5 Surface Chemistry

Facts that Matter

- **Adsorption:** The accumulation of molecular species at the surface rather than in the bulk of a solid or liquid.
- **Adsorbate:** The molecular species or substance, which concentrate at the surface.
- **Adsorbent:** The material on the surface of which the adsorption takes place.
  Adsorption is essentially a surface phenomenon.
- **Desorption:** The process of removing an adsorbed substance from the surface on which it is adsorbed.

Factors Featuring Adsorption

The extent of adsorption increases with increase of surface area per unit mass of the absorbent at a given temperature and pressure. Easily liquefiable gases (i.e., with higher critical temperatures) are readily adsorbed. Adsorption is accompanied by decrease in enthalpy as well as decrease in the entropy of the system.

- **Types of Adsorption**

Physical adsorption	Chemical adsorption
1. It arises because of van der Waals' forces.	1. It is caused by chemical bond formation.
2. It is not specific in nature.	2. It is highly specific in nature.
3. It is reversible in nature.	3. It is irreversible.
4. Enthalpy of adsorption is low (20–40 kJ mol^{-1}) in this case.	4. Enthalpy of adsorption is high (80–240 kJ mol^{-1}) in this case.
5. No appreciable activation energy is needed.	5. High activation energy is sometimes needed.
6. It results into multimolecular layers on the adsorbent surface under high pressure.	6. It results into a unimolecular layer.

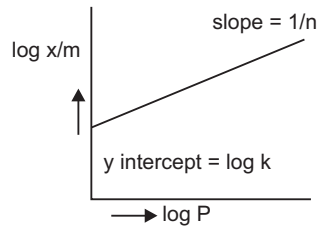
- **Freundlich adsorption isotherm:** Empirical relationship between the quantity of gas adsorbed by the unit mass of solid adsorbent and pressure at a particular temperature:

$$x/m = k.P^{1/n} \quad (n > 1)$$

where x is the mass of the gas adsorbed on mass m of the adsorbent at pressure P, k and n are constants which depend upon the nature of the adsorbent and the gas at a particular temperature.

Taking logarithm

$$\log x/m = \log k + 1/n \log P$$



Freundlich isotherm

When $1/n = 0$, x/m = constant, i.e., adsorption is independent of pressure.
When $1/n = 1$, $x/m = k$P i.e. the adsorption varies directly with pressure.

- **Catalysis**

Catalysts: Substances, which alter the rate of a chemical reaction and themselves remain chemically and quantitatively unchanged after the reaction.
Promoters: Substances that enhance the activity of a catalyst.
For example, in Haber's process for the manufacture of ammonia, molybdenum acts as a promoter for iron.
Poisons: Substances that decrease the activity of a catalyst.

Homogeneous Catalysis

When the reactants and the catalyst are in the same phase (*i.e.*, liquid or gas).
Eg.: Oxidation of sulphur dioxide into sulphur trioxide with dioxygen in the presence of oxides of nitrogen as the catalyst in the lead chamber process.

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

Heterogeneous Catalysis

The catalytic process in which reactants and the catalyst are in different phases is known as heterogeneous catalysis.
Eg: Oxidation of sulphur dioxide into sulphur trioxide in the presence of Pt.

$$2SO_2(g) \xrightarrow{Pt} 2SO_3(g)$$

- **The mechanism of heterogeneous catalysis involve 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 a chemical reaction on the catalyst surface through the formation of an intermediate.
  - (*iv*) Desorption of reaction products from the catalyst surface.
  - (*v*) Diffusion of reaction products away the catalyst surface.
- **Important features of solid catalysts**
  - (*a*) **Activity.** The activity of a catalyst depends upon the strength of chemisorption to a large extent. The reactants must get adsorbed reasonably strongly on the catalyst (but not so strongly) to become active.

    Eg. $2H_2(g) + O_2(g) \xrightarrow{Pt} 2H_2O(l)$
  - (*b*) **Selectivity.** The selectivity of a catalyst is its ability to direct a reaction to yield a particular product. For example;

Shape-selective catalysis: The catalytic reaction that depends upon the pore structure of the catalyst and the size of the reactant. Zeolites are good shape-selective catalysts.

E.g.: ZSM-5 converts alcohols directly into gasoline (petrol) by dehydrating them to give a mixture of hydrocarbons.

Enzymes: The enzymes are called **biochemical catalysts.**

E.g.: **Inversion of cane sugar:** The invertase enzyme converts cane sugar into glucose and fructose.

Colloids

A colloid is a heterogeneous system in which one substance is dispersed (dispersed phase) as very fine particles in another substance called dispersion medium. Range of diameters is between 1 to 1000 nm.

- **Classification of Colloids:**

(*i*) Based on the physical state of Dispersed Phase and Dispersion Medium:

Solids in liquids—sols, e.g. starch sol.

Liquids in solids—gels, e.g. butter.

Liquids in liquids—emulsions, e.g. milk.

(*ii*) Based on the nature of interactions between dispersed phase and the dispersion medium:

Lyophilic colloids	Lyophobic colloids
1. Solvent liking	1. Solvent hating
2. Reversible sols	2. Irreversible sols
3. Quite stable	3. Unstable. Need stabilising agents to preserve
4. Cannot be easily coagulated	4. Can be coagulated easily by adding small amount of electrolyte

(*iii*) Based on the type of particles of the dispersed phase:

Multimolecular colloids	Macromolecular colloids	Associated colloids (Micelles)
Atoms or molecules aggregate together to form colloidal range species.	Solutions in which the size of the macro–molecules may be in the colloidal range.	At low concentration the sol behave as normal strong electrolytes, but at higher concentrations they exhibit colloidal behaviour due to the formation of aggregates.
E.g., gold sol, sulphur sol	E.g., starch sol	E.g., soaps & detergents

- **Kraft temperature (T_k):** Temperature above which the formation of micelles take place.
- **Critical micelle concentration (CMC):** Concentration above which the formation of micelles take place.

- **Peptization:** Process of converting a precipitate into a colloidal sol by shaking it with the dispersion medium in the presence of a small amount of electrolyte.
- **Dialysis:** It is a process of removing a dissolved substance from a colloidal solution by means of diffusion through a suitable membrane.
- **Electro-dialysis:** Dialysis can be made faster by applying an electric field if the dissolved substance in the impure colloidal solution is only an electrolyte.

