7. SURFACE CHEMISTRY

Synopsis: This chapter includes:

- 1) Adsorption 2) Colloids 3) Catalysis

  Adsorption : The phenomenon in which the molecules of a substance are attracted and adhered to the surface of a solid or liquid.
- Adsorption is a surface phenomenon.
- Adsorption is a exothermic reaction. Released heat is called Heat of adsorption.
- **Adsorbent :** The liquid or solid on the surface of which the molecule of the substance are adsorbed is called adsorbent.
- **Adsorbate :** The substance whose molecules are attracted by the adsorbent and there by if the substance is adhered to the surface of the adsorbent. Then the substance is called adsorbate.

  $C_2H_4 + H_2 \xrightarrow{Pt\ (or)\ Ni} C_2H_6$
- Surface of solids extends upto 100 nm.
- In the exterior of solid unbalanced forces and interior of the solid balanced forces are present.
- Due to unbalanced forces on the surface it attracts molecules of gas or liquid.
- The attraction and accumulation of gas or liquid molecules on to the surface of solid is called Adsorption.
- If gas or liquid molecules are uniformly distributed through out the interior is called absorption.
- Thus adsorption is surface phenomenon and absorption is bulk phenomenon.
- In most of the instances both absorption and adsorption will occur simultaneously and they are not easily distinguishable.
- If both absorption and adsorption will occur it is called sorption, given by mc Bain.
- If the adsorbed gas or liquid leaves the surface it is called as dissipation.
- Generally absorption occur at uniform rate while adsorption occurs rapidly in the beginning.

  Example :

Adsorption	Absorption
1. Charcoal adsorbs aceticacid from solutions.	Sponge absorbs water.
2. Animal charcoal adsorbs colours and impurities from cane sugar solutions.	An hydrous $CaCl_2$ absorbs moisture
3. Activated charcoal adsorbs noble gases.	NaOH absorbs moisture and $CO_2 \rightarrow$ hygroscopic
4. Silica gel adsorbs moisture	Ammonical cuprous chloride absorbs CO and acetylene.
5. Transition metals adsorbs gases like H_2, N_2, O_2 etc.,	Terpentyne oil absorbs ozone.
6. Fullers earth (impure clay) adsorbs impurities from vegetable oils.	Pyrogallol absorbs oxygen.
7. Ni adsorbs H_2 gas in the manufacture of Dalda.	Chalk dipped in ink.

- **Adsorbent (medium) :**
- It is the substance whose surface adsorbs gas or liquid molecules.
- **Adsorbate** $\rightarrow$ the substance whose molecules are adsorbed on to the surface of adsorbent.
- Adsorbent may be a solid or liquid.
- Adsorbate may be gas or liquid.
- Based on the nature of forces holding the adsorbate molecules to the adsorbent surface.
- Adsorption are of two types.

1) Physical adsorption :

- Weak – Vanderwall's forces exist between adsorbent and adsorbate.

Eg: Charcoal adsorbs gases. Charcoal adsorbs acetic acid ; Silica jel adsorbs moisture.

2) Chemical adsorption :

- Strong chemical forces will exists between adsorbate and adsorbent and these forces may be ionic or covalent.
- Adsorption of H_2, N_2,O_2 gases by Ni, Pd, Pt etc..

PHYSICAL	CHEMICAL
1. Weak vander – wall forces	1. Strong forces
2. It is weak adsorbtion	2. Strong adsorbtion
3. Enthalpy is low 20 – 40 kJ	3. High that 40 – 400 k.J
4. Less activation energy	4. More activation energy
5. Not specific that any adsorbent can adsorbs any gas	5. Specific that is a particular adsorbent adsorbs particular gas.
6. With in increase in pressure physical adsorbtion increases.	6. Both adsorbate and adsorbent effect of pressure is neglizable.
7. It is favourable at low temperature that is adsorption decreases with rise in temperature	7. Adsorbtion increases with rise in temperature.
8. It is mutimolecular layer [at low pressure unimolecular layer and high pressure multi molecular layer is formed.	8.Unimolecular layer formation.
9. If is reversible and affects equilibrium.	9. It is irreversible
10.easily liquefied gases are more adsorbed.	10.No relation between liquefaction & adsorbtion

- **Adsorption of a gas by solids :**

Surface area $\rightarrow$ with increase in surface area adsorption increases.

