1 THE LANGUAGE OF CHEMISTRY

SYLLABUS

(i) Symbol of an element; valency; formulae of radicals and formulae of compounds. Balancing of simple chemical equations.

- *Symbol – definition; symbols of the elements used often.*
- *Valency – definition; hydrogen combination and number of valence electrons of the metals and non-metals; mono, di, tri and tetra valent elements.*
- *Radicals – definition; formulae and valencies*
- *Compounds – name and formulae.*
- *Chemical equation – definition and examples of chemical equations with one reactant and two or three products, two reactants and one product, two reactants and two products and two reactants and three or four products; balancing of equations. (by hit and trial method).*

(ii) Relative Atomic Masses (atomic weights) and Relative Molecular Masses (molecular weights): either — standard H atom or 1/12th of carbon 12 atom.

- *Definitions*
- *Calculation of Relative Molecular Mass and percentage composition of a compound.*

1.1 INTRODUCTION

Chemistry is a branch of science in which we study about matter, *i.e.* what is matter made up of, what is its nature, structure and what changes are observed when it is subjected to different conditions.

Many theories were proposed regarding matter which helped us to discover the real essence of matter, *i.e.* matter is nothing but a complex relationship between elements. *An element is a simple and pure form of matter which cannot be decomposed into simpler substances.* All elements are made of atoms, the smallest particles of an element which represent all the properties of an element. A set of atoms of the same type together form the molecule of the element. Molecules can be **monoatomic**, **diatomic** and even **polyatomic**.

Monoatomic molecules – elements having only one atom in their molecules, *e.g.* helium, neon and other inert gas molecules.

Diatomic molecules – elements having two atoms in their molecules, *e.g.* hydrogen (H_2), Oxygen (O_2), Nitrogen (N_2).

Tetratomic molecules – elements having four atoms in their molecules, *e.g.* phosphorus (P_4).

Octatomic molecules – elements having eight atoms in their molecules, *e.g.* sulphur (S_8).

Thus, we can say that a molecule is the smallest particle that has capability to exist independently. The molecule of an element exhibits all the properties of that element.

When atoms or molecules of different elements combine, they form the molecule of a compound. To name a few, sodium chloride (NaCl), water (H_2O), ammonia (NH_3) are molecules of compounds.

The names of elements and compounds are abreviated by using certain symbols and formulae.

Before 1600 A.D., alchemists tried to represent the substances that they used for their experiments by different kinds of pictographic symbols, such as a *triangle* for the earth, a *crescent* for silver, *etc*. **Dalton** used some other types of symbols to represent elements, such as *a circle* [○] for an oxygen atom, *a circle with a dot in its centre* [⊙] for hydrogen, etc.

Later, **Johann Berzelius** suggested that the initial letter of an element written in capitals should represent that particular element, such as O for *oxygen*, H for *hydrogen*, C for *carbon*, and so on. But in some cases, the suggested symbol did not agree with the English name of the element. This was because some of the symbols were based on the Latin names of the elements, as shown in Table 1.1.

Table 1.1 : Symbols of certain elements based on their Latin names

Name of element	Symbol	Latin name
1. Gold	Au	Aurum
2. Silver	Ag	Argentum
3. Mercury	Hg	Hydrargyrum
4. Copper	Cu	Cuprum
5. Lead	Pb	Plumbum
6. Iron	Fe	Ferrum
7. Sodium	Na	Natrium
8. Potassium	K	Kalium
9. Tin	Sn	Stannum
10. Antimony	Sb	Stibium
11. Tungsten	W	Wolfram

However, the method suggested by him laid the basis of the IUPAC (International Union of Pure and Applied Chemistry) system of chemical symbols and formulae.

1.2 CHEMICAL SYMBOLS

*A **symbol** is the short form that stands for the atom of a specific element or the abbreviations used for the names of elements.*

Each element is denoted by a symbol, which is usually the first letter of its name in English or Latin, written in capital.

Example : Sulphur, an element, is denoted by the symbol 'S'. Similarly, hydrogen is denoted by the symbol 'H'.

However, when the first letter of more than one element is the same, the elements are denoted by two letters. The first letter is written in *capital,* while the second one is written in *small*.

Example : Carbon, cobalt, copper, calcium, cadmium, chromium, and chlorine are elements whose first letter is C. Therefore, only carbon is denoted by the symbol 'C'. Cobalt is denoted by two letters 'Co'. Copper is denoted by the two letters 'Cu' [taken from its Latin name *cuprum*]. Calcium by Ca, Cadmium by Cd, Chromium by Cr and Chlorine by Cl.

A symbol is not merely an abreviation for the name of an element but also has significance.

Significance of a symbol

It represents :

(i) Name of the element

Symbols of some common elements

Name in English	Symbol	Name in English	Symbol
Magnesium	Mg	Hydrogen	H
Aluminium	Al	Nitrogen	N
Calcium	Ca	Oxygen	O
Chromium	Cr	Fluorine	F
Manganese	Mn	Chlorine	Cl
Cobalt	Co	Bromine	Br
Nickel	Ni	Iodine	I
Zinc	Zn	Carbon	C
Silver	Ag	Sulphur	S
Barium	Ba	Phosphorus	P
Arsenic	As	Boron	B
Platinum	Pt	Silicon	Si
Radium	Ra	Arsenic	As
Uranium	U	Helium	He
Lithium	Li	Neon	Ne
Germanium	Ge	Argon	Ar

(ii) One atom of the element

(iii) Quantity of the element equal in mass to its atomic mass or gram atomic mass.

For example, the symbol N stands for

(i) The element Nitrogen

(ii) One atom of Nitrogen

(iii) 14 parts by weight of Nitrogen. This weight being the atomc weight of the element.

Note : Be careful about capital and small alphabets.

For example : Co means the element cobalt.

CO means the compound carbon monoxide.

1.3 FORMULA

Atoms of elements combine to form molecules. So it is possible to represent the molecules in terms of symbols of the constituent atoms. The symbolic representation of a molecule is known as **formula or molecular formula.**

*A molecular formula also known as **chemical formula** employs symbols to denote the molecule of an element or of a compound.*

A molecule of an element may contain one or more atoms of it. *For example* a molecule of elements hydrogen, oxygen, nitrogen, chlorine, bromine, iodine, contains two atoms and are written as H_2, O_2, N_2, Cl_2 Br_2 and I_2 respectively.

In case of a compound, the molecule containing different atoms united in certain fixed ratio, is represented by placing symbols of the elements present in it side by side indicating their numbers written in subscript. Thus, NH_4Cl represents one molecule of ammonium chloride containing one atom of nitrogen four atoms of hydrogen and one atom of chlorine.

Na_2CO_3 denotes one molecule of sodium carbonate which contains two atoms of sodium, one atom of carbon and three atoms of oxygen.

$2H_2O$ represents two molecules of water *i.e.* dihydrogen oxide, each molecule containing two atoms of hydrogen and one atom of oxygen.

Thus by looking at a formula, we understand the ratio in which the different atoms are united to form the molecule.

Significance of molecular formula

The molecular formula of a compound has quantitative significance. It represents :

(i) both the molecule and the molecular mass of the compound.

(ii) the respective numbers of different atoms present in one molecule of the compound.

(iii) the ratios of the respective masses of the elements present in the compound.

For example, the formula CO_2 means that:

(i) the molecular formula of carbon dioxide is CO_2;

(ii) each molecule contains one carbon atom joined by chemical bonds with two oxygen atoms;

(iii) the molecular mass of carbon dioxide is 44, given that the atomic mass of carbon is 12 and that of oxygen is 16.

1.4 VALENCY

Valency is the combining capacity of an atom or of a radical.

Valency is measured in terms of hydrogen atoms or oxygen atoms. It is the number of hydrogen atoms or double the number of oxygen atoms that can combine with it.

Since no other element has combining capacity less than that of hydrogen, its valency is taken to be one (1) and is considered a standard.

Modern Definition of Valency

The number of electrons, that atom can lose, gain or share during a chemical reaction is called its **valency**. (For details refer to chapter ***Atomic Structure***).

Elements with one, two or three electrons in their outermost shell (valence shell) are usually **metals**. Electrons in the outermost shell are known as *valence electrons*. To attain stable electronic configuration, these atoms lose their valence electrons and form positive ions*.

$Na - e^- \rightarrow Na^+$ (univalent)
2, 8, 1 → 2, 8

$Mg - 2e^- \rightarrow Mg^{2+}$ (divalent)
2, 8, 2 → 2, 8

$Al - 3e^- \rightarrow Al^{3+}$ (trivalent)
2, 8, 3 → 2, 8

Positive ions are known as **cations**.

