+2 SCIENCE/MANAGEMENT/ HUMANITIES/LAW

XAVIER INTERNATIONAL COLLEGE

Foundation and Fundamentals

Unit -1

Physical chemistry

PRESENTED BY: SAIBU KHADKA

Scope of Chemistry

Scope of chemistry is vast and diverse, it is studied by classifying into different branches:

- Physical Chemistry
- Organic Chemistry
- Inorganic Chemistry
- Biochemistry
- Environmental chemistry
- Applied chemistry
- Analytical Chemistry, etc.

XAVIER
INTERNATIONAL COLLEGE

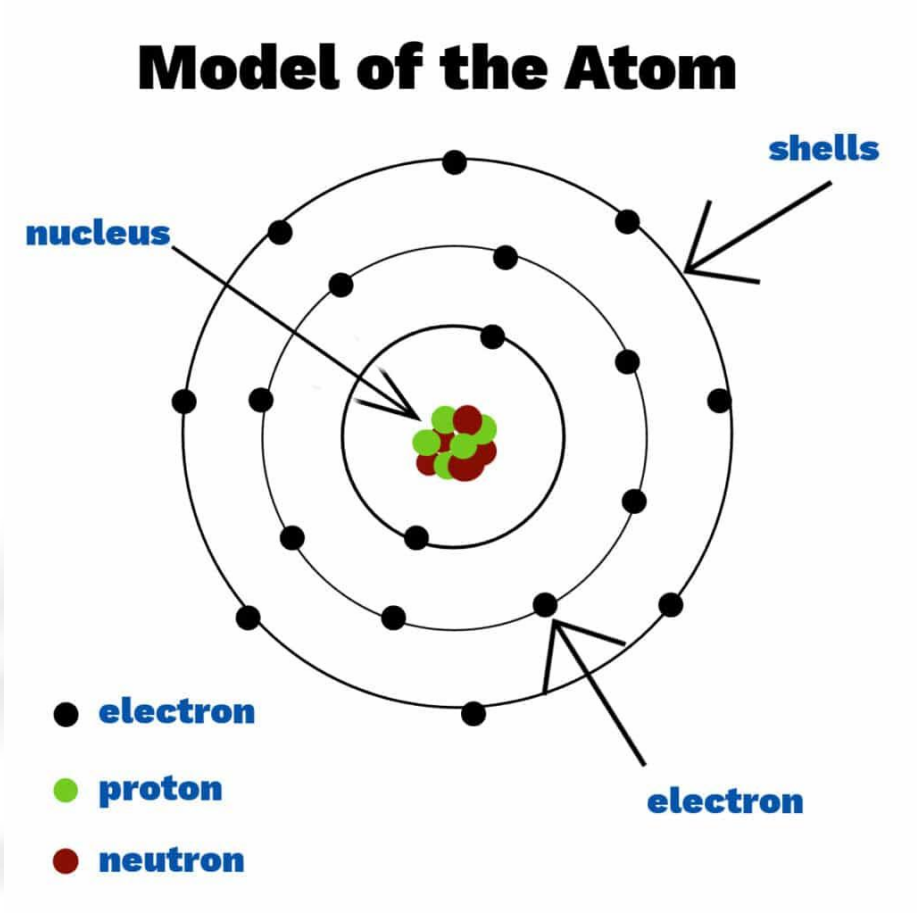
Importance of Chemistry

- production of many commodities such as paper, glass, cement, oils, petrol, plastics, drugs, metals and alloys
- synthesis of camphor, cocaine, plant pigments, and red colouring matter of blood, etc.
- development of other science like physiology, geology, agriculture etc
- examination of crimes and frauds
- invention and production of medicines, rockets, high explosives, poison gases etc

XAVIER
INTERNATIONAL COLLEGE

Basic concept of Chemistry

- **Atom**: An atom is the smallest particle of an element which can take part in chemical reaction
- Atom consists of three fundamental particles like proton, neutron and electron
- Atoms of same elements are similar in properties whereas atoms of different elements are different in properties. Example:- 'H' represent the atom of hydrogen