Colloidal Solutions

- **Properties of colloidal solutions:**
  - (*i*) **Tyndall effect:** The scattering of light rays by colloidal particles due to which the path of light is illuminated. Tyndall effect is observed only when
    - (*a*) The diameter of the dispesed particles is not much smaller than the wavelength of the light used.
    - (*b*) The refractive indices of the dispersed phase and the dispersion medium differ greatly in magnitude.
  - (*ii*) **Brownian movement:** The zig-zag movement of the colloidal particles due to the unbalanced bombardment of the dispersed particles with the molecules of the dispersion medium.
  - (*iii*) **Electrophoresis:** The movement of colloidal particles under an applied electric potential.
- **Charge on colloidal particles:** The colloidal particles develop a charge due to the following reasons:
  - (*a*) Electron capture by sol particles during electrodispersion of metals.
  - (*b*) Due to preferential adsorption of ions from the solutions.
  - (*c*) Due to formulation of electrical double layer.

  Coagulation or precipitation of colloidal particles: The process of settling of colloidal particles.

  Caused due to (*a*) addition of electrolytes, (*b*) electrophoresis, (*c*) boiling, (*d*) mixing of two oppositely charged sols.
- **Hardy-Schulze rule:** Greater the valence of the coagulating ion added to the sol, the greater is its power to cause precipitation. The coagulation power of some of the cations is in the order: $Al^{3+} > Ba^{2+} > Na^{+}$. The coagulating power of some of the anions is in the order: $[Fe(CN)_6]^{4-} > PO_4^{3-} > SO_4^{2-} > Cl^{-}$.

  Coagulating value of an electrolyte: The minimum concentration of an electrolyte in millimols per litre required to cause precipitation of a sol in two hours.
- **Emulsion:** Colloidal system where a liquid is dispersed in another liquid.

  Type of emulsions:
  - (*a*) oil in water type (o/w): e.g. milk, vanishing cream
  - (*b*) water in oil type (w/o): e.g. butter, cold cream

  Emulsions are stabilised by emulsifying agents, e.g. soaps.

NCERT IN-TEXT QUESTIONS SOLVED

5.1. Write any two characteristics of Chemisorption.

Ans. Two characteristics are:

(*i*) It is highly specific in nature.

(*ii*) It involves the compound formation between adsorbent and adsorbate, so it is generally irreversible.

5.2. Why does physisorption decreases with the increase of temperature?

Ans. Physisorption is an exothermic process:

$$\underset{\text{(Adsorbent)}}{\text{Solid}} + \underset{\text{(Adsorbate)}}{\text{Gas}} \rightleftharpoons \underset{\text{(Gas adsorbed on solid)}}{\text{Gas/Solid}} + \text{Heat}$$

According to Le-Chatelier's Principle, on increasing the temperature the equilibrium will shift in the backward direction. So, the gas is released from the adsorbed surface.

5.3. Why are powdered substances more effective adsorbents than their crystalline forms?

Ans. Powdered substances have greater surface area as compared to their crystalline forms. Greater the surface area, greater is the adsorption.

5.4. In Haber's process, hydrogen is obtained by reacting methane with steam in presence of NiO as catalyst. The process is known as steam reforming. Why is it necessary to remove CO when ammonia is obtained by Haber's process?

Ans. CO acts as a poison for the catalyst used in the manufacture of ammonia by Haber's process. Hence, it is necessary to remove it.

5.5. Why is the ester hydrolysis slow in the beginning and becomes faster after some–time?

Ans. The ester hydrolysis takes place as follows:

$$\underset{\text{Ester}}{\text{RCOOR}'} + \underset{\text{Water}}{\text{H}_2\text{O}} \rightleftharpoons \underset{\text{Acid}}{\text{RCOOH}} + \underset{\text{Alcohol}}{\text{R}'\text{OH}}$$

The acid produced in the reaction acts as the catalyst (autocatalyst) for the reaction. Hence, the reaction becomes faster after sometime.

5.6. What is the role of desorption in the process of catalysis?

Ans. Desorption makes the surface of the solid catalyst free for fresh adsorption of the reactant particles on the surface of the solid.

5.7. What modification can you suggest in the Hardy Schulze law?

Ans. According to Hardy Schulze law, the coagulating ion has charge opposite to that of the colloidal particles. Hence, the charge of the colloidal particles is neutralised and coagulation will occur. The law can be modified into the following form:

When oppositely charged sols are mixed in proper proportions to neutralise the charge of ions, coagulation of both the sols will occur.

5.8. Why is it essential to wash the precipitate with water before estimating it quantitatively?

Ans. Some amount of the electrolyte mixed to form the precipitate remains adsorbed on the surface of the particles of the precipitate. Hence, it is essential to wash the precipitate with water in order to remove the sticking electrolyte (or any other impurities) before estimating it quantitatively.

NCERT TEXTBOOK QUESTIONS SOLVED

5.1. Distinguish between the meaning of the terms adsorption and absorption. Give one example of each:

Ans.

Adsorption	Absorption
1. Substance is concentrated only at the surface and does not penetrate from the surface to the bulk of the adsorbent.	1. Substance is uniformly distributed throughout the bulk of the solid.
2. It is a surface phenomenon. **Example:** Silica gel adsorbs water vapour on its surface.	2. It is a bulk phenomenon. **Example:** Anhydrous $CaCl_2$ absorbs water vapours in it.

5.2. What is the difference between physisorption and chemisorption?

Ans.

Physisorption	Chemisorption
1. In this there is weak van der Waals' forces for cell of attraction of adsorbate with the adsorbent.	1. It takes place due to the formation of chemical bond of the adsorbate with the adsorbent.
2. It is reversible in nature.	2. It is irreversible.
3. Enthalpy of adsorption is low (20–40 kJ mol^{-1}) in this case.	3. Enthalpy of adsorption is high (80–240 kJ mol^{-1}) in this case.
4. It increases with increase in pressure.	4. It first increases and then becomes independent of pressure.
5. It is not specific in nature.	5. It is highly specific in nature.
6. It decreases with increase of temperature.	6. It increases with increase of temperature.
7. It results into multimolecular layers on adsorbent surface under high pressure.	7. It results into unimolecular layer.

5.3. Give reason why a finely divided substance is more effective as an adsorbent?

Ans. The extent of adsorption increases with increase of surface area of the adsorbent that's why finely divided and porous substances having large surface area are good adsorbents.

5.4. What are the factors which influence the adsorption of a gas on a solid?

Ans. (*i*) ***Nature of adsorbate*:** Easily liquifiable gases like NH_3, HCl, CO_2, *etc.,* are adsorbed to greater extent whereas H_2, O_2, N_2, *etc.,* are adsorbed to a lesser extent. Higher the critical temperature, more will be the extent of adsorption.

(*ii*) ***Nature of adsorbent*:** Activated carbon, metal oxides, silica gel are commonly used adsorbents. They have their specific properties depending upon their pore size.

(*iii*) ***Surface area of the adsorbent*:** Greater the specific area, more will be the extent of adsorption, that is why porous or finely divided form of adsorbents adsorb larger quantities of adsorbate.

(*iv*) ***Pressure of gas*:** Physical adsorption increases with increase in pressure.

