms in linear chains. When rings are combined with chains, the number of hydrocarbons is virtually infinite. There are also hydrocarbons arranged in rings.

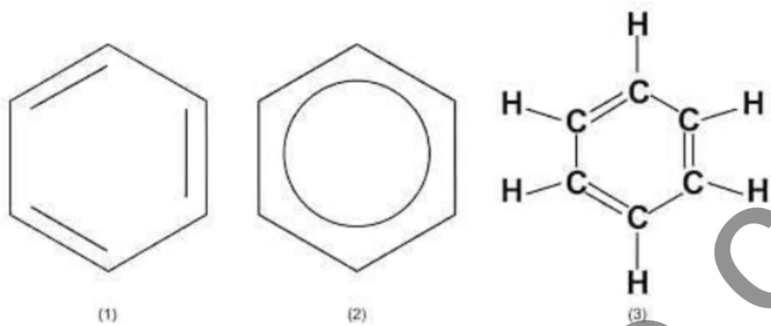
<u>Some examples follow:</u>

- **Cyclohexane -** A saturated hydrocarbon with the atoms arranged in a hexagonal ring: **C_6H_{12}**



Cyclohexane

Benzene - An industrial solvent. The **Benzene Ring** is one of the most important structures in organic chemistry. In reality, its alternate double and single bonds are "spread around" the ring so that the molecule is symmetrical: C_6H_6



Benzene

- **Naphthalene -** Used in mothballs. This can be depicted as two fused Benzene Rings: $C_{10}H_8$

Naphthalene

➢ **Carbon, Hydrogen and Oxygen**

When Oxygen atoms are added, the variety of compounds grows enormously.
Here are some examples where each molecule has a single functional group:

- **Alcohols:** Alcohols have the OH (hydroxyl) group in the molecule. A group of atoms that gives an organic series its distinctive character is called a **functional group**. These have a general formula: $C_nH_{2n+1}OH$.

  Examples:

  (i) Methanol (wood alcohol) CH_3OH

(ii) Ethanol(drinking alcohol) C_2H_5OH
(iii) Phenol(carbolic acid - used as a disinfectant) C_6H_5OH

- **Ethers** (Ethers have an O atom attached to two hydrocarbon chains) $\mathbf{(C_nH_{2n+1})_2O}$.
  <u>Examples</u>:
  (i) Dimethyl Ether(a gas) $(CH_3)_2O$
  (ii) Diethyl Ether (a liquid used as an anaesthetic) $(C_2H_5)_2O$
- **Ketones** (Ketones have a CO group attached to two hydrocarbon chains). These have a general **formula:** $\mathbf{(C_nH_{2n+1})_2CO}$.
  Example: Dimethyl Ketone (Also known as acetone: Nail varnish remover), CH_3COCH_3
- **Aldehydes** (Aldehydes have a CHO group attached to a hydrocarbon chain). These have a general formula: $\mathbf{C_nH_{2n+1}CHO}$.
  <u>Example</u>**:**
  (i) Formaldehyde (preservative in labs)- HCHO
  (ii) Acetaldehyde- CH_3CHO
- **Fatty Acids** (Fatty Acids contain the CO_2H (or COOH) group attached to a hydrocarbon chain or ring). These have a general formula: $\mathbf{C_nH_{2n+1}CO_2H}$.
  <u>Example</u>**:**
  (i) Formic Acid(in ant bites and stinging nettles)- $\mathbf{HCO_2H}$**.**
  (ii) Acetic Acid(vinegar)- $\mathbf{CH_3CO_2H}$**.**
  (iii) Butyric Acid(the rancid butter smell)- $\mathbf{C_2H_5CO_2H}$.
- **Esters** (Esters are similar to Fatty Acids except that the H in the COOH group is another hydrocarbon chain. They are usually very sweet-smelling liquids used in perfumes). These have a general formula: RCO_2R'(R and R' are Hydrocarbon chain or rings).
  Examples: Methyl Methoate (the essence of pear drops) - $\mathbf{CH_3CO_2CH_3}$.

It is possible to have two or more functional groups on a molecule. These can be the same group (as in Oxalic Acid - a poison found in rhubarb leaves - which has two fatty acid groups) or different (as in **Hydroxyethanoic Acid** - which has a hydroxyl group and a fatty acid group): **Oxalic Acid-** $\mathbf{(COOH)_2}$, **Hydroxyethanoic Acid-** $\mathbf{CH_2OHCOOH}$.
The most **famous compounds containing Carbon**, **Hydrogen and Oxygen** are the **Carbohydrates**. An example is the common sugar, **Sucrose** ($C_{12}H_{22}O_{11}$).