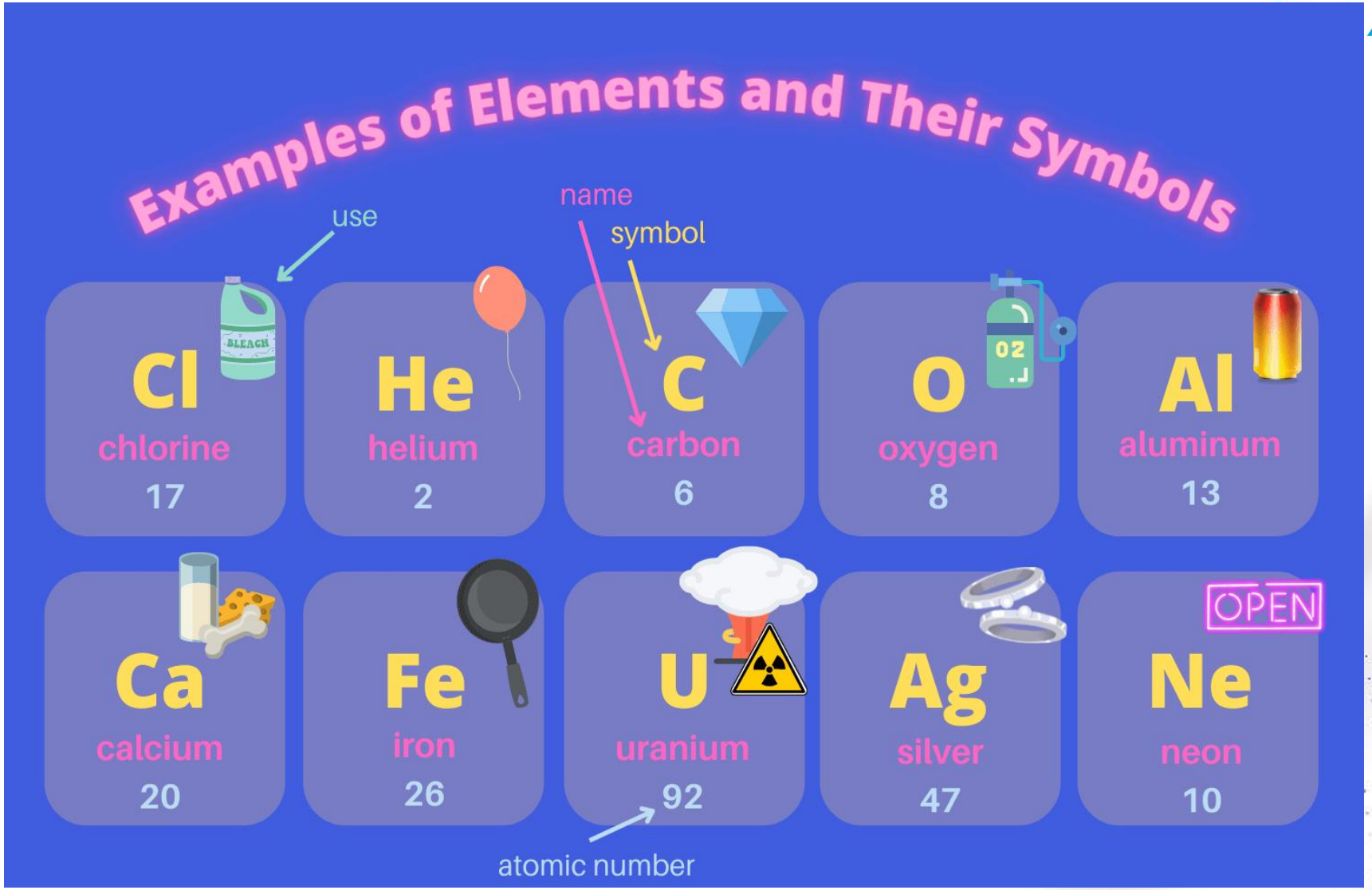


Chemical symbols

- short characteristic notation of an element; an abbreviatted form for the full name of an element or atom
- full name of atom maybe Latin, German, English, in honour of Scientist, planets etc

Element	Symbol	Latin Name
Antimony	Sb	Stibium
Copper	Cu	Cuprum
Gold	Au	Aurum
Iron	Fe	Ferrum
Lead	Pb	Plumbum
Mercury	Hg	Hydragyrum
Potassium	K	Kalium
Silver	Ag	Argentum
Sodium	Na	Natrium
Tin	Sn	Stannum
Tungsten	W	Wolfram