Elements with five, six or seven electrons in their outermost shell are normally **non-metals**. To attain stability, these atoms have to have eight electrons in their outermost orbit; so they gain electrons.

Note : Out of the elements that have four electrons in the outermost orbit — Carbon is a non-metal, Silicon and Germanium are metalloid and rest are metals.

$Cl + e^- \rightarrow Cl^-$ (univalent)
(2, 8, 7) → 2, 8, 8

$O + 2e^- \rightarrow O^{2-}$ (divalent)
(2, 6) → 2, 8

$N + 3e^- \rightarrow N^{3-}$ (trivalent)
(2, 5) → 2, 8

Negative ions are known as **anions**.

No. of electron(s) in outermost shell	1	2	3	4	5	6	7	8
Valency	1	2	3	4	3	2	1	0

The valency of an element or of a radical is the number of hydrogen atoms that will combine with or displace one atom of that element or radical.

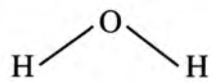
Examples of sharing of atoms :

(i) One atom of **chlorine** combines with one hydrogen atom to form a molecule of hydrogen chloride. So, the valency of chlorine is **one**.

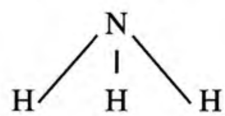
H – Cl

* Ions are charged particles which are formed by loss or gain of electrons

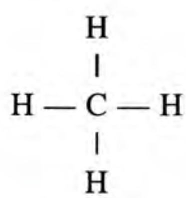
(ii) One atom of **oxygen** combines with 2 atoms of hydrogen to form a molecule of water. So, the valency of oxygen is **two**.



(iii) In an ammonia molecule, one atom of **nitrogen** combines with 3 atoms of hydrogen. So, the valency of nitrogen is **three**.



(iv) In a methane molecule, one **carbon** atom combines with 4 hydrogen atoms. So, the valency of carbon is **four**.



Variable valency

Certain elements exhibit more than one valency, *i.e.* they show variable valency.

Reasons for variable valency

An atom of an element can sometimes lose more electrons than are present in its valence shell, *i.e.* there is a loss of electrons from the penultimate shell too. Therefore, such an element is said to exhibit variable valency.

If an element exhibits two different positive valencies, then we *use the suffix "ous"* for the *lower valency* and *the suffix "ic"* for the *higher valency*. Modern chemists use Roman numerals in place of these trivial names. *For example*, $SnCl_2$, *i.e.* stannous chloride is written as Tin (II) chloride, $SnCl_4$, *i.e.* stannic chloride is written as Tin (IV) chloride.

Non-metals like nitrogen, phosphorus and sulphur also show variable valency. Nitrogen and phosphorus exhibit valencies of 3 and 5 while sulphur exhibits valencies of 2, 4 and 6.

Table 1.2 : Examples of variable valency

Metal	Valency	Name of compound formed		Formula
Iron	2	*Ferrous*	[Iron (II)] oxide	FeO
	3	*Ferric*	[Iron (III)] oxide	Fe_2O_3
Copper	1	*Cuprous*	[Copper (I)] oxide	Cu_2O
	2	*Cupric*	[Copper (II)] oxide	CuO
Mercury	1	*Mercurous*	[Mercury (I)] oxide	Hg_2O
	2	*Mercuric*	[Mercury (II)] oxide	HgO
Lead	2	*Plumbous*	[Lead (II)] oxide	PbO
	4	*Plumbic*	[Lead (IV)] oxide	PbO_2
Tin	2	*Stannous*	[Tin (II)] chloride	$SnCl_2$
	4	*Stannic*	[Tin (IV)] chloride	$SnCl_4$

1.5 RADICALS

The molecule of a compound is usually made up of two parts, these parts separately are known as radicals. *For example,* molecule of potassium chloride has two parts, potassium and chloride, so potassium is one radical and chloride is the other radical; similarly magnesium sulphate has magnesium and sulphate as radicals.

*A radical is an atom or a group of atoms of the same or of different elements that behaves as a single unit with a **positive or negative charge.***

A radical is called **simple radical** when it is an atom only like sodium (Na^+) and magnesium (Mg^{2+}). It is known as a **compound radical** when it is made up of a group of two or more different atoms (**polyatomic**) like sulphate (SO_4^{2-}) made up of one sulphur atom and four oxygen atoms.

Note : An acid reacts with a base to produce salt and water as a result of neutralisation.

Potassium hydroxide (Base)	+	Hydrochloric acid (Acid)	→	Potassium chloride (Salt)	+	Water

In the formation of potassium chloride, the **potassium** radical has been contributed by the base potassium hydroxide and is therefore called **basic radical**, the chloride radical has been contributed by hydrochloric acid and is, therefore, termed an **acid radical**.

When a salt is dissolved in water, it splits up into constituent radicals, the basic radicals are found to carry positive charge and so are termed **electro-positive radicals** or **cations**. The other part carries negative charge and so are called **electronegative radicals** or **anions**.

Thus, in potassium chloride, potassium is electropositive and chloride is electronegative radical. Similarly, in magnesium sulphate, magnesium is electropositive and sulphate is electronegative radical.

List of basic radicals is given in **Table 1.3**.

List of acid radicals is given in **Table 1.4**.

Table 1.3 : List of some common electrovalent positive ions (basic radicals)

Monovalent electropositive		Divalent electropositive		Trivalent electropositive	
1. Ammonium	NH_4^+	1. Argentic [Silver(II)]	Ag^{2+}	1. Aluminium	Al^{3+}
2. Aurous [Gold (I)]	Au^+	2. Barium	Ba^{2+}	2. Arsenic	As^{3+}
3. Argentous [Silver (I)]	Ag^+	3. Calcium	Ca^{2+}	3. Auric [Gold (III)]	Au^{3+}
4. Cuprous [Copper (I)]	Cu^+	4. Cupric [Copper(II)]	Cu^{2+}	4. Bismuth	Bi^{3+}
5. Hydrogen	H^+	5. Ferrous [Iron (II)]	Fe^{2+}	5. Chromium	Cr^{3+}
6. Lithium	Li^+	6. Magnesium	Mg^{2+}	6. Ferric [Iron (III)]	Fe^{3+}
7. Sodium	Na^+	7. Manganese	Mn^{2+}		
8. Potassium	K^+	8. Mercuric [Mercury (II)]	Hg^{2+}	**Tetravalent electropositive**	
9. Mercurous [Mercury (I)]	Hg^+	9. Nickel	Ni^{2+}	1. Plumbic [Lead (IV)]	Pb^{4+}
		10. Plumbous [Lead (II)]	Pb^{2+}	2. Platinic [Platinium (IV)]	Pt^{4+}
		11. Platinous [Platinum (II)]	Pt^{2+}	3. Stannic [Tin (IV)]	Sn^{4+}
		12. Stannous [Tin (II)]	Sn^{2+}		
		13. Zinc	Zn^{2+}		

Table 1.4 : List of some common electrovalent negative ions (acid radicals)

Monovalent electronegative		Divalent electronegative		Trivalent electronegative	
1. Acetate	CH_3COO^-	1. Carbonate	CO_3^{2-}	1. Arsenate	AsO_4^{3-}
2. Bicarbonate or Hydrogen carbonate	HCO_3^-	2. Dichromate	$Cr_2O_7^{2-}$	2. Nitride	N^{3-}
3. Bisulphide or Hydrogen sulphide	HS^-	3. Oxide	O^{2-}	3. Aluminate	AlO_3^{3-}
4. Bisulphate or Hydrogen sulphate	HSO_4^-	4. Peroxide	O_2^{2-}	4. Arsenite	AsO_3^{3-}
5. Bisulphite or Hydrogen sulphite	HSO_3^-	5. Sulphate	SO_4^{2-}	5. Phosphide	P^{3-}
6. Bromide	Br^-	6. Sulphite	SO_3^{2-}	6. Phosphite	PO_3^{3-}
7. Chloride	Cl^-	7. Sulphide	S^{2-}	7. Phosphate	PO_4^{3-}
8. Permanganate	MnO_4^-	8. Silicate	SiO_3^{2-}	8. Borate	BO_3^{3-}
9. Fluoride	F^-	9. Thiosulphate	$S_2O_3^{2-}$		
10. Hydride	H^-	10. Zincate	ZnO_2^{2-}	**Tetravalent electronegative**	
11. Hydroxide	OH^-	11. Plumbite	PbO_2^{2-}	1. Carbide	C^{4-}
12. Iodide	I^-	12. Stannate	SnO_3^{2-}	2. Ferrocyanide	$Fe(CN)_6^{4-}$
13. Cyanide	CN^-	13. Manganate	MnO_4^{2-}		
14. Nitrate	NO_3^-	14. Chromate	CrO_4^{2-}		
15. Nitrite	NO_2^-	15. Oxalate	$(COO)_2^{2-}$		
16. Chlorite	ClO_2^-				
17. Hypochlorite	ClO^-				
18. Chlorate	ClO_3^-				
19. Perchlorate	ClO_4^-				
20. Meta-aluminate	AlO_2^-				

Radicals have their own combining power (valency), and it is according to this combining power that they form chemical formulae.

