Chemistry Study Materials for Class 12
(NCERT Based Notes of Chapter – 05)
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Surface Chemistry

Applications of adsorption

The important applications of adsorption are:

1. Production of high vacuum: For the complete evacuation of a vessel, activated charcoal is used.
2. Gas masks: The poisonous gases in coal mines can be removed by using gas masks containing activated charcoal.
3. Control of humidity: Silica and aluminium gels are used as adsorbents for removing moisture and controlling humidity.
4. Animal charcoal is used for the purification of cane sugar solution.
5. Adsorption finds application in heterogeneous catalysis.
6. A mixture of noble gases can be separated by adsorption on coconut charcoal at different temperatures.
7. In curing diseases: A number of drugs are used to kill germs by getting adsorbed on them.
8. In froth floatation process for the purification of sulphide ores in metallurgy.
9. Adsorption indicators like eosin, fluoresce in etc. are used in volumetric analysis.
10. Chromatographic analysis for the separation of a mixture is based on adsorption.

CATALYSIS

A catalyst is a substance that changes the rate of a chemical reaction without undergoing any permanent chemical change by itself. The process of changing the rate of a chemical reaction by a catalyst is known as Catalysis.

Eg: MnO_2 (Manganese dioxide) acts as a catalyst in the decomposition of $KClO_3$ (Potassium chlorate) $2KClO_3 \rightarrow 2KCl + 3O_2$

Promoters and poisons

Promoters are substances that enhance the activity of a catalyst while poisons decrease the activity of a catalyst. For example, in Haber's process for the manufacture of ammonia, molybdenum (Mo) acts as a promoter for the catalyst iron.

$$N_2 + 3H_2 \xrightarrow{Fe/Mo} 2NH_3$$

Types of Catalysis

Positive and Negative Catalyst

A catalyst that increases the rate of a chemical reaction is called Positive catalyst and that decreases the rate of a chemical reaction is called negative catalyst (inhibitors).

E.g. In the Haber's process for the manufacture of ammonia, Fe acts as a positive catalyst

$$N_2 + 3H_2 \xrightarrow{Fe/Mo} 2NH_3$$

For decreasing the rate of dissociation of H_2O_2, Phosphoric acid is used as a negative catalyst.

Homogenous and Heterogeneous Catalysis

Homogeneous Catalysis

A catalytic process in which the reactants and the catalyst are in the same phase (i.e., liquid or gas), is said to be homogeneous catalysis.

e.g.: (i) In the *lead chamber process* for the manufacture of Sulphuric acid, oxidation of sulphur dioxide into sulphur trioxide is done in the presence of Nitric Oxide as catalyst

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

Here the reactants (sulphur dioxide and oxygen) and the catalyst (nitric oxide) are all in the same phase.

(ii) Acid catalysed hydrolysis of methyl acetate

$$CH_3COOCH_3(l) + H_2O(l) \xrightarrow{HCl(l)} CH_3COOH(aq) + CH_3OH(aq)$$

(iii) Hydrolysis of sugar is catalysed by H^+ ions furnished by sulphuric acid.

$$C_{12}H_{22}O_{11}(l) + H_2O(l) \xrightarrow{H2SO4} C_6H_{12}O_6(aq) + C_6H_{12}O_6(aq)$$

Heterogeneous catalysis

The catalytic process in which the reactants and the catalyst are in different phases is known as heterogeneous catalysis.

Some of the examples of heterogeneous catalysis are:

(i) In *contact process* for the manufacture of H_2SO_4, Oxidation of sulphur dioxide into sulphur trioxide is done in presence of V_2O_5.

$$2SO_2(g) + O_2(g) \xrightarrow{V2O5(s)} 2SO_3(g)$$

Here the reactants are in gaseous state while the catalyst is in the solid state.

(ii) In *Haber's process* for the manufacture of ammonia finely divided iron is used as catalyst.

$$N_2(g) + 3H_2(g) \xrightarrow{Fe(s)} 2NH_3(g)$$

Here the reactants are in gaseous state while the catalyst is in the solid state.

(iii) Oxidation of ammonia into nitric oxide in the presence of platinum gauze in Ostwald's process.

$$4NH_3(g) + 5O_2(g) \xrightarrow{Pt(s)} 4NO(g) + 6H_2O(g)$$

Here also the reactants are in gaseous state while the catalyst is in the solid state.

(iv) Hydrogenation of vegetable oils in the presence of finely divided nickel as catalyst.

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 isomerization. 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 catalyzes 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.

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

Cane sugar Glucose Fructose

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

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

Glucose Ethanol

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

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

Starch Maltose

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

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

Maltose Glucose

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

$$NH_2CONH_2(aq) + H_2O(l) \xrightarrow{\text{Urease}} 2\,NH_3(g) + CO_2(g)$$

Urea Ammonia Carbon dioxide

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