XAVIER
INTERNATIONAL COLLEGE



Some terms

- **Nucleon**: a proton and a neutron of an element, eg if an atom consists of 6 proton and 6 neutron, then there is 12 neutrons on that atom
- **Atomic number (Z)**: total number of proton in an atom, eg atomic number of Carbon is 6
- **Atomic mass number (A)**: total number of proton and neutron in an atom

Atomic mass number (A)= Total number of P + Total number of n

= Atomic number(Z) + n

Eg; atomic mass of Magnesium (Mg) = 12 +12 = 24

- **Isotopes**: different species of an element having same atomic number but different atomic mass numbers, identical chemically but are physically different

  Eg: Hydrogen- 3 isotopes; protium $^{1}H_{1}$, deuterium $^{2}H_{1}$ or D and tritium $^{3}H_{1}$ or T

- **Atomic mass unit (amu)**: unit mass of microscopic particle(atom, ion or molecule), it is the mass of 1/12th of an atom of C-12 isotope
- mass of one atom= 6.023x 10^{23} g

It is defined as $\frac{1}{12}$ th of the mass of one $_{6}C^{12}$ atom

i.e., $$1 \text{ a.m.u.} = \frac{1}{12} \times \frac{12}{6.023 \times 10^{23}}$$

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

- **Molecules**: smallest discrete particle of a substance(atom or compounds) which can be divisible unlike atoms,

  Eg: Cl_2, HCl etc

- **Radicals**: an intregal fragment of a molecule having +ve or -ve or no charge

  Eg: acidic radicals= Cl^-, $NO3^-$, etc basic radicals= Na^+, Ca^{++} etc

- **Valency**: combining capacity of an atom or group of atom, measured as the number of H atom that one radical can combine to form molecule

  Eg: valency of Mg is 2, it means 1atom of Mg can combine with 2atoms of H

- **Variable valency**: some elements show more than one valency in their compunds

  Eg: ferrous chloride($FeCl_2$) and Ferric Chloride($FeCl_3$) have valency of Fe 2 and 3 resp.

XAVIER INTERNATIONAL COLLEGE

- **Relative mass unit**: average mass of one atom of an element with respect to mass of 1/12th C-12 atom isotope, it is average atomic mass and is fractional in nature

  Eg: natural mixture of H contains **99.2% of protium ($^{1}_{1}H$) and 0.8% of deuterium ($^{2}_{1}H$), observed atomic mass of H is the average atomic mass**

  = **99.2% of isotopic mass of $^{1}_{1}H$ + 0.8% of isotopic mass of $^{2}_{1}H$**

  = 99.2/100 x 1amu + 0.8/100 x 2amu

  = **1.008 amu** (fractional number)

  similarly, **Cl contains 75% of ^{35}Cl and 25% of ^{37}Cl in natural mixture**

  Atomic mass= 35.5 amu (SELF PRACTICE OF STUDENTS)

XAVIER
INTERNATIONAL COLLEGE

- **Oxidation state of positive and negative radicals:** a compound is constituted from two diferent radicals; one less electronegative radical(positive) and another more electropositive radical(negative) , in solution they are called cation and anion respectively
- metals form cations and non-metals form anions, **NH_4^+** and **H^+** are exceptional
- **the valences of these radicals when expressed with their charge are called as oxidation states**

  Eg; in HNO_3 the radicals H^+ and NO_3^- have O.S +1 and -1 resp.
- neutral compounhd is constituted by the combination of +ve and -ve radicals

Valency	Symbol	Name
Monovalent (1)	Hydrogen	H^+
	Sodium	Na^+
	Potassium	K^+
	Ammonium	NH_4^+
	Copper (I) / Cuprous	Cu^+
	Silver (I) / Argentous	Ag^+
	Mercury (I) / Mercurous	Hg^+
Bivalent (2)	Magnesium	Mg^{2+}
	Calcium	Ca^{2+}
	Barium	Ba^{2+}
	Zinc	Zn^{2+}
	Nickel	Zn^{2+}
	Copper (II) / Cupric	Cu^{2+}
	Iron (II) / Ferrous	Fe^{2+}
	Lead (II) / Plumbous	Pb^{2+}
	Tin (II) / Stannous	Sn^{2+}
	Silver (II) / Argentite	Ag^{2+}
	Mercury (II) / Mercuric	Hg^{2+}
	Manganese (II) / Manganous ion	Mn^{2+}