- Finely divided metals and porous substances with large surface area have more adsorption capacity.
- **Activation:** Removal of impurities and cleaning the surface of adsorbent is called activation.
- Activation is done by heating in vaccum or in presence of inert gas.
- Activated adsorbent has more adsorption capacity.

Nature of the gas :

- The gas with higher critical temperature is easily liquefiable.
- The easily liquefiable gases are more readily adsorbed.

  Eg: HCl, SO_2, NH_3, CO_2

  Pressure : With increase in pressure physical adsorption increases, effect of pressure on chemical adsorption is negligible

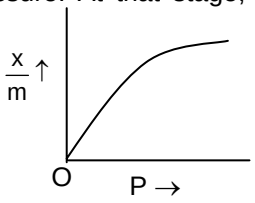
  Temperature : Low temperature favours physical adsorption and high temperature favours chemical adsorption.
- In some cases increases in temperature will convert physical adsorption into chemical adsorption.

  Eg: At 463 K N_2 is physically adsorbed by iron.

  At 773 K N_2 is chemical adsorbed by iron.
- **Adsorption isotherm :**

  [Freundlich adsorption isotherm]

  These adsorption isotherms will explain the variation magnitude of adsorption with pressure at given temperature. These are obtained by plotting magnitude of adsorption Vs pressure.
- As shown below rate of adsorption increases with pressure after reaching a limiting value rate of adsorption remains constant and that pressure is called equilibrium pressure. At that stage, rate of adsorption and rate of disorption are same.



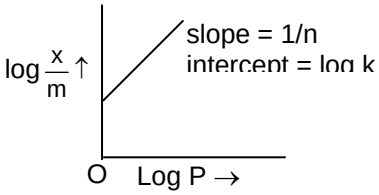
  Freundlich adsorption isotherm,

  $\frac{x}{m} \propto p^{1/n}$; $\frac{x}{m} = kp^{1/n}$

  $\left(\frac{x}{m}\right) = \frac{1}{n}\log p + \log k$

  $\frac{x}{m}$ = magnitude of adsorption. P = pressure

  x = amount of gas adsorbed m = mass of adsorbent



  value of n is equal to 0 to 1

  at low pressure n = 1

  at high pressure n = 0

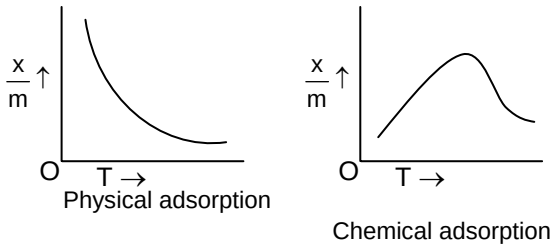
  at optimum pressure n = > 0 / < 1

  by applying logarithm on both sides of Freundlich equation.

  $\text{Log}\frac{x}{m} = \log k + \frac{1}{n}\log p$ by plotting log(x/m) verses 'logp' = a straight line is obtained, slope gives n and intercept gives 'logk'.

- **Adsorption isobar :**

  These isobar will explain variation of magnitude of adsorption with temperature at given pressure .
- These are obtained by plotting x/m verses temperature at constant pressure.
- These adsorption isobars are useful to distinguish physical and chemical adsorption.
- In physical adsorption x/m decreases with increase in temperature.
- In chemical adsorption x/m increases with T upto a limiting value and then decrease.



Physical adsorption Chemical adsorption

Langmuir adsorption isotherm :

- Langmuir has theoretically derived the following expression which explains the variation of adsorption with pressure at given temperature

$$\frac{x}{m} = \frac{bp}{1+ap}$$ p = pressure, a, b = constant

- Freundlich isotherm is a special case of langmuir adsorption isotherms.
- Langmuir adsorption isotherms is applicable for unimolecular layer adsorption.
- Both Freundlich and langmuir adsorption isotherms hold good at low pressure and fail at high pressure.

