SHORT NOTES: CLASS 9
CHAPTER 3: ATOMS AND MOLECULES

Antoine L. Lavoisier: *Known as the father of chemistry.*

Laws of Chemical Combination:

Law of Conservation of Mass: It was given by French Chemist "Antoine Lavoisier". It states that

(a) The total mass of the products of a chemical reaction is equal to the total mass of the reactants that have combined. http://www.physicsinduction.com

(b) Mass can neither be created nor destroyed, in a chemical reaction.

e.g., if a chemical reaction is represented as follows:

$A + B \rightarrow C + D$

Then, according to the law of conservation of mass,

Mass of A + Mass of B = Mass of C + Mass of D.

Law of Constant Proportion or Definite Composition: This law was given by French Chemist "Joseph Louis Proust". According to this law, in a chemical substance, the elements are always present in definite proportion by mass. http://www.physicsinduction.com

e.g., In a compound such as water, the ratio of the mass of hydrogen to oxygen is always 1:8. CO_2 is found to be made up of the same elements, i.e., C and O in a fixed ratio of 12:32 or 3:8 by mass.

Dalton's Atomic theory: According to Dalton's Atomic theory, all matter whether an element a compound, or a mixture is composed of small particles called matter. This theory was given by him in 1808. Its main postulates are:

i. Matter is made up of very small particles called atoms, which can't be divided further. i.e., Atoms are indivisible.
ii. Atoms can neither be created nor be destroyed. (Law of conservation of mass)
iii. Atoms of a given element are identical in mass and chemical properties.
iv. Atoms of different elements have different masses and chemical properties.
v. Atoms combine in the ratio of small whole numbers to form compounds. (Law of definite proportion)
vi. The relative number and kinds of atoms are constant in a given compound. i.e., atoms of different elements combine in simple numerical ratios.

e.g., $H_2O \rightarrow$ 2:1 $CO_2 \rightarrow$ 1:2 $CO \rightarrow$ 1:1

Note: Atoms of two elements can combine in more than one ratio to produce more than one compound.

e.g., $H_2O \rightarrow$ 2:1 $H_2O_2 \rightarrow 2:2 \rightarrow 1:1$ $CO \rightarrow$ 1:1 $CO_2 \rightarrow$ 1:2

$NO \rightarrow$ 1:1 $NO_2 \rightarrow$ 1:2 $N_2O \rightarrow$ 2:1

Drawbacks of Dalton's Atomic theory: http://www.physicsinduction.com

i. Atoms consist of subatomic particles. These are electrons, protons, and neutrons.
ii. Atoms of the same element can have different masses. (Isotopes)
iii. Atoms of different elements can have the same mass. (Isobars)

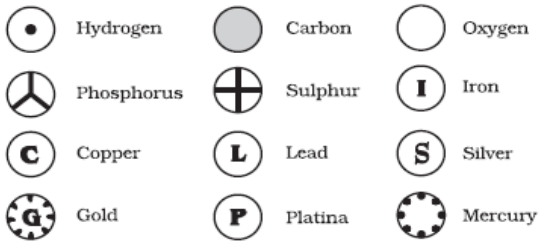
Atoms: The building blocks of all matter are atoms. An atom is the smallest particle of an element that can take part in a chemical reaction. With the help of a scanning tunneling microscope (STM), it has become possible to take photographs of some atoms.

Characteristics:

i. Atoms are extremely tiny particles with a radius of about 1×10^{-10}m.
ii. Atoms may or may not exist in a Free State. http://www.physicsinduction.com
iii. Each atom of an element shows all the properties of that element.
iv. All the atoms of a given element are similar but they differ from atoms of other elements.

Symbols of Atoms: A symbol is an abbreviation used to represent an element.

Dalton gave pictorial representation for elements.



Berzilius suggested that the symbols of elements be made from one or two letters of the name of the element. http://www.physicsinduction.com

Nowadays, the IUPAC (International Union of Pure and Applied Chemistry) approves names of elements. It requires the first letter to be written as a capital letter(uppercase) and the second letter (if any) as a small letter(lowercase).

