Surface Chemistry

Adsorption Theory of Heterogeneous Catalysis

This theory explains the mechanism of heterogeneous catalysis. According to this theory the catalytic activity takes place on the surface of the catalyst. The mechanism involves five steps:

(i) Diffusion of reactants to the surface of the catalyst.

(ii) Adsorption of reactant molecules on the surface of the catalyst.

(iii) Occurrence of chemical reaction on the catalyst's surface through formation of an intermediate.

(iv) Desorption of reaction products from the catalyst surface.

(v) Diffusion of reaction products away from the catalyst's surface.

This theory explains why the catalyst remains unchanged in mass and chemical composition at the end of the reaction and is effective even in small quantities.

But it does not explain the action of catalytic promoters and catalytic poisons.

Important features of solid catalysts

1. ***Activity***

The activity is the ability of a catalyst to increase the rate of a chemical reaction.

It depends upon the strength of chemisorption.

e.g.: H_2 combines with O_2 to form H_2O in presence of Platinum (Pt) catalyst

$$H_2 + O_2 \xrightarrow{Pt} H_2O$$

In absence of Pt, the reaction does not take place.

2. ***Selectivity***

It is the ability of a catalyst to direct a chemical reaction to a particular product.

e.g.: CO reacts with H_2 to form different products based on the nature of the catalyst.

(i) $CO(g) + 3H_2(g) \xrightarrow{Ni} CH_4(g) + H_2O(g)$

(ii) $CO(g) + 2H_2(g) \xrightarrow{Cu/ZnO\text{-}Cr_2O_3} CH_3OH(g)$

(iii) $CO(g) + H_2(g) \xrightarrow{Cu} HCHO(g)$

Shape-Selective Catalysis by Zeolites

The catalytic reaction that depends upon the pore structure of the catalyst and the size of the reactant and product molecules is called shape-selective catalysis.

Zeolites are good shape-selective catalysts because of their honey comb-like structures. They are micro porous aluminosilicates with three dimensional networks of silicates in which some silicon atoms are replaced by aluminium atoms. They contain Al–

O–Si framework. The reactions taking place in zeolites depend upon the size and shape of reactant and product molecules as well as upon the pores and cavities of the zeolites.

They are found in nature as well as prepared artificially.

Zeolites are used as catalysts in petrochemical industries for cracking of hydrocarbons and isomerisation. An important Zeolite catalyst used in the petroleum industry is *ZSM-5*. It converts alcohols directly into gasoline (petrol) by dehydrating them to give a mixture of hydrocarbons.

Enzyme Catalysis

Enzymes are complex nitrogenous organic compounds which are produced by living plants and animals. They are actually protein molecules of high molecular mass. They are very effective catalysts and catalyses numerous reactions taking place in plants and animals. So enzymes are also called ***biochemical catalysts*** and the phenomenon is known as ***biochemical catalysis***.

e.g.: (i) *Inversion of cane sugar*:

The enzyme invertase converts cane sugar into glucose and fructose.

$$\underset{\text{Cane sugar}}{C_{12}H_{22}O_{11}(aq)} + H_2O(l) \xrightarrow{\text{invertase}} \underset{\text{Glucose}}{C_6H_{12}O_6(aq)} + \underset{\text{Fructose}}{C_6H_{12}O_6(aq)}$$

(ii) *Conversion of glucose into ethyl alcohol*: The enzyme zymase converts glucose into ethyl alcohol and carbon dioxide.

$$\underset{\text{Glucose}}{C_6H_{12}O_6(aq)} \xrightarrow{\text{zymase}} \underset{\text{Ethanol}}{2C_2H_5OH(aq)} + 2CO_2(g)$$

(iii) *Conversion of starch into maltose*: The enzyme diastase converts starch into maltose.

$$\underset{\text{Starch}}{2(C_6H_{10}O_5)n(aq)} + nH_2O(l) \xrightarrow{\text{Diastase}} \underset{\text{Maltose}}{n\ C_{12}H_{22}O_{11}(aq)}$$

(iv) *Conversion of maltose into glucose*: The enzyme maltase converts maltose into glucose.

$$\underset{\text{Maltose}}{C_{12}H_{22}O_{11}(aq)} + H_2O(l) \xrightarrow{\text{Maltase}} \underset{\text{Glucose}}{2C_6H_{12}O_6(aq)}$$

(v) *Decomposition of urea into ammonia and carbon dioxide*: The enzyme urease catalyses this decomposition.

$$\underset{\text{Urea}}{NH_2CONH_2(aq)} + H_2O(l) \xrightarrow{\text{Urease}} \underset{\text{Ammonia}}{2\ NH_3(g)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

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