Adsorption from solutions:

- Like gases are adsorbed by solids, powdered substance adsorb various dissolved substances from solution.
- Charcoal or activated charcoal adsorbs colours and acetic acid from solution.
- Animal charcoal adsorbs colours and impurities from raw sugar solution.
- Freshly precipitated metal hydroxides $Fe(OH)_3$, $Al(OH)_3$ are better adsorbent for dyes.
- In column chromatography the mixture of organic and inorganic substances can be separated based on the difference in the rate of adsorption.

  Al_2O_3 is used as adsorbent.
- In froth floatation process in the concentration of sulphide ore froth adsorbs oar particles.

Applications of adsorption:

- In heterogeneous catalysis, catalyst adsorbs gaseous reactants.

  1) Haber's process 2) Ostwald process 3) Contact process
- In chromatography.
- In the production of gas masks. In producing high vacuum's.
- In washing by detergents. In softening of hard water.
- In metallurgy for the concentration of ores
- In the digestion of food and assimilation of various medicines.

Colloids : Thomas Graham has classified the substance into

- **Crystalloids :** Which diffuse rapidly through parchment membrane.
- **Colloids :** which diffuse slowly through parchment membrane are Eg: starch, gum, gelatin etc.,
- In practice it is found that a crystalloid can be made into colloid and some of the colloids were found to be crystalline in nature.
- There fore the term colloidal substance is replaced by colloidal state.
- Based on the size of disperse particle in a medium the binary systems are classified into 3 types.

- **True solution :**

Properties	Colloidal solution	True solution	Suspension
Size	1 mμ → 1 μ	Less than 1 m μ	More than 1μ
Diffusion through animal membrane	Diffuses slowly	Diffuses rapidly	Will not diffuse
Settling of particles	Will not settle by gravity but settles by centrifugation	Will not settle at all	Settles by just gravity
Filterability	Can not be filtered	Can not be filtered	Can be filtered
Filtration with ultrafiltor	Can be filtered	Can not be filtered	Can be filtered
Appearance	Turbid (clear)	Very clear	Opaque
Nature	Heterogeneous	Homogenous	Heterogeneous
Tyndall effect	Will show tyndall effect	Does not show	Will show tyndall effect
Number of molecules are in one particle	Particle is the aggregate of few hundreds of molecules	Particle is single molecule or ion	Particle is the aggregate of millions of molecule

- **Colloidal solution :**
- It is the heterogeneous binary system in which the dispersed particle is the aggregate of few hundreds of molecules or ions.
- Colloid consists of two phases.
  1. dispersed phase → particles which are dispersed in medium . It is also called distentinuous phase or internal phase.
  2. Dispersion medium → It is the medium in which particles are dispersed. It is also called as external phase.
- Dispersed phase can be a solid or liquid or gas.
- Dispersion medium can be a solid or liquid or gas.
- Based on the physical state phase and medium colloids are classified into 8 types.
- Gas in gas will not form colloid because it is homogenous mixture.
- Most common type among the colloidal solution side is sol that is solid in liquid.

Type of colloidal solution	Adsorpbate	Adsobent	Name	Example
1. Gas in liquid	Gas	Liquid	Froths	Shaving cream, soda water froth, soap surf lemonade froths
2. Gas in solid	Gas	Solid	Solid foam	Rubber cork, foam heads, pumice stones.
3. Solid in liquid	Solid	Liquid	Sol	Blood, starch in water, metal particles in water ink etc.

4. Solid in gas	Solid	Gas	Solid aerosol	Smoke, dust.
5. Solid in solid	Solid	Solid	Solid sol	Coloured glass
6. Liquid in gas	Liquid	Gas	Liquid aerosol	Clouds, fog
7. Liquid in liquid	Liquid	Liquid	Emulsion	Milk, cod liver oil, syrups, tonics
8. Liquid in solid	Liquid	Solid	Gels	Shoe polish, butter, cheese

- Based on the nature of medium sols are of many types.

  Eg. : If water is medium it is aquasol or hydrosol.

  If alcohol is medium it is alchasol.

  If Benzene is medium it is Benzosol.

- Based on the affinity between particles and medium, colloids are classified into two types

  1) Lyophilic colloids (or) Hydrophilic colloids :

  Strong attractions will exist between colloids particles and medium.

  Eg: organic substances like Starch, RBC, Albumin, Blue gelatin etc., and certain polymers in organic medium also formed.

