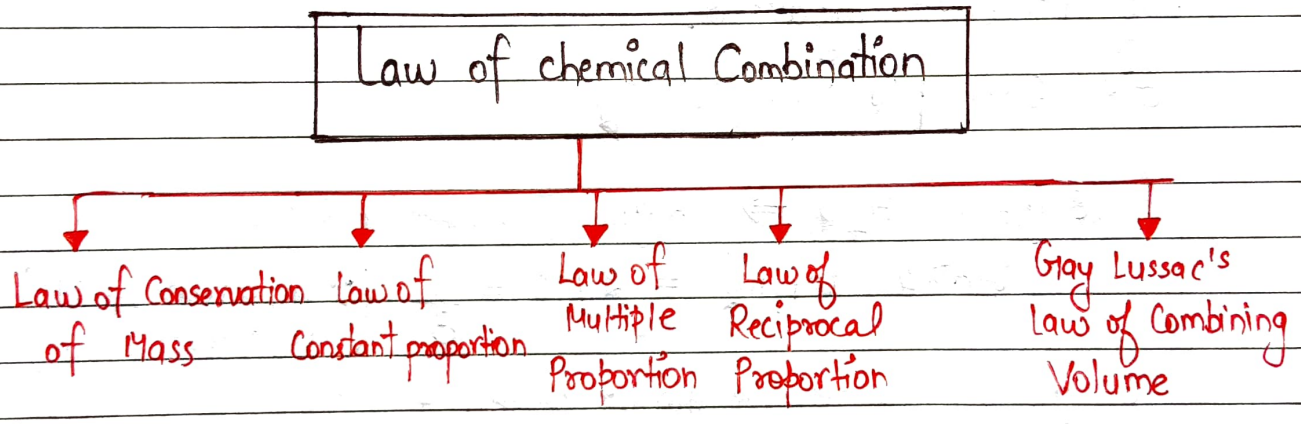
Dt.:
Pg.:

ATOMS & MOLECULE

- Laws of chemical combination :

The chemical reaction between two or more substances giving rise to products is governed by Certain laws. These Laws are called Laws of chemical Combination.



- Law of Conservation of Mass :

According to this law, "Mass can neither be created nor destroyed." It means During a chemical reaction total mass of reactants will be equal to total mass of Products.

for example $\underset{\text{(Reactant)}}{A + B} \longrightarrow \underset{\text{(Product)}}{AB}$

then $\boxed{m_A + m_B = m_{AB}}$

Example : In a reaction 5.3 gm of sodium carbonate reacted with 6 gm of ethanoic acid. The products were 2.2 gm of CO_2, 0.9 gm of H_2O and 8.2 gm of sodium ethanoate. Show that these observation are all in agreement with law of conservation of mass.

Sodium carbonate + Ethanoic acid → Sodium ethanoate + CO_2 + H_2O

Solution :

$$\underbrace{\text{Sodium carbonate + Ethanoic acid}}_{\text{Reactants}} \rightarrow \underbrace{\text{Sodium ethanoate + } CO_2 + H_2O}_{\text{Products}}$$

Now, according to the law of conservation of mass :

Mass of sodium carbonate + Mass of ethanoic acid = Mass of sodium ethanoate + Mass of CO_2 + Mass of H_2O

Putting values of masses from the equation :

$$5.3 \text{ gm} + 6.0 \text{ gm} = 8.2 \text{ gm} + 2.2 \text{ gm} + 0.9 \text{ gm}$$

Or $$11.3 \text{ gm} = 11.3 \text{ gm}$$

Since, LHS = RHS

∴ Law of conservation of mass is in agreement with the given values in equation.

Dt.:
Pg.:

MOLE & MOLECULE

- **Law of constant Proportion :**

According to this law, "A pure chemical compound always contain the same elements combined together in the same proportion by mass irrespective of the fact from where the sample has been taken or from which procedure has it been produced.