List of Common Electropositive Radicals

Monovalent	Divalent	Trivalent	Tetravalent	
Hydrogen H^+	Cupric Cu^{2+}	Aluminium Al^{3+}	Stannic Sn^{4+}	Sulphur S^{4+} in SO_2
Sodium Na^+	Barium Ba^{2+}	Ferric Fe^{3+}	Plumbic Pb^{4+}	Manganese in
Potassium K^+	Calcium Ca^{2+}	Chromium Cr^{3+}	Platinum Pt^{4+}	MnO_2, Mn^{4+}
Cuprous Cu^+	Mercuric Hg^{2+}	Auric Au^{3+}	Carbon C^{4+}	
Mercurous Hg^+	Cobalt Co^{2+}	Arsenious As^{3+}	Nitrogen in NO_2	
or Hg_2^{2+}	Stannous Sn^{2+}	Bismuth Bi^{3+}	and N_2O_4, N^{4+}	
Silver Ag^+	Nickel Ni^{2+}	Boron B^{3+}	Silicon Si^{4+}	
Ammonium NH_4^+	Ferrous Fe^{2+}	Antimonous Sb^{3+}	**Pentavalent**	
Aurous Au^+	Magnesium Mg^{2+}	Phosphorus P^{3+}	Arsenic As^{5+}	
Lithium Li^+	Manganese Mn^{2+}	Nitrogen in N_2O_3,	Antimonic Sb^{5+}	
Rubidium Rb^+	Cadmium Cd^{2+}	N_3^+		
Caesium Cs^+	Strontium Sr^{2+}	Gallium Ga^{3+}	Phosphorus P^{5+}	
Nitrogen in $N_2O(N^{+1})$	Zinc Zn^{2+}	Scandium Sc^{3+}	Vanadium V^{5+}	
	Plumbous Pb^{2+}		Nitrogen in N_2O_5, N^{5+}	
	Beryllium Be^{2+}			
	Nitrogen in NO, N^{2+}			
	Palladium Pd^{2+}			

List of Common Electronegative Radicals

Monovalent	Divalent	Trivalent	Tetravalent
Fluoride F^-	Carbonate CO_3^{2-}	Phosphate PO_4^{3-}	Carbide C^{4-}
Chloride Cl^-	Sulphide S^{2-}	Arsenate AsO_4^{3-}	Ferrocyanide $[Fe(CN)_6]^{4-}$
Superoxide O_2^-	Sulphite SO_3^{2-}	Phosphite PO_3^{3-}	Silicide Si^{4-}
Bromide Br^-	Sulphate SO_4^{2-}	Arsenite AsO_3^{3-}	Pyrophosphate ion $P_2O_7^{4-}$
Iodide I^-	Thiosulphate $S_2O_3^{2-}$	Borate BO_3^{3-}	
Hydride H^-	Oxide O^{2-}	Phosphide P^{3-}	
Hydroxide OH^-	Peroxide O_2^{2-}	Nitride N^{3-}	
Cyanide CN^-	Chromate CrO_4^{2-}	Ferricyanide	
Acetate CH_3COO^-	Dichromate $Cr_2O_7^{2-}$	$[Fe(CN)_6]^{3-}$	
Sulphocyanide	Oxalate $C_2O_4^{2-}$	Boride B^{3-}	
or (thiocyanate) SCN^-	Manganate MnO_4^{2-}	Arsenate AsO_4^{3-}	
Nitrite NO_2^-	Silicate SiO_3^{2-}		
Nitrate NO_3^-	Stannite SnO_2^{2-}		
Bisulphide HS^-	Stannate SnO_3^{2-}		

XAVIER
INTERNATIONAL COLLEGE

Molecular Formula

- Symbolic expression for a substance is called formula, molecule is written with the help of symbole it is called molecular formula
- shorthand expression of the composition of a molecule is molecular formula
- it tells about the number and kinds of atoms used in a molecule
- the algebric sum of positive and negative charges in molecule must be zero

Relative Molecular Mass

- defined as the mass of molecule of substance with respect to the mass of 1/12th C-12 isotope
- calculated by the summation of atomic mass of all atoms present in its molecular formula

Eg; molecular mass of calcium carbonate ($CaCO_3$)