➢ Isomerism

- An interesting phenomenon with organic molecules is called isomerism. Let us look at two compounds introduced earlier. Dimethyl Ether: $\mathbf{(CH_3)_2O}$ and Ethanol: $\mathbf{C_2H_5OH}$. The first is a gas which will knock you out if inhaled. The second is common alcohol drunk in spirits. Both compounds contain **2** Carbon atoms, **6 Hydrogen atoms** and **1 Oxygen atom**.

- Even though the atoms are the same, they are arranged differently. This yields two different compounds with the same number of atoms. These compounds are isomers and the phenomenon is called **Isomerism**. Isomerism increases the number of Organic compounds. The more carbon atoms in a compound, the more ways of arranging the atoms and the larger number of isomers.

➢ **Compounds Containing Nitrogen**

- **Adding Nitrogen:** Many, very important organic compounds contain **Nitrogen**. This produces more series of **compounds**.
  (a) Amines (Amines have one or more of the Hydrogen atoms in Ammonia (NH_3) replaced by a Hydrocarbon chain or ring).
  These have a general formula: $C_nH_{2n+1}NH_2$.
  <u>**Examples:**</u>
  (i) Methylamine (a pungent, water-soluble gas)- CH_3NH_2
  (ii) Cyanides (Cyanides have the CN group)
  » These have a general formula: $C_nH_{2n+1}CN$
  Example: Methyl Cyanide- CH_3CN
  (iii) Amino Acids (Amino Acids have two functional groups: the amine (HN_2) group and the fatty acid (COOH) group
  » These have a general formula: $C_nH_{2n}NH_2COOH$
  Example: Glycine (the simplest amino acid)- CH_2NH_2COOH
  (iv) A famous compound containing Nitrogen is **TrinitroToluene ($C_6H_2CH_3(NO)_3$)** - usually abbreviated to **TNT**). This is an artificially made explosive.

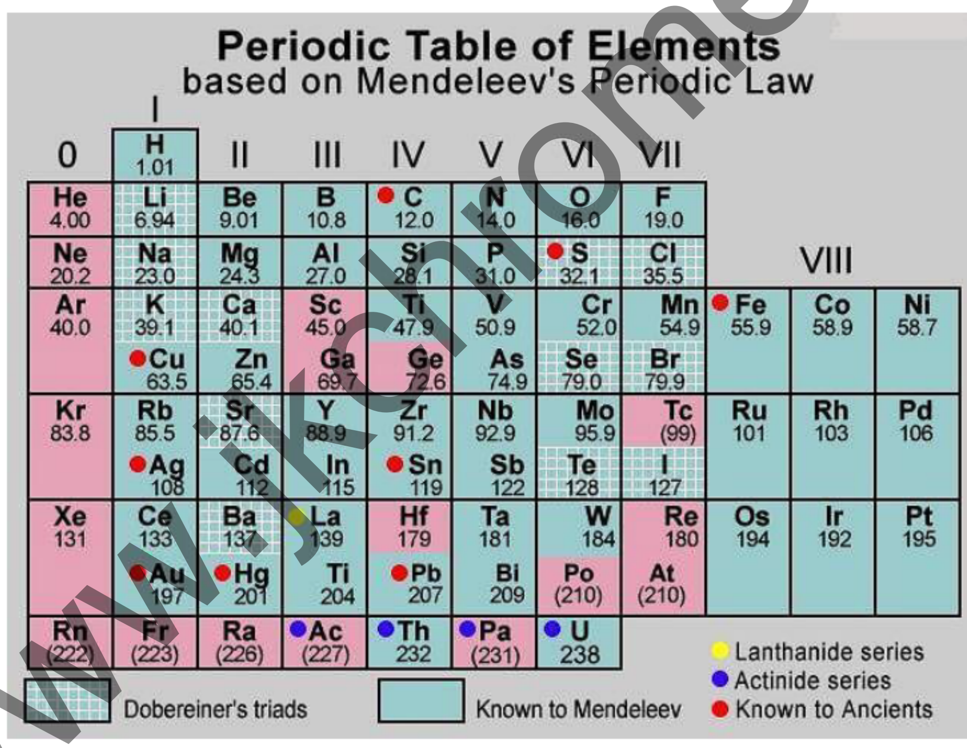
The vast majority of organic compounds contain Carbon, Hydrogen, Oxygen and Nitrogen. Other types of atoms can be included to form even more compounds. These can contain atoms like Phosphorus, Sulphur (**Example:** Thiamine,), Chlorine (**Example:** Chlorophyll-$CHCl_3$, Dichloro Diphenyl Trichloro Methane – DDT $C_{14}H_9Cl_{15}$) and Iron (**Example:** Haemoglobin).

Periodic Classification of Elements

- The grouping of elements with similar properties together and the separation of elements with dissimilar properties is known as classification of elements. The table, which classifies elements on the basis of their properties, is called the periodic table. Döbereiner grouped the elements into triads and Newlands gave the **Law of Octaves**.

