

## CHAPTER - 3 “Atoms and Molecules”

### CONCEPT DETAILS

KEY CONCEPTS : [ \*rating as per the significance of concept]

1. Laws of Chemical Combination	***
2. John Daltons Atomic Theory	**
3. Atoms, ions & Chemical Formula	****
4. Mole Concept	*****
5. Molar Mass & Avogadro constant	****



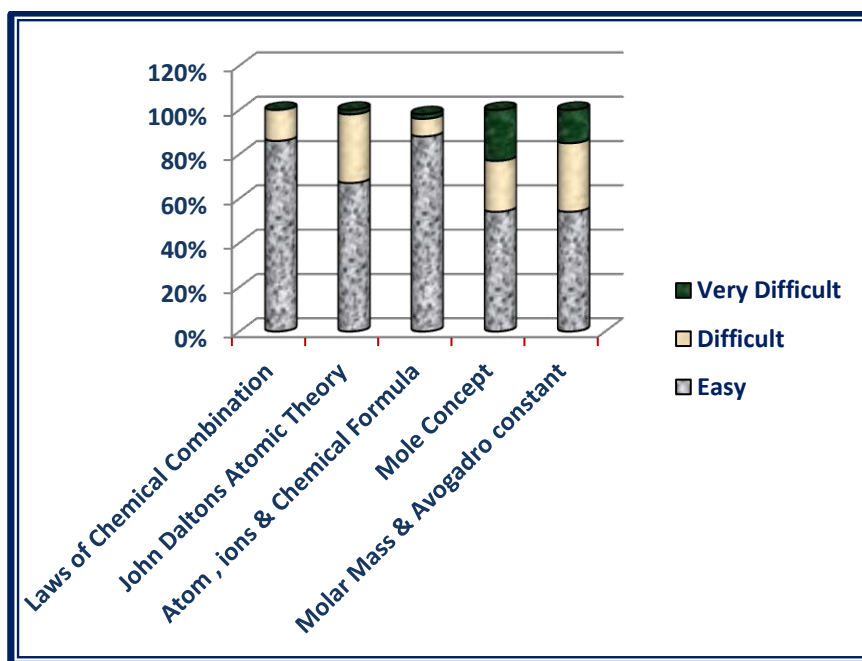
#### Pre requisites

*Basic knowledge all states of matter.*

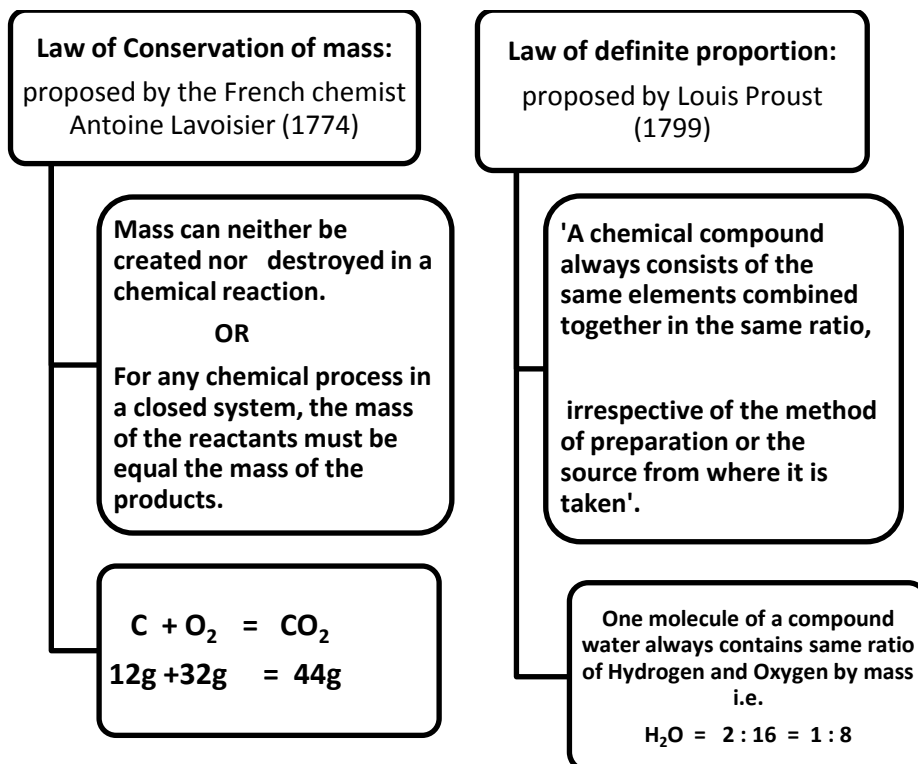
*Difference in the different states of matter .*

