Chapter - 1
CHEMICAL REACTIONS & EQUATIONS

CHEMICAL EQUATION

Chemical equation is a description of a chemical reaction. For example, this chemical equation describes the chemical reaction of changing sodium hydroxide and hydrogen chloride into salt (sodium chloride) and water:

$$NaOH + HCl \longrightarrow NaCl + H_2O$$

The equation above was a fairly simple equation, both sides were already *balanced*. Balanced means that all the atoms present among the reactants (the left side of the equation) were accounted for among the products (the right side).

Now lets take a simple unbalanced equation and try to balance it. This is the reaction of turning oxygen and hydrogen into water (unbalanced) :

$$H_2 + O_2 \longrightarrow H_2O$$

Notice that there are two hydrogens and two oxygens on the left side. But there are only two hydrogens and *one* oxygen on the right side. For the equation to be correct, it must be balanced, so both sides have equal amounts of atoms. To do that, we must adjust the coefficients of the equation. When the equation is finally balanced, it is :

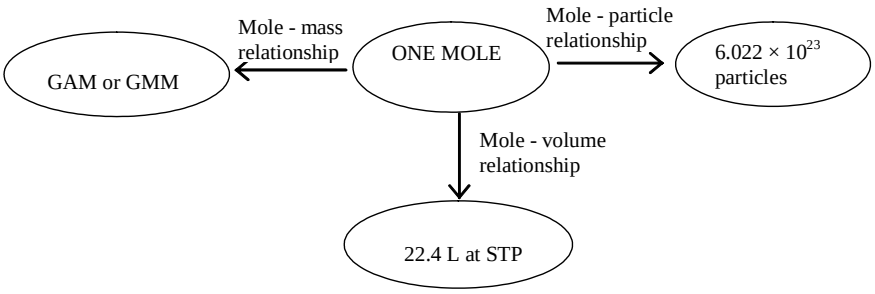
$$2H_2 + O_2 \longrightarrow 2H_2O$$

Now on both sides, there are four hydrogen atoms and two oxygen atoms. The equation now states, for every two moles of hydrogen gas, two moles of water can be formed, and for every one mole of oxygen gas, two moles of water can be formed.

MOLES

Number of particles equal to number of atoms present in 12 gm of C^{12} is 1 mole. The collection of 6.023×10^{23} particles is called a mole. Particles can be molecules of an element or ions of a compound or atoms or electrons or protons etc.

This number, 6.023×10^{23} is known as **Avogadro Number (N_A)**



Q. One mole of N_2 gas will have gram molecular mass as _____, number of particles _____, and volume at STP _____?

A. 28, 6.022×10^{23}, 22.4 L at STP.

Q. 10 moles of H_2 will have mass as _____, number of particles _____, and volume at STP _____?

A. 20, 60.22×10^{23}, 224 L.

Types of Chemical Reactions

All chemical reactions can be placed into one of six categories. Here they are, in no particular order:

(1) **Combustion :** A combustion reaction is when oxygen combines with another compound to form water and carbon dioxide. These reactions are exothermic, meaning they produce heat. An example of this kind of reaction is the burning of napthalene:

$$C_{10}H_8 + 12\ O_2 \rightarrow 10\ CO_2 + 4\ H_2O + \text{heat}$$

(2) **Synthesis :** A synthesis reaction is when two or more simple compounds combine to form a more complicated one. These reactions come in the general form of:

$$A + B \rightarrow AB$$

One example of a synthesis reaction is the combination of iron and sulfur to form iron (II) sulfide:

$$8\ Fe + S_8 \rightarrow 8\ FeS$$

(3) **Decomposition :** A decomposition reaction is the opposite of a synthesis reaction - a complex molecule breaks down to make simpler ones. These reactions come in the general form:

$$AB \rightarrow A + B$$

One example of a decomposition reaction is the electrolysis of water to make oxygen and hydrogen gas:

$$2\ H_2O \rightarrow 2\ H_2 + O_2$$

(4) **Single displacement :** This is when one element replaces another element in a compound. These reactions come in the general form of:

$$A + BC \rightarrow AC + B$$

One example of a single displacement reaction is when magnesium replaces hydrogen in water to make magnesium hydroxide and hydrogen gas:

$$Mg + 2\ H_2O \rightarrow Mg(OH)_2 + H_2$$

(5) **Double displacement :** This is when the anions and cations of two different molecules switch places, forming two entirely different compounds. These reactions are in the general form:

$$AB + CD \rightarrow AD + CB$$

One example of a double displacement reaction is the reaction of lead (II) nitrate with potassium iodide to form lead (II) iodide and potassium nitrate:

$$Pb(NO_3)_2 + 2\ KI \rightarrow PbI_2 + 2\ KNO_3$$

(6) **Acid-base :** This is a special kind of double displacement reaction that takes place when an acid and base react with each other. The H^+ ion in the acid reacts with the OH^- ion in the base, causing the formation of water. Generally, the product of this reaction is some ionic salt and water, such type of reaction is also known as neutralisation reaction.

$$HA + BOH \rightarrow H_2O + BA$$

One example of an acid-base reaction is the reaction of hydrobromic acid (HBr) with sodium hydroxide:

$$HBr + NaOH \rightarrow NaBr + H_2O$$

Redox-Reactions

Redox reactions are those chemical reactions during which both oxidation and reduction take place simultaneously.

e.g., $\overset{+3}{2FeCl_3} + \overset{+2}{SnCl_2} \longrightarrow \overset{+2}{2FeCl_2} + \overset{+4}{SnCl_4}$

$\overset{0}{C} + 4\overset{+5}{HNO_3} \longrightarrow \overset{+4}{CO_2} + 4\overset{+4}{NO_2} + 2H_2O$

A number of chemical process like burning of LPG gas or coal, corrosion of metals like rusting of iron, digestion of food in living beings, creation of holes in ozone layer by oxidation of CFC are certain interesting examples of redox reactions

Oxidation

An oxidation is that kind of chemical process during which

(a) Oxygen is added.

(b) Hydrogen is removed.

(c) De-electronation either from an atom or an ion take place.

(d) Oxidation number of an atom increases.

(e) Some extra energy is required in order to do work against the force of attraction acting between the valence electron and the nucleus. (i.e., it is an endothermic process).

e.g., $Na \longrightarrow Na^{+} + e^{-}$ $\quad Cl^{-} \longrightarrow Cl^{o} + e^{-}$ $\quad Fe^{+2} \longrightarrow Fe^{+3} + e^{-}$

The tendency of an atom to undergo oxidation increases down the groups from top to bottom while it decreases along the periods from left to right.

Reduction

Reduction is that chemical process during which

(a) oxygen is removed.

(b) hydrogen is added.

(c) electronation of either an atom or an ion take place.

(d) oxidation no. of an atom decreases.

(e) some energy is released (it is an exothermic process).

$Cl + e^{-} \longrightarrow Cl^{-}$ $\quad Fe^{+3} + e^{-} \longrightarrow Fe^{+2}$

The tendency of an atom to undergo reduction decreases down the groups from top to bottom while it increases along the periods from left to right.

Oxidising and Reducing Agent :

Oxidising agent (OA) :

An oxidising agent is that

(a) which undergoes reduction.

(b) which accept electron/electrons.

(c) whose oxidation number decreases.

(d) oxidise others but itself reduced.

e.g., $KMnO_4$, H_2SO_4, HNO_3, F_2 etc.

Identification :

(a) Generally the names of an oxidising agent end either in "ate" or "ic".

e.g., $H_2SO_4 \longrightarrow$ Sulphuric acid.

$HNO_3 \longrightarrow$ Nitric acid.

$KMnO_4 \longrightarrow$ Potassium permanganate.

$K_2Cr_2O_7 \longrightarrow$ Potassium dichromate.

(b) The oxidation number of an atom of such molecules should be in it's highest value.

e.g., $\overset{+6}{H_2SO_4}, \overset{+5}{HNO_3}, \overset{+7}{KMnO_4}, \overset{+6}{K_2Cr_2O_7}$

(c) Except carbon, all the non-metals are oxidising agents. F is the strongest non-metal; being most electronegative.