5.5. What is an adsorption isotherm? Describe Freundlich adsorption isotherm.

Ans. Adsorption isotherm: The variation in the amount of gas adsorbed by the adsorbent with pressure at constant temperature can be expressed by means of a curve formed as adsorption isotherm.

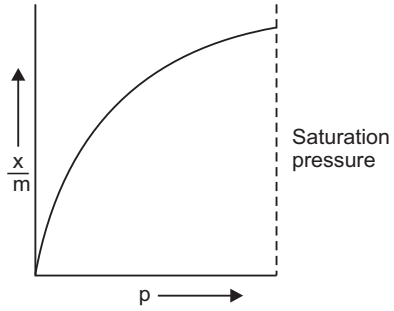
Freundlich adsorption isotherm: Freundlich in 1909 gave an empirical relationship between the quantity of gas adsorbed by the unit mass of a solid adsorbent and the pressure of gas at a particular temperature. The relationship can be expressed as:

$$\frac{x}{m} = k \cdot P^{1/n} \quad (n>1)$$

x = mass of the gas adsorbed

m = mass of the adsorbent at pressure P

n and k = Constants which depends on the nature of the adsorbent and the gas at a particular temperature.



5.6. What do you understand by activation of adsorbent? How is it achieved?

Ans. **Activation of adsorbent:** It means increasing the adsorbing power of an adsorbent. This is usually done by increasing the surface area of the adsorbent which can be achieved in one or more of the following ways:

(*i*) ***By making the surface of the adsorbent rough*:** *e.g.,* by mechanical rubbing or by chemical action or by depositing the purely dispersed metals on the surface of the adsorbent by electroplating.

(*ii*) ***By subdividing the adsorbent into smaller pieces or grains*:** This method also increases the surface area but it has a practical limitation, i.e. if the adsorbent is broken into too fine particles it becomes almost powder, then the penetration of the gas becomes difficult and this will obstruct the phenomena of adsorption.

(*iii*) ***By removing the gases already adsorbed*:** *e.g.,* charcoal is activated by heating in super heated steam or in vacuum in the temperature range between 623 to 1273 K.

5.7. What role does adsorption play in heterogeneous catalysis?

Ans. In heterogeneous catalysis, generally the reactants are gases whereas catalyst is a solid. The reactant molecules are adsorbed on the surface of the solid catalyst by physical adsorption or chemisorption. As a result, the concentration of the reactant molecules on the surface increases and hence the rate of reaction increases.

Alternatively, one of the reactant molecules undergoes fragmentation on the surface of the solid catalyst producing an active species which reacts faster. The product molecules in either case have no affinity for the solid catalyst and are desorbed making the surface free for fresh adsorption. This theory often referred to as called adsorption theory.

5.8. Why is adsorption always exothermic?

Ans. During adsorption, there is always a decrease in the residual forces of the surface, there is a decrease in the surface energy which appears as heat. Adsorption, therefore is invariably an exothermic process. In other words ΔH of adsorption is always negative.

5.9. How are colloidal solutions classified on the basis of physical states of the dispersed phase and dispersion medium?

Ans. Depending upon whether the dispersed phase and the dispersion medium are solids, liquids or gases, eight types of colloidal systems are possible. A gas mixed with another gas forms a homogeneous mixture and hence is not a colloidal system.

Many familiar commercial products and natural objects are colloids.

For example: whipped cream in a foam, which is a gas dispersed in a liquid.

Most biological fluids are aqueous sols (Solids dispersed in water)

S. No.	Dispersed Phase	Dispersion Medium	Types of Colloids	Examples
1.	Solid	Solid	Solid sol	Some coloured glasses, gemstones,
2.	Solid	Liquid	Sol	Paints, colloids
3.	Solid	Gas	Aerosol	Smoke, dust
4.	Liquid	solid	Gel	Cheese, butter
5.	Liquid	Liquid	Emulsion	Milk, hair cream,
6.	Liquid	Gas	Aerosol	Fog, mist, cloud.
7.	Gas	Solid	Solid sol	Pumic stone, foam rubber.
8.	Gas	Liquid	Foam	Fork, whipped cream, soap lather.

5.10. Discuss the effect of pressure and temperature on the adsorption of gases on solids.

Ans. Effect of temperature: Studying the adsorption of any particular gas at some particular adsorbent, it is observed that adsorption decreases with increase of temperature and vice versa. **For example:** One gram of charcoal adsorbs about 10 cm^2 of N_2 at 273 K, 20 cm^3 at 244 K and 45 cm^3 at 195 K.

The decrease of adsorption with increase of temperature may be explained as follows:

$$\text{Gas (Adsorbate)} + \text{Solid (Adsorbent)} \underset{\text{Evaporation}}{\overset{\text{Condensation}}{\rightleftharpoons}} \text{Gas adsorbed on solid} + \text{Heat}$$

Applying Le Chatelier's principle, it can be seen that increase of temperature decreases the adsorption and vice versa.

Effect of pressure: At constant temperature, the adsorption of a gas increases with increase of pressure. It is observed that at 100 °C temperature, the adsorption of a gas increases very rapidly as the pressure is increased from small values.

5.11. What are lyophilic and lyophobic sols? Give one example of each type. Why are hydrophobic sols easily coagulated? [*CBSE* (*Delhi*) 2013]

Ans. Lyophilic Sols: Colloidal sols directly formed by mixing substances like gums gelatin, starch, rubber, *etc.* with a suitable liquid (The dispersion medium) are lyophilic sols.

An important characteristic of these sols is that if the dispersion medium is separated from the dispersed phase (say by evaporation) the sol can be reconstituted by simply remixing with the dispersion medium. That is why these sols are also called reversible sols. These sols are quite stable and cannot be easily coagulated.

Lyophobic sols: These colloidal sols can only be prepared by some special methods. These sols are readily precipitated on the addition of small amount of electrolytes, by heating or by shaking and hence are not stable.

Hydrophobic sols are water hating. They are formed by indirect method. These sols are irreversible sols. These sols are readily precipitated by the addition of small amount of electrolytes, by heating or by shaking and hence are not stable.

They need stabilising agents for their preservation.

5.12. What is the difference between multimolecular and macromolecular colloids? Give one example of each. How are associated colloids different from these two types of colloids?

Ans. **Multimolecular colloids:** On dissolution, a large number of atoms or smaller molecules of a substance aggregate together to form species having size in the colloidal range (diameter > 1 nm). The species thus formed are called multimolecular colloids.

For Example: A gold sol may contain particles of various sizes having many atoms.

Macromolecular colloids: When certain substances having big size molecules, called macromolecules having large molecular masses dissolved in a suitable liquid, they form a solution in which the molecules of the substance, *i.e.* the dispersed particles have size in the colloidal range. Such substances are called macromolecular colloids. These macromolecular substances are usually polymers with very high molecular masses. **For Example,** naturally occurring macromolecules such as starch, cellulose, gelatin, protein, etc.