### SURVEY ANALYSIS

Conceptual levels of comprehension on the basis of feedback taken from the students

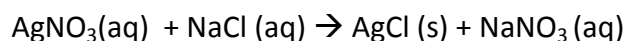


## 1.Laws of Chemical Combination



### Verification of “Law of Conservation of mass”

A solution of sodium chloride and silver nitrate are taken separately in the two limbs of an 'H' shaped tube. The tube is sealed and weighed precisely. The two reactants are made to react by inverting the tube. The following reaction takes place.



The whole tube is kept undisturbed for sometime so that the reaction is complete.

When the tube is weighed again it is observed that:

Weight before the reaction = Weight after the reaction

### Limitation of “Law of definite proportion”

*This law does not hold good when the compound is obtained by using different isotopes of the combining elements .*

Q.1 Why chemical reactions are in accordance with the Law of conservation of mass?

Q.2 Calculate the ratio of atoms present in 5 g of magnesium and 5 g of iron.

[Atomic mass of Mg=24 u, Fe=56 u]

## 2. John Daltons Atomic Theory

[ for postulates ,refer NCERT text book article 3.1.2 -page no.32 ]

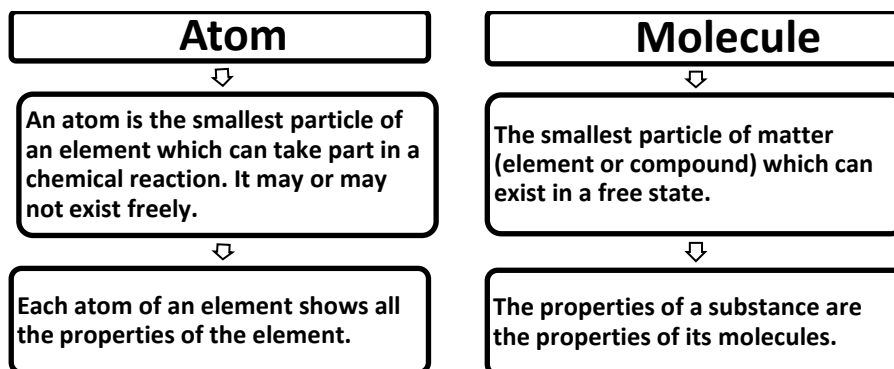
Using his theory, Dalton rationalized the various laws of chemical combination which were in existence at that time. However, **he assumed that the simplest compound of two elements must be binary.**

Q.1 In what respect does Dalton's Atomic theory hold good even today?

Q.2 Which of the following is not the postulate of Dalton's Atomic theory of matter ?

- a) Each element is made up of extremely small particles called atoms.
- b) Atoms of a given element are identical in chemical properties but have different physical properties.
- c) Atoms cannot be created nor destroyed.
- d) Compounds are formed by the chemical union of atoms of two or more elements in fixed proportion .

## 3. Atoms ,Molecules, Ions & Chemical Formula



- **MOLECULES OF ELEMENT** : The molecules of an element are constituted by the same type of atoms.
- **MOLECULES OF COMPOUND**: Atoms of different elements join together in definite proportions to form molecules of compounds.(hetero atomic molecules)
- **ATOMICITY** : The number of atoms contained in a molecule of a substance (element or compound) is called its atomicity.

Element	Formula	Atomicity
Ozone	O <sub>3</sub>	3
Phosphorus	P <sub>4</sub>	4
Sulphur	S <sub>8</sub>	8
Oxygen	O <sub>2</sub>	2

- Based upon atomicity molecules can be classified as follows.

**Monoatomic molecules:** Noble gases helium, neon and argon exist as He Ne and Ar respectively.

**Diatomic molecules:**  $H_2$ ,  $O_2$ ,  $N_2$ ,  $Cl_2$ ,  $CO$ ,  $HCl$ .

**Triatomic molecules:**  $O_3$ ,  $CO_2$ ,  $NO_2$ .

➤ **SYMBOLS**

- The abbreviation used to represent an element is generally the first letter in capital of the English name of element.