Reducing Agent (R.A.) :

A reducing agent is that atom or molecule :

(a) which undergo oxidation during reactions.

(b) which loose electron/electrons.

(c) whose oxidation number increases.

(d) reduce others but itself oxidised

e.g., H_2S, FeS, Cu_2O, $FeCl_2$, Na, C, Fe etc.

Identification :

(a) Generally the names of reducing agents end either in "ous" or "ide".

$FeCl_2 \longrightarrow$ Ferrous chloride.

$H_2S \longrightarrow$ Hydrogen sulphide.

(b) The O.N. of a constituent atom should be in it's lowest oxidation number value. $H_2\overset{-2}{S}$; $\overset{-1}{HI}$.

(c) All the metals are reducing agents. Cs is the strongest reducing metal.

* Oxidising property increases along the periods from left to right while reducing property of the elements increases down the groups from top to bottom.

* Highest O.N. = groups no. in Mendeleev's table (Exception Cu & Au).

* Lowest O.N. = group no. – 8

where, G = groups no. of the element in long form of P.T.

* (a) If the O.N. of a atom will be equal to its highest O.N. value then it will be an oxidising agent.

(b) If the O.N. of an atom in a molecule will be equal to its lowest O.N. value then it will be a reducing agent.

(c) If the O.N. of an atom will be in between highest & lowest O.N. then the molecule will behave like an oxidising as well as a reducing agent.

$\overset{-2}{H_2S}$	$\overset{+4}{SO_2}$	$\overset{+6}{H_2SO_4}$
(R.A.)	(RA + OA)	(O.A.)

* If the same atom will form two different molecules in different O.N., then the molecule with lower O.N. atom will behave like a reducing agent while the molecule with higher O.N. value will be an oxidising agent.

$+2$	$+3$	$+1$	$+2$
$FeCl_2$	$FeCl_3$	Cu_2O	CuO
R.A.	O.A.	R.A.	O.A.

Oxidation number :

Oxidation number of an atom is either real or imaginary charge which appears to be associated with an atom either in a molecule or an ion. In case of electrovalent molecules the charge will be real while in case of polar covalent molecules the charge will be imaginary. It suggests the extent of oxidation and reduction of an atom during reactions. **It may be either a whole no., fraction or even zero.** The positive O.N. suggest the oxidation while negative O.N. suggests the reduction.

$+1\ \ -1$	$+1\ -1$
Na Cl	H Cl
O.N. of Na in NaCl = +1	O.N. of H = +1
O.N. of Cl in NaCl = –1	O.N. of Cl = –1

Calculation of oxidation number

(1) In uncombined state or free state the oxidation number of an element is zero.

Na^o, P_4^o, F^o, Ca^o

(2) In case of a molecule, the algebraic sum of the oxidation numbers of the atoms present in the molecule is equal to zero.

(3) In case of ions or complex ion, the sum of the O.N. of the atoms present in the ion is equal to the charge present on the ion.

(4) In combined forms :

(a) O.N. of Alkali metals is always +1.

Li, Na, K, Rb, Cs are alkali metals.

(b) O.N. of alkaline earth metals is always +2

Be, Mg, Ca, Sr, Ba are alkaline earth metals.

(c) O.N. of Al is always +3.

(5) In combined forms

(a) O.N. of F is always –1.

(b) O.N. of H is usually +1, in metallic hydrides it is –1. In interstitial hydrides it is 0.

(c) Usually oxygen show –2 oxidation no. In peroxide its O.N. is –1. It can show positive O.N. with F.

In super oxides it is $-\frac{1}{2}$ (eg. Pot. superoxide KO_2).

In ozonides it is $-\frac{1}{3}$ (e.g., Pot. Ozonide KO_3).