For example, in the compound ammonium carbonate $(NH_4)_2CO_3$ ammonium (NH_4^+) is a basic radical with combining power 1 and carbonate (CO_3^{2-}) is an acidic radical with combining power 2.

1.6 WRITING CHEMICAL FORMULAE

The following steps should be taken while attempting to write a formula. The method is called **criss-cross method**.

(i) Write the symbols side by side, basic radical is written first and then acidic radical.

(ii) Write the valency of each atom on top of its symbol.

(iii) Divide the valency numbers by their highest common factor (H.C.F.), if any, to get the simple ratio. Ignore the (+) or (–) symbols of the radicals. Interchange the valencies of the radicals.

(iv) Write the interchanged valency numbers to the lower right of the radicals. If the radical is a group of atoms and has a valency number more than 1, enclose it within brackets.

Based on the steps, mentioned alongside formulae can be written in the following way.

Name of Compound	Symbols with valencies	Exchange of valency	Formula
Magnesium chloride	Mg^{2+} Cl^{1-}	Mg^2 × Cl^1 Mg_1 Cl_2	$MgCl_2$
Calcium oxide	Ca^{2+} O^{2-} [Dividing by H.C.F. it becomes Ca^{1+} O^{1-}	Ca^2 × O^2 Ca_2 O_2	CaO Cancelling common factor
Aluminium hydroxide	Al^{3+} $(OH)^{1-}$	Al^3 × $(OH)^1$ Al_1 $(OH)_3$	$Al(OH)_3$
Phosphorus trioxide	P^{3+} O^{2-}	P^3 × O^2 P_2 O_3	P_2O_3
Sodium meta aluminate	Na^+ AlO_2^-	Na^+ × AlO_2^- Na_1 $(AlO_2)_1$	$NaAlO_2$
Sodium aluminate	Na^+ AlO_3^{3-}	Na^+ × AlO_3^{3-} Na_3 $(AlO_3)_1$	Na_3AlO_3

IMPORTANT FORMULAE

Chemical Name	Symbol with charge	Formula
Potassium chloride	$K^{1+}Cl^{1-}$	KCl
Potassium bromide	$K^{1+}Br^{1-}$	KBr
Potassium iodide	$K^{1+}I^{1-}$	KI
Potassium hydroxide	$K^{1+}OH^{1-}$	KOH
Potassium nitrite	$K^{1+}NO_2^{1-}$	KNO_2
Potassium nitrate	$K^{1+}NO_3^{1-}$	KNO_3
Potassium hydrogen carbonate	$K^{1+}HCO_3^{1-}$	$KHCO_3$
Potassium hydrogen sulphite	$K^{1+}HSO_3^{1-}$	$KHSO_3$
Potassium hydrogen sulphate	$K^{1+}HSO_4^{1-}$	$KHSO_4$
Potassium metaluminate	$K^{1+}AlO_2^{1-}$	$KAlO_2$
Potassium permanganate	$K^{1+}MnO_4^{1-}$	$KMnO_4$
Potassium sulphite	$K^{1+}SO_3^{2-}$	K_2SO_3
Potassium sulphate	$K^{1+}SO_4^{2-}$	K_2SO_4
Potassium carbonate	$K^{1+}CO_3^{2-}$	K_2CO_3
Potassium dichromate	$K^{1+}Cr_2O_7^{2-}$	$K_2Cr_2O_7$
Potassium zincate	$K^{1+}ZnO_2^{2-}$	K_2ZnO_2

Chemical Name	Symbol with charge	Formula
Potassium plumbite	$K^{1+}PbO_2^{2-}$	K_2PbO_2
Sodium chloride	$Na^{1+}Cl^{1-}$	NaCl
Sodium hydroxide	$Na^{1+}OH^{1-}$	NaOH
Sodium nitrite	$Na^{1+}NO_2^{1-}$	$NaNO_2$
Sodium nitrate	$Na^{1+}NO_3^{1-}$	$NaNO_3$
Sodium hydrogen carbonate	$Na^{1+}HCO_3^{1-}$	$NaHCO_3$
Sodium hydrogen sulphite	$Na^{1+}HSO_3^{1-}$	$NaHSO_3$
Sodium hydrogen sulphate	$Na^{1+}HSO_4^{1-}$	$NaHSO_4$
Sodium metaluminate	$Na^{1+}AlO_2^{1-}$	$NaAlO_2$
Sodium sulphite	$Na^{1+}SO_3^{2-}$	Na_2SO_3
Sodium sulphate	$Na^{1+}SO_4^{2-}$	Na_2SO_4
Sodium carbonate	$Na^{1+}CO_3^{2-}$	Na_2CO_3
Sodium zincate	$Na^{1+}ZnO_2^{2-}$	Na_2ZnO_2
Sodium plumbite	$Na^{1+}PbO_2^{2-}$	Na_2PbO_2
Silver chloride	$Ag^{1+}Cl^{1-}$	AgCl
Ammonium chloride	$NH_4^{1+}Cl^{1-}$	NH_4Cl
Ammonium sulphate	$NH_4^{1+}SO_4^{2-}$	$(NH_4)_2SO_4$
Ammonium hydroxide	$NH_4^{1+}OH^{1-}$	NH_4OH

Cont...