Oxygen → O

Nitrogen → N

- When the names of two or more elements begin with the same initial letter, the initial letter followed by the letter appearing later in the name is used to symbolize the element

Barium → Ba

Bismuth → Bi

**Symbols of some elements are derived from their Latin names**

ELEMENT	LATIN NAME	SYMBOL
Sodium	Natrium	Na
Copper	Cuprum	Cu
Potassium	Kalium	K
Iron	Ferrum	Fe
Mercury	Hydragyrum	Hg
Tungsten	Wolfram	W

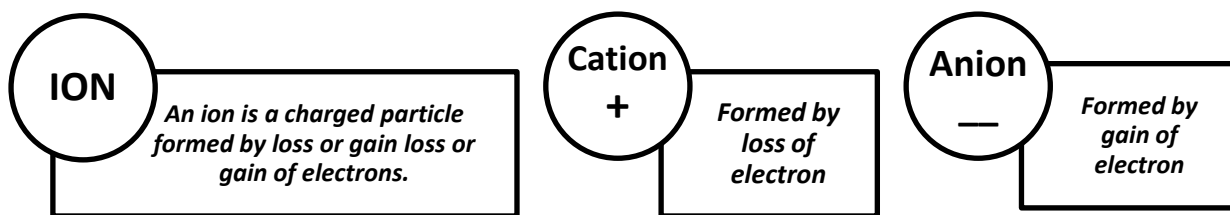
*Q.1 Give one example each of molecule of element & molecule of compound.*

*Q.2 How does an atom differ from molecule ?*

*Q.3 Name a triatomic gas.*

*Q.4 Name the element represented by Hg, Pb, Au.*

*Q.5 What is the difference between an atom of hydrogen and a molecule of hydrogen?*



**Polyatomic Ion** : A group of atoms carrying a charge is as polyatomic ion.

eg:  $\text{NH}_4^+$  - Ammonium Ion ;  $\text{CO}_3^{2-}$  - Carbonate ion

**Valency** : The number of electrons which an atom can lose , gain or share to form a bond.

**OR**

It is the combining capacity of an atom of the element.

*[ for valency of various cations & anions ,refer NCERT text book table 3.6 , page no. 37 ]*

❖ **Chemical Formula**: A chemical formula is a short method of representing chemical elements and compounds.

### Writing a Chemical Formula -CRISS-CROSS rule

<b>RULE 1 [a]</b>	<b>write the correct symbols of two elements.</b>
	Ex : Aluminium & Oxygen      Al O
↓	
<b>[ b]</b>	<b>above each symbol, write the correct valence</b>
	Al <sup>3+</sup> O <sup>2-</sup>
↓	
<b>[c]</b>	<b>Criss-cross the valence and drop the algebraic sign.</b>
	Al <sub>2</sub> O <sub>3</sub>

<b>RULE 2 &gt;</b>	<b>When the subscript is number 1, subscript is not written.</b>
	Ex. Sodium Chloride      - Na <sup>1+</sup> Cl <sup>1-</sup> --- NaCl

<b>RULE 3&gt;</b>	<b>When the valence of both elements are numerically equal , the subscripts are also not written.</b>
	Ex. Calcium Oxide-      - Ca <sup>2+</sup> O <sup>2-</sup> --- CaO

<b>RULE 4 &gt;</b>	When there are multiple numbers of an individual polyatomic ion , parentheses must be used to separate the polyatomic ion from the subscript.		
	Ex. Ammonium Sulphate-	- $\text{NH}_4^{1+} \text{SO}_4^{2-}$	..... $(\text{NH}_4)_2 \text{SO}_4$

<b>RULE 5 &gt;</b>	All subscripts must be reduced to lowest term (except for molecular or covalent compound).		
	Ex. Tin (IV) Chloride ~	$\text{Sn}^{4+} \text{O}^{2-}$	----- $\text{SnO}_2$