अरे Example से समझो ↘

18 gm of H_2O ⇒ 16 gm of oxygen + 2 gm of hydrogen

मतलब $m_1/m_2 = 2/16 = \frac{1}{8}$ ($\because m_1$ = mass of H, m_2 = mass of O)

36 gm of H_2O ⇒ 32 gm of oxygen + 4 gm of hydrogen

$m_1/m_2 = 4/32 = \frac{1}{8}$

Compound के mass का proportion हमेशा same रहेगा।
(Element के)

Example : Hydrogen and oxygen combine in the ratio 1 : 8 by mass to form water. What mass of oxygen gas would be required to react completely with 3.0 gm of hydrogen gas ?

Solution : $\frac{m_H}{m_O} = \frac{1}{8}$ Given in equation (For H_2O)

But, $m_H = 3.0$ gm (given)

Or $\frac{3}{m_O} = \frac{1}{8}$

Or $m_O = 24$ gm

∴ Mass of oxygen will be 24 gm.

Or it will be a sample of 27 gm of H_2O where 3 gm of hydrogen is present with 24 gm of oxygen.

• Dalton's Atomic Theory :

- All matter is made up of very tiny particles called Atoms.
- Atom are indivisible particles, which can't be created or destroyed in a chemical reaction. { law of Conservation of mass }
- Atoms of an element have identical mass and chemical Properties.
- Atoms combine in the ratio of small whole numbers to form Compounds. { Law of constant proportion }
- The relative number and kinds of atoms are constant in given Compound.

■ ATOM :

- Each element का smallest particle Atom होता है। during the chemical reaction, the atom maintain its identity throughout chemical or physical change.
- Atoms को eyes से नहीं देख सकते, we use very very high power microscope to see Atoms.
- Atomic radius of smallest atom in hydrogen is 0.37×10^{-10} m or 0.037 nm.

देखो $\boxed{1\ nm = 10^{-9}\ m}$ nm = nanometer

IUPAC (International Union of Pure & Applied Chemistry) Symbols of Atoms of Different Elements

Element	Symbol	Element	Symbol
Aluminium	Al	Iodine	I
Argon	Ar	Iron	Fe
Barium	Ba	Lead	Pb
Calcium	Ca	Nitrogen	N
Carbon	C	Oxygen	O
Chlorine	Cl	Potassium	K
Cobalt	Co	Silicon	Si
Copper	Cu	Silver	Ag
Fluorine	F	Sulphur	S
Gold	Au	Zinc	Zn
Hydrogen	H		

Atomic Mass :

- The mass of an atom of an element is called its atomic Mass.
- In 1961, IUPAC have accepted 'atomic mass unit' (u) to express atomic & molecular mass of elements and Compounds.

Atomic mass unit :

The atomic mass unit is defined as the quantity of mass equal to 1/12 of mass of an atom of Carbon-12.

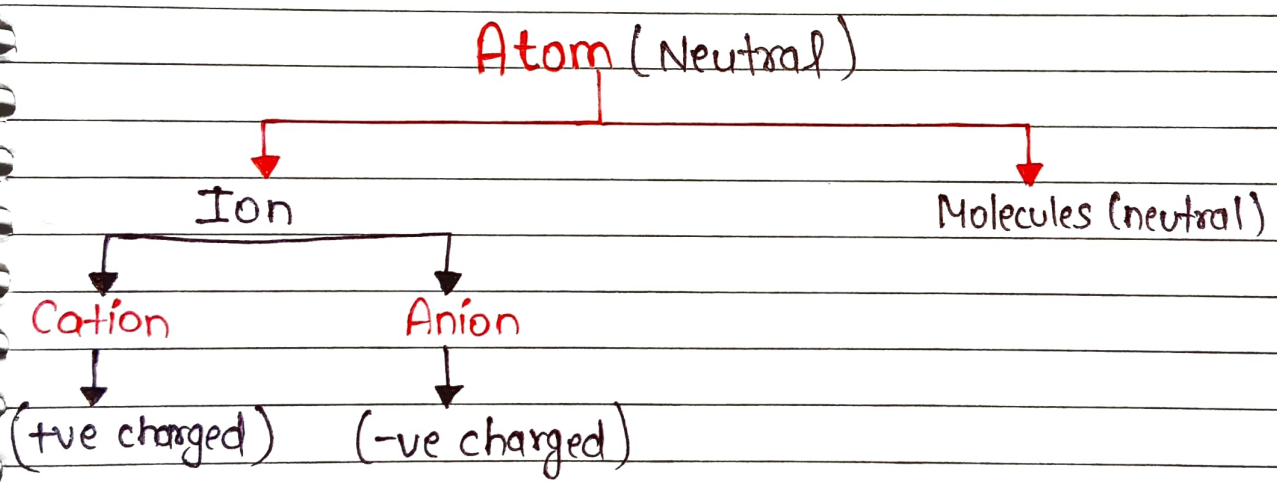
$$1 \text{ amu or } u = \frac{1}{12} \times \text{Mass of an atom of C}$$