Associated colloids: These are formed by aggregation of a large number of ions in a concentrated solution., e.g. soap solutions. Higher is the concentration, greater are the van der Waals' forces.

5.13. What are enzymes? Write in brief the mechanism of enzyme catalysis.

Ans. Enzymes are complex nitrogenous organic compounds which are produced by living plants and animals. They are actually protein molecules of high molecular mass and form colloidal solutions in water. They are very effective catalysts, catalyses number of reactions, especially those connected with natural processes.

The enzymes are thus termed as biochemical catalysts.

Many enzymes have been obtained in pure crystalline state from living cells.

The following are some of the examples of enzyme-catalysed reactions:

(*i*) **Inversion of cane sugar:** The invertase enzyme 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 zymase enzyme converts glucose into ethyl alcohol and carbon dioxide.

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

Mechanism of enzyme catalysis: There are number of cavities present on the surface of colloidal particles of enzymes. These cavities are of characteristic shape and possess active groups such as – NH_2, – COOH, – SH, –OH, *etc.* These are actually the active centres on the surface of enzyme particles. The molecules of the reactant (substrata) which have complementary shape, fit into these cavities just like a key fits into a lock. On account of the presence of active groups, an activated complex is formed which then decomposes to yield the products.

Thus, the enzyme-catalysed reactions may be considered to proceed in two steps:

Step I: Binding of enzyme to substrate to form an activated complex.

$$E + S \longrightarrow ES^{\neq}$$

Step II: Decomposition of the activated complex to form the product

$$ES^{\neq} \longrightarrow E + P$$

5.14. How are colloids classified on the basis of:

(*i*) Physical states of components (*ii*) Nature of dispersion medium

(*iii*) Interaction between dispersed phase and dispersion medium?

Ans. (*i*) Depending upon the physical state of components, eight types of colloidal system are possible.

The examples of the various types of colloids along with their typical names are listed below:

S. No.	Dispersed Phase	Dispersion Medium	Types of Colloids	Examples
1.	Solid	Solid	Solid sol	Some coloured glasses, gem stones
2.	Solid	Liquid	Sol	Paints, cell fluids
3.	Solid	Gas	Aerosol	Smoke, dust
4.	Liquid	solid	Gel	Cheese, butter
5.	Liquid	Liquid	Emulsion	Milk, hair cream,
6.	Liquid	Gas	Aerosol	Fog, mist, cloud
7.	Gas	Solid	Solid sol	Pumice stone, foam rubber
8.	Gas	Liquid	Foam	Froth, whipped cream, soap lather

(*ii*) Depending upon the type of the particles of the dispersed phase, colloids are classified as: Multimolecular, macromolecular and associated colloids.

(*a*) **Multimolecular colloids:** The colloids in which the colloidal particles consist of aggregates of atoms or small molecules with diameter less than 1 nm are called multimolecular colloids.

For Example: A gold sol may contain particles of various sizes having several atoms of gold, a sulphur sol consists of particles containing about a thousand of 58 molecules. They are held together by van der Waals' forces.

(*b*) **Macromolecular colloids:** These are the colloids in which the dispersed particles are themselves large molecules (usually polymers).

Since these molecules have dimensions comparable to those of colloidal particles, therefore their dispersions are called macromolecular colloids.

Example: Proteins, starch and cellulose form macromolecular colloids.

(c) **Associated colloids (Micelles):** Those colloids which behave as normal strong electrolytes at low concentration but show colloidal properties at higher concentration due to the formation of aggregated particles of colloidal dimensions.

Such substances are also referred to as associated colloids.

(*iii*) Depending upon the nature of interactions between the dispersed phase and the dispersion medium, colloidal sols are divided into two types:

(*a*) **Lyophilic colloids (Solvent attracting):** Colloidal sols directly formed by mixing substances like gum, gelatine, starch, rubber etc. with a suitable liquid are called lyophilic sols. These are reversible sols. These are quite stable and cannot be coagulated easily.

(*b*) **Lyophobic colloids (solvent repelling):** Substances like metals, their sulphides etc. when simply mixed with the dispersion medium do not form the colloidal sols. Their colloidal sols can be prepared only by special methods. These sols are readily precipitated by the addition of small amount of electrolytes either by heating or by shaking and hence are not stable. These sols are irreversible sols.

5.15. Explain what is observed when

(*i*) A beam of light is passed through a colloidal sol.

(*ii*) An electrolyte, NaCl is added to hydrated ferric oxide sol.

(*iii*) Electric current is passed through the colloidal sol?

Ans. (*i*) When a beam of light is passed through a colloidal sol placed in a dark room, the path of beam gets illuminated with a bluish light when viewed at right angle to the direction of the passage of light. The path of light becomes visible due to scattering of light by the colloidal particles.

(*ii*) Ferric hydroxide is a positively charged sol and it is coagulated by Cl^- ions furnished by NaCl.

(*iii*) This is due to charge on the colloidal particles so that they migrate towards the oppositely charged electrode.

5.16. What are emulsions? What are their different types? Give example of each type.

Ans. Emulsions: An emulsion is a colloidal solution in which both the dispersed phase and the dispersion medium are liquids. (The two liquids involved are otherwise immiscible).

Preparation: The process of making an emulsion is known as emulsification. An emulsion is prepared by shaking the mixture of two liquids. The emulsion thus prepared from the pure liquids are usually not stable and two liquids usually separated out on standing. To get a stable emulsion, a small quantity of certain other substances are added to stabilise the emulsions. These substances are called emulsifiers or emulsifying agents.

The substances commonly used as emulsifying agents are soaps of various kinds, long chain sulphonic acids.

Types of Emulsions:

(*i*) **Emulsion of oil in water:** In this type of emulsion, oil is the dispersed phase and water is the dispersion medium.

For example: milk is an emulsion of liquid fat dispersed in water. Another example is vanishing cream.

(*ii*) **Emulsion of water in oil:** In this type of emulsions water is the dispersed phase and oil is the dispersion medium.

For example: Cod liver oil is an emulsion of water in oil. Some other common examples are butter and cream.

5.17. What is demulsification? Name two demulsifiers.

Ans. The process of separation of the constituent liquids of an emulsion is called demulsification. Demulsification can be done by centrifuging or boiling.

5.18. Action of soap is due to emulsification and micelle formation. Comment.

Ans. The cleansing action of soap is due to the fact that soap molecules forms micelle around the oil droplet in such a way that hydrophobic part of the stearate ions is in the droplet and hydrophilic part projects out of the grease droplet like the bristles. Since the polar groups can interact with water, the oil droplet surrounded by stearate ions is now pulled in water and removed from the dirty surface. Thus, soap helps in emulsification and washing away from oils and fats.