  2) Lyophobic colloids or Hydrophobic colloids:

  No attractions will exist between colloidal particles and medium

  Eg: Metalsols, Metaloxidesols, Metalsulphide sols.

Some example of colloids:

Property	Lyophilic	Lyophobic
Attractive forces	Strong attractions will exist [H –H bonds]	No attractions will exist
Salvation	Particles are more solvated	Particles are not solvated
Viscosity	Is more than that of medium	Same as that of medium
Ease of preparation	Can be easily prepared by direct mixing of particles with medium	Cannot be prepared by direct mixing and requires special methods.
Reversible nature	Reversible	Irreversible
Tyndall effect	Weak	Strong Tyndall effect
Stability	More stable due to salvation	Less stable because of no salvation.
Presence of electric charge	Particles may carry little charge or no charge	Particles defiantly carry charge
Ease of coagulation	Not easily coagulated. It requires large amounts of electrolyte for coagulation.	Easily coagulated by adding little amount of electrolyte.

SMOKE IS :

- An aerosol,
- A colloidal solution of carbon in air.
- A lyophobic colloid, dispersion phase is carbon and dispersion medium is air.
- A solid in gas sol. Carbon particles are precipitated electrically to avoid pollution in electrified chimney, where carbon particals can get discharged.

CLOUD :

- Is an aerosol.
- It is a colloidal suspension of water droplets in air.
- It is a lyophobic colloid.
- Droplets in cloud precipitate as rain.
- It is a liquid in gas sol.
- Dispersion phase is droplets of water (liquid) and dispersion medium is air (gas).

BLOOD :

- It is an aquasol or hydrosol.
- It is a colloidal suspension of albuminoid substance in water.
- Addition of ferric chloride (large amounts) coagulates the blood and clot during bleeding of wound.
- Dispersion phase is albuminoid substance containing RBC (erythrocytes) WBC (leucocytes).
- Dispersion medium is water containing some inorganic ions and organic molecules.
- It is a solid in liquid colloid.
- Impure blood is purified by kidneys through dialysis.
- It is a negative colloid, It coagulates with positive ions like Al^{+3} or Fe^{+3} etc,.

MILK :

- It is an emulsion.
- It is an oil in water (O/W) type emulsion.
- It is a liquid in liquid type colloid.
- Dispersion phase is droplets of liquid fat and dispersion medium is water.
- Milk on coagulation gives emulsified fat (casein).
- Milk cream from milk can be separated by centrifugation.
- Curding of milk is coagulation of milk.
- On souring lactose in milk converts to lacticacid which coagulates the milk.

STARCH SOLUTION.

- It is an aquasol or hydrosol.
- It is a lyophilic sol.
- It is a solid in liquid type colloid.
- Small amounts of electrolyte cannot coagulate starch sol.
- Large quantities of electrolytes can coagulate starch sol.
- Dispersion phase is starch and dispersion medium is water.

GOLD SOL :

- It is an aquasol or hydrosol.

- It is a lyophobic colloid.
- It is a solid in liquid type colloid.
- It is coagulated by adding small amount of electrolytes.
- Dispersion phase is gold particles and dispersion medium is water.
- It is prepared by **Bredig arc** method.
- **Preparation of gold sol by Briedig arc's method :**

  Two gold rods are immersed in water. When electric arc is struck between the gold rods. Some of the gold is vapourised. Gold vapour then gets condensed. In condensation gold atoms will aggregate to form colloid size particles. Which are dispersed in water.
- If gold particle is big in size it is blue colour.
- If particle is small gold sol is red in colour.
- Pumice stone is gas in solid type colloid in which dispersion phase is gas and dispersion medium is solid.
- Cheese, butter, boot polish are liquid in solid type colloids in which dispersion phase is solid and dispersion medium is liquid. These are called **gels.**
- Gems and rubies, coloured glass are solid in solid type colloids.