### EXAMPLES

CATION	ANION	FORMULA	NAME
$\text{Al}^{3+}$	$\text{SO}_4^{2-}$	$\text{Al}_2(\text{SO}_4)_3$	Aluminium sulphate
Ca	$\text{HCO}_3^-$	$\text{Ca}(\text{HCO}_3)_2$	Calcium bicarbonate
$\text{NH}_4^+$	$\text{Cl}^-$	$\text{NH}_4\text{Cl}$	Ammonium chloride
$\text{Na}^+$	$\text{CO}_3^{2-}$	$\text{Na}_2\text{CO}_3$	Sodium carbonate
$\text{Mg}^{2+}$	$\text{OH}^-$	$\text{Mg}(\text{OH})_2$	Magnesium hydroxide
$\text{Na}^+$	$\text{PO}_4^{3-}$	$\text{Na}_3\text{PO}_4$	Sodium phosphate

Q.1 What is the difference between an anion & cation ?

Q.2 Write down chemical formula of

i) Hydrogen peroxide

ii) Tin chloride

iii) Barium sulphate

iv) Silver chloride

Q.3 Write chemical names of

i)  $\text{Ni}(\text{NO}_3)_2$

ii)  $\text{CdCO}_3$

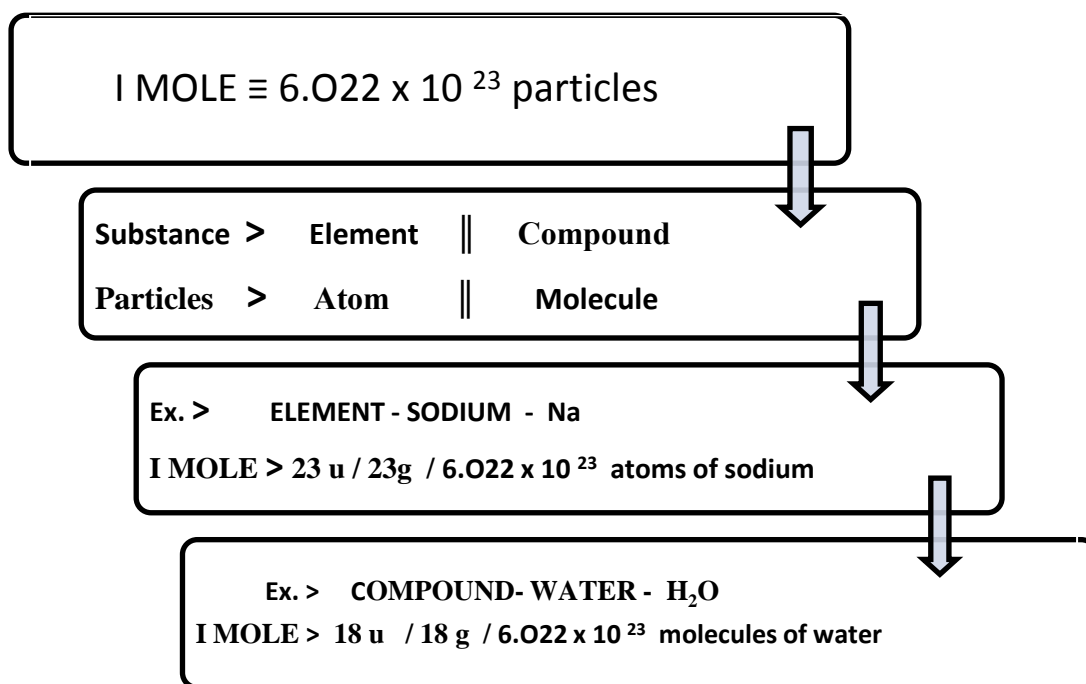
iii)  $\text{NaOH}$

iv)  $\text{NH}_4\text{NO}_2$

## 4. Mole Concept

The *mole (mol)* is the amount of a substance that contains as many elementary entities as there are atoms in exactly 12.00 grams of  $^{12}\text{C}$

**The Avogadro constant is named after the early nineteenth century Italian scientist Amedeo Avogadro.**



S.No.	Symbol / formula of atom / molecule	Atomic / molecular mass ( u )	1mole ( in g )	Avogadro no.	Molar mass ( g mol <sup>-1</sup> )
1.	O	16 u	16 g	$6.022 \times 10^{23}$ atoms	16 g mol <sup>-1</sup>
2.	N <sub>2</sub>	28 u	28 g	$6.022 \times 10^{23}$ molecules	28 g mol <sup>-1</sup>
3.	HCl	36.5 u	36.5 g	$6.022 \times 10^{23}$ molecules	36.5 g mol <sup>-1</sup>

### GRAM MOLECULAR MASS

Gram molecular mass is the mass in grams of one mole of a molecular substance.