Mendeléev arranged the elements in increasing order of their atomic masses and according to their chemical properties.

- **Dobereiner's Triads** arranged elements in an increasing order of atomic mass, in groups of three. The atomic mass of the middle element was the arithmetic mean of the other two elements of the triad.
- **Newland's law of octaves** states that on arranging elements in increasing order of their atomic mass, the eighth element resembles the first in physical and chemical properties, just like the eighth note on a musical scale resembles the first note.
- **According to Mendeleev's periodic law**, the physical and chemical properties of elements are periodic functions of their atomic mass. Mendeleev corrected the atomic masses of a few elements on the basis of their positions in the periodic table. Mendeléev even predicted the existence of some yet to be discovered elements on the basis of gaps in his Periodic Table.



- **Mendeléev's Periodic Table contains** vertical columns called 'groups' and horizontal rows called 'periods'. While developing the Periodic Table, there were a few instances where Mendeléev had to place an element with a slightly greater atomic mass before an element with a slightly lower atomic mass. The sequence was inverted so that elements with similar properties could be grouped together.

- Mendeleev's table could not assign a proper position to hydrogen or to the lanthanides and actinides and isotopes. Isotopes of all elements posed a challenge to Mendeleev's Periodic Law. Another problem was that the atomic masses do not increase in a regular manner in going from one element to the next. So it was not possible to predict how many elements could be discovered between two elements — especially when we consider the heavier elements.
- In 1913, **Henry Moseley** showed that the atomic number of an element is a more fundamental property than its atomic mass. Accordingly, Mendeléev's Periodic Law was modified and atomic number was adopted as the basis of Modern Periodic Table and the Modern Periodic Law.
- The vertical columns are called **groups**, while the horizontal rows are called **periods**. The noble gases are on the extreme right of the table and on the table's extreme left, are the alkali metals. Transition elements are placed in the B subgroups in the middle of the table. The inner transition elements - **lanthanides** and **actinides**, are placed in two separate series at the bottom of the periodic table.
- **Group number** is number of electrons in the valence shell. Elements having the same valence number, are grouped together. The number of shells present in the atom gives period number.
- **Atomic size:** The term atomic size refers to the radius of an atom. The atomic size may be visualised as the distance between the centre of the nucleus and the outermost shell of an isolated atom.

PROPERTIES OF GASES

1. Properties of Gases

- First, we know that a gas has no definite volume or shape; a gas will fill whatever volume is available to it. Contrast this to the behavior of a liquid, which always has a distinct upper surface when its volume is less than that of the space it occupies.
- The other outstanding characteristic of gases is their low densities, compared with those of liquids and solids. The most remarkable property of gases, however, is that to a very good approximation, they all behave the same way in response to changes in temperature and pressure, expanding or contracting by predictable amounts. This is very different from the behavior of liquids or solids, in which the properties of each particular substance must be determined individually.
- All gases expand equally due to equally due to equal temperature difference.
- **Diffusion of gases:** The phenomenon in which a substance mixes with another because of molecular motion, even against gravity- is called diffusion.
- **The pressure of a gas:** The molecules of a gas, being in continuous motion, frequently strike the inner walls of their container. As they do so, they immediately bounce off without loss of kinetic energy, but the reversal of direction (acceleration) imparts a force to the container walls. This force, divided by the total surface area on which it acts, is the pressure of the gas.
- The unit of pressure in the SI system is the pascal (Pa), defined as a force of one newton per square metre ($1\ Nm^{-2} = 1\ kg\ m^{-1}s^{-2}$.)
- Temperature and Temperature Scales: Temperature is defined as the measure of average heat. Temperature is independent of the number of particles or size and shape of the object. The water boiling temperature is same for all type of containers.
- **Thermometer:** The device which is used to define the measure of temperature of an object is Thermometer.