$$\boxed{1u = 1.66 \times 10^{-27} \text{ kg}}$$

Element	Atomic Mass	Element	Atomic mass
Hydrogen	1u	Magnesium	24u
Carbon	12u	Sulphur	32u
Nitrogen	14u	chloride	35.5u
Oxygen	16u	Calcium	40u
Sodium	23u		

How do atoms exist ?

- Atoms of most of the elements are very reactive and does not exist in free state.
- Only the atoms of noble gases (such as He, Ne, Ar, Kr, Xe) are chemically unreactive and can exist in free state as single atom.
- Atoms of all other elements combine together to form molecules or ions.



Molecule :

- A molecule is a group of two or more atoms which are chemically bonded with each other.
- A molecule is the smallest particle of matter (except element) which is capable of an independent existence and show all properties of that substance.

Molecules

- Homoatomic molecules of elements → *Eg.*, O_2, N_2, O_3, S_8, P_4 etc.
- Heteroatomic molecules compounds → *Eg.*, H_2O , NO_2, SO_2 etc.

Atomicity

The number of atoms present in one molecule of an element is called its atomicity.

	Name	Formula	Atomicity	
1.	Argon	Ar	Monoatomic (1)	Noble gasses constitute monoatomic molecules
2.	Helium	He	Monoatomic (1)	
3.	Oxygen	O_2	Diatomic (2)	
4.	Hydrogen	H_2	Diatomic (2)	
5.	Phosphorus	P_4	Tetratomic (4)	
6.	Sulphur	S_8	Polyatomic (8)	
7.	Ozone	O_3	Triatomic (3)	

Chemical formulae

It is the symbolic representation of the composition of a compound.

Characteristics of chemical formulae

- The valencies or charges on ion must balance.
- When a compound is formed of metal and non-metal, symbol of metal comes first. *E.g.*, CaO, NaCl, CuO.
- When polyatomic ions are used, the ions are enclosed in brackets before writing the number to show the ratio. E.g., $Ca(OH)_2$, $(NH_4)_2 SO_4$

Molecular Mass

It is the sum of atomic masses of all the atoms in a molecule of that substance.

E.g., Molecular mass of H_2O = 2 x Atomic mass of Hydrogen + 1 x Atomic mass of Oxygen

So, Molecular mass of $H_2O = 2 \times 1 + 1 \times 16 = 18\ u$

Formula Unit Mass

It is the sum of atomic mass of ions and atoms present in formula for a compound.

E.g., In NaCl, Na = 23 a.m.u. Cl = 35.5 a.m.u.

So, Formula unit mass = 1 x 23 + 1 x 35.5 = 58.5 *u*

Rule for writing chemical formulae

Rule-1 (i) We first write symbols of elements which form compound.

(ii) Below the symbol of each element, we should write their valency.

(iii) Now criss cross the valencies of combining atoms.

(iv) with first atom, we write the valency of second atom (as a subscript).

(v) with second atom, we write the valency of first atom (subscript).

Rule-2 When the velency is one, subscript is not written.

Rule-3 When there are multiple number of polyatomic ion, bracket must be used to separate the Polyatomic ion from subscript.