Calcium chloride	$Ca^{2+}Cl^{1-}$	$CaCl_2$
Calcium hydroxide	$Ca^{2+}OH^{1-}$	$Ca(OH)_2$
Calcium nitrate	$Ca^{2+}NO_3^{1-}$	$Ca(NO_3)_2$
Calcium hydrogen carbonate	$Ca^{2+}HCO_3^{1-}$	$Ca(HCO_3)_2$
Calcium hydrogen sulphite	$Ca^{2+}HSO_3^{1-}$	$Ca(HSO_3)_2$
Calcium sulphite	$Ca^{2+}SO_3^{2-}$	$CaSO_3$
Calcium sulphate	$Ca^{2+}SO_4^{2-}$	$CaSO_4$
Calcium carbonate	$Ca^{2+}CO_3^{2-}$	$CaCO_3$
Calcium oxide	$Ca^{2+}O^{2-}$	CaO
Calcium silicate	$Ca^{2+}SiO_3^{2-}$	$CaSiO_3$
Calcium nitride	$Ca^{2+}N^{3-}$	Ca_3N_2
Magnesium chloride	$Mg^{2+}Cl^{1-}$	$MgCl_2$
Magnesium hydroxide	$Mg^{2+}OH^{1-}$	$Mg(OH)_2$
Magnesium nitrate	$Mg^{2+}NO_3^{1-}$	$Mg(NO_3)_2$
Magnesium oxide	$Mg^{2+}O^{2-}$	MgO
Magnesium nitride	$Mg^{2+}N^{3-}$	Mg_3N_2
Zinc chloride	$Zn^{2+}Cl^{1-}$	$ZnCl_2$
Zinc hydroxide	$Zn^{2+}OH^{1-}$	$Zn(OH)_2$
Zinc nitrate	$Zn^{2+}NO_3^{1-}$	$Zn(NO_3)_2$
Zinc sulphate	$Zn^{2+}SO_4^{2-}$	$ZnSO_4$
Zinc carbonate	$Zn^{2+}CO_3^{2-}$	$ZnCO_3$
Zinc oxide	$Zn^{2+}O^{2-}$	ZnO
Lead [II] chloride	$Pb^{2+}Cl^{1-}$	$PbCl_2$
Lead [II] bromide	$Pb^{2+}Br^{1-}$	$PbBr_2$
Lead [II] hydroxide	$Pb^{2+}OH^{1-}$	$Pb(OH)_2$
Lead [II] nitrate	$Pb^{2+}NO_3{}^{1-}$	$Pb(NO_3)_2$
Lead [II] sulphate	$Pb^{2+}SO_4^{2-}$	$PbSO_4$
Lead [II] oxide	$Pb^{2+}O^{2-}$	PbO
Manganese chloride	$Mn^{2+}Cl^{1-}$	$MnCl_2$
Manganese sulphate	$Mn^{2+}SO_4^{2-}$	$MnSO_4$
Aluminium chloride	$Al^{3+}Cl^{1-}$	$AlCl_3$
Aluminium sulphate	$Al^{3+}SO_4^{2-}$	$Al_2(SO_4)_3$
Aluminium hydroxide	$Al^{3+}OH^{1-}$	$Al(OH)_3$
Aluminium sulphide	$Al^{3+}S^{2-}$	Al_2S_3
Aluminium oxide	$Al^{3+}O^{2-}$	Al_2O_3
Chromium chloride	$Cr^{3+}Cl^{1-}$	$CrCl_3$
Chromium sulphate	$Cr^{3+}SO_4^{2-}$	$Cr_2(SO_4)_3$
Chromium oxide	$Cr^{3+}O^{2-}$	Cr_2O_3
Copper [I] (cuprous)		
Copper [I] chloride	$Cu^{1+}Cl^{1-}$	$CuCl$
Copper [I] oxide	$Cu^{1+}O^{2-}$	Cu_2O
Copper [I] sulphide	$Cu^{1+}S^{2-}$	Cu_2S
Copper [II] (cupric)		
Copper [II] chloride	$Cu^{2+}Cl^{1-}$	$CuCl_2$
Copper [II] hydroxide	$Cu^{2+}OH^{1-}$	$Cu(OH)_2$
Copper [II] nitrate	$Cu^{2+}NO_3^{1-}$	$Cu(NO_3)_2$
Copper [II] sulphate	$Cu^{2+}SO_4^{2-}$	$CuSO_4$
Copper [II] sulphide	$Cu^{2+}S^{2-}$	CuS
Copper [II] oxide	$Cu^{2+}O^{2-}$	CuO
Iron [II] (ferrous)		
Iron [II] chloride	$Fe^{2+}Cl^{1-}$	$FeCl_2$
Iron [II] hydroxide	$Fe^{2+}OH^{1-}$	$Fe(OH)_2$
Iron [II] nitrate	$Fe^{2+}NO_3^{1-}$	$Fe(NO_3)_2$
Iron [II] sulphate	$Fe^{2+}SO_4^{2-}$	$FeSO_4$
Iron [II] sulphide	$Fe^{2+}S^{2-}$	FeS
Iron [II] oxide	$Fe^{2+}O^{2-}$	FeO
Iron [III] (ferric)		
Iron [III] chloride	$Fe^{3+}Cl^{1-}$	$FeCl_3$
Iron [III] sulphate	$Fe^{3+}SO_4^{2-}$	$Fe_2(SO_4)_3$
Iron [III] hydroxide	$Fe^{3+}OH^{1-}$	$Fe(OH)_3$
Iron [III] sulphide	$Fe^{3+}S^{2-}$	Fe_2S_3
Iron [III] nitrate	$Fe^{3+}NO_3^{1-}$	$Fe(NO_3)_3$
Iron [III] oxide	$Fe^{3+}O^{2-}$	Fe_2O_3

1.7 NAMING CERTAIN COMPOUNDS

1. ***A metal and a non-metal :*** The metal is written first and then the non-metal, the suffix *ide* is added to the non-metal.

   For example :

   Calcium + Nitrogen → Calcium nitride [Ca_3N_2]

2. ***Two non-metals :*** The prefix *tri* or *tetra* or *penta,* etc. is added, as the case may be.

   For example, PCl_3 is phosphorus trichloride and PCl_5 is phosphorus pentachloride.

3. ***Two elements and oxygen :*** Oxygen is represented at the end of the formula.

   The name of the compound depends on the number of oxygen atoms present in the compound.

The prefix '*hypo*' is used if the number of oxygen atoms is less than 2.

$NaClO$ – Sodium hypochlorite

The suffix *'ite'* is used if the number of oxygen atoms is 2.

$NaClO_2$ – Sodium chlorite

The suffix '*ate*' is used if the number of oxygen atoms is 3.

$NaClO_3$ – Sodium chlorate

The prefix *per* is used when the number of oxygen atoms is more than 3.

$NaClO_4$ – Sodium perchlorate

4. *Naming of acids*

(a) Names of binary acids are given by adding the prefix '*hydro*' and the suffix '*ic*' to the name of the second element.

Examples : (i) HCl is hydrochloric acid

(ii) HF is hydrofluoric acid

(b) Names of acids containing radicals of polyatomic groups are given on the basis of the second element present in the molecule, and the prefix '*hydro*' is not used.

Examples : (i) In H_2SO_4, the second element is sulphur, hence the name *sulphuric acid.*

(ii) In HNO_3, the second element is nitrogen, hence the name *nitric acid.*

(iii) In H_3PO_4, the second element is phosphorus, hence the name *phosphoric acid.*

If the number of oxygen atoms is less, then suffix 'ous' is used instead of 'ic'. Thus H_2SO_3 is sulphurous acid, HNO_2 is nitrous acid.

5. *Trivial names*

There are certain compounds with names that do not follow any systematic rule. Such names are called trivial or common names, and they are widely accepted.

Examples : (i) Nitrogen trihydride is called ammonia [NH_3]

(ii) Hydrogen monoxide or dihydrogen oxide is called water [H_2O].

1.8 TO CALCULATE THE VALENCY FROM THE FORMULA

The valency of elements can be determined based on the knowledge of the valencies of negative radicals and of the fact that the valency of :

Hydrogen [H] = 1 ;

Oxygen [O] = 2 ;

Chlorine [Cl] = 1

Procedure to find the valency	Example
1. Write the given formula.	NO_2
2. Interchange the subscript and write it as superscript.	N^2O^1
3. The valency of oxygen is taken as 2, therefore, multiply both the superscripts by 2.	$N^{2\times2}O^{1\times2}$
4. The result gives the valency of the elements.	N^4O^2
Thus, from the formula NO_2, we find that the valency of nitrogen is 4.	

EXCERCISE 1(A)

1. What is a symbol ? What information does it convey ?
2. Why is the symbol S for sulphur, but Na for sodium and Si for silicon ?
3. If the symbol for Cobalt, Co, were written as CO, what would be wrong with it ?
4. What do the following symbols stand for ?
   (a) H (b) H_2 (c) 2H.
5. (a) Explain the terms 'valency' and 'variable valency'.
   (b) How are the elements with variable valency named ? Explain with an example.
6. Give the formula and valency of :
   (a) aluminate ....
   (b) chromate ....
   (c) aluminium ....
   (d) cupric ....
7. What is a chemical formula ? What is the rule for writing a formula correctly ?
8. What do you understand by the following terms ?
   (a) Acid radical (b) Basic radical

9. Match the following : (Refer common names in the beginning of the book)

Compound	Formula
(a) Boric acid	(i) NaOH
(b) Phosphoric acid	(ii) SiO_2
(c) Nitrous acid	(iii) Na_2CO_3
(d) Nitric acid	(iv) KOH
(e) Sulphurous acid	(v) $CaCO_3$
(f) Sulphuric acid	(vi) $NaHCO_3$
(g) Hydrochloric acid	(vii) H_2S
(h) Silica (sand)	(viii) H_2O
(i) Caustic soda (sodium hydroxide)	(ix) PH_3
(j) Caustic potash (potassium hydroxide)	(x) CH_4
(k) Washing soda (sodium carbonate)	(xi) NH_3
(l) Baking soda (sodium bicarbonate)	(xii) HCl
(m) Lime stone. (calcium carbonate)	(xiii) H_2SO_3
(n) Water	(xiv) HNO_3
(o) Hydrogen sulphide	(xv) HNO_2
(p) Ammonia	(xvi) H_3BO_3
(q) Phosphine	(xvii) H_3PO_4
(r) Methane	(xviii) H_2SO_4

10. Select the basic and acidic radicals in the following compounds.

(a) $MgSO_4$ (b) $(NH_4)_2SO_4$
(c) $Al_2(SO_4)_3$ (d) $ZnCO_3$
(e) $Mg(OH)_2$

11. The valency of an element *A* is 3 and that of element *B* is 2. Write the formula of the compound formed by the combination of *A* and *B*.

12. Write chemical formula of the sulphate of Aluminium, Ammonium and Zinc.

13. Write the chemical names of the following compounds :

(a) $Ca_3(PO_4)_2$ (b) K_2CO_3
(c) K_2MnO_4 (d) $Mn_3(BO_3)_2$
(e) $Mg\ (HCO_3)_2$ (f) $Na_4Fe(CN)_6$
(g) $Ba\ (ClO_3)_2$ (h) Ag_2SO_3
(i) $(CH_3COO)_2Pb$ (j) Na_2SiO_3

11. Write the basic radicals and acidic radicals of the following and then write the chemical formulae of these compounds.

