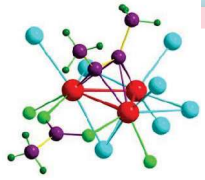


Chapter - 3

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

Dalton's Atomic Theory

(Atoms) are:
- tiny particles
- indivisible
  (Can neither be created nor destroyed)
- Identical mass and chemical properties
  (Same element)
- Different mass and chemical properties
  (different elements)
- Combine in the same ratio

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

Molecule
- Smallest particle of element or compound
- Properties of the substances are the properties of molecules

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

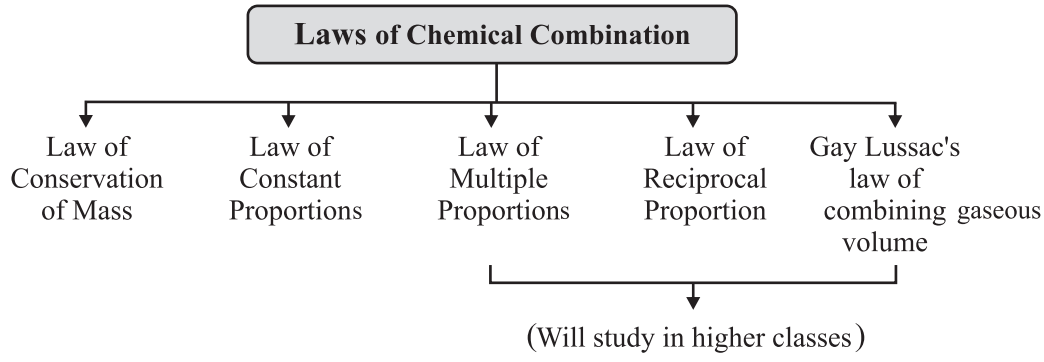
Existence of Atom
- Reactive Molecule, Ions
- Free
- Molecule can be
  - Monoatomic (free)
  - Polyatomic Molecule (Reactive)

Ions
- Cations (+vely charged)
- Anions (–vely charged)

- Types of molecule → 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

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."

In a chemical reaction, this law can be understood in the following way:

" During a chemical reaction total mass of reactants will be equal to total mass of products."

For example, $A + B \rightarrow AB$

Reactant Product

Then, $m_A + m_B = m_{AB}$

where, m_A = Mass of A

m_B = Mass of B

m_{AB} = Mass of AB

$2H_2$ (g) + O_2 (g) $\rightarrow 2H_2O$ (l)

2 x 2 = 4 gm + 2 x 16 = 32 gm $\rightarrow$ 2 x (2 + 16) = 36 gm

4g + 32g = 36gm

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 observations are all in agreement with law of conservation of mass.

Sodium carbonate + Ethanoic acid $\rightarrow$ 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.

Law of Constant Proportions

According to this law, "A pure chemical compound always contains 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."

For example :

- 18 gm of $H_2O \Rightarrow$ 16 gm of oxygen + 2 gm of hydrogen,

  i.e., $m_H/m_O = 2/16 = 1/8$
- 36 gm of $H_2O \Rightarrow$ 32 gm of oxygen + 4 gm of hydrogen,

  i.e., $m_H/m_O = 4/32 = 1/8$
- 9 gm pf $H_2O \Rightarrow$ 8 gm of oxygen + 1 gm of hydrogen,

  i.e., $m_H/m_O = 1/8$

From the above three cases, differently weighing H, O samples were taken but the ratio of mass of 'H' to mass of 'O' comes out to be '1/8' is same, proving law of constant proportion.

Likewise, if a sample of 'H_2O' was taken from anywhere *i.e.,* from well, pond, lake or anywhere the ratio of masses of 'H' to 'O' will come out to be same as '1/8'.

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

Based upon laws of chemical combination, Dalton's Atomic Theory provided an explanation for the Law of Conservation of Mass and Law of Constant Composition.

Postulates of Dalton's atomic theory are as follows :

- 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. (Proves 'Law of Conservation of Mass')
- Atoms of an element have identical mass and chemical properties.
- Atoms of different elements have different mass and chemical properties.
- Atom combine in the ratio of small whole numbers to form compounds. (Proves 'Law of Constant Proportion')
- The relative number and kinds of atoms are constant in a given compound.