- **Temperature scale:** A reference scale with respect to which the temperatures can be measured is known as 'scale of temperature'. Various scales of temperatures are in use. Important scales of temperature are:
  i. Celsius scale
  ii. Kelvin scale
  iii. Fahrenheit scale
- To devise a scale of temperature, fixed reference points (temperature) are required, with respect to which all other temperatures are measured. For both Celsius and Fahrenheit Scales of temperatures, the fixed points are as follows:
  (i) Lower fixed point: Melting point of pure ice at normal atmospheric pressure is regarded as the lower fixed point.
  (ii) Upper fixed point: Boiling point of pure water at normal atmospheric pressure is regarded as the lower fixed point.
- **Celsius scale:** In this scale the lowest fixed point is the freezing temperature of pure substance. The upper fixed point is the boiling point of water. The interval is divided into 100 divisions all are at equal distance. Every division being denoted as one degree Celsius(ºC). The Celsius scale is also called as centigrade scale because the range of temperature is divided into 100 equal divisions.
- **Kelvin scale:** Another type of scale which is used to define the measure of temperature is Kelvin scale. The Kelvin scale is also known as absolute scale of temperature. The lowest fixed point is taken from the lowest temperature to which a substance to be cooled such as -273.15ºC. According to the scale, a temperature is denoted by simply K.
- **Absolute zero:** The temperature at which a given mass of gas does not occupy any volume or does not exert pressure is called the "absolute zero". Absolute zero i.e., 0K or -273ºC is the lowest possible temperature that can be reached. At this temperature the gas has a theoretical volume of zero. In the Kelvin scale, the lowest possible temperature is taken as zero. This temperature is called as absolute zero. At the point absolute zero there is no molecular motion and there is no heat energy. At absolute zero all atomic and molecular motions stop. Hence the absolute zero is the lowest possible temperature which is denoted by 0K or -273.15º C.
- **Fahrenheit Scale of Temperature:** The lower and upper fixed points in this scale are considered as 320 F and 2120 F respectively. The interval of 1800 F is divided into 180 equal parts. Each part is known as 10 F. This is widely used by doctors.
- The volume of a gas is simply the space in which the molecules of the gas are free to move. If we have a mixture of gases, such as air, the various

gases will coexist within the same volume. In these respects, gases are very different from liquids and solids, the two condensed states of matter. The SI unit of volume is the cubic metre, but in chemistry we more commonly use the litre and the millilitre (ml). The cubic centimetre (cc) is also frequently used; it is very close to 1 milliliter (mL).

- **Compressibility:** Particles of a gas have large intermolecular spaces among them. By the application of pressure much of this space can be reduced and the particles be brought closer. Hence the volume of a gas can be greatly reduced. This is called compressing the gas.

2. Gas Laws

- All gases, irrespective of their chemical composition, obey certain laws that govern the relationship between the volume, temperature and pressure of the gases. A given mass of a gas, under definite conditions of temperature and pressure, occupies a definite volume. When any of the three variables is altered, then the other variables get altered. Thus these Gas laws establish relationships between the three variables of volume, pressure and temperature of a gas.
- **Boyle's Law:** Robert Boyle (1627 - 1691) discovered this law in 1662 and it was named after him. It can be restated as "The product of the volume and pressure of a given mass of dry gas is constant, at constant temperature". P "1/ V(at constant temperature) or PXV= K (where K is constant).
- **Charles' Law:** "At constant pressure, the volume of a given mass of gas increases or decreases by 1/273 of its original volume at 32o F, for each degree centigrade rise or lowering in temperature." Assume a given mass of gas has a volume of V1 at a temperature T1 Kelvin at a constant pressure, then, according to Charles' Law we can write: V "T or VT=K (Constant).
- **Pressure Law:** Volume remaining constant, the pressure of a given mass of gas increases or decreases by a constant fraction (=1/273) of its pressure at 00C for each degree celsius rise or fall of temperature. If the pressure of a given mass of gas at 0ºC be Po; then for a rise or fall of temperature of T0C, its pressure Pt is given by Pt= Po{1±(t/273)} • Avogadro's Law: This is quite intuitive: the volume of a gas confined by a fixed pressure varies directly with the quantity of gas. Equal volumes of gases, measured at the same temperature and pressure, contain equal numbers of molecules. Avogadro's law thus predicts a directly proportional relation between the number of moles of a gas and its volume.

- **Gay-Lussac's Law:** When different gases react with each other chemically to produce gaseous substances, then under the same condition of temperature and pressure, the volume of the reacting gases and product gases bear a simple ration among one another.
- **Avogadro's hypothesis:** Under the same condition of pressure and temperature, equal volumes of all gases contain equal number of molecules.
- The molecular weight of an element or compound is the sum-total of the atomic weights of the atoms which constitute a molecule of the substance. Example: The molecular formula formula of nitric acid is HNO_3; hence its molecular weight = H + N + 3 × O = 1 + 14 + 3 × 16 = 63 (taking atomic weight of hydrogen as 1).
- **Gram-Atomic Weight:** A quantity of any substance whose mass in grams is numerically equal to its atomic weight, is called its Gram-Atomic Weight. • Gram-Molecular Weight: A quantity of any substance whose mass in grams is numerically equal to its molecular weight, is called its Gram-Molecular Weight or mole.
- Molecular volume occupied by a mole of any gas is called the gram-molecular volume or molar volume. On the basis of Avogadro's hypothesis, the gram molecular volume of any gas at normal temperature and pressure is 22.4 litres.
- **Avogadro Number:** From Avogadro's hypothesis, we know equal volume of all gases contain equal number of molecules at normal temperature and pressure. Also we know that at normal temperature and pressure one mole of any gas occupies 22.4 litres. Combining the two, we can say that that, gram molecular volume of all gases contain equal number of molecules at normal temperature and pressure. This number is known as Avogadro Number and is equal to $6.06X10^{23}$.
- **The Gas Equation:** According to Boyle's Law, the volume of a gas varies inversely as the pressure, temperature remaining constant, i.e., V "1/ P and according to Charles' law, the volume of a gas varies directly as the absolute temperature, pressure remaining constant, i.e. V "T Both, these laws can be combined as: The volume of a given mass of a gas varies inversely with the pressure and directly with the temperature. V "(1/ P)XT or V "T/P or (PXV)/T = K(constant). In other words, For a given mass of a gas, if the initial conditions are P1, V1, and T1, then the altered conditions are P2, V2, and T2. Thus, (P1X V1)/ T1 = (P2X V2)/ T2 .
- The ideal gas equation of state: If the variables P, V, T and n (the number of moles) have known values, then a gas is said to be in a definite state, meaning that all other physical properties of the gas are also defined. The relation between these state variables is known as an equation of state. By combining the expressions of Boyle's, Charles', and Avogadro's