Micelles :

- It is the colloidal size particles formed by the spontaneous aggregation of soap anions or molecules at higher concentration (CMC).
- **PROTECTIVE COLLOIDS & GOLD NUMBER**
- Lyophobic sols are less stable than lyophilic colloids
- On addition of electolytes lyophobic colloids are precipitated. This phenomenon is called coagulation or flocculation
- Positively charged colloid is coagulated by negative ion and negatively charged colloid is coagulated by the positive ion of the added salt
- The coagulating effect is more when the charge of the ion is more
- A lyophobic sol can be protected from coagulation by adding a lyophilic colloid to the lyophobic sol
- The lyophilic sol added is called protective colloid or protective agent
- Zigmondy introduced the term gold number to measure the protective power of different colloids
- Weight in milligrams of a protective colloid which checks the coagulation of 10 ml of a given gold solution on adding 1 ml of a 10 % solution of sodium chloride is called **gold number**
- Smaller the gold number of a lyophilic colloid, greater is its protective power
- In the given examples
- Gelatin is the most effective protective colloid and strach is the least effective protective colloid
- Gold numbers of some protective colloids

PROTECTIVE COLLOID	**GOLD NUMBER**
Gelatin	0.005-0.01
Haemoglobin	0.03 - 0.07
Casein	0.01 - 0.02
Albumin	0.1 - 0.2
Gum Arabic	0.15 - 0.25

Potato Strach 25

Associated colloides :

- If the dispersed phase consists of micelles, such a colloid is called Associated colloid.
- Soaps and detergents will form micelles at higher concentrations. The minimum concentration above which micelles are formed is called critical micellisation concentration.
- At very low concentration soaps and detergents exist a true solution.

Soap : Sodium stearate : $C_{17}H_{35}COO^{-}Na^{\oplus}$

stearate : $C_{17}H_{35}COO^{-}$

Detergent : Sod. Lauryl sulphate – $C_{12}H_{25}OSO_3Na$

Lauryl sulphate $\rightarrow$ $C_{12}H_{25}OSO_3$

- **Cleaning action of soap :**

  In aqueous solution of soap head is towards the surface of water and tail is pointing away from the water, tail part being non – polar it has affinity towards greeze, dust on the clothes.
- Micelles are formed by the soap with greeze or dust. The micelles are then emulsified by soap.
- The charged layer present around the micelle will present from aggregation.
- **Emulsion :**

  Emulsion is liquid in liquid type colloid. These two liquids are immiscible with one another.
- One of the liquid is water and other one is oil in nature.
- Based on the relative amounts of these two liquids.

  Emulsions are two types

  1) **Oil in water type :**

     Eg : Milk [liquid disguised liquid water)

     Kerosene oil in H_2O ; Vanishing cream.

  2) **Water in oil type :**

     Cold cream, stiff greases, cold liver oil
- These emulsions are unstable. As they contain immiscible liquid.

Emulsifier :

- Emulsifier or emulisfing agent is the substance which stabilizes the emulsion when added to it.
- Emulsifier stabilizes the emulsion by reducing the surface tension.
- Any hydrophilic colloid can act as emulsifier.

  Eg : Gelatin, Egg albumin, Soap, Mercuric iodide etc.
- Soap emulsified kerosene oil in water.
- Egg albumen emulsifies oil volume in water.
- Hg I_2 emulsified water in benzene.
- The type emulsion [o/w or w/o] form will depend on

  a) the relative proportion of two liquids

  b) the liquid with lower surface tension acts as medium.

  c) the liquid which is more soluble in emulsifier will act as medium.

Applications of emulsions :

1) In washing and cleaning of clothes by soaps and detergents.
2) In the digestion of fats in small intestine.
3) In the conversion of cream in to butter.
4) In metullary for concentration of oars.
5) Various medicines, lotions, ointments etc are used in the forms of emulsions.
6) In pharmaceutical and cosmetic industry.
7) In the separation of oil from water [emulsification, in nature oils of well].

- **Catalysis :** Cata = Wholly Lysis – breaking

  According to Berzilius, catalysts increases the rate of reaction by loosening the bonds in reactants.

- Catalyst is the substance which alters the speed of reaction without undergoing any chemical change.