Atom

- According to modern atomic theory, an atom is the smallest particle of an element which takes part in chemical reaction such that during the chemical reaction, the atom maintains its identity, throughout the chemical or physical change.
- Atoms are very small and hence can't be seen even through a very powerful microscope.
- Atomic radius of smallest atom of Hydrogen is 0.37×10^{-10} m or 0.037 nm.

Such that, $1 \text{ nm} = 10^{-9}$ m

IUPAC (International Union of Pure and 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

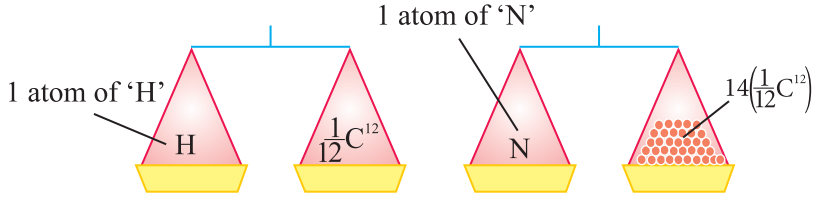
- The mass of an atom of an element is called its atomic mass.
- In 1961, IUPAC have accepted 'atomic mass unit' (u) to express atomic and molecular mass of elements and compounds respectively.

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.

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

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

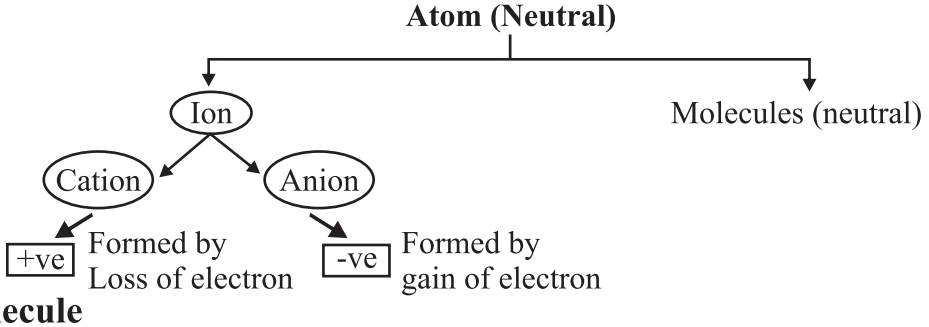


Atomic Mass of H = 1u Atomic Mass of N = 14 u

Atomic Mass of some elements					
Element	**Symbol**	**Atomic Mass**	**Element**	**Symbol**	**Atomic Mass**
Hydrogen	H	1u	Sodium	Na	23u
Helium	He	4u	Magnesium	Mg	24u
Lithium	Li	7u	Aluminium	Al	27u
Beryllium	Be	9u	Silicon	Si	28u
Boron	B	11u	Phosphorous	P	31u
Carbon	C	12u	Sulphur	S	32u
Nitrogen	N	14u	Chlorine	Cl	35.5u
Oxygen	O	16u	Potassium	K	39u
Fluorine	F	19u	Calcium	Ca	40u
Neon	Ne	20u	Iron	Fe	56u

How do atoms exist ?

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



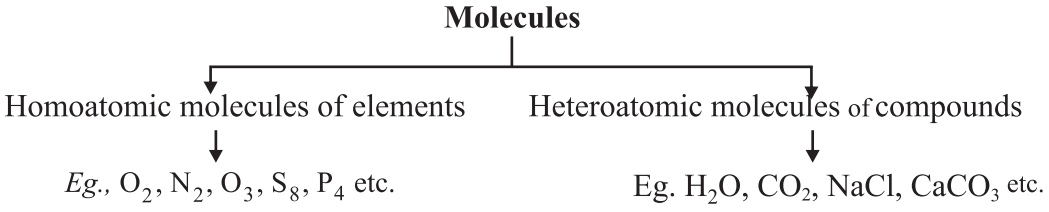
Molecule

- 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.

E.g., 'H_2O' is the smallest particle of water which shows all the properties of water.

- A molecule may have atom of same or different elements, depending upon this, molecule can be categorized into two categories :

Homoatomic molecules (containing atoms of same element) and **Heteroatomic molecules** (containing atoms of different elements)



Molecules of some compounds	
Compound	**Combining Elements**
Water (H_2O)	Hydrogen, Oxygen
Ammonia (NH_3)	Nitrogen, Hydrogen
Carbon Dioxide (CO_2)	Carbon, Oxygen
Hydrogen Chloride (HCl)	Hydrogen, Chlorine
Methane (CH_4)	Carbon, Hydrogen
Ethane (C_2H_6)	Carbon, Hydrogen
Sodium Chloride (NaCl)	Sodium, Chlorine
Copper Oxide (CuO)	Copper and Oxygen

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 gases 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. It is also expressed in Atomic mass units.