(a) Barium sulphate (b) Bismuth nitrate
(c) Calcium bromide (d) Ferrous sulphide
(e) Chromium sulphate (f) Calcium silicate
(g) Potassium ferrocyanide
(h) Stannic oxide (i) Calcium silicate
(j) Magnesium phosphate (k) Sodium zincate
(l) Stannic phosphate (m) Sodium thiosulphate
(n) Potassium manganate (o) Nickel bisulphate

12. Give the names of the following compounds.

(a) NaClO (b) $NaClO_2$
(c) $NaClO_3$ (d) $NaClO_4$

13. Complete the following statements by selecting the correct option :

(a) The formula of a compound represents
 (i) an atom (ii) a particle
 (iii) a molecule (iv) a combination.
(b) The correct formula of aluminium oxide is
 (i) AlO_3 (ii) AlO_2 (iii) Al_2O_3
(c) The valency of nitrogen in nitrogen dioxide (NO_2) is
 (i) one (ii) two
 (iii) three (iv) four.

1.9 CHEMICAL EQUATION

A chemical equation is the symbolic representation of a chemical reaction using the symbols and formulae of the substances involved in the reaction.

For example: Burning of coal in air is a chemical reaction in which a new substance, carbon dioxide, is formed.

The reaction can be represented by either a word equation or a chemical equation (using formulae and symbols), as shown below :

Word equation :

Carbon + Oxygen $\xrightarrow{\text{heat}}$ Carbon dioxide

Chemical equation :

$$C + O_2 \xrightarrow{\text{heat}} CO_2$$

Steps involved in writing a chemical equation :

(i) Write the symbols or the formulae of the **reactants** on the left hand side, with a (+) sign between them.

(ii) Write the symbols or the formulae of the **products** on the right hand side, with a (+) sign between them.

(iii) Put the sign of an arrow (→) in between the reactant side and the product side.

(iv) Represent the reactants and the products in their molecular forms [because their atomic forms are usually neither stable nor capable of separate existence].

For example :

Sodium reacts with water to form sodium hydroxide and hydrogen.

$$2Na + 2H_2O \rightarrow 2NaOH + H_2$$

A chemical equation tells us what substances are involved in a given reaction **(REACTANTS)** and what are the substances formed as a result of the reaction (**PRODUCTS**).

For example :

$$\underbrace{CuSO_4 + 2NaOH}_{\text{Reactants}} \rightarrow \underbrace{Cu(OH)_2 + Na_2SO_4}_{\text{Products}}$$

In the given equation copper sulphate and sodium hydroxide (REACTANTS) react to produce copper hydroxide and sodium sulphate (PRODUCTS).

Chemical reactions may involve :

(i) one reactant and two or more products
(ii) two reactants and one product
(iii) two reactants and two products
(iv) two reactants and three or more products

(i) *one reactant and two or more products*

Examples :

(a) $CaCO_3 \rightarrow CaO + CO_2$
(b) $2Pb(NO_3)_2 \rightarrow 2PbO + 4NO_2 + O_2$

(ii) *two reactants and one product*

Examples :

(a) $NH_3 + HCl \rightarrow NH_4Cl$
(b) $N_2 + 3H_2 \rightarrow 2NH_3$

(iii) *two reactants and two products*

Examples :

(a) $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$
(b) $Na_2SO_4 + BaCl_2 \rightarrow BaSO_4 + 2NaCl$

(iv) *two reactants and three or more products*

Examples :

(a) $Cu + 2H_2SO_4 \rightarrow CuSO_4 + 2H_2O + SO_2$
(b) $2KMnO_4 + 16HCl \rightarrow 2KCl + 2MnCl_2 + 8H_2O + 5Cl_2$

Skeleton equation : It is an equation that represents a chemical change but is unbalanced. In other words, *the total number of atoms of each element on the two sides are not equal.* The following example will make the point clear.

$$KNO_3 \rightarrow KNO_2 + O_2$$

In the above chemical equation, the number of oxygen atoms in the reactant (KNO_3), on the left side, is not equal to the number of oxygen atoms in the products formed ($KNO_2 + O_2$), on the right side.

1.9.1 Balanced equation

It is an equation in which *the total number of atoms of each element in the reactants, on the left side of the equation, is the same as the number of atoms in the products formed, on the right side of the equation.*

Examples :

(a) $CaCO_3 \rightarrow CaO + CO_2$

In this equation, the number of atoms of Ca, C and O on both sides is the same, *i.e.* the equation is balanced.

(b) $KNO_3 \rightarrow KNO_2 + O_2$

In this equation, since the number of atoms of oxygen on both sides is not the same, the equation is not balanced. The balanced form of the equation is :

$$2KNO_3 \rightarrow 2KNO_2 + O_2$$

Why should an equation be balanced ?
An equation must be balanced in order to comply with the "*Law of Conservation of Matter*", which states that *matter is neither created nor destroyed in the course of a chemical reaction.* An unbalanced equation would imply that atoms have been created or destroyed.

1.9.2 How to balance a chemical equation

There are two methods of balancing an equation:

(i) Hit and trial method
(ii) Partial equation method

1. Balancing by hit and trial method

This method consists of counting the number of atoms of each element on both sides and trying to equalize them. Take the following steps :

(i) Count the number of times (frequency) an element occurs on either side.

(ii) The element with the least frequency of occurrence is balanced first.

(iii) When two or more elements have the same frequency, the metallic element is balanced first.

Example 1 : Balance the following equation

$Cu + H_2SO_4 \rightarrow CuSO_4 + SO_2 + H_2O$

Solution :

Step 1: Count the number of atoms of all the elements on either side of the chemical equation.

Element	Reactant side	Product side
Cu	1	1
H	2	2
S	1	2
O	4	7

Step 2: Copper and hydrogen are equal on both sides so to equalise sulphur atoms multiply H_2SO_4 by 2.

$Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + H_2O$

Step 3: To equalise hydrogen atoms, multiply H_2O by 2.

This gives the balanced equation.

$Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O$

Example 2 : Balance the following skeleton equation.

$As_2O_3 + SnCl_2 + HCl \rightarrow SnCl_2 + As + H_2O$

Solution :

Step 1: Count the number of atoms of all the elements on both sides of the equation.

Element	Reactant side	Product side
As	2	1
Sn	1	1
Cl	3	2
H	1	2
O	3	1

Step 2: To equalise As and O, multiply As by 2 and H_2O by 3.

$As_2O_3 + SnCl_2 + HCl \rightarrow SnCl_4 + 2As + 3H_2O$

Step 3: To equalise H atoms multiply HCl by 6.

$As_2O_3 + SnCl_2 + 6HCl \rightarrow SnCl_4 + 2As + 3H_2O$

Step 4: Multiply $SnCl_2$ and $SnCl_4$ both by 3.

$As_2O_3 + 3SnCl_2 + 6HCl \rightarrow 3SnCl_4 + 2As + 3H_2O$

This is te balanced chemical equation.

Example 3 : Balance the following skeletal equation:

$Fe + H_2O \rightarrow Fe_2O_3 + H_2$

Solution :

Step 1: Count the number of atoms of all the elements on both sides of the chemical equation.

Element	Reactant side	Product side
Fe	1 atom	2 atoms
H	2 atoms	2 atoms
O	1 atom	3 atoms

Step 2: To balance Fe atoms, multiply Fe on the LHS by 2.

$2Fe + H_2O \rightarrow Fe_2O_3 + H_2$

Step 3: To balance oxygen atoms on the RHS, write 3 before H_2O on the reactant side.

$2Fe + 3H_2O \rightarrow Fe_2O_3 + H_2$

Step 4: Now there are 6 hydrogen atoms on the reactant side and only 2 hydrogen atoms on the product side. To balance the hydrogen atoms, write 3 before hydrogen on the product side.

$\mathbf{2Fe + 3H_2O \rightarrow Fe_2O_3 + 3H_2}$

The above equation is a balanced equation

Example 4 : Ammonia is prepared by heating a mixture of ammonium chloride and calcium hydroxide. Write a balanced equation of the reaction.

Solution :

(i) $NH_4Cl + Ca(OH)_2 \rightarrow CaCl_2 + NH_3 + H_2O$

This is the skeleton equation.

