ATOMS AND MOLECULES

Atom

Ancient thoughts about 'atom': The idea about the divisibility of matter was given by Indian and Greek philosophers around 500 BC. The smallest indivisible particle was called 'parmanu' or 'atom' (in Greek).

Laws of chemical combination (based on experiments)

(a) Law of conservation of mass. Mass can neither be created nor destroyed or in any chemical reaction, the total mass of the reactants is equal to the total mass of the products.

For example, for the reaction,

$AgNO_3$ (aq)+ NaCl (aq) $\longrightarrow$ AgCl (s) + $NaNO_3$ (aq),

Total mass of $AgNO_3$ (aq) + NaCl (aq) = Total mass of AgCl (s) + $NaNO_3$ (aq).

(b) Law of constant proportions. A chemical compound is always made up of two or more atoms of same or different elements combined together in the same fixed proportion by mass. For example, H_2O always contains H and O in the fixed ratio of 1 : 8 by mass.

Dalton's Atomic Theory. This theory was put forward by Dalton (1808) to explain the laws of chemical combination.

Properties of Atoms

- **Atom:** An atom is the smallest particle of an element, which may or may not be able to exist freely. It is, however, the smallest particle that takes part in a chemical reaction.
- **Size of atoms:** Atoms are so small in size that they cannot be seen even under a microscope. Their radii are of the order of 10^{-10} m ($1\text{nm} = 10^{-9}$ m).
- **How do atoms exist?** Atoms of most of the elements exist in the combined state (as H_2, O_2, etc. or H_2O, NH_3 etc.) or as ions in the aqueous solution (as H^+, Cu^{2+}, Ag^+ etc.).
- **Symbols of atoms:** Short hand method of representing full name of an element is called its symbol. It is first capital letter or first capital letter and another small letter from the full name. For example, carbon (C), cobalt (Co), chlorine (Cl), copper (Cu, from Latin name, cuprum).
- **Atomic mass unit (amu) or unified mass (u):** It is $1/12^{th}$ of the mass of an atom of carbon-12 isotope.
- **Atomic mass:** Atomic mass of an element is the average relative mass of its atoms as compared with mass of carbon-12 isotope taken as 12 units.
- **Molecule:** A molecule is the smallest particle of an element or a compound, which is capable of free existence.
- **Atomicity:** The number of atoms present in one molecule of the substance is called its atomicity. Thus, we have monoatomic, diatomic, triatomic, tetratomic or polyatomic molecules.
- **Some molecules of elements:** Monoatomic = He, Ne, Na, Al, Fe etc. Diatomic = H_2, O_2, N_2 etc. Triatomic = O_3. Tetratomic = P_4.
- **Some molecules of compounds:** Diatomic = HCl, CO etc. Triatomic = H_2O, SO_2, CO_2

etc. Tetratomic = NH_3, H_2O_2 etc., Polyatomic = H_2SO_4, P_2O_5 etc.

- **Molecular mass:** It is the average relative mass of its molecules as compared with that of an atom of C-12 isotope taken as 12. It is calculated by adding atomic masses of all the atoms present in one molecule of the substance.

- **Ion:** An atom or a group of atoms which carries positive or negative charge is called an "ion", e.g., Na^+, K^+, Ca^{2+}, Mg^{2+} etc.(cation) or Cl^-, Br^-, I^-, NO_3^-, CO_3^{2-}, SO_4^{2-} etc. (anion)

Names and symbols of some ions

Valency	Metallic element	Symbol	Non-metallic element	Symbol	Polyatomic ions	Symbol
1.	Sodium	Na^+	Hydrogen	H^+	Ammonium	NH^{4+}
	Potassium	K^+	Hydride	H^-	Hydroxide	OH^-
	Silver	Ag^+	Chloride	Cl^-	Nitrate	NO_3^-
	Copper (I)*	Cu^+	Bromide	Br^-	Hydrogen carbonate	HCO_3^-
			Iodide	I^-		
2.	Magnesium	Mg^{2+}	Oxide	O^{2-}	Carbonate	CO_3^{2-}
	Calcium	Ca^{2+}	Sulphide	S^{2-}	Sulphite	SO_3^{2-}
	Zinc	Zn^{2+}			Sulphate	SO_4^{2-}
	Iron (II)*	Fe^{2+}				
	Copper (II)*	Cu^{2+}				
3.	Aluminium	Al^{3+}	Nitride	N^{3-}	Phosphate	PO_4^{3-}
	Iron (III)*	Fe^{3+}				

- **Cations and Anions:** The ion carrying positive charge is called "cation" whereas an ion carrying a negative charge is called an "anion".

- **Monoatomic and Polyatomic ions:** Ions consisting of only single atom are called monoatomic whereas ions consisting of groups of atoms are called polyatomic.

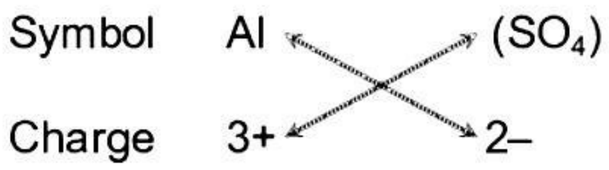
- **Valency:** Valency of an element is defined as its combining capacity. It is equal to the number of H-atoms or number of Cl-atoms or double the number of O-atoms with which one atom of the element combines. In case of ions, valency is defined as the number of units of charge present on the ion. Thus, we generally have monovalent, divalent or trivalent ions.

- **Examples of cations:** Monovalent = H^+, Na^+, K^+, Ag^+, NH_4^+ etc.

  Divalent = Mg^{2+}, Ca^{2+}, Ba^{2+}, Zn^{2+}, Cu^{2+} etc. Trivalent = Al^{3+}, Fe^{3+} etc.

- **Examples of anions:** Monovalent = Cl^-, Br^-, I^-, NH_3^- etc. Divalent = O^{2-}, S^{2-}, CO_3^{2-}, SO_4^{2-} etc. Trivalent = PO_4^{3-} etc.

- **Writing chemical formulae:** Write symbols of elements or ions (polyatomic in brackets). Write their respective valencies below them. Apply crisscross of valencies. Cancel out common factor, if any. For example, for aluminium sulphate,



Formula = $Al_2(SO_4)_3$

Mole Concept

- **Gram atomic mass:** Atomic mass of an element expressed in grams is called its gram atomic mass. This amount is called 'one gram atom'.

- **Gram molecular mass:** Molecular mass of a substance expressed in grams is called gram molecular mass. This amount is called 'one gram molecule'.

- **Gram formula unit mass:** For ionic compounds, the formula unit mass expressed in grams is called gram formula unit mass.

- **Avogadro's number (N_0):** Avogadro's number of particles = 6.022×10^{23} particles. Particles can be atoms, molecules, ions, grains, sand etc.

Mole

- One mole of atoms has mass equal to gram atomic mass and contains Avogadro's number of atoms.

- One mole of molecules has mass equal to gram molecular mass and contains Avogadro's number of molecules or has a volume of 22.4 L at STP if the substance is a gas.

- One mole of an ionic compound has mass equal to gram formula unit mass and contains Avogadro's number of formula units.

- **Molar mass:** The mass of one mole of the substance is called its molar mass. Its units are g mol^{-1}. Thus, it can be equal to gram atomic mass or gram molecular mass or gram formula mass depending upon whether the substance is atomic, molecular or ionic