Examples:

(i) Symbol : H S

Valencies : 1 2 H_2S_1 or H_2S (Hydrogen sulphide)

(ii) Symbol : C O eg. $(NH_4)_2SO_4$, $Al_2(SO_4)_3$

Valencies : 4 2 C_2O_4 or CO_2 (Carbon dioxide)

[Take 2 common and divide the formula by 2]

(iii) For Hydrochloric acid (Hydrogen chloride)

H Cl

1 1 H_1Cl or HCl

(iv) For Carbon tetrachloride

C Cl

4 1 C_1Cl_4 or CCl_4

(v) For Magnesium chloride

Mg Cl

2 1 $MgCl_2$

(vi) For aluminium oxide

Al O

3 2 Al_2O_3

(vii) For Calcium oxide

Ca O

2 2 Ca_2O_2 or CaO

[Take 2 common and divide the formula by 2]

+1 1-

Ions

An ion may be defined as an atom or group of atoms having positive or negative charge.

Some positively charged ions : Na^+, K^+, Ca^{2+}, Al^{3+}

Some negatively charged ions : Cl- (chloride ion), S^{2-} (sulphide ion), OH^- (hydroxide ion), SO_4^{2-} (sulphate ion)

Monoatonic Tons	Polyatomic Ions
Mg^{2+} (Magnesium ion)	NH_4^+ (Ammonium ion)
Na^+ (Sodium ion)	CO_3^{2-} (Carbonate ion)
Cl^- (Chloride ion)	SO_4^{2-} (Sulphate ion)
Al^{3+} (Aluminium ion)	OH^- (Hydroxide ion)

Chemical Formulae of Ionic Compounds (Polyatomic)

(i) Sodium carbonate

Na^{1+} CO_3^{2-} → Na_2CO_3

(ii) Aluminium sulphate

Al^{3+} SO_4^{2-} → $Al_2(SO_4)_3$

(iii) Calcium hydroxide

Ca^{2+} OH^{-1} → $Ca(OH)_2$

(iv) Ammonium sulphate

NH_4^{1+} SO_4^{2-} → $(NH_4)_2SO_4$

Molar Mass

The molar mass of a substance is the mass of 1 mole of that substance.

It is equal to the 6.022×10^{23} atoms of that element/substance.

Example :

(a) Atomic mass of hydrogen (H) is 1 *u*. Its molar mass is 1 g/mol.

(b) Atomic mass of nitrogen is 14 *u*. So, molar mass of nitrogen (N) is 14 g/mol.

(c) Molar mass of S_8 = Mass of S x 8 = 32 x 8 = 256 g/mol

(d) Molar mass of HCl = Mass of H + Mass of Cl

= 1 = 35.5 = 36.5 g/mol

Mole concept

A group of 6.022×10^{23} Particles (atoms, molecules or ions) of a substance is called a mole of that substance.

1 mole of atoms = 6.022×10^{23} atoms

1 mole of molecules = 6.022×10^{23} molecules

Example, 1 mole of oxygen = 6.022×10^{23} oxygen atoms

6.022×10^{23} is Avogadro Number (L).

- 1 mole of atoms of an element has a mass equal to gram atomic mass of the element.

Improtant Formulae

(i) Number of moles $(n) = \dfrac{\text{Given mas}}{\text{Molar mass}} = \dfrac{m}{M}$

(ii) Number of moles $(n) = \dfrac{\text{Given number of particles}}{\text{Avogadro's number}}$

$$n = \frac{N}{N_0}$$

(iii) $\dfrac{m}{M} = \dfrac{N}{N_0}$ $\qquad m = \dfrac{MxN}{N_0}$

(iv) Percentage of any atom in given compound $= \frac{\text{Mass of element} \times 100}{\text{Mass of compound}}$

Example. *Calculate no. of iron atoms in a piece of iron weighing 2.8 gm (At mass = 54 u).*

Solution : 1 mole of iron = 56 gm (Gram atomic mass of iron)

1 mole of iron element contains 6.022×10^{23} atoms of iron.