$\overset{+2}{O}F_2$ $\quad$ $\overset{+1}{O_2}F_2$ $\quad$ $H_2\overset{-1}{O_2}$ $\quad$ $K\overset{-\frac{1}{2}}{O_2}$ $\quad$ $K\overset{-\frac{1}{3}}{O_3}$

(d) O.N. of halogens are usually –1. But in interhalogen compounds it show +ve O.N. value

$\overset{+1}{Cl}\overset{-1}{F}$ $\quad$ $\overset{+1}{Br}\overset{-1}{Cl}$

F always show –ve O.N. value.

(6) Higher O.N. of an atom of an element in a molecule or an ion can't exceed its group no. in Mendeleev's periodic table except Cu & Au (cupric and auric as +2 and +3 respectively while they belong to first B group in Mendeleev's table).

(7) Alkyl groups like $-CH_3$ or $-C_2H_5$ or –alkyl are taken as +1 in oxidation number.

CORROSION

Any process of deterioration (destruction) and consequent loss of a solid metallic material through an unwanted chemical or electrochemical attack by its environment starting at its surface is called corrosion. Corrosion always occurs at anodic areas. More active metals are corroded more easily. Corrosion is enhanced by the presence of (a) impurities, (b) air and moisture, (c) electrolytes and (d) stains in metal like dents, scratches, welding parts, etc. Corrosion of iron is called rusting. In the process of rusting, Fe metal is converted to dark brown coloured rust with formula $Fe_2O_3 \cdot xH_2O$ and therefore it is in oxidation process for iron metal and oxidising agent is oxygen in presence of weak acid (H_2CO_3). **Hence rusting of iron is a redox process.**

$$Fe + 2H^+ + \frac{1}{2}O_2 \longrightarrow Fe^{2+} + H_2O \; ; \; E^0_{cell} = 1.67 \text{ V}$$

The Fe^{2+} ions so formed move through water and reach at the surface of iron where they are oxidised to Fe^{3+} ions by atmospheric oxygen and constitute the rust which is hydrated ferric oxide.

$$2Fe^{2+} + \frac{1}{2}O_2 + 2H_2O \longrightarrow Fe_2O_3 + 4H^+$$

$$Fe_2O_3 + x\,H_2O \longrightarrow \underset{\text{Rust}}{Fe_2O_3 \cdot xH_2O}$$

Prevention of corrosion

(1) By coating with a suitable material (barrier protection)

(2) By alloying with suitable metals e.g. Fe, Cr, V, Ni, W, etc.

(3) By cathodic protection

(4) By using artificial anode (Sacrificial protection) Galvanisation.

RANCIDITY

Rancidity is a condition produced by aerial oxidation of unsaturated fat present in foods and other products, marked by unpleasant odour or flavour. When a fatty substance is exposed to air, its unsaturated components are converted into hydroperoxides, which break down into volatile aldehydes, esters, alcohols, ketones, and hydrocarbons, some of which have disagreeable odours. Butter becomes rancid by the foregoing process and by hydrolysis, which liberates volatile and malodorous acids, particularly butyric acid. Saturated fats such as beef tallow are resistant to oxidation and seldom become rancid at ordinary temperatures.

ASSIGNMENT

I. Multiple Choice Questions

1. In the reaction $Zn + CuSO_4 \longrightarrow ZnSO_4 + Cu$, Zn is

(a) Oxidising agent (b) Reducing agent

(c) Neutral (d) Both oxidising and reducing agent

2. Oxidation number of S in $Na_2S_2O_3$ is

(a) + 3 (b) + 4

(c) + 2 (d) + 1

3. How many atoms of Hydrogen are there in 34 gm NH_3 ?

(a) $2 \times N_A$ (b) $3 \times N_A$

(c) $6 \times N_A$ (d) $8 \times N_A$

4. Which of the following reactions is balanced ?

(a) $N_2 + H_2 \longrightarrow NH_3$ (b) $H_2 + O_2 \longrightarrow H_2O$

(c) $H_2 + Cl_2 \longrightarrow HCl$ (d) $2N_2 + 2O_5 \longrightarrow 2N_2O_5$

5. $2KClO_3 \xrightarrow{\Delta} 2KCl + 3O_2$ is

(a) synthesis reaction (b) decomposition reaction

(c) combustion reaction (d) redox reaction

6. Which of the following contain largest number of atoms each having volume 1 lit at S.T.P. ?

(a) H_2 (b) Ne (c) CO_2 (d) NH_3

7. A person adds 1.7 gm of sugar ($C_{12}H_{22}O_{11}$) in order to sweeten his tea. The number of C atoms added are (mol. mass of sugar = 342)