Atomic mass: Each element has a characteristic atomic mass. It is very difficult to determine the masses of individual atoms because of their small size. Today, we have sophisticated techniques like mass spectroscopy for determining the atomic masses quite accurately. However, in the nineteenth century, scientists could determine the mass of one atom relative to another by experimental means. They calculated the mass of one atom as **relative mass.**

Relative Atomic mass: http://www.physicsinduction.com

- The 'Relative Atomic Mass' could be obtained by fixing the mass of some atom of a particular element as standard mass. The masses of other atoms could be compared relative to it.
- The 'Relative Atomic Mass' is expressed in units known as 'Atomic Mass Unit' (a.m.u.) or simply represented as unified mass(u).
- Scientists initially took $\frac{1}{16}^{th}$ of the mass of an atom of naturally occurring oxygen as the unit due to two reasons.
- It reacts with a large number of elements to form compounds. http://www.physicsinduction.com
- This atomic mass unit gave masses of many elements as whole numbers.
- However, in 1961, the Carbon-12 isotope was chosen as the standard reference for measuring atomic masses. One atomic mass unit is the mass unit equal to exactly $\frac{1}{12}^{th}$ the mass of one atom of carbon-12.
- **Relative Atomic Mass of an element** = $\frac{\boldsymbol{Mass\ of\ 1\ atom\ of\ the\ element}}{\frac{\boldsymbol{1}}{\boldsymbol{12}}\boldsymbol{Mass\ of\ 1\ atom\ of\ C-12}}$
- 1 amu = 1.66056 x 10^{-27} Kg = 1.66056 x 10^{-24} g
- Mass of an atom of hydrogen = 1.6736 x 10^{-24} g

∴ Mass of Hydrogen (amu) = $\frac{1.6736 \times 10^{-24}\ g}{1.66056 \times 10^{-24}\ g}$ 1.0078 amu ≈ 1.0080amu

Molecules:

- A group of two or more atoms (same or different) chemically bonded to each other and held together by strong attractive forces. http://www.physicsinduction.com
- It can also be defined as the smallest particle of matter (element or compound) that can exist in a free state exhibiting all the properties of that matter.

Characteristics:

- Molecules are stable species with less energy content.
- All molecules of any given compound are similar. e.g., All water molecules → H_2O
- Molecules of different compounds are different.

e.g., water molecules → H_2O & Carbon dioxide molecules → CO_2

Atomicity: The total number of atoms constituting a molecule is called its atomicity.

Types of Molecules: http://www.physicsinduction.com

Based on the type of atoms: i. Molecules of Elements ii. Molecules of Compounds

Based on atomicity: i. Monoatomicii. Diatomic iii. Triatomic and so on

Molecules of Elements: Molecules of an element are constituted by the same type of atoms. (i.e., Homoatomic).

e.g., He, Ne, Ar (Monoatomic) H_2, Cl_2, O_2 (Diatomic) O_3 (Triatomic) Phosphorus, P_4(Tetra-atomic) Sulphur, S_8(Octa-atomic) Buckminster fullerene, C_{60} (Polyatomic)

Molecules of Compounds: Atoms of different elements join together in definite proportions to form molecules of compounds. The molecules of the compounds are heteroatomic in the sense that different atoms are present in them.

e.g., HCl (Diatomic) NH_3 (Tetra-atomic) http://www.physicsinduction.com

Calculation of ratio by mass using ratio by number of atoms: Carbon dioxide (CO_2):

Elements	**C**	**O**
Atomic Mass(u)	12	16
Ratio by number of atoms	1	2
Ratio by mass (Number of atoms x atomic mass)	1 x 12 = 12	2 x 16 = 32
Simplest Ratio	3	8

Calculation of ratio by number of atoms using ratio by mass: Water (H_2O):

Element	**Ratio by mass**	**Atomic mass(u)**	**Mass ratio/Atomic mass**	**Simplest ratio**
Hydrogen (H)	1	1	$\frac{1}{1} = 1$	2
Oxygen (O)	8	16	$\frac{8}{16} = \frac{1}{2}$	1

Ions: Charged species are called ions. A positively charged ion is called **Cation** and a negatively charged ion is called **Anion**. http://www.physicsinduction.com

An atom consists of subatomic particles, i.e., protons, neutrons, and electrons. Protons and neutrons are present in the nucleus of an atom while electrons are present in the extranuclear space. The addition and removal of electrons are possible in an atom. This addition and removal of electrons leads to the formation of charged atoms, known as ions.

*The distribution or arrangement of electrons around the nucleus is called **electronic configuration**.

***Valency** is the combined capacity of an atom. The valency of an ion is defined as the units of positive or negative charge present on that ion. http://www.physicsinduction.com