**Ex:** The molecular mass of N<sub>2</sub> is 28, so the gram molecular mass of N<sub>2</sub> is 28 g.

### ATOMIC MASS UNIT

An atomic mass unit or amu is one twelfth of the mass of an unbound atom of carbon-12. It is a unit of mass used to express atomic masses and molecular masses.

**Also Known As: Unified Atomic Mass Unit (u).**

**MOLECULAR MASS** : A number equal to the sum of the atomic masses of the atoms in a molecule. The molecular mass gives the mass of a molecule relative to that of the  $^{12}\text{C}$  atom, which is taken to have a mass of 12.

**Examples:** The molecular mass of  $\text{C}_2\text{H}_6$  is approximately 30 or  $[(2 \times 12) + (6 \times 1)]$ . Therefore the molecule is about 2.5 times as heavy as the  $^{12}\text{C}$  atom or about the same mass as the NO atom with a molecular mass of 30 or  $(14+16)$ .

Q.1 What term is used to represent the mass of 1 mole molecules of a substance?

Q.2 What is the gram atomic mass of i) Hydrogen ii) oxygen ?

Q.3 Calculate molar mass of  $\text{C}_2\text{H}_2$ .

## 5. Molar Mass & Avogadro Constant

```

graph TD
    MASS[MASS] -- "to get" --> A["Molarmass / 1mol"]
    A -- "Multiply by" --> MOLE[MOLE]
    MOLE -- "to get" --> B["1mol / Molar mass"]
    B -- "Multiply by" --> MASS
        
```

**Ex: i) Convert 35 g of Al into mol.**

A: Molar mass of Al = 27 g  
 $27 \text{ g} = 1 \text{ mol}$   

$$= 35 \text{ g} \times \frac{1 \text{ mol}}{27 \text{ g}}$$

$$= 1.3 \text{ mol of Al}$$

**ii) How many grams of  $\text{SiO}_2$  are present in 0.8 mol ?**

A: Molar mass of  $\text{SiO}_2$  = 60.1 g  
 $1 \text{ mol} = 60.1 \text{ g}$   

$$= 0.8 \text{ mol of SiO}_2 \times \frac{60.1 \text{ g of SiO}_2}{1 \text{ mol of SiO}_2}$$

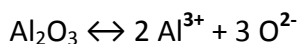
$$= 48.1 \text{ g SiO}_2$$



<p><b>MOLE</b></p> <p>1mol / 22.4 L</p> <p><b>VOLUME AT STP</b></p> <p>22.4 L / 1mol</p>	<p><i>Ex . How many mol of CO<sub>2</sub> are present in 55.5 L ?</i></p> <p>A: 22.4 L = 1mol</p> $= 55.5 \text{ L} \times \frac{1 \text{ mol}}{22.4 \text{ L}}$ $= 2.48 \text{ mol of CO}_2$
<p><b>MOLE</b></p> <p>1mol / 6.02 X 10<sup>23</sup> particles</p> <p><b>Number of representative particles</b></p> <p>6.02 X 10<sup>23</sup> particles / 1mol</p>	<p>Ex Calculate number of molecules in 200 g of N<sub>2</sub>O. Molar mass of N<sub>2</sub>O = 44 g</p> <p>i ) to find number of moles:- 44 g = 1 mol</p> $= 200 \text{ g} \times \frac{1 \text{ mol}}{44.0 \text{ g}}$ $= 4.55 \text{ mol of N}_2\text{O}$ <p>ii) to find number of molecules 1 mol = 6.02 x 10<sup>23</sup> molecules</p> $= \frac{6.02 \times 10^{23} \text{ molecules N}_2\text{O}}{1 / 4.55}$ $= 2.74 \times 10^{24} \text{ molecules N}_2\text{O}$