=atomic mass of Ca + atomic mass of C + 3 x atomic mass of O

=(40+12+3x16)amu

=100 amu

it means the mass of one molecule of $CaCO_3$ is 100 times the mass of 1/12th of C-12 isotope

Significance of Molecular Formula and % Composition

- qualitative and quantative significance, the formula of a compound tells:

❖ the elements constituting the molecule ,eg; H_2O tells that a molecule of water consists of hydrogen and oxygen

❖ the number of atoms of each elements present in a compound, eg; H_2O tells that a molecule of water consists of two atoms of H and one atom of O

❖the weigh ratio and % of the element present in compound, eg; the weight ratio of H and O in H_2O is 2:16 i.e 1:8

here, % of H in H_2O = wt of H /wt of H_2O x100 =2/18x100= 11.11%

and % of O in H_2O = wt of O/wt of H_2O x100 = 16/18x100= 88.89%

XAVIER
INTERNATIONAL COLLEGE

- molecular weight of a substance as a sum of atomic weight of all the atoms present in a molecule
  - eg: molecular weight of H_2O = (2x1+16)= 18 amu
- the numerical coefficient written before the formula gives the number of molecules
  - eg: $2H_2O$ represents two molecules of water

XAVIER
INTERNATIONAL COLLEGE

Significance of a Formula

Qualitatively, it tells,

- name of the substance
- what elements the substance contains
- how the atoms are arranged in the molecule

Quantitatively, it tells

- 1 mole of substance that equals to 6.023×10^{23} number of molecules
- number of molecules present
- the number of each atoms present
- % composition of each elements present
- molecular mass of substance

XAVIER
INTERNATIONAL COLLEGE

Questions

1)Molecular formula of Glucose is $C_6H_{12}O_6$, Calculate

a) molecular mass of the compound

b) weight ratio and % composition of elements present in a compound.

2)Molecular formula of Water is H_2O , what does it significe?

XAVIER
INTERNATIONAL COLLEGE

Empirical formula

- simplest formula of a compound that gives the ratio of atoms present in a molecule of compound
- it may not give the actual number of atoms present in a molecule but it is essential to establish molecular formula of a compound as

  molecular formula= (empirical formula)n

  where n= 1,2,3,....

Eg: empirical formula of methane, ethane, hydrogen peroxide, glucose are CH_4, CH_3, HO, $C_6H_{12}O_6$

XAVIER INTERNATIONAL COLLEGE

Chemical change and Chemical Equation

- chemical change is a process that involves formation of one or more substance having properties entirely different from the original substance
- Reactant→ Product
- eg, burning of coalo, rusting of iron, souring of milk

Character of chemical changes or chemical reaction:

- a chemical change is permanent
- a chemical change is accompained either by energy(heat) evolution or absorbtion
- a chemical change is always conserved in mass

Physical vs Chemical Changes

Chemical

- not easily reversed
- new product(s) formed
- reactants used up
- often heat / light / sound / fizzing occurs
- electricity may be produced
- *a precipitate may form
- e.g. wood burning.

Physical

- easily reversible
- no new products,
- often just a state change
- e.g. ice melting.

XAVIER INTERNATIONAL COLLEGE

Chemical Equation

- symbolic representation of a chemical change
- reactant and products of a chemical reaction are denoted by their formulae

$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

Significance of Chemical Equation

- **Qualitative significance**

  $6CO_2(g) + 6H_2O(g) \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$

  it tells that carbondioxide gas and water vapour undergoes photosynthesis reaction to give glucose and oxygen gas

- **Quantitative significance**

  $6CO_2(g) + 6H_2O(g) \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$

  - it tells that, 6 molecules of CO_2 + 6molecules of H_2O gives 1 molecule of $C_6H_{12}O_6$ + 6 molecules of O_2

  or, 6 mol of CO_2 + 6 mol of H_2O gives 1 mol of $C_6H_{12}O_6$ + 6 mol of O_2

  - molecular mass of a substance expressed in gram is one mole or g. mole
  - 6x44 g of CO_2 + 6x18 g of H_2O gives 180 g of $C_6H_{12}O_6$ + 192 g of O_2