So, 56 gm of iron $= 6.022 \times 10^{23}$ atoms

2.8 gm of iron $= \frac{6.022 \times 10^{23} \times 2.8}{56}$

$= 3.011 \times 10^{22}$ atoms

Example. *Mass of one molecule of a substance is 5.32×10^{-23} g. What is its molecular mass ?*

Solution : Mass of 1 molecule of substance

$= 5.32 \times 10^{-23}$ g

Mass of 6.022×10^{23} molecules of substance

$= 5.32 \times 10^{-23} \times 6.022 \times 10^{23}$

$= 32$g

Example. *Calculate the mass of 0.5 mole of N_2 gas.*

Solution: 1 mole of N_2 = Gram molecular mass of N_2

Or 1 mole of N_2 = 28 gm

∴ 0.5 mole of N_2 gas $= 0.5 \times 28$

$= 14$ gm of N_2

Example. *Calculate the total number of O_2 molecules present in 8 gm of O_2*

Solution: Gram molecular mass of O_2

$= 6.022 \times 10^{23}$ O_2 molecules

Or 32 gm of O_2 $= 6.022 \times 10^{23}$ O_2 molecules

Or 8 gm of O_2 $= 6.022 \times 10^{23} \times 8/32$ O_2 molecules

$= 1.51 \times 10^{23}$ O_2 molecules

QUESTIONS

VERY SHORT ANSWER TYPE QUESTIONS

1. Name two laws of Chemical combination.
2. What is atomicity.
3. State law of conservation of mass.
4. State law of constant proportion.
5. Calculate molecular mass of CO_2.
   (At. mass of C = 12 *u*, At. Mass of O = 16u)
6. In what form do atoms of noble gases occur in nature.
7. Define molecular mass.
8. What do you understand by term 1 mole.
9. Write the chemical symbols of nitrogen gas and oxygen gas.
10. Name the elements by reading the given symbols.
    Na, K, Ar, Nc, N, Mg, Al, Ca.

SHORT ANSWER TYPE QUESTIONS

1. Write the chemical formulae of-

   (a) Calcium chloride
   (b) Magnesium bicarbonate
   (c) Aluminum sulphate
   (d) Sodium carbonate
   (e) Lead Nitrate
   (f) Calcium Phosphate
   (g) Iron (II) sulphide
   (h) Mercury (I) chloride.

2. Write the molecular formulae of all the compounds that can be formed by the combination of following ions.

   Cu^{2+}, Na^{+}, Fe^{3+}, Cl^{-}, SO_4^{2-}, PO_4^{3-}

3. Write the cations (Positively ions) and anions (negatively changed ions) **Present** (If any) in the following compounds.

(a) NaCl (c) NH_4NO_3

(b) H_2 (d) $Ca(HCO_3)_2$

4. Give the formulae of the compounds formed from the following sets of elements

(a) Calcium and fluorine (d) Sulphur and Oxygen

(b) Nitrogen and Hydrogen (e) Carbon and Oxygen

(c) Nitrogen and Oxygen (f) Carbon and Chlorine

5. Classify each of the following on the basis of their atomicity.

(a) F_2 (b) NO_2 (c) CH_4 (d) P_4 (e) H_2O_2

(f) P_4O_{10} (g) O_3 (h) HCl (i) He (j) Ag

6. Calculate the number of moles of magnesium present in a magnesium ribbon weighing 12 gm. Molar atomic mass of Magnesium is 24 gm/mol.

7. write postulates of Daltion's atomic theory (atleast three).

8. what is the difference between the molecules of an element and the molecule of a compound? Give one example of each.

9. What is the difference between 2H and H_2? (atleast 2 dif.)

10. (a) what would be gm atomic mass of 5 moles of chlorine?

(b) Calculate the gm atomic mass of one atom of oxygen.

(gm at. mass of oxygen = 16 gm.)

LONG ANSWER TYPE QUESTIONS

1. Verify by calculating that 5 moles of CO_2 and 5 moles of H_2 do not have the same mass.

[Hint : molar mass of CO_2 = 44 g and molar mass of H_2O = 18 g]

2. If you take 5 moles of carbon atoms in a container and your friend take 5 moles of sodium atoms in another container of same weight.
   [Hint : molar mass of carbon = 12 gm. molar mass of sodium = 23 gm]
   (a) Whose container will be heavier?
   (b) Whose ontainer has more number of atoms?
3. Which has more number of atoms?
   100 gm of N_2 or 100 gm of Ammonia NH_3

$$\left[\text{Hint : No. of atoms} = \frac{\text{mass}}{\text{molar mass}} \text{X } 6.022 \text{ X } 10^{23}\right]$$