**Ex. Calculate the number of aluminium ions present in 0.051 g of aluminium oxide.**

Ans : Molar mass of  $\text{Al}_2\text{O}_3 = 102 \text{ g}$



102 g of  $\text{Al}_2\text{O}_3$  contains =  $2 \times 6.02 \times 10^{23} \text{ Al}^{3+} \text{ ions}$

$$\begin{aligned} 0.051 \text{ g of } \text{Al}_2\text{O}_3 \text{ contains} &= \frac{2 \times 6.02 \times 10^{23} \text{ Al}^{3+} \text{ ions}}{102} \times 0.051 \\ &= 2 \times 6.02 \times 10^{20} \text{ Al}^{3+} \text{ ions} \end{aligned}$$

*Q.1 Calculate the mass of one atom of sodium?*

*Q.2 The atomic mass of calcium is 40 u. What will be the number of calcium atoms in 0.4 u of calcium?*

*Q.3 How many atoms of oxygen are present in 120 g of nitric acid ?*

### QUESTION BANK [ \*HOTS ]

#### 1 Mark Questions:

1. Who gave law of conservation of mass ?
2. What term is used to represent the mass of 1 mole molecules of a substance?
3. What name is given to the number  $6.023 \times 10^{23}$  ?
4. What is molecular mass?
5. Give Latin names for sodium & mercury.
6. \*How many atoms are there in exactly 12 g of carbon ?
7. Define mole.
8. Calculate formula unit mass of  $\text{CaCl}_2$ . [ At. Mass : Ca = 40 u , Cl = 35.5 u ]
9. Name a diatomic gas.
10. How many atoms are present in  $\text{H}_2\text{SO}_4$ .

## **2 Marks Questions:**

1. Give the chemical symbols for the following elements: Gold, Copper , Potassium & Iron.
2. \*What do the following symbols represent - i)  $1\text{ H}$  & ii)  $\text{H}_2$
3. Neon gas consists of single atoms , what mass of neon contains  $6.022 \times 10^{23}$  atoms.
4. What elements do the following compounds contain ?  
i) Water      ii) Lead nitrate
5. State the differences between an atom and a molecule.
6. Molar Mass of water is  $18\text{ g mol}^{-1}$  , what is the mass of 1 mole of water? .
7. \*The number of atoms in 1 mole of hydrogen is twice the number of atoms in one mole of helium. Why?
8. Write the chemical formulas for the following:  
i) Silver oxide      ii) Iron (III) sulphate
9. Calculate molar mass of  $\text{H}_2\text{O}_2$  &  $\text{HNO}_3$ .
10. What is the mass of 0.2 moles of oxygen molecules?

## **3 Marks Questions:**

1. State the main postulates of John Dalton's atomic theory.
2. What are polyatomic ions ? Give two examples.
3. State the following  
i) Law of conservation of mass.      ii) Law of constant proportion
4. What is the mass of :  
i) 1 mol of N atoms.      ii) 4 mol of Al atoms.
5. What is meant by the term atomicity ? State the atomicity of i) Phosphorous  
ii) Sulphur

## **5 Marks Questions:**

1. i) What is molecular formula ? State with example what information can be derived from a molecular formula .  
ii) Write the names of the compounds represented by the following formulas:  
a)  $\text{Mg}(\text{NO}_3)_2$       b)  $\text{K}_2\text{SO}_4$       c)  $\text{Ca}_3\text{N}_2$

2.\* i) What is gram molecular mass?

ii) Write the formulas & names of the compounds formed between :

- |                                |                                |
|--------------------------------|--------------------------------|
| a) Ferrous and sulphide ions   | b) Aluminium and sulphate ions |
| c) Potassium and chlorate ions | d) Barium and chloride ions    |

3. i) Calculate the number of moles for the following:

- |               |                             |
|---------------|-----------------------------|
| a) 52 g of He | b) 17 g of H <sub>2</sub> O |
|---------------|-----------------------------|

ii) How many molecules are present in 34 g of ammonia ?

iii) Calculate the mass of 0.5 mole of sugar (C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>).

<b>You are expected to know.....</b>
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- Laws of Chemical combination.
- John Dalton's imagination about atom & the limitation of his theory.
- Difference between an atom & molecule.
- Types of ions
- Writing chemical formula of compounds.
- Relationship between Mole , Molar Mass & Avogadro Constant

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