- **Limitation of chemical equation:**

1. chemical equation does not give the concentration of reactant at the start and concentration of product at the end
2. it does not give rate of reaction and the time required for the completion of the reaction
3. it does not give conditions required to carry out chemical reaction
4. it does not give wheather heat is absorbed or released in the reaction unless it is modified by thermochemical equation

XAVIER
INTERNATIONAL COLLEGE

- **Removal of Defects**:

1. physical state of components are denoted by the symboles s,l,g and aq for solid, liquid, gas and aqueous

   $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

2. Reversibility of reaction is denoted by the notation $\rightleftharpoons$ in the chemical reaction as

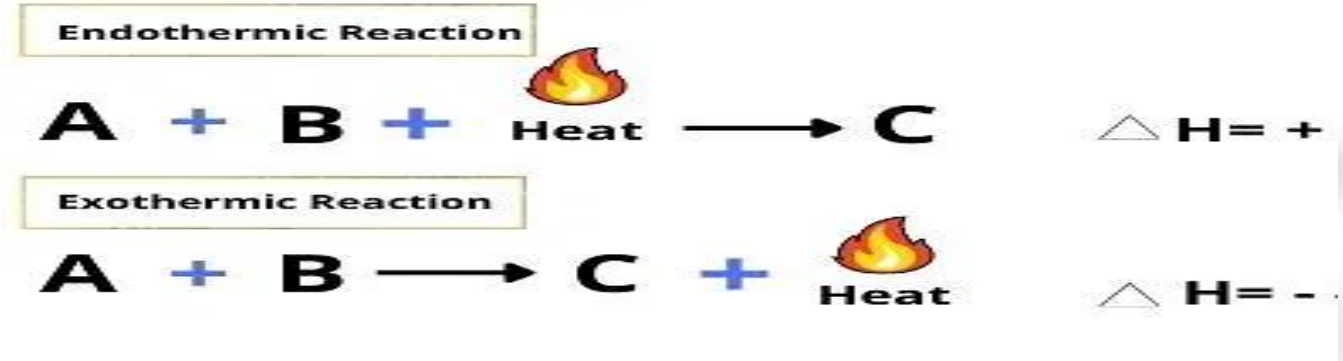
$$N_{2\,(g)} + 3H_{2\,(g)} \rightleftharpoons 2NH_{3\,(g)}$$

3. External conditions such as temperature, pressure and catalyst can be given above and below the arrow indicating chemical reaction

$$N_2(g) + 3H_2(g) \xrightleftharpoons[Fe]{4500C,\ 200atm} 2NH_3(g) \quad \Delta H = -22.4Kcal$$

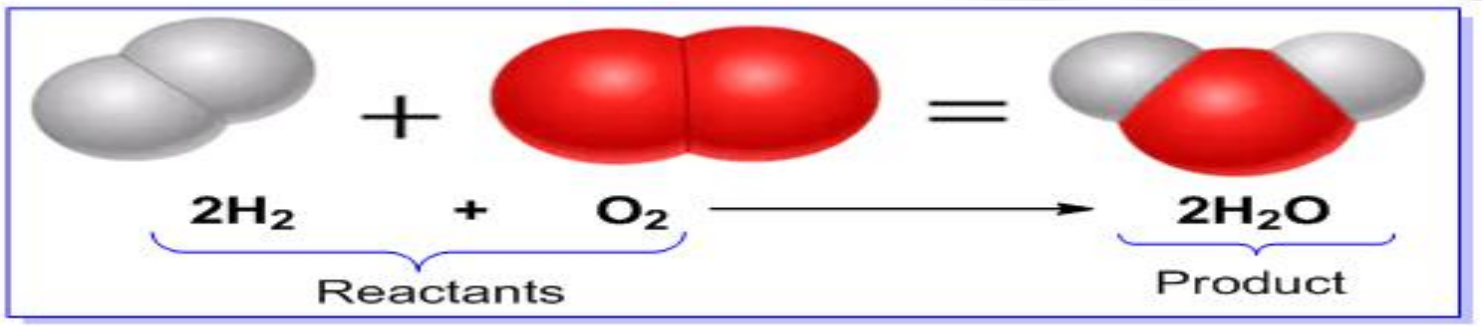
4. In thermodynamics, ΔH = -ve is exothermic reaction which means heat is evolved