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 x 1 + 1 x 16 = 18 *u*

Formula Unit Mass

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

e.*g.*, In NaCl, Na = 23u and C1 = 35.5u

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

Rules of writing chemical formulae :

Rule 01:

- Write symbols of atoms of element.
- Then write their valencies / charges below the symbols.
- Now crossover the valencies of constituent atoms.
- As a result, the first atom gets valency of second atom and the second atom gets the valency of the first atoms.
- By crossover chemical formula is formed.

Rule 02 :

- If valency is 1, it is not written below.

Rule 03 :

- In case we have two or more same polyatomic ions, we use brackets and then write subscript.

Examples:

(i) Symbol : H S

valency : 1 2 H_2S_1 or H_2S (Hydrogen sulphide)

(ii) Symbol : C O

valency : 4 2 C_2O_4 or CO_2(Carbon dioxide)

[Take 2 common and dividethe formula by2]

(iii)For Hydrochloric acid (Hydrogen chloride)

Symbol H Cl

valency 1 1 H_1Cl or HCl

(iv)For Carbon tetrachloride

Symbol C Cl

valency 4^+ 1- C_1Cl_4 or CCl_4

(v) For Magnesium chloride

Symbol Mg Cl

valency 2^+ 1- Mg_1Cl_2 or $MgCl_2$

(vi)For aluminium oxide

Symbol Al O

valency 3^+ 2- Al_2O_3

(vii) For Calcium oxide

Symbol Ca O

valency 2^+ 2- Ca_2O_2 or CaO

[Take 2 common and divide the formula by 2]

(viii)For Sodium nitrate

Symbol Na NO_3

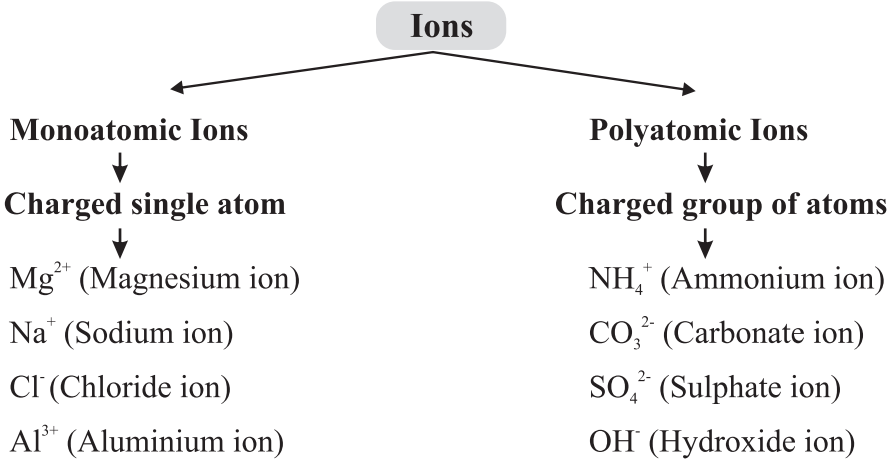
valency 1^+ 1- $NaNO_3$

Ions

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

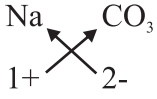
Some positively charged ions : Na^{+}, K^{+}, Ca^{2+}, Al^{3+} etc.

Some negatively charged ions : Cl^{-} (chloride ion), S^{2-} (sulphide ion), OH^{-} (hydroxide ion), SO_4^{2-} (sulphate ion) NO_3^{-} (Nitrate ion)



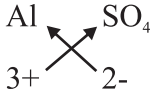
Chemical Formulae of Ionic Compounds (Polyatomic ions)

(i) Sodium carbonate



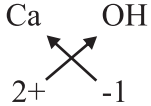
Na_2CO_3

(ii) Aluminium sulphate



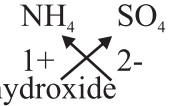
$Al_2(SO_4)_3$

(iii) Calcium hydroxide



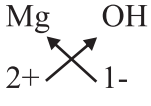
$Ca(OH)_2$

(iv) Ammonium sulphate



$(NH_4)_2SO_4$

(v) Magnesium hydroxide



$Mg(OH)_2$