5.19. Give four examples of heterogeneous catalysis.

Ans. (*i*) Oxidation of sulphur dioxide into sulphur trioxide in the presence of Pt-metal.

$$2SO_2(g) \xrightarrow{Pt(s)} 2SO_3(g)$$

(*ii*) Combination between dinitrogen and dihydrogen gases to form ammonia in the presence of finely divided iron in Haber's process:

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

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

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

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

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

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

$$\text{vegetable oils}(l) + H_2(g) \xrightarrow{Ni(s)} \text{vegetable ghee } (s)$$

One of the reactants is in liquid state and the other is in gaseous state while the catalyst is in solid state.

5.20. What do you mean by activity and selectivity of catalysts?

Ans. Activity of catalyst: The activity of a catalyst depends upon the strength of chemisorption to a large extent. The reactants must get adsorbed reasonably strong on the catalyst to become active. In other words, we can say that it is the ability of a catalyst to accelerate the chemical reaction. For e.g.,

$$2H_2 + O_2 \xrightarrow{Pt} 2H_2O$$

Selectivity of catalyst: It is the ability of catalyst to direct a reaction to form a particular product (excluding other).

For example:

(*i*) *n*-Heptane selectively gives toluene in the presence of a platinum catalyst.

(*ii*) CO and H_2 reacts to form different products in the presence of different catalysts as follows:

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

(*b*) $CO(g) + 2H_2(g) \xrightarrow{Ca/ZnO - Cr_2O_3} CH_3OH(g)$

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

5.21. Describe some features of catalysis by zeolites.

Ans. Zeolites are good shape-selective catalysts because of their honey-comb like structures. They are microporous aluminosilicates with three-dimensional network of silicates in which some silicon atoms are replaced by aluminium atoms giving Al–O–Si framework.

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

5.22. What is shape-selective catalysis?

Ans. The catalytic reaction that depends upon the pore structure of the catalyst and the size of the reactant and the product molecules is called shape-selective catalysis. Zeolites are good shape-selective catalysts because of their honey-comb-like structures.

5.23. Explain the following terms:

(*i*) Electrophoresis (*ii*) Coagulation (*iii*) Dialysis (*iv*) Tyndall effect

Ans. (*i*) **Electrophoresis:** The movement of colloidal particles under an applied electric potential is called electrophoresis. Positively charged particles move towards the cathode while negatively charged particles move towards the anode.

(*ii*) **Coagulation:** The stability of the lyophobic sols is due to the presence of charge on colloidal particles. If somehow, the charge is removed, the particles will come nearer to each other to form aggregates and settle down under the force of gravity.

The process of settling of colloidal particles is called coagulation or precipitation of the sol.

The coagulation of lyophobic sols can be carried out in the following ways:

(*a*) By electrophoresis. (*b*) By mixing two oppositely charged sols.

(c) By boiling. (*d*) By persistent dialysis.

(*e*) By addition of electrolytes.

(*iii*) **Dialysis:** It is a process of removing a dissolved substance from a colloidal solution by means of diffusion through a suitable membrane. Since particles (ions or smaller molecules) in a true solution can pass through animal membrane (bladder) or parchment paper or cellophane sheet but not the colloidal particles, the membrane made from it can be used for dialysis.

The apparatus used for this purpose is called dialyser. A bag of suitable membrane containing the colloidal solution is suspended in a vessel through which fresh water is continuously flowing. The molecules and ions diffuses through the membrane into the outer water and pure colloidal solution is left behind.

(*iv*) **Tyndall effect:** This effect was first observed by Faraday and later studied in detail by Tyndall and is termed as Tyndall effect.

The tyndall effect is due to the fact that colloidal particles scatter light in all the directions in space. This scattering of light illuminates the path of beam in the colloidal dispersion. Tyndall effect is observed only when the following two conditions are satisfied:

(*a*) The diameter of the dispersed particles is not much smaller than the wavelength of the light used.

(*b*) The retractive indices of the dispersed phase and the dispersion medium differ greatly in magnitude.

5.24. Give four uses of emulsions.

Ans. (*i*) The cleansing action of soap is due to emulsions.

(*ii*) It is used in the preparation of vanishing cream.

(*iii*) It is used in the preparation of cod liver oil.

(*iv*) It is used the preparation of butter, cream, *etc.*

5.25. What are micelles? Give an example of a micelles system. [AI CBSE 2014]

Ans. Micelles are also known as associated colloids.

They behave as normal strong electrolytes at low concentration but they show colloidal properties at higher concentration due to the formation of aggregated particles of colloidal dimensions.

Surface active agents like soap and synthetic detergents belong to this class.

5.26. Explain the term with suitable examples:

(*i*) Alcosol (*ii*) Aerosol (*iii*) Hydrosol.

Ans. (*i*) **Alcosol:** A colloidal sol in which dispersion medium is alcohol. **Example:** Colloidion.

(*ii*) **Aerosols:** When dispersion medium is a gas and dispersed phase is either solid or a liquid, the colloidal system is called aerosol. **Example:** fog, cloud, smoke, *etc.,* Colloidal suspension in the air are also called aerosols.

(*iii*) **Hydrosols:** Colloids in water are called hydrosols. **Example:** Milk, proteins and nucleic acid are colloidal-sized particles dispersed in an aqueous solution for ions.

5.27. Comment on the statement that "colloid is not a substance but a state of substance".

Ans. The statement is true. Because the same substance may exist as a colloid under certain conditions and as a crystalloid under certain other conditions. For example, NaCl in water behaves as a crystalloid while in benzene, it behaves as a colloid. Similarly, dilute soap solution behaves like a crystalloid while concentrated solution behaves as a colloid. It is the size of the particles which matters. That is the state in which the substance exists. If the size of the particles lies in the range 1 nm to 100 nm, it is in the colloidal state.

ADDITIONAL QUESTIONS SOLVED

I. Very Short Answer Type Questions

(1 *Mark*)

Q1. Explain the following term giving a suitable example, emulsification.

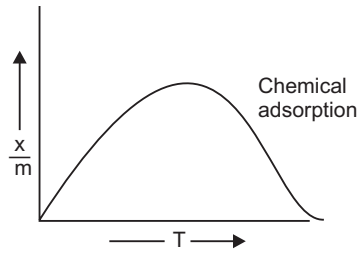
[*CBSE* 2007]

Ans. The process of making emulsion using a mixture of two immiscible or partially miscible liquids is called emulsifica-tion. For example, Cod liver oil is an emulsion made up of water in oil.

Q2. How does chemical adsorption of a gas on a solid vary with temperature?

[*CBSE* 2003]

Ans. Chemical adsorption first increases with increase in temperature and then it decreases, if the pressure remains constant.



