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

Homogeneous catalysis :

Catalyst and reactions are in some physical state.

Usually catalysts or reactants are gases or liquids.

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

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

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

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

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

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

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

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 : $A + x \rightarrow Ax$

$Ax + B \rightarrow AB + x$

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:

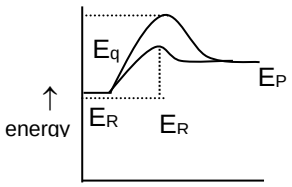
It mainly explains heterogeneous catalysis reaction:

- 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.

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

$2AsH_3 \rightarrow 2As + 3H_2$

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