laws (you should be able to do this!) we can write the very important ideal gas equation of state: PV= nRT, where the proportionality constant R is known as the gas constant. This is one of the few equations you must commit to memory in this course; you should also know the common value and units of R.

- An ideal gas is an imaginary gas that follows the gas laws and has 0 volume at 0 K i.e., the gas does not exist

SOME COMMON ELEMENTS & COMPOUNDS

1. Hydrogen: Symbol H, formula H2. The first element in the periodic table and the most basic and common of all elements in the universe. Over ninety percent of all the atoms in the universe are hydrogen atoms and they are the lightest of all elements. The name hydrogen comes from the Latin word “hydro” which means water. Scientists use the letter “H” to represent hydrogen in all chemical equations and descriptions.

- Hydrogen atom has one electron in its valence shell like alkali metals.
- Hydrogen generally shows + 1 valency like alkali metals.
- Hydrogen is a good reducing agent like other alkali metals.
- The isotopes of hydrogen: Protium has an atomic number 1, and mass number 1, Deuterium, has an atomic number 1, and mass number 2 and Tritium has an atomic number 1, and mass number 3.
- It has a vapour density of 1, which is 14.4 times lighter than air.

2. Carbon: The sixth element in the periodic table. It is a very stable element. Because it is stable, it can be found in many naturally occurring compounds and by itself. Scientists describe the three states of carbon as diamond, amorphous, and graphite.

- Carbon exhibits allotropy and shows maximum catenation.
- Normal valency of carbon is four due to the presence of four valence electrons. Thus all four bonds are generally covalent.
- Carbon occurs both in free state as diamond, coal etc. and also in the combined form as CO_2.
- Diamond is one of the allotropic forms of carbon and is the purest form of natural carbon. It is the hardest natural substance. Diamond is a giant framework that forms a rigid structure with no free electrons to conduct electricity.
- Graphite is also an allotropic form of carbon, which is very soft and slippery. Graphite has a mobile cloud of electrons on the horizontal planes, which makes it a good conductor of electricity.

- Apart from diamond and graphite, which are crystalline forms of carbon, all other forms of carbon are amorphous allotropes of carbon. Destructive distillation of coal gives products like coal gas, gas carbon, coal tar and ammonical liquor.
- Lamp Black is also known as Soot. Soot is obtained by the incomplete combustion of carbonaceous, fuels, especially oil fuels, in limited supply of air. The soot settles on the cooler parts of the chamber, and can be collected by scrapping it.
- Wood charcoal is obtained by the destructive distillation of wood. The chief products formed are wood charcoal, wood tar, pyroligneous acid and wood gas.
- Sugar charcoal can be obtained by dehydrating cane sugar, either by treating it with concentrated sulphuric acid or by heating it in the absence of air.
- Bone charcoal is a black powder called as 'ivory black'. It is porous and can adsorb colouring matter. It is mostly used in sugar industry to decolourise sugar.

3. Nitrogen: It is the seventh element of the periodic table located between carbon and oxygen. Almost eighty percent of Earth's atmosphere is made of nitrogen gas. Nitrogen is a clear gas that has no smell when it is in its pure form. It is not very reactive when it is in a pure molecule, but it can create very reactive compounds when combined with other elements including hydrogen (ammonia). There are 7 electrons in a nitrogen atom.

- Nitrogen has 5 electrons in its valence shell. It has a valency of 3 with respect to hydrogen and a valency upto 5 with respect to oxygen.
- In the laboratory nitrogen is prepared by the action of heat on a mixture of ammonium nitrite and ammonium chloride. Nitrogen is collected by the downward displacement of water and is called chemical nitrogen.
- Nitrogen is a neutral gas and is neither combustible nor a supporter of combustion.