Q3. Define the term: enthalpy of adsorption.

Ans. Adsorption generally occurs with release in energy, *i.e.* it is exothermic in nature.

The enthalpy change for the adsorption of one mole of adsorbate on the surface of adsorbent is called the enthalpy or heat of adsorption.

Q4. How does addition of alum purify water?

Ans. Addition of alum coagulate the suspended impurities and make water fit for drinking purpose.

Q5. What is meant by the term: peptisation? [*CBSE* 2014]

Ans. Peptisation is the process of converting a precipitate into a colloidal sol by shaking it with dispersion medium in the presence of a small amount of electrolyte. The electrolyte used for this purpose is called the peptising agent.

Q6. What happens when an electric field is applied to a colloidal sol?

Ans. When an electric fixed is applied to a colloidal sol due to the charge on colloidal particles they migrate towards the oppositely charged electrode.

Q7. Mention one application of emulsion.

Ans. Cod liver oil is an emulsion of water in oil.

Q8. What are the physical states of dispersed phase and dispersion medium of froth?

[*CBSE Sample Paper* 2008]

Ans. Dispersed phase — Air
Dispersion medium — Liquid

Q9. Give an example of an associated colloid.

Ans. Soaps and detergents are associated colloids.

Q10. How does chemical adsorption of a gas on a solid vary with temperature? [*AI* 2003]

Ans. The rate of chemical adsorption first increases and then decreases as the temperature increases.

Q11. What causes Brownian movement in a colloidal solution? [*AI* 2008]

Ans. The molecules of dispersion medium due to their kinetic motion strike against the colloidal particles (dispersed phase) from all the sides with different forces causing them to move. However, colloidal particles being comparatively heavier, move with a slower speed.

Q12. In physisorption and chemisorption which type of adsorption has a higher enthalpy of adsorption? [*AI* 2008]

Ans. Enthalpy of chemisorption is high (80–240 kJ mol^{-1}) as it involves chemical bond formation.

Q13. Describe 'electrophoresis' briefly. [*AI CBSE* 2008]

Ans. Electrophoresis: When an electric potential is applied across the two platinum electrodes dipping in a colloidal solution, the colloidal particles move towards one or the other electrodes. The movement of colloidal particles under an applied electric potential is called electrophoresis.

Q14. Why does physisorption decrease with the increase of temperature? [*AI* 2008]

Ans. Since adsorption process is exothermic and physical adsorption occurs readily

at two temperatures and decreases with increase in temperature, (Le Chatelier's principle).

Q15. Define the term 'Tyndall effect'. [*AI* 2009]

Ans. When a beam of light is passed through a colloidal solution and viewed perpendicular to the path of the incident light, the path of light becomes visible. This phenomenon is called Tyndall effect.

Q16. What is 'coagulation process'? [*AI* 2009]

Ans. The process of setting of colloidal particles is called coagulation or precipitation of the sol.

Q17. What is adsorption isotherm?

Ans. When a graph is plotted between $\frac{x}{m}$ (extent of adsorption) with pressure at constant temperature, the curve thus obtained is called adsorption isotherm where 'x' is the mass of the adsorbate, and 'm' is the mass of adsorbent.

Q18. State two uses of adsorption.

Ans. (*i*) Chromatography is based on differential adsorption.
(*ii*) In gas masks, wood charcoal is used to adsorb poisonous gases.

Q19. What name is generally given to a phenomenon when adsorption also occurs along with absorption?

Ans. Sorption.

Q20. What is meant by critical micelle concentration?

Ans. The micelle may be defined as the aggregated particles formed by associated colloids in solution. The formation of micelle takes place above a certain concentration called critical micelle concentration (CMC).

Q21. Give one example each of 'oil in water' and 'water in oil' emulsions.

Ans. Milk is an example of oil in water and butter is an example of water in oil emulsions.

Q22. What is the name given to the substance which is getting adsorbed?

Ans. Adsorbate is a substance which is getting adsorbed.

Q23. What are aerosols?

Ans. When solid particles are dispersed in the gaseous dispersion medium, sol is called aerosols.

Q24. Why are lyophillic sols self-stabilised?

Ans. It is due to the force of attraction between the dispersed phase and the dispersion medium.

Q25. What is collodion?

Ans. Collodion is cellulose nitrate peptised with ethanol.

Q26. What is sorption?

Ans. Sorption is the process in which adsorption and absorption takes place simultaneously, *e.g.* dyeing of cotton fibres by azodyes.

Q27. To which colloidal system does milk belong?

Ans. Milk is an emulsion.

Q28. How can dialysis be made fast?

Ans. Dialysis can be made faster in the presence of an electric field.

Q29. Give one example each of positively charged sol and negatively charged sol.

Ans. $Fe(OH)_3$ is a positively charged, colloid whereas As_2S_3 is a negatively charged colloid.

Q30. What name is given to the sol in which dispersion medium is benzene?

Ans. Benzosol.

Q31. Indicate a chemical reaction involving a homogeneous catalyst?

Ans. $2SO_2(g) + O_2(g) \underset{}{\overset{NO(g)}{\rightleftharpoons}} 2SO_3(g)$

Q32. Name two industrial processes in which heterogeneous catalysts are employed.

Ans. Contact process:

$$2SO_2(g) + O_2(g) \underset{770\ K}{\overset{V_2O_5}{\rightleftharpoons}} 2SO_3(g)$$

Ostwald's process:

$$4NH_3(g) + 5O_2(g) \underset{1120\ K}{\overset{Pt}{\rightleftharpoons}} 4NO(g) + 6H_2O(g)$$

Q33. If we add equimolar amount of $Fe(OH)_3$ to As_2S_3 sol, what will happen?

Ans. Mutual coagulation will take place because $Fe(OH)_3$ is a positively charged colloid whereas As_2S_3 is a negatively charged colloid.

Q34. Are the sols of metals hydrophilic or hydrophobic?

Ans. Sols of metals are hydrophobic in nature.

Q35. What is the function of an emulsifying agent?

Ans. The main function of an emulsifying agent is to stabilise the emulsion.

Q36. What is desorption?

Ans. The process of removal of an adsorbed substance is called desorption.

Q37. What is flocculation or coagulation value?

Ans. It is defined as the number of millimoles of an electrolyte which must be added to one litre of the sol as to bring about the complete coagulation. It is called the coagulation or flocculation value of the the electrolyte for the sol.

Q38. Of NH_3 and N_2 which gas will be adsorbed more readily on the surface of charcoal and why?

Ans. NH_3 will be adsorbed more easily due to greater surface area. This is also because it has more van der Waals' forces of attraction and it is easily liquifiable as compared to N_2.

Q39. What is meant by 'specific surface area' of a solid?

Ans. Specific surface area is defined as the area available for the adsorption process of the adsorbent.