Element	**Symbol**	**Atomic Mass(u), A**	**Atomic Number Z**	**Electronic Configuration**	**Valency**	**Charge**
i. Hydrogen	H	1.008	1	1	1	± 1
ii. Helium	He	4	2	2	0	Inert/Noble gas
iii. Lithium	Li	7	3	2,1	1	+1
iv. Beryllium	Be	9	4	2,2	2	+2
v. Boron	B	10.8	5	2,3	3	+3

vi. Carbon	C	12	6	2,4	4	Covalent Bond
vii. Nitrogen	N	14	7	2,5	3	-3
viii. Oxygen	O	16	8	2,6	2	-2
ix. Fluorine	F	18.9	9	2,7	1	-1
x. Neon	Ne	20	10	2,8	0	Inert/Noble gas
xi. Sodium	Na	23	11	2,8,1	1	+1
xii. Magnesium	Mg	24	12	2,8,2	2	+2
xiii. Aluminium	Al	27	13	2,8,3	3	+3
xiv. Silicon	Si	28	14	2,8,4	4	Covalent Bond
xv. Phosphorus	P	31	15	2,8,5	3, 5	-3, +5
xvi. Sulphur	S	32	16	2,8,6	2	-2
xvii. Chlorine	Cl	35.5	17	2,8,7	1	-1
xviii. Argon	Ar	40	18	2,8,8	0	Inert/Noble gas
xix. Potassium	K	39	19	2,8,8,1	1	+1
xx. Calcium	Ca	40	20	2,8,8,2	2	+2

Polyatomic ions: A group of atoms having an electric charge is called a polyatomic ion. Positively charged polyatomic ions are called polyatomic cations and negatively charged polyatomic ions are called polyatomic anions. http://www.physicsinduction.com

Examples:

Polyatomic cation: Ammonium ion, NH_4^+; Phosphonium ion, PH_4^+

Polyatomic anion: Sulphate ion, SO_4^{2-}; Nitrate ion, NO_3^-; Phosphate ion, PO_4^{3-}

List of some common ions:

Silver: Ag^+	Chloride: Cl^-	Nitrate: NO_3^-	Manganate: MnO_4^{2-}
Gold: Au^+, Au^{3+}	Bromide: Br^-	Nitrite: NO_2^-	Permanganate: MnO_4^-
Barium: Ba^{2+}	Iodide: I^-	Carbonate: CO_3^{2-}	Oxalate: $C_2O_4^{2-}$
Zinc: Zn^{2+}	Sulphide: S^{2-}	Bicarbonate: HCO_3^-	Chromate: CrO_4^{2-}
Cobalt: Co^{2+}	Oxide, O^{2-}	Cyanide: CN^-	Dichromate: $Cr_2O_7^{2-}$
Copper: Cu^{2+}	Nitride: N^{3-}	Sulphate: SO_4^{2-}	Ammonium ion: NH_4^+
Chromium: Cr^{3+}	Phosphide: P^{3-}	Sulphite: SO_3^{2-}	Hydride: H^-
Iron: Fe^{2+}, Fe^{3+}	Hydroxide: OH^-	Borate: BO_3^{3-}	Hydrogen: H^+
Fluoride: F^-	Phosphate: PO_4^{3-}	Arsenate: $(AsO_3)^{3-}$	Chlorate: ClO_3^-

Chemical formula: A chemical formula represents the composition of a molecule of the substance in terms of symbols of elements present in the molecule. http://www.physicsinduction.com

Molecular formula: The molecular formula represents the actual number of atoms of various elements present in one molecule of the compound.

Chemical Formulae of Compounds:

Symbol	H	Cl
Valency	1	1
Formula = HCl		

The formula of hydrogen chloride:

Molecular Mass: The molecular mass of a substance is the sum of the atomic masses of all the atoms present in a molecule of the substance. It is, therefore, the relative mass of a molecule expressed in the atomic mass unit(u). http://www.physicsinduction.com

Formula Unit Mass: The formula unit mass of a substance is the sum of the atomic masses of all the atoms in a formula unit of a compound.

*Formula unit mass and molecular mass both are calculated in the same manner. The only difference is that the word formula unit is used for those substances whose constituents' particles are ions. http://www.physicsinduction.com

Mole Concept: One mole of any species (atoms, molecules, ions, or particles) is that quantity in number having mass equal to atomic/molecular mass in grams.

The number of particles present in 1 mole is fixed and is equal to 6.022×10^{23}. This is an experimentally observed value and it is called Avogadro's number, N_o.

e.g., 1 mole of H atom contains 6.022×10^{23} H atoms.

1 mole of O_2 molecule contains 6.022×10^{23} O_2 molecules.

1 mole of Na^+ ion contains 6.022×10^{23} Na^+ ions. http://www.physicsinduction.com

$$\textbf{Number of moles} = \frac{\textbf{Given the number of particles, N}}{\textbf{Avogadro's Number, } N_o}$$

$$\textbf{Number of moles (For elements)} = \frac{\textbf{Given mass, m}}{\textbf{Gram atomic mass, M}}$$

$$\textbf{Number of moles (For compounds)} = \frac{\textbf{Given mass, m}}{\textbf{Gram molecular mass, M}}$$

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