4. Oxygen: Symbol O, formula O_2. Alone, oxygen is a colorless and odorless compound that is a gas at room temperature. Oxygen molecules are not the only form of oxygen in the atmosphere; you will also find oxygen as ozone and carbon dioxide. There are 8 electrons in an oxygen atom. In the laboratory oxygen is usually obtained by heating a mixture of potassium chlorate and manganese dioxide. Manganese dioxide facilitates the decomposition of potassium chlorate, but it itself remain unchanged in mass and composition and hence acts as a catalyst in the reaction. Oxygen is noncombustible but a good supporter of combustion. An oxide is a compound of two elements, one of which is oxygen. It can be liquefied and solidified. It is employed in welding process and also used in hospitals for artificial respiration. Oxygen shows a valency of -2.

5. Chlorine: Chlorine belongs to group VII A. Members of this group are called halogens which means 'salt producers. Chlorine has seven electrons in its outer most shell and so has a valency of 1. Chlorine is prepared by the oxidation of concentrated hydrochloric acid using oxidising agents like manganese dioxide, lead dioxide, trilead tetra oxide, potassium permanganate and potassium dichromate. Chlorine is a noncombustible gas but supports the burning of certain metals and nonmetals. Chlorine is highly reactive. It reacts with hydrogen, other non metals and metals to form the corresponding chlorides. Chlorine being an acidic gas turns moist blue litmus paper to red and then bleaches it.

6. Water (H2O):

- Water is the only substance that can exist simultaneously in all the three states of matter, i.e., solid, liquid and gaseous on this earth.
- Pure water is a colourless, odourless and tasteless liquid.
- The density of water is 1 g cm-3 at 4ºC.
- The boiling point of water is 100ºC at a pressure of 760 mm of Hg. The melting point of ice is 0ºC at a pressure of 1 atmosphere.
- Ice has a relative density of 0.92. The specific heat capacity of water is 1 cal/g at 15ºC.
- Water is called the "Universal Solvent". Almost all substances dissolve in water to a certain extent. Hence, it known as a universal solvent. Because of this property, it is impossible to get chemically pure water on the earth. • Metals such as gold, silver, copper, tin, etc. do not react with water. Ordinary iron gets rusted and aluminium gets tarnished.
- Water is described as being 'hard' if it does not lather readily with soap. 'Soft water', on the other hand, is described as the one, which lathers readily with soap. Chemically, natural water is never pure and contains varying amounts of the dissolved impurities absorbed from the natural or manmade environment. Temporary hardness and permanent hardness are the two types of hardness occurring in hard water: Water is said to be temporarily hard when it contains bicarbonates of calcium and magnesium (or hydrogen carbonates). This type of hardness can be

easily removed by boiling. Water is said to be permanently hard when it contains sulphates and chlorides of calcium and magensium. Water becomes permanently hard when it passes over the rocks, which contain sulphates or chlorides of calcium and magnesium to form insoluble calcium bicarbonates or magnesium bicarbonates (or hydrogen carbonates). This hardness cannot be removed by boiling.

- Heavy water is prepared either by prolonged electrolysis or by fractional distillation of ordinary water. Heavy water (D_2O) is colourless, tasteless and odourless liquid. It has all higher values for physical constants than the corresponding values of ordinary water. Fission in uranium-235 is brought by slow speed neutron. Heavy water is used for this purpose in nuclear reactors as moderators.

7. Ammonia (NH3):

- Ammonia is present in atmospheric air and in natural water in trace amounts. However in sewage water, it is present in greater proportion. Ammonia is present in the combined form as various ammonium salts. The two most popular salts are ammonium chloride and ammonium sulphate.
- Ammonia is generally obtained from Ammoniacal liquor obtained by the destructive distillation of coal, destructive distillation of nitrogenous organic matters such as horns, hoofs, bones etc. of animals, Ammonium salts.
- In the laboratory, ammonia is usually prepared by heating a mixture of ammonium chloride and slaked lime in the ratio of 2 : 3 by mass.
- Ammonia is a colorless gas. Its vapor density is 8.5. Hence it is lighter than air (vapor density of air = 14.4). When cooled under pressure ammonia condenses to a colorless liquid, which boils at -33.4ºC. When further cooled, it freezes to a white crystalline snow-like solid, which melts at -77.7ºC. Ammonia is one of the most soluble gases in water. At 0ºC and 760 mm of Hg pressure one volume of water can dissolve nearly 1200 volumes of ammonia. This high solubility of ammonia can be demonstrated by the fountain experiment. Ammonia is neither combustible in air nor does it support combustion. However it burns in oxygen with a greenish yellowish flame producing water and nitrogen. Ammonia reacts with the acids to form their respective ammonium salts. Ammonia is highly soluble in water and forms ammonium hydroxide.