Q40. How is dialysis carried out? Mention its one application.

Ans. Dialysis is used for purification of colloidal solutions. It is carried out by putting an impure colloidal solution in a parchment paper bag and then dipping it in distilled water.

Q41. What is Tyndall effect due to?

Ans. It is due to scattering of light by the colloidal particles, when light is made to fall on them.

Q42. State one difference between an emulsion and a sol.

Ans. Emulsion is a liquid in liquid type colloidal dispersion whereas sol is a solid dispersed in a liquid colloid.

Q43. Give an example of heterogeneous catalysed reaction.

Ans. $$2SO_2(g) + O_2(g) \xrightarrow[heat]{Pt\ or\ V_2O_5(s)} 2SO_3(g)$$

Q44. On passing H_2S gas through dilute HNO_3 the colourless solution becomes turbid the Why?

Ans. It is due to the formation of colloidal sulphur.

$$H_2S + [O] \xrightarrow{dil.\ HNO_3} H_2O + S$$

Q45. What is observed when sodium chloride is added to a colloidal solution of ferric hydroxide?

Ans. Coagulation of the coloidal sol. take place.

Q46. Give an example of a peptising agent.

Ans. $FeCl_3$ is a peptising agent used for $Fe(OH)_3$ sol.

Q47. What happens when an electric field is applied to a colloidal solution?

Ans. Colloidal particles will move towards oppositely charged electrode.

Q48. What is the range of size of particles in the colloidal sol?

Ans. Size of colloidal particles lies between 1 nm to 1000 nm.

Q49. How does addition of alum purify water?

Ans. Alum is an electrolyte, it coagulates the mud from the river water and thus helps in purification of water.

Q50. Adsorption is always exothermic. Why?

Ans. Adsorption decreases the surface energy of the adsorbent, which appears as heat. So it is always exothermic.

Q51. The enthalpy of adsorption of chemisorption is high. Why?

Ans. Chemisorption involves chemical bond formation.

Q52. When a solution of acetic acid in water is shaken with charcoal the concentration of the acid decreases in the solution. Why?

Ans. This is because a part of the acid is adsorbed by the charcoal.

Q53. What is meant by co-enzyme?

Ans. The non-proteinaceous substance present alongwith enzymes, which enhances the activity of enzymes.

Q54. 1 gm of activated charcoal adsorb more $SO_2(g)$ (critical temperature 630 K) than methane (critical temperature 190 K). Why?

Ans. Easily liquefiable gases (higher critical temperature) are easily adsorbed by a solid because near the critical temperature the van der Waals forces between the gas molecules and the solid adsorbent is very strong.

Q55. Why is $FeCl_3$ preferred over KCl in case of a cut that leads to bleeding?

Ans. $FeCl_3$ helps in coagulation of blood more effectively than KCl. This is because as per Hardy Schulze rule, greater the valency of the coagulating ion, more will be the coagulating power.

Q56. What is the effect of temperature on chemisorption? [*CBSE* 2014]

Ans. High temperature is favourable for adsorption. In increases with the increase of temperature.

Q57. Write a method by which lyophobic colloids can be coagulated.

[*CBSE* 2015]

Ans. Lyophobic colloids can be coagulated by the electrophoresis method. The colloidal particles move towards the oppositely charged electrode where they get discharged and get precipitated.

II. Short Answer Type Questions

(2 *or* 3 *Marks*)

Q1. Explain the following observations:

(*a*) Ferric hydroxide sol gets coagulated on addition of sodium chloride solution.

(*b*) Cottrell smoke precipitator is fitted at the mouth of the chimney used in factories.

(*c*) Physical adsorption is multilayered, while chemisorption is monolayered.

[*CBSE Sample Paper*-II 2009]

Ans. (*a*) As ferric hydroxide, $Fe(OH)_3$ is a positively charged sol, so it gets coagulated by chloride ions, Cl^- released by NaCl solution.

(*b*) Cottrell's smoke precipitator, neutralises the charge on the unburnt carbon particles, coming out of the chimney and they get precipitated and settle down at the floor of the chamber.

(*c*) As physical adsorption involves only weak van der Waals' forces of interaction, so many layers of adsorbate get attached, while chemisorption involves chemical bond formation between the adsorbate and adsorbent. So, only a monolayar is formed.

Q2. (*a*) Adsorption of a gas on the surface of solid is generally accompanied by a decrease in entropy. Still it is a spontaneous process. Explain.

(*b*) How does an increase in temperature affect both physical as well as chemical adsorption?

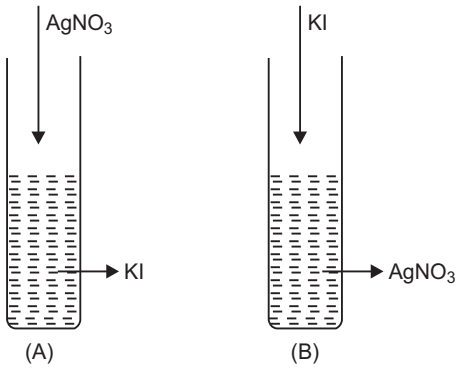
Ans. (*a*) According to the equation:

$$\Delta G = \Delta H - T\Delta S$$

For a process to be spontaneous, ΔG should be negative. ΔH of adsorption is always negative. For a gas, ΔS is also negative. Thus, in an adsorption process, which is spontaneous, a combination of these two factors always makes ΔG negative.

(*b*) On increasing the temperature desorption occurs in case of physical adsorption. Chemical adsorption first increases and then decreases with increase in temperature.

Q3. A colloidal solution of AgI is prepared by two different methods as shown below:



(*i*) What is the charge of AgI colloidal particles in the two test tubes (A) and (B)?

(*ii*) Give reasons for the origin of charge.

Ans. (*i*) Test tube (A) has negative charge and test tube (B) has positive charge on the colloidal particles.

(*ii*) In test tube (A), I^- is adsorbed on AgI. [or AgI/I^- is formed]
In test tube (B), Ag^+ is adsorbed on AgI [or AgI / Ag^+ is formed]

Q4. Distinguish between micelles and colloidal particles. Give one example of each. [*AI* 2008]

Ans. Micelles: When small (particles) (ions) of an electrolyte or soap or detergent molecules form the aggregate particles which behaves like the colloidal particles, these aggregate particles are known as micelles. Examples: Soaps and detergents.

Colloidal particles: Colloidal particles have an enormous surface area per unit mass as a result of their small size. Its size range between 1 nm to 100 nm.

Q5. (*a*) What is the difference between a colloidal solution and an emulsion? Give one example of each.

(*b*) What are emulsifiers? [*AI* 2008]

Ans. (*a*) In a colloidal solution, the dispersed phase is a solid and the dispersion medium is a liquid. In an emulsion, both the dispersed phase and the dispersion medium are liquid. Example: Colloidal sol — cell fluids, muddy water;
Emulsion — milk, cold cream.