ΔH= +ve is endothermic reaction which means heat is applied



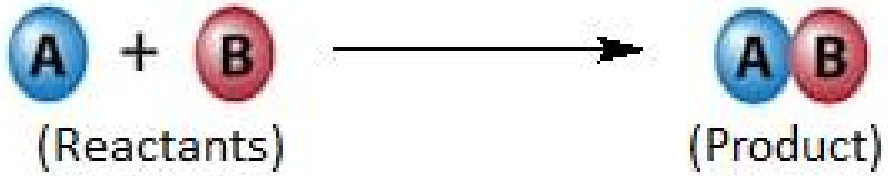
Chemical Reaction

- Chemical reactions are the processes by which chemicals interact to form new chemicals with different compositions
- a chemical reaction is the process where reactants are transformed into products.
- A reactant is a substance that is present at the start of a chemical reaction and a product is a substance that is present at the end of a chemical reaction.



Types of chemical reaction

- **Combination or synthesis reaction**:In combination reaction, two or more substances (i.e. reactants) unite together to produce a new substance (i.e. product).



- Eg:

$$2Na + Cl_2 \longrightarrow 2NaCl$$

$$2Mg + O_2 \longrightarrow 2MgO$$

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

$$CaO + H_2O \longrightarrow Ca(OH)_2$$

XAVIER INTERNATIONAL COLLEGE

- **Decomposition or analysis reaction**: In this reaction, a single compound is decomposed or broken into two or more products.

- Eg:

$CaCO_3 \xrightarrow{\Delta} CaO + CO_2$

$2HgO \xrightarrow{\Delta} 2Hg + O_2$

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

$2KMnO_4 \xrightarrow{\Delta} K_2MnO_4 + MnO_2 + 2O_2$

Thermal decomposition

$2H_2O \xrightarrow{electricity} 2H_2 + O_2$ [Electrolysis]

- **Displacement or Replacement or Substitution reaction**: the process of displacing one of the constituents of a compound and occupying its position by another constituent is called displacement reaction or replacement reaction.
- It is of two types – single displacement and double displacement reactions.
- Single displacement reaction :In this reaction, one element displaces another element from a compound

- Eg:

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$$

XAVIER
INTERNATIONAL COLLEGE

- **Double displacement reaction** :In this reaction, there is mutual exchange of ions between two pairs of reacting compounds

- Eg:

$NaCl_{(aq.)} + AgNO_3 \longrightarrow AgCl_{(s)}\downarrow + NaNO_{3\ (aq.)}$

$3NH_4OH + FeCl_3 \longrightarrow 3NH_4Cl + Fe(OH)_3\downarrow$

$FeS + H_2SO_4 \longrightarrow FeSO_4\downarrow + H_2S$

$BaCl_{2\ (aq)} + H_2SO_{4(aq)} \longrightarrow BaSO_4\downarrow + 2HCl_{\ (aq)}$

} Precipitation reaction

- **Acid – base reaction or Neutralization reaction:** A chemical reaction in which acid reacts with base to give salt and water is called acid base reaction or neutralization reaction.
- It is also a double displacement reaction. Examples :

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

$$2HCl + Ca(OH)_2 \longrightarrow CaCl_2 + 2H_2O$$

$$\underset{\text{(acid)}}{HNO_3} + \underset{\text{(base)}}{NaOH} \longrightarrow \underset{\text{(salt)}}{NaNO_3} + \underset{\text{(water)}}{H_2O}$$

- **Hydrolysis reaction**:A chemical reaction which is done by the action of water on any substance to form product is known as hydrolysis.
- It is the interaction of ions of salt with water to produce acidic or basic solution. Examples:
- a) Sodium carbonate dissolves in water to produce strong base and weak acid (i.e. basic solution).

$$Na_2CO_{3\,(s)} + 2H_2O_{(l)} \rightleftharpoons \underset{\text{(strong base)}}{2NaOH_{\,(aq.)}} + \underset{\text{(weak acid)}}{H_2CO_{3\,(aq.)}}$$

b) Ferric chloride is dissolved in water to produce strong acid and weak base (i.e. acidic solution).

$$FeCl_{3\,(s)} + 2H_2O_{(l)} \rightleftharpoons \underset{\text{(weak base)}}{Fe(OH)_{3\,(s)}} + \underset{\text{(strong acid)}}{3HCl_{\,(aq.)}}$$

XAVIER
INTERNATIONAL COLLEGE

Thank you!