8. Hydrochloric Acid (HCL):

- Hydrochloric acid is prepared by dissolving hydrogen chloride gas in water. Hydrogen chloride is a covalent compound, but when dissolved in water it ionizes to form hydrogen ions and chloride ions.
- Hydrochloric acid is produced along with the industrial preparation of caustic soda (sodium hydroxide). During the electrolysis of sodium chloride, large quantities of hydrogen and chlorine gas are obtained as by-products. These two gases are burnt to form hydrogen chloride gas. The hydrogen chloride gas so formed is dissolved in water to form hydrochloric acid. A saturated solution of the acid has a density of 1.2 g cm^{-3}. It contains about 40% by mass of hydrogen chloride.

  1. It turns litmus paper from blue to red.
  2. It turns methyl orange from yellow to pink.
  3. It reacts with metals to form their respective chlorides and liberates hydrogen.
  4. It reacts with bases to form their respective chlorides and water.
  5. It combines with carbonates and hydrogen carbonates to form their respective chlorides and liberate carbon dioxide.
  6. Hydrochloric acid is used in the production of dyes, drugs, paints, photographic chemicals and in the preparation of aqua-regia for dissolving metals like gold and platinum.

9. Nitric Acid (HNO_3):

- Nitric acid is produced in large quantities in the atmosphere during thunder storms. It is manufactured by the Ostwald's Process by the reaction of ammonia and air in presence of platinum as catalyst at 700-800º C.
- Nitric acid is colourless in pure form. Commercial nitric acid is yellowish due to the presence of dissolved nitrogen dioxide.
- Pure nitric acid is not very stable. Even at ordinary temperature, in presence of sunlight it undergoes slight decomposition. As the temperature increases, the rate of decomposition also increases. On strong heating it decomposes completely to give nitrogen dioxide, water and oxygen.
- Nitric acid is a strong monobasic acid. It ionizes in water readily.
- Nitric acid usually does not behave as an acid, with metals to form the corresponding salt and liberate hydrogen. However, magnesium and manganese are the only two metals, which react with cold and very dilute (1%) nitric acid to evolve hydrogen.

- Nitric acid is a strong oxidizing agent. When it undergoes thermal decomposition, it yields nascent oxygen

10. Sodium (Na):

- Sodium belongs to Group I in the periodic table. This group is otherwise known as the alkali metals group. Since the atomic number of sodium is 11, its electronic configuration is 2,8,1. Sodium easily loses the lone electron to attain the stable configuration of neon. Therefore alkali metals like sodium that are univalent can easily form ionic compounds.
- Since alkali metals like sodium are highly electropositive (tendency to lose an electron and become a cation), their carbonates and bicarbonates are highly stable to the action of heat.
- Some of the important sodium compounds are:

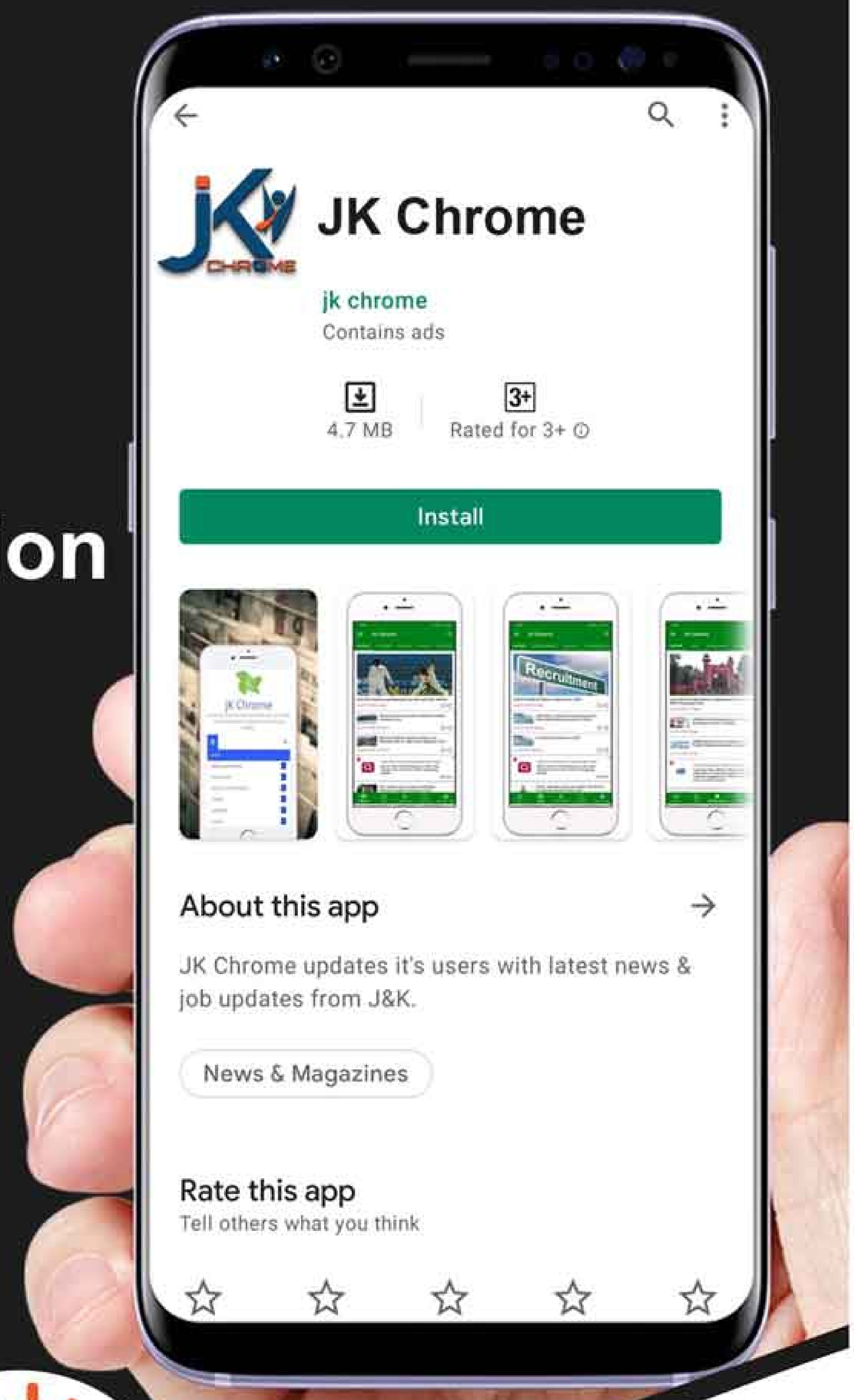
  1. Sodium Carbonate (Na_2CO_3): Popularly known as washing soda or soda ash, sodium carbonate is a commercially important compound.
  (a) Transparent crystalline solid with ten molecules of water per molecule.
  (b) Soluble in water.
  (c) Washing soda solution is alkaline due to hydrolysis.
  (d) Has detergent or cleansing properties.
  (e) Sodium carbonate is used as washing soda in laundry as a cleansing agent, for softening hard water, in manufacturing glass, paper, soap and caustic soda.

  2. Sodium Bicarbonate ($NaHCO_3$): Sodium bicarbonate is commonly called baking soda. Sodium bicarbonate is prepared in the laboratory by saturating a cold solution of sodium carbonate with carbon dioxide.
  (a) Sodium bicarbonate separates as white crystals. This is because it is very sparingly soluble in water.
  (b) Sodium bicarbonate is sparingly soluble in water.
  (c) Used in the preparation of carbon dioxide.
  (d) Used as a constituent of baking powder, and in effervescent drinks. Baking powder has sodium bicarbonate and tartaric or citric acid. When it is dissolved in water or heated carbon dioxide is produced. This carbon dioxide gas causes the puffiness and lightness of cakes, biscuits etc.
  (e) Sodium bicarbonate is used to extinguish fire as it produces carbon dioxide gas.

11. Calcium (Ca):

- The elements of Group II like calcium are called the alkaline earth metals. The atomic number of calcium is 20 and its configuration is 2,8,8,2. Calcium loses two electrons and becomes Ca^{2+} ion with the stable configuration of argon. Calcium is therefore bivalent in nature. Some of the important calcium compounds:

1. Bleaching Powder ($CaOCl_2$):
(a) Calcium oxychloride is the chemical name of bleaching powder.
(b) Passing chlorine gas over dry slaked lime ($Ca(OH)_2$), gives bleaching powder.
(c) It is soluble in water. The lime present is always left behind as an insoluble salt. For this reason it is also called chloride of lime.
(d) Bleaching powder is commonly used for bleaching clothes. It is also used in bleaching wood pulp in the paper industry, to disinfect drinking water, to manufacture of chloroform ($CHCl_3$), an anaesthetic
2. Plaster of Paris ($(CaSO_4)_2.H_2O$): Chemically, plaster of paris is known as calcium sulphate hemihydrate (hemi means half). When gypsum is heated to 120ºC, it loses 75% of its water of crystallization to form plaster of Paris. It is a white powder. When mixed with water, it forms a plastic mass. After about half an hour, this mass sets into a hard solid mass constituting interlaced gypsum crystals. Plaster of Paris is used to set fractured bones due to its setting property on hydration, as a sealant in laboratories, manufacture of blackboard chalk.



JK Chrome
jk chrome
Contains ads
4.7 MB
Rated for 3+
Install
About this app
JK Chrome updates it's users with latest news & job updates from J&K.
News & Magazines
Rate this app
Tell others what you think