4. Hydrogen and oxygen combine in the ratio of 1:8 by mass to form water, What mass of oxygen gas would be required to react completely with 3 gm of Hydrogen gas?
5. (a) Which postulate of Dalton's atomic theory is the result of the law of conservation of mass?
   (b) Which postulate of Dalton's atomic theory can explain the law of constant

Objective Type Questions

1. Which of the following statements is not true about an atom?
   a. Atoms are not able to exist independently
   b. Atoms are the basic units from which molecules and ions are formed
   c. Atoms are always neutral in nature
   d. Atoms aggregate in large numbers to form the matter that we can see, feel or touch
2. The chemical symbol for nitrogen gas is
   a, Ni
   b. N_2
   c. N^+
   d. N

3. The Chemical symbol for sodium is
   a. So
   b. Sd
   c. NA
   d. Na
4. Which of the following correctly represents 360 g of water?
   i. 2 moles of water.
   ii. 20 moles of water
   iii. 6.022 x 1023 molecules of water
   iv. 1.2044 x 1025 molecules of water
   a. i.
   b. i.and iv
   c. ii and iii
   d. ii and iv
5. Give the formulae of the formed from the following sets of elements
   a. Calcium and fluorine
   b. Hydrogen and sulphur
   c. Nitrogen and hydrogen
   d. Carbon and chlorine
   e. Sodium and oxygen
   f. Carbon and oxygen
6. Write the molecular formulae for the following compounds
   a. Copper (II) bromide. .....
   b. Aluminium (III) nitrate. .....
   c. Calcium (II) phoshate .....
   d. Iron (III) sulphide .....
   e. Mercury (II) chloride .....
   f. Magnesium (II) chloride .....

7. Write the molecular formulae of the compounds that can be formed by the combination of following ions

a. Cu^{2+} and Cl^{-} .....

b. Na^{+} and NO_3- .....

c. Fe^{3+} and SO_4^{2-} .....

d. Fe^{3+} and Cl^{-} .....

8. classify each of the following on the basis of their atomicity.

Elements	Atomicity
F_2	
NO_3	
N_2O	
P_4	
H_2O_2	
He	
Ag	
CH_4	
P_4O_{10}	

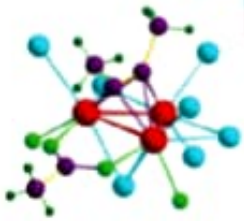
9. Fill in the blanks

a. In a chemical reaction, the sum of the masses of the reactants and product remains unchanged. This is called .....

b. A group of atoms carrying a fixed charge on them is called .....

c. The formula unit mass of $Ca_3(PO_4)_2$ is .....

d. Formula of sodium carbonate is ..... and that of ammonium sulphate is .....



Chapter - 3

Atoms And Molecules

CONCEPT MAPPING

Law of Chemical Combination

Law of conservation of mass

- mass can neither be created nor be destroyed
- eg. $C+O_2 \rightarrow CO_2$
  $12gm + 32gm \rightarrow 44gm$

Law of constant proportion

- Compound consists of the elements combined together in the same ratio
- $H_2O = 2 : 16$
  $1 : 8$

Dalton's Atomic Theory

(Atom) are :
tiny particle

- indivisible
  (Can neither be created nor destroyed)
- Identical mass and chemical Properties
  (Same element)
- Different mass and chemical properties
  (diff. elements)
- Combine in a same ratio

Atom

- Smallest particle of an element
- Each atom shows all the properties of element

Molecule

- Smallest particle of elements or compounds
- Properties of the substances are the properties of molecules

Atomic mass

- mass of an atom
- equals to $\frac{1}{12}$ of mass C-12 atom

Existence of Atom

- Reactive
- Free
- Combine to form

Ions

- Monoatomic
- Polyatomic

- Types of molecute → Homoatomic, Heteroatomic
- Molecular mass → Sum of masses of all atoms
- Formula unit mass → Sum of atomic mass of ions and atoms
- Atomicity → no. of atoms present in one molecule