  Eg: $N_2 + 3H_2 \xrightarrow{Fe,Mo} 2NH_3$ $\quad Fe \rightarrow H_2S$

  $2H_2 + O_2 \xrightarrow{Pt} 2H_2O$ $\quad Pt \rightarrow Co$

- **Characteristics of catalysts :**

  1) Catalyst can speed up a chemical reaction but can not initiate the reaction.
  2) A catalyst may change physically but remains unchanged chemically.
  3) Catalyst may take part in the reaction but not consumed in the reaction.
  4) Small amounts of catalyst is sufficient to catalise large amounts of reactions.
  5) Catalyst will be effective in its functioning at optimum conditions. (temperature, pH, pressure)
  6) Finely divided catalyst are more effective than in their undivided form.
  7) At higher temperature it may loose its catalytic activities.
  8) Promoter is the substance added to the catalyst to increase the efficiency of catalyst.
  9) The impurities present in the reactants will act as catalytic poison and they decrease the efficiency of catalyst.

     Eg: In Haber's process, Fe is poisoned by H_2S

     In contact process, pt is poisoned by AS_2O_3

     In the oxidation of H_2 pt is poisoned by CO
  10) The catalytic activity is highly specific that is products may change by changing catalysts.

      $C_2H_5OH \xrightarrow{Al_2O_3} C_2H_4 + H_2O$

      $C_2H_5OH \xrightarrow{Cu\ (or)\ As} CH_3 - CHO + H_2$
  11) Catalyst will not effect the chemical equilibrium because it increases the speeds of both forward back ward reactions equally.
  12) Negative catalyst or inhibiter decreases the rate of reactions.

      Eg : Decomposition of H_2O_2 in presence of glycerol

- **Type of catalysis :**

  Based on the physical states reactants and catalysts catalysis is of two types

  1) Homogeneous catalysis :

  Catalyst and reactions are in some physical state.

Usually catalysts or reactants are gases or liquids.

$2SO_2 + O_2 \xrightarrow[(g)]{NO} 2SO_3$

$CH_3COOC_2H_{5(l)} + H_2O_{(l)} \xrightarrow{H^+_{(l)}} C_2H_5OH_{(l)} + CH_3COOH_{(l)}$

$2CO + O_2 \xrightarrow[g]{NO} 2CO_2$

$2H_2O_2 \xrightarrow[l]{I^-} 2H_2O + O_2$

$CH_3COOC_2H_5 + H_2O \xrightarrow{H^\oplus \text{ (or) } OH^-} CH_3COOH + C_2H_5OH$

$C_{12}H_{22}O_{11} + H_2O \xrightarrow[l]{H^\oplus} C_6H_{12}O_6 + C_6H_{12}O_6$

$2KClO_3 \xrightarrow[(s)]{MnO_2} 2KCl + 3O_2$

- **Heterogeneous catalysis :**

If the reactants and catalyst are in different physical states it is called Heterogeneous catalysis.

Usually reactants may be gases or liquids and catalysts are solids.

$2SO_2 + O_2 \xrightarrow[s]{Pt} 2SO_3 \rightarrow$ contact process

$N_2 + 3H_2 \xrightarrow[s]{Fe/MO} 2NH_3 \rightarrow$ Habers process

$NH_3 + O_2 \xrightarrow[s]{pt} NO + H_2O \rightarrow$ Ostwald process

$CO + 2H_2 \xrightarrow[s]{Zno+CuO} CH_3 - OH \rightarrow$ Synthesis of methanol

$CO + H_2 \xrightarrow[s]{Fe}$ Hydrocarbons$\rightarrow$ Synthesis of petrol

$CH_2 = CH_2 + H_2 \xrightarrow[s]{Ni} CH_3 - CH_3 \rightarrow$ Hydrogenation of ethylene

$R - CH = CH - R + H_2 \xrightarrow[s]{Ni} R - CH_2 - CH_2 - \overset{1}{R}$

$2H_2O_2 \xrightarrow[Ag]{MnO_2} 2H_2O + O_2$

$nCH_2 = CH_2 \xrightarrow[s]{TiCl_4 + R_3Al} (-CH_2 - CH_2 -)_n$

- **Theories of catalysis :**

The following two theories will explain the functioning of catalysts.

1) Intermediate compound formation theory:

Catalyst combines with one of the reactants to form an intermediate compound. This Intermediate compound either decomposes on its own or combines with another reactant to give products and catalyst back.

- This theory mostly will explain homogeneous catalysis.