(ii) To equalise Cl atoms multiply NH_4Cl by 2

$2NH_4Cl + Ca(OH)_2 \rightarrow CaCl_2 + NH_3 + H_2O$

(iii) To equalise nitrogen atoms multiply NH_3 by 2

$2NH_4Cl + Ca(OH)_2 \rightarrow CaCl_2 + 2NH_3 + 2H_2O$

(iv) To equalise oxygen atoms multiply H_2O by 2

$2H_4Cl + Ca(OH)_2 \rightarrow CaCl_2 + 2NH_3 + 2H_2O$

The above equation is a balanced equation.

Example 5 : Potassium dichromate reacts with hydrochloric acid to produce potassium chloride, chromium chloride, water and chlorine.

Write the skeletal equation of the reaction and balance it.

Step 1: The *skeletal equation is*

$K_2Cr_2O_7 + HCl \rightarrow KCl + CrCl_3 + H_2O + Cl_2$

Step 2: Balance oxygen, hydrogen, potassium, chromium and chlorine, starting with *oxygen* because *it occurs at the minimum number of places.*

- To equalize oxygen, multiply H_2O by 7;

$$K_2Cr_2O_7 + HCl \rightarrow KCl + CrCl_3 + 7H_2O + Cl_2$$

- To equalize hydrogen, multiply HCl by 14;

$$K_2Cr_2O_7 + 14HCl \rightarrow KCl + CrCl_3 + 7H_2O + Cl_2$$

- To equalize K and Cr, multiply both KCl and $CrCl_3$ by 2;

$$K_2Cr_2O_7 + 14\ HCl \rightarrow 2KCl + 2CrCl_3 + 7H_2O + Cl_2$$

- To equalize Cl, multiply it by 3, *i.e.* $3Cl_2$

$$K_2Cr_2O_7 + 14\ HCl \rightarrow 2KCl + 2\ CrCl_3 + 7\ H_2O + 3\ Cl_2$$

Now the equation is balanced.

Note : A balanced equation need not represent the real reaction.

For example : $Cu + H_2SO_4 \rightarrow CuSO_4 + H_2$

is a balanced reaction, but experiments show that copper reacts with conc. H_2SO_4 to give SO_2 and not hydrogen.

The correct chemical equation is :

$$Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O.$$

The **hit and trial method** is very useful for balancing simple chemical equations, but it has some limitations.

(i) It takes time to balance complicated equations.

(ii) The mechanism (steps of the reaction *i.e.* how the reaction has taken place) of the reaction is not clear.

Balancing can be done more easily by supposing the complex reaction to take place in steps.

Write the equations for these individual steps and then add the equations. This method is known as balancing by **partial equation method***.

The following examples will make it more clear.

Example 6 : Liberation of iodine from potassium iodide by reacting it with hydrogen peroxide is supposed to be completed in the following two steps :

(i) H_2O_2 decomposes to give water + nascent oxygen

$$H_2O_2 \rightarrow H_2O + O \qquad ....(i)$$

(ii) Nascent oxygen so produced oxidizes potassium iodide in the presence of water to give iodine and potassium hydroxide.

$$2KI + H_2O + O \rightarrow 2KOH + I_2 \qquad .....(ii)$$

Adding the two equations (i) and (ii) we get

$$H_2O_2 \rightarrow H_2O + O$$
$$2KI + H_2O + O \rightarrow 2KOH + I_2$$
$$\mathbf{2KI + H_2O_2 \rightarrow 2KOH + I_2}$$

H_2O and O occur on the product side, in the first reaction, while on the reactant side in the second reaction, so they get cancelled. The resultant equation is a balanced chemical equation.

1.9.3 Information conveyed by a balanced chemical equation

Refer to the following equations :

(1) $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

The above equation tells us :

(a) about the actual result of the chemical change.

(b) about the reactants involved and the products formed as a result of the reaction.

(c) about the number of molecules of each substance taking part and formed in the reaction. Here two molecules of sodium hydroxide and one molecule of sulphuric acid react to give one molecule of sodium sulphate and two molecules of water.

(d) *about the chemical composition of the respective molecules;* one molecule of sodium hydroxide (NaOH) contains one atom of sodium, one atom of oxygen and one atom of hydrogen.

(e) About molecular mass; that 80 parts by weight of sodium hydroxide reacts with 98 parts by weight of sulphuric acid to produce 142 parts by weight of sodium sulphate and 36 parts by weight of water.

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$
$$2(23+16+1) + (2+32+64) = (46+32+64) + 2(2+16)$$
$$\Rightarrow \quad 80 + 98 = 142 + 36$$
$$\Rightarrow \quad 178 = 178$$

(f) *It also proves the law of conservation of mass, i.e.* the total mass of the substances on either side of the equation is the same. According to the above equation, 178 gram of reactants are producing 178 gram of products.

* Not in syllabus

Note : On the basis of experimentas it is found that 22.4 litres of every gas, at 760 mm pressure and temperature of 0°C (STP), weighs the same as its molar mass *i.e.* molecular mass expressed in grams.

For example :

22.4 litres of hydrogen at S.T.P. will weigh 2 g.

22.4 litres of ammonia at S.T.P. will weigh 17 g, and so on.

(2) $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$

100 73 111 18 44

This balanced chemical equation conveys the following information :

(a) One molecule of calcium carbonate reacts with two molecules of hydrochloric acid to produce one molecule each of calcium chloride, water and carbon dioxide.

(b) 100 g of calcium carbonate reacts with 73 g of hydrochloric acid to produce 111 g of calcium chloride, 18 g of water and 44 g of carbon dioxide.

(*Note that the masses of the reactants and the products are taken in grams*)

(c) 100 g of calcium carbonate, on treatment with 73 g of HCl, will produce 22.4 litres of carbon dioxide at S.T.P.

1.9.4 Limitations of a chemical equation

A chemical equation does not tell us :

(a) the physical state of the reactants and the products, *i.e.* whether the substances are solid, liquid or gas.

(b) the time taken for the completion of the reaction.

(c) whether heat is given out or absorbed during the reaction.

(d) the respective concentrations of the reactants and the products.

(e) the rate at which the reaction proceeds.

(f) whether the reaction is reversible or irreversible.

(g) whether the reaction is completed or it is not completed.

1.9.5 A chemical equation can be made more informative by writing the following additional information to it.

(a) Information regarding temperature, pressure, catalyst, etc. is provided above and or below the arrow (→) separating reactants and products.

For example : Nitrogen reacts with hydrogen in the presence of catalyst Fe and promoter Mo at 450°C and 200 to 900 atmospheric pressure, to produce ammonia.

$$N_2 + 3H_2 \xrightarrow[450°C]{Fe + Mo} 2NH_3$$
$$200 - 900 \text{ atm}$$

(b) Physical states of reactants and products can be provided by using the letters (*s*) for solid, (*l*) for liquid, (*g*) for gas and (*aq*) for solution in water.

For example : Zinc, a solid metal, reacts with hydrochloric acid in aqueous state to produce zinc chloride in aqueous state and a gas hydrogen.

$$Zn(s) + HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

(c) Chemical reactions proceed with evolution or absorption of heat. This information is provided by adding a heat term.

For example :

$$C(s) + O_2(g) \rightarrow CO_2(g) + \text{Heat}$$

$$2C(s) + O_2(g) \rightarrow 2CO(g) - \text{Heat}$$

(d) Concentration of acids can also be added to the reaction.

For example : Magnesium reacts with dilute sulphuric acid to produce magnesium sulphate and hydrogen.

$$Mg(s) + H_2SO_4(dil) \rightarrow MgSO_4(aq) + H_2(g)$$

EXCERCISE 1(B)

1. Balance the following equations :

(a) $Fe + H_2O \rightarrow Fe_3O_4 + H_2$

(b) $Ca + N_2 \rightarrow Ca_3N_2$

(c) $Zn + KOH \rightarrow K_2ZnO_2 + H_2$

(d) $Fe_2O_3 + CO \rightarrow Fe + CO_2$

(e) $PbO + NH_3 \rightarrow Pb + H_2O + N_2$

(f) $Pb_3O_4 \rightarrow PbO + O_2$

(g) $PbS + O_2 \rightarrow PbO + SO_2$

(h) $S + H_2SO_4 \rightarrow SO_2 + H_2O$

(i) $S + HNO_3 \rightarrow H_2SO_4 + NO_2 + H_2O$

(j) $MnO_2 + HCl \rightarrow MnCl_2 + H_2O + Cl_2$

(k) $C + H_2SO_4 \rightarrow CO_2 + H_2O + SO_2$

(l) $KOH + Cl_2 \rightarrow KCl + KClO + H_2O$

(m) $NO_2 + H_2O \rightarrow HNO_2 + HNO_3$

(n) $Pb_3O_4 + HCl \rightarrow PbCl_2 + H_2O + Cl_2$

(o) $H_2O + Cl_2 \rightarrow HCl + O_2$

(p) $NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$

(q) $HNO_3 + H_2S \rightarrow NO_2 + H_2O + S$

(r) $P + HNO_3 \rightarrow NO_2 + H_2O + H_3PO_4$

1.10 RELATIVE ATOMIC MASS (ATOMIC WEIGHT)

Atoms being extremely small, cannot be seen or weighed directly. But indirect methods of physics have enabled us to know the absolute mass of nearly all kinds of atoms. The mass of a hydrogen atom is found to be $1{\cdot}66 \times 10^{-24}$ g while that of carbon atom is $1{\cdot}9926 \times 10^{-23}$ g. As these masses are too small, it is not convenient to use kilograms or grams as unit. It has, therefore, been considered appropriate to use the mass of some standard atom as a unit and then relate masses of other atoms to it. The resulting masses of atoms are thus known as ***Relative Atomic Mass** (RAM)* or ***Atomic Weight***.

