Characteristics of catalysis.

The following are the characteristics which are common to most of catalytic reactions.

(1) A catalyst remains unchanged in mass and chemical composition at the end of the reaction.

(2) **A small quantity of the catalyst is generally sufficient to catalysis almost unlimited reactions**

(i) For example, in the decomposition of hydrogen peroxide, one gram of colloidal platinum can catalysis 10^8 liters of hydrogen peroxide.

(ii) In the some reaction the rate of the reaction is proportional to the concentration of the catalyst. For example the acid and alkaline hydrolysis of an ester, the rate of reaction is proportional to the concentration of H^+ or OH^- ions.

$$RCOOR'(l) + H_2O(l) \xrightarrow[OH^-]{H^+ or} RCOOH(l) + R'OH(l)$$

(iii) In Friedel – craft's reaction, anhydrous aluminum chloride is required in relatively large amount to the extent of 30% of the mass of benzene,

$$C_6H_6 + C_2H_5Cl \xrightarrow{AlCl_3} C_6H_5C_2H_5 + HCl$$

(iv) In certain heterogeneous reactions, the rate of reaction increases with the increase of area of the catalytic surface.

(3) **The catalyst cannot initiate the reaction:** The function of the catalyst is to alter the speed of the reaction rather than to start it.

(4) **The catalyst is generally specific in nature:** A substance, which acts as a catalyst for a particular reaction, fails to catalyze the other reaction, different catalysts for the same reactant may for different products.

Examples:

$$C_2H_5OH_{(l)} \xrightarrow{Al_2O_3} C_2H_4(g) + H_2O(g) \quad \text{(Dehydration)}$$

$$C_2H_5OH_{(l)} \xrightarrow{Cu} CH_3CHO(g) + H_2(g) \quad \text{(Dehydrogenation)}$$

$$HCOOH(l) \xrightarrow{Cu} CO_2(g) + H_2(g) \quad \text{(Dehydrogenation)}$$

$$HCOOH(l) \xrightarrow{Al_2O_3} CO(g) + H_2O(g) \quad \text{(Dehydration)}$$

(5) **The catalyst cannot change the position of equilibrium:**The catalyst catalyze both forward and backward reactions to the same extent in a reversible reaction and thus have no effect on the equilibrium constant.

(6) **Catalytic promoters:**Substances which themselves are not catalysts, but when mixed in small quantities with the catalysts increase their efficiency are called as **promoters** or **activators.**

(i) For example, in Haber's process for the synthesis of ammonia, traces of molybdenum increases the activity of finely divided iron which acts as a catalyst.

(ii) In the manufacture of methyl alcohol from water gas $(CO + H_2)$, chromic oxide (Cr_2O_3) is used as a promoter with the catalyst zinc oxide (ZnO).

(iii) In the hydrogenation of oils, the activity of the catalyst nickel increases on adding small amount of copper.

(7) **Catalytic poisons:**Substances which destroy the activity of the catalyst by their presence are known as **catalytic poisons.**

(i) For example, the presence of traces of arsenious oxide (As_2O_3) in the reacting gases reduces the activity of platinized asbestos which is used as catalyst in contact process for the manufacture of sulphuric acid.

(ii) The activity of iron catalyst is destroyed by the presence of H_2S or CO in the synthesis of ammonia by Haber's process.

(iii) The platinum catalyst used in the oxidation of hydrogen is poisoned by CO.

Note: The poisoning of the catalyst is probably due to the preferential adsorption of poison on the surface of the catalyst, thus reducing the space available for the adsorption of reacting molecules.

(8) **Change of temperature alters the rate of catalytic reaction as it does for the same reaction in absence of catalyst:**By increasing the temperature, there is an increase in the catalytic power of a catalyst but after a certain temperature its power begins to decrease. A catalyst has thus, a particular temperature at which its catalytic activity is maximum. This temperature is termed as **optimum temperature.**

(9) **A positive catalyst lowers the activation energy**

(i) According to the collision theory, a reaction occurs on account of effective collisions between the reacting molecules.

(ii) For effective collision, it is necessary that the molecules must possess a minimum amount of energy known as activation energy (E_a).
(iii) After the collision molecules form an activated complex which dissociate to yield the product molecules.
(iv) The catalyst provides a new pathway involving lower amount of activation energy. Thus,

E_a Decreases $\Rightarrow$ $\frac{E_a}{RT}$ Decreases $\Rightarrow$ $-\frac{E_a}{RT}$ Increases $\Rightarrow$ $e^{-Ea/RT}$ Increases $\Rightarrow$ k Increases $\Rightarrow$ Reaction speeds up

Larger number of effective collisions occur in the presence of a catalyst in comparison to effective collisions at the same temperature in absence of a catalyst. Hence the presence of a catalyst makes the reaction to go faster.

(v) Figure shows that activation energy E_a, in absence of a catalyst is higher than the activation energy E_a, in presence of a catalyst.
(vi) E_R and E_p represent the average energies of reactants and products. The difference gives the valueof ΔG, i.e., $\Delta G = E_R - E_P$