Eg : $A + B \xrightarrow{x} AB \rightarrow$ Reaction

Mechanism : $A + x \rightarrow Ax$

$Ax + B \rightarrow AB + x$

TYNDAL EFFECT

- It is an optical property
- The phenomen of the scattering of light by the colloidal particles is called Tyndall effect
- The illuminated beam or cone formed by the scattering of light by the sol particles is reffered as Tyndal beam or tyndall cone.
- Tyndall effect is observed only when
- The diameter of the disperesed particles is not much smaller than the wave length of light used
- The refractive indices of the dispersed phase and dispersion medium differ greatly in magnitude
- **EXAMPLES OF TYNDALL EFFECT**
- Blue appearance of sky and sea water
- Visibility of tails of comets
- **BROWNIAN MOVEMENT (KINETIC PROPERTY)**
- The continuous rapid zig - zag movement excecuted by colloidal particle in a liquid dispersion medium is called Brownian motion.
- Brownian motion is independent of the nature of colloid but depends on the size of the particles and viscosity

  of solution
- Smaller the size and lesser the viscosity, faster is the motion of colloidal particles
- Brownian movement increases with rise in temperature

1) reaction : $2SO_2 + O_2 \xrightarrow{NO} 2SO_3$

mechanism : $NO + O_2 \rightarrow NO_2$

$2SO_2 + NO_2 \rightarrow 2SO_3 + NO$

2) reaction : $2CO + O_2 \xrightarrow{NO} 2CO_2$

mechanism : $NO + O_2 \rightarrow NO_2$

$CO + NO_2 \rightarrow NO + CO_2$

3) reaction : $H_2 + \frac{1}{2}O_2 \xrightarrow{Cu} H_2O$

mechanism : $Cu + O_2 \rightarrow Cu_2O$

$H_2 + Cu_2O \rightarrow H_2O + 2Cu$

4) reaction : $2C_2H_5OH \xrightarrow[140^0C]{H_2SO_4} C_2H_5 - O - C_2H_5$

mechanism : $C_2H_5OH + H - HSO_4 \rightarrow C_2H_5 - HSO_4 + H_2O$

$C_2H_5 - HSO_4 + C_2H_5 - OH \rightarrow C_2H_5 - O - C_2H_5 + H_2SO_4$

5) reaction : $2KClO_3 \xrightarrow{MnO_2} 2KCl + 3O_2$

mechanism : $KClO_3 + MnO_2 \rightarrow KCl + MnO_3$

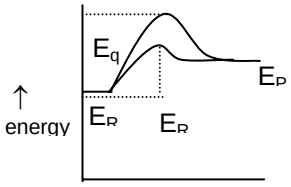
$MnO_3 \rightarrow MnO_2 + O_2$

- **Adsorption theory :**

  It mainly explains heterogeneous catalysis reaction:
- Rate of chemical reaction is proportional to concentration of reactions.
- Solid catalyst adsorbs gaseous reactants on to its surface. AS a result the reactant molecule become closer and concentration increases and there by rate of reaction increases.
- It involves,
  1) Diffusion of reactants on to the surface of catalyst.
  2) Adsorption of reactants by catalyst
  3) Formation of adsorption complex.
  4) Decomposition of adsorption complex and then desorption.

  Eg : $CH_2 = CH_2 + H_2 \xrightarrow{Ni} CH_3 - CH_3$

Activation energy theorem :



- The minimum excess amount of energy required by the reactant molecules to make effective collisions and change into products is called activation energy
- Lower the activation energy higher is the rate of reaction and vice– versa.
- If activation energy is less, the number of effective collisions will increase and the rate of reaction increases.
- Catalyst increases rate of reaction by decreasing the activation energy.
- Catalyst decreases the activation energy by changing the path of the reaction.

Auto catalysis :

- If one of the products of reaction or intermediate acts as catalyst that reaction is called autocatalysis.
- Auto catalysis reaction is slow in the beginning and then picks up.
- The initial slow period in which auto catalyst is formed in sufficient quantity is called induction period.

$2KMnO_4 + 3H_2SO_4 + 5H_2C_2O_4 \rightarrow K_2SO_4 + 2MnSO_4 + 10CO_2 + 8H_2O$

$2AsH_3 \rightarrow 2As + 3H_2$

$3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO_2 + 4H_2O$