In the beginning, the mass of the hydrogen atom (hydrogen element being the lightest) was chosen as a unit and masses of other atoms were compared with it. In 1961, *carbon-12 was finally selected, because its adoption least affected the values of the atomic mass of the various elements on the old standard.*

> The **relative atomic mass** or ***atomic weight*** *of an element is the number of times one atom of the element is heavier than $\frac{1}{12}$ times of the mass of an atom of carbon-12. Thus:*
>
> $$\text{Relative atomic mass} = \frac{\textit{Mass of 1 atom of the element}}{\frac{1}{12}\textit{th the mass of one C-12 atom}}$$

Atomic mass is expressed in atomic mass units [a.m.u.]. **Atomic mass unit is defined as 1/12 the mass of carbon atom C-12.** (The mass of an atom of carbon–12 isotope was given the atomic mass of 12 units, *i.e.* 12 amu or simply 12 u).

Thus, the mass of a hydrogen atom is 1 amu, and those of oxygen and helium are 16 amu and 4 amu respectively (Atomic masses of elements are given in the preliminary pages of this book).

Note : Experimentally it is found that one atom of C^{12} (carbon having atomic mass 12) atom has a mass of $1{\cdot}9926 \times 10^{-23}$ grams. On dividing this mass by 12, atomic mass unit (amu or U) is obtained. It is equal to $1{\cdot}6605 \times 10^{-24}$ gram. Thus,

1 amu or 1 U = $1{\cdot}6605 \times 10^{-24}$ g

1.11 RELATIVE MOLECULAR MASS (MOLECULAR WEIGHT)

> The relative molecular mass (or molecular weight) of an element or a compound is the number that represents how many times one molecule of the substance is heavier than 1/12 of the mass of an atom of carbon-12.

The Relative Molecular Mass (RMM) is obtained by adding together the relative atomic masses (atomic weights) of all the various atoms present in a molecule.

For example, relative molecular mass of sulphuric acid (H_2SO_4) is calculated as:

One molecule of sulphuric acid has two atoms of hydrogen, one atom of sulphur and four atoms of oxygen.

Mass of 2 atoms of hydrogen is $1 \times 2 = 2$ amu

Mass of 1 atom of sulphur is 32 amu

Mass of 4 atoms of oxygen is $16 \times 4 = 64$ amu

So mass of H_2SO_4 is $2 \times 1 + 32 + 16 \times 4 = 98$ amu

Thus the molecular mass of a substance is the sum of the atomic masses of the constituent atoms present in one molecule of that substance.

Example 7 : *Calculate the relative molecular masses (or molecular weights) of the following compounds:*

(a) Copper sulphate crystals, $CuSO_4 \cdot 5H_2O$

(b) Ammonium sulphate, $(NH_4)_2SO_4$

(c) Cane sugar, $C_{12}H_{22}O_{11}$

Given that the relative atomic masses of Cu = 63·5, S = 32, O = 16, N = 14 and C = 12

Solution :

(a) The relative molecular mass of $CuSO_4 \cdot 5H_2O$

= 63·5 + 32 + (16 × 4) + 5(2 + 16)

= 159·5 + 90 = **249·5** **Ans.**

(b) The relative molecular mass of $(NH_4)_2SO_4$

= $N_2H_8SO_4$

= 14 × 2 + 1 × 8 + 32 + 16 × 4

= 28 + 8 + 32 + 64 = **132** **Ans.**

(c) The relative molecular mass of $C_{12}H_{22}O_{11}$

= 12 × 12 + 1 × 22 + 16 × 11

= 144 + 22 + 176 = **342** **Ans.**

1.12 PERCENTAGE COMPOSITION

Percentage composition of a compound, is the percentage by weight of each element present in it.

Percentage of an element in a compound

$$= \frac{\text{Total wt. of the element in one molecule}}{\text{Gram molecular weight of the compound}} \times 100$$

Example 8 : *Calculate percentage of hydrogen in water.*

Given that the relative atomic masses of H = 1, O = 16.

Solution :

Relative molecular mass of H_2O

$= 1 \times 2 + 16$

$= 18$

Since 18 g of water contains 2 g of hydrogen

∴ 100 g of water contains $\frac{2}{18} \times 100 = 11{\cdot}11$ g of Hydrogen

Answer : Hydrogen in water is 11·1%

Example 9 : *Calculate the percentage of nitrogen in urea NH_2CONH_2.*

Given : R.A.M. of N = 14, C = 12, O = 16, H = 1

Solution :

Relative molecular mass of urea NH_2CONH_2 is

Element	No of atoms	Atomic mass	Total
N	2	14	28
C	1	12	12
H	4	1	4
O	1	16	16
			60

∴ R.A.M. = 60

$$\text{Percentage of nitrogen} = \frac{\text{Wt. of nitrogen}}{\text{Total wt. of urea}} \times 100$$

$$= \frac{28}{60} \times 100 = 46{\cdot}666 \text{ or } 46{\cdot}67\%$$

Example 10 : *Calculate the percentage composition of various elements in :*

Sodium carbonate, Na_2CO_3

Given that the relative atomic masses of O = 16, Na = 23 and C = 12.

Solution :

Relative molecular mass of Na_2CO_3

$= 23 \times 2 + 12 + 16 \times 3$

$= 46 + 12 + 48 = 106$

Since 106 g of Na_2CO_3 contains 46 g of sodium,

∴ 100 g of Na_2CO_3 contains $\frac{46 \times 100}{106}$ of sodium

$= \frac{4600}{106} = 43{\cdot}4$ g of Sodium

Similarly, 106 g Na_2CO_3 contains 12 g of carbon.

∴ 100 " " $\frac{12 \times 100}{106}$

$= \frac{1200}{106} = 11{\cdot}3$ g of Carbon

Again, 106 g of Na_2CO_3 contains 48 g of oxygen.

∴ 100 " " $\frac{48 \times 100}{106}$

$= \frac{4800}{106} = 45{\cdot}3$ g of Oxygen

Answer : In Na_2CO_3 : Na = 43·4%, C = 11·3% and O = 45·3%

Example 11 : *Find the percentage mass of water in washing soda crystals $Na_2CO_3 \cdot 10H_2O$.*

Solution :

Relative molecular mass of

$Na_2CO_3 \cdot 10H_2O$

$= 23 \times 2 + 12 + 16 \times 3 + 10 (2 + 16)$

$= 106 + 180 = 286$

286 g of washing soda contains 180 g of water of crystallisation.

$\therefore$ 100 " " $\frac{180 \times 100}{286}$

$= \frac{18000}{286} = 62 \cdot 9$ g of H_2O

Answer : The % of H_2O in $Na_2CO_3 \cdot 10H_2O = 62 \cdot 9$

1.13 EMPIRICAL FORMULA OF A COMPOUND

The empirical formula of a compound is the simplest formula, which gives the simplest ratio in whole numbers of atoms of different elements present in one molecule of the compound.

For example, the empirical formula of hydrogen peroxide (H_2O_2) is HO. It indicates the simplest ratio (1 : 1) between the hydrogen and oxygen atoms in its molecule whereas its actual formula is H_2O_2.

Similarly, the empirical formula of glucose ($C_6H_{12}O_6$) is CH_2O. It indicates that the ratio of C, H and O atoms in a molecule of glucose is 1 : 2 : 1.

***The empirical formula mass** is the sum of atomic masses of various elements present in the empirical formula.*

Thus, for hydrogen peroxide (H_2O_2), the empirical formula is HO and its empirical formula mass is 1 + 16 = 17.