(a) 3.6×10^{22} (b) 7.2×10^{21} (c) 0.05 (d) $6.6NO^{22}$

8. Oxidation number of C in C_3O_2 is

(a) $-\frac{4}{3}$ (b) $+\frac{4}{3}$ (c) $-\frac{2}{3}$ (d) $+\frac{2}{3}$

9. Which of the following in a redox reaction ?

(a) $NaCl + KNO_3 \longrightarrow NaNO_3 + KCl$

(b) $CaC_2O_4 + 2HCl \longrightarrow CaCl_2 + H_2C_2O_4$

(c) $Mg(OH)_2 + 2NH_4Cl \longrightarrow MgCl_2 + 2NH_4OH$

(d) $Zn + 2AgCN \longrightarrow 2Ag + Zn(CN)_2$

II. Fill in the blanks

(i) The compound which itself gets reduced is called _____ agent.

(ii) In the reaction $KMnO_4 \longrightarrow MnCl_2$, the oxidation number of Mn _____.

(iii) The weight of Avogadro number of particles of a sample is its _____.

(iv) _____ is the cause for rusting of Fe.

(v) In combustion C is converted to _____.

(vi) Formation of a positive ion from an atom is _____.

III. True / False

(i) $2CO + O_2 \longrightarrow 2CO_2$ is a synthesis reaction.

(ii) It is also a combustion reaction .

(iii) It is also a substitution reaction.

(iv) In this reaction C is oxidised.

(v) Oxygen is oxidising agent.

IV. Subjective Type Questions

1. How many electrons are there is 18 gm of water ?

2. Balance the following reaction :

$C_4H_{10} + O_2 \longrightarrow CO_2 + H_2O$

3. Out of NO, N_2O_3, N_2O_4 and N_2O_5 which has N in highest oxidation number ?

4. Out of 1 gm O, 1 gm O_2 and 1 gm O_3 which has maximum number of oxygen atoms ?

5. Which of the following can not act as oxidising agent ?

$KMnO_4$, H_2SO_4, H_2S.

6. Arrange the following in order of -

(a) increasing oxidation no. of N

NH_3, N_3H, N_2O, NO, N_2O_5

(b) decreasing oxidation no.

HXO, HXO_3, HXO_2, HXO_4

ANSWERS

I. Multiple Choice Questions :

1. (b) **2.** (c) **3.** (c) **4.** (d) **5.** (b)

6. (d) **7.** (a) **8.** (b) **9.** (d)

II. Fill in the blanks :

(i) oxidising

(ii) decreases

(iii) molecular weight

(iv) Corrosion

(v) CO_2

(vi) oxidation

III. True / False

(i) True

(ii) True

(iii) False

(iv) True

(v) True

IV. Answers :

1. (i) 6.023×10^{24}

2. (ii) $C_4H_{10} + 13/2O_2 \longrightarrow 4CO_2 + 5H_2O$

3. (iii) N_2O_5

4. (iv) All have same no. of oxygen atoms.

5. (v) H_2S.

6. (a) increasing oxidation no. of N

$\overset{-3}{N}H_3, \overset{-1/3}{N_3}H, \overset{+1}{N_2}O, \overset{+2}{N}O, \overset{+5}{N_2}O_5$

$NH_3 < N_3H < N_2O < NO < N_2O_5$

(b) decreasing oxidation no.

$H\overset{+1}{X}O, H\overset{+5}{X}O, H\overset{+3}{X}O_2, H\overset{+7}{X}O_4$

$HXO_4 > HXO_3 > HXO_2 > HXO$