CHAPTER AT A GLANCE

- **Symbol** is the short form that stands for the atom of a specific element.
- **Valency** is the combining capacity of an atom or a radical. It is equal to the number of electron(s) lost/gained or shared while combining with another atom or radical. Some elements, like iron, mercury, lead, show variable valencies.
- **Radical** is an atom or a group of atoms of the same or different elements, that behave as a single unit and has positive or negative charge. A radical with positive charge is a cation, e.g. NH_4^+ (ammonium ion), Na^+ (sodium ion) and a radical with negative charge is an anion, e.g. Cl^- (chloride), CO_3^{-2} (carbonate).
- **Molecular formula** is a shorthand notation for the molecule of a substance in terms of symbols and numbers of atoms of each element present in it.
- **Atomic mass unit (amu)** is equal to one twelfth the mass of an atom of carbon–12 (atomic mass of carbon taken as 12).
- **Molecular mass or relative molecular mass** of a substance is the relative mass of its molecule as compared with the mass of a carbon –12 atom, taken as 12 units.
- **Chemical equation** is the symbolic representation of a chemical reaction using symbols and formulae of the substances involved in the reaction. Since matter is neither created nor destroyed in the course of a chemical reaction, so every equation needs to be balanced.
- **Balanced chemical equation** tells us (i) which substances take part is a chemical reaction (reactants) and which substances are formed (products) and (ii) the number of molecules of each substance involved.
- The **relative atomic mass** or ***atomic weight*** *of an element is the number of times one atom of the element is heavier than* $\frac{1}{12}$ *times of the mass of an atom of carbon-12.*
- The **relative molecular mass** (or molecular weight) of an element or a compound is the number that represents how many times one molecule of the substance is heavier than 1/12 of the mass of an atom of carbon-12.
- The empirical formula of a compound is the simplest formula, which gives the simplest ratio in whole numbers of atoms of different elements present in one molecule of the compound.

EXCERCISE 1(C)

1. Fill in the blanks :

(a) Dalton used symbol .... for oxygen .... for hydrogen.

(b) Symbol represents .... atoms(s) of an element.

(c) Symbolic expression for a molecule is called ....

(d) Sodium chloride has two radicals. Sodium is a .... radical while chloride is a .... radical.

(e) Valency of carbon in CH_4 is ...., in C_2H_6 ...., in C_2H_4 .... and in C_2H_2 is ....

(f) Valency of Iron in $FeCl_2$ is .... and in $FeCl_3$ it is ....

(g) Formula of iron (III) carbonate is ....

2. Complete the following table.

Acid Radicals → Basic Radicals ↓	Chloride	Nitrate	Sulphate	Carbonate	Hydroxide	Phosphate
Magnesium	$MgCl_2$	$Mg(NO_3)_2$	$MgSO_4$	$MgCO_3$	$Mg(OH)_2$	$Mg_3(PO_4)_2$
Sodium						
Zinc						
Silver						
Ammonium						
Calcium						
Iron (II)						
Potassium						

3. Sodium chloride reacts with silver nitrate to produce silver chloride and sodium nitrate

(a) Write the equation.

(b) Check whether it is balanced, if not balance it.

(c) Find the weights of reactants and products.

(d) State the law which this equation satisfies.

4. What information does the following chemical equations convey ?

(a) $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

(b) $Mg + 2HCl \rightarrow MgCl_2 + H_2$

5. (a) What are poly-atomic ions ? Give two examples.

(b) Name the fundamental law that is involved in every equation.

6. What is the valency of :

(a) fluorine in CaF_2 (b) sulphur in SF_6

(c) phosphorus in PH_3 (d) carbon in CH_4

(e) nitrogen in the following compounds :

(i) N_2O_3 (ii) N_2O_5 (iii) NO_2 (iv) NO

7. Why should an equation be balanced ? Explain with the help of a simple equation.

8. Write the balanced chemical equations of the following reactions.

(a) Sodium hydroxide + sulphuric acid → sodium sulphate + water

(b) Potassium bicarbonate + sulphuric acid → potassium sulphate + carbon dioxide + water

(c) Iron + sulphuric acid → ferrous sulphate + hydrogen.

(d) Chlorine + sulphur dioxide + water → sulphuric acid + hydrogen chloride

(e) Silver nitrate → silver + nitrogen dioxide + oxygen

(f) Copper + nitric acid → copper nitrate + nitric oxide + water

(g) Ammonia + oxygen → nitric oxide + water

(h) Barium chloride + sulphuric acid → barium sulphate + hydrochloric acid

(i) Zinc sulphide + oxygen → zinc oxide + sulphur dioxide

(j) Aluminium carbide + water → aluminium hydroxide + methane

(k) Iron pyrites (FeS_2) + oxygen → ferric oxide + sulphur dioxide

(l) Potassium permanganate + hydrochloric acid → potassium chloride + manganese chloride + chlorine + water

(m) Aluminium sulphate + sodium hydroxide → sodium sulphate + sodium meta aluminate + water.

(n) Aluminium + sodium hydroxide + water → sodium meta aluminate + hydrogen

(o) Potassium dichromate + sulphuric acid → potassium sulphate + chromium sulphate + water + oxygen.

(p) Potassium dichromate + hydrochloric acid → potassium chloride + chromium chloride + water + chlorine.

(q) Sulphur + nitric acid → sulphuric acid + nitrogen dioxide + water.

(r) Sodium chloride + manganese dioxide + sulphuric acid → sodium hydrogen sulphate + manganese sulphate + water + chlorine.

9. (a) Define atomic mass unit.

(b) Calculate the molecular mass of the following :

(i) $CuSO_4 \cdot 5H_2O$ (ii) $(NH_4)_2CO_3$

(iii) $(NH_2)_2CO$ (iv) Mg_3N_2

Given atomic mass of Cu = 63·5, H = 1, O = 16, C = 12, N = 14, Mg = 24, S = 32

10. Choose the correct answer from the options given below.

(a) Modern atomic symbols are based on the method proposed by

(i) Bohr (ii) Dalton

(iii) Berzelius (iv) Alchemist

(b) The number of carbon atoms in a hydrogen carbonate radical is

(i) one (ii) two

(iii) three (iv) four

(c) The formula of iron (III) sulphate is

(i) Fe_3SO_4 (ii) $Fe(SO_4)_3$

(iii) $Fe_2(SO_4)_3$ (iv) $FeSO_4$

(d) In water, the hydrogen-to-oxygen mass ratio is

(i) 1 : 8 (ii) 1 : 16

(iii) 1 : 32 (iv) 1 : 64

(e) The formula of sodium carbonate is Na_2CO_3 and that of calcium hydrogen carbonate is

(i) $CaHCO_3$

(ii) $Ca(HCO_3)_2$

(iii) Ca_2HCO_3

(iv) $Ca(HCO_3)_3$

11. Correct the following statements

(a) A molecular formula represents an element.

(b) Molecular formula of water (H_2O) represents 9 parts by mass of water.

(c) A balanced equation obeys the law of conservation of mass and so does an unbalanced equation.

(d) A molecule of an element is always monoatomic.

(e) CO and Co both represent cobalt.

12. Calculate the relative molecular masses of :
[For atomic masses, refer page no (v)]
(a) $CHCl_3$ (b) $(NH_4)_2\ Cr_2O_7$
(c) $CuSO_4 \cdot 5H_2O$ (d) $(NH_4)_2SO_4$
(e) $CH_3\ COONa$ (f) Potassium chlorate
(g) Ammonium chloroplatinate $(NH_4)_2\ PtCl_6$

13. Give the empirical formula of :
(a) Benzene (C_6H_6) (b) Glucose $(C_6H_{12}O_6)$
(c) Acetylene (C_2H_2) (d) Acetic acid (CH_3COOH)

14. Find the percentage mass of water in the Epsom salt $MgSO_4{\cdot}7H_2O$.

15. Calculate the percentage of phosphorus in :
(a) Calcium hydrogen phosphate $Ca(H_2PO_4)_2$
(b) Calcium phosphate $Ca_3(PO_4)_2$

16. Calculate the percentage composition of each element in Potassium chlorate, $KClO_3$.

17. Urea is a very important nitrogenous fertilizer. Its formula is CON_2H_4. Calculate the percentage of carbon in urea. (C = 12, O = 16, N = 14 and H = 1)

ANSWERS

12. (a) 119·5 (b) 252 (c) 249·5 (d) 132 (e) 82 (f) 122·5 (g) 444
15. (a) 26·5% (b) 20% 16. K = 31·83%, Cl = 28·98%, O = 39·18% 17. 20%