(*b*) **Emulsifiers:** The substance which are added to stabilise the emulsions are called emulsifiers. Example: Soaps of various kinds and lyophilic colloids (proteins, gum, *etc.*,)

Q6. Explain what is observed when:

(*i*) KCl, an electrolyte, is added to an hydrated ferric hydroxide sol.

(*ii*) An electric current is passed through a colloidal solution.

(*iii*) A beam of light is passed through a colloidal solution. [*AI* 2008]

Ans. (*i*) Ferric hydroxide $Fe(OH)_3$ is a positively charged sol, so it gets coagulated by the chloride ions released from KCl solution.

(*ii*) When an electric current is passed through a colloidal solution due to charge on the colloidal particles they migrate towards the oppositely charged electrode.

(*iii*) When a beam of light is passed through a colloidal solution the path of light becomes visible.

Q7. Describe the following types of colloids, giving an example for each.

(*i*) Multimolecular colloids

(*ii*) Macromolecular colloids

[*AI* 2007]

Ans. (*i*) **Multimolecular colloids:** When the particles of a substance which constitute dispersed phase are of molecular dimensions but when brought in colloidal state, a large number of such atoms or molecules group together into larger aggregates of colloidal size. These are called multimolecular colloids.

(*ii*) **Macromolecular colloids:** In some substances such as starch, proteins, asbestos fibres, the size of the particles is of colloidal dimensions, *i.e.* between 1–100 nm. Such substances are known as macromolecular colloids.

Q8. Explain the following terms with suitable example in each case?

(*i*) Shape-selective catalysis

(*ii*) Dialysis [*AI* 2007]

Ans. (*i*) **Shape-selective catalysis:** Shape selective catalysis is the catalytic reaction that depends on the pore structure of the catalyst. Zeolites are generally used as shape-selective catalysts. Depending on the size of the reactant and product molecules as compared to the size of the pores of the zeolites, reaction proceeds in a particular manner.

(*ii*) **Dialysis:** Dialysis is a process to separate a crystalloid from a colloid by diffusion through a semipermeable membrane. When dialysis is carried out under the influence of an electric field, this process is called electro-dialysis.

Q9. Explain the following terms giving a suitable example in each case:

(*i*) Emulsification

(*ii*) Homogeneous catalysis

[*AI* 2007]

Ans. (*i*) **Emulsification:** The process of making an emulsion is known as emulsification. To stabilise an emulsion, an emulsifying agent or emulsifier is added. Soaps and detergents are the most frequently used as emulsifiers.

(*ii*) **Homogeneous catalysis:** When the reactants and the catalyst are in the same phase, the process is said to be homogeneous catalysis.

Example: Oxidation of sulphur dioxide to sulphur trioxide with oxygen gas in the presence of oxides of nitrogen as the catalyst in the lead chamber process:

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

The reactants, sulphur dioxide and oxygen and the catalyst nitric oxide, are all in the same phase.

Q10. Define adsorption. Write any two features which distinguish physisorption from chemisorption.

[*AI* 2007]

Ans. **Adsorption:** Molecules in the solid gaseous or liquid phase can adhere to the solid surface this phenomenon is called adsorption.

Physisorption: In physisorption, the adsorbate is held on the surface by weak van der Waals' forces. It is reversible in nature.

Chemisorption: In chemisorption, the forces holding the adsorbate on the surface are as strong as experienced in chemical bonding. It is irreversible in nature.

Q11. Write three distinct differences between physical adsorption and chemisorption. [*Delhi* 2013]

Ans.

Physical adsorption	Chemial adsorption
1. Forces of attraction between the adsorbent and adsorbate molecules are weak van der Waals' forces. 2. Heat of adsorption is low (20–40 $kJmol^{1}$) 3. It is temporary and reversible.	1. Forces between the adsorbent and the adsorbate are strong chemical bond. 2. Heat of adsorption is high (80–240 kJ mol^{-1}). 3. It is permanent and irreversible.

Q12. (*a*) How can a colloidal solution and a true solution of the same colour be distinguished from each other?

(*b*) List four applications of adsorption. [*AI* 2006]

Ans. (*a*) The path of light becomes visible when passed through a colloidal solution while it is not visible in case of a true solution. This is because of Tyndall effect caused by the scattering of light by colloidal particles.

(*b*) Applications of adsorption.

(*i*) Activated charcoal is used in gas masks to remove poisonous gases such as CH_4, CO, *etc.*

(*ii*) Animal charcoal is used as decolouriser in the manufacture of sugar.

(*iii*) Silica is used for removing moisture.

(*iv*) The ion exchange resins are used for removing hardness of water.

Q13. Explain the following observations?

(*a*) Lyophilic colloid is more stable than lyophobic colloid.

(*b*) Coagulation takes place when sodium chloride solution is added to a colloidal solution of ferric hydroxide.

(*c*) Sky appears blue in colour. [*CBSE* 2008]

Ans. (*a*) A lyophilic sol is stable due to the charge and the hydration of the sol particles. Such a sol can only be coagulated by removing the water and adding solvents like alcohol, acetone, *etc.* and then an electrolyte. On the other hand, a lyophobic sol is stable due to charge only and hence it can be easily coagulated by adding small amount of an electrolyte.

(*b*) The colloidal particles get precipitated, *i.e.* ferric hydroxide is precipitated.

(*c*) The atmospheric particles of colloidal range scatter blue component of the white sunlight preferentially. That is why the sky appears blue.

Q14. What are micelles? How do they differ from a normal colloidal solution? [*CBSE* 2005 *C*]

Ans. It is an aggregated bulky ion in a soap or detergent molecule which arranges in a radial manner. For example, when concentrated solution in a soap say sodium stearate is prepared then stearate ions form micelles.

Micelles differ from a normal colloidal solution. Infact they are the aggregates of the bulky ions of soaps and detergents arranged in a radial manner.

To the contrary, normal colloids are either aggregates of atoms or molecules or even ions or molecules of colloidal size.

However, in the former case the particles are held together by weak van der Waals' forces. The above are known as multimolecular or macromolecular colloids, respectively.

Q15. Explain the following:

(*a*) Same substance can act as both colloids and crystalloids.

(*b*) Artificial rain is caused by spraying salt over clouds.

(*c*) When a beam of light is passed through a colloidal sol, the path of the beam gets illuminated. [*CBSE* 2005, *Delhi* 2013]

Ans. (*a*) The same substance can act as both colloid and crystalloid. It depends upon the size of the particles, When the size of the particles lies between 1nm to 1000 nm, it behaves as a colloid. If the particle size is less than 1 nm, then it exists as a true solution and behaves like a crystalloid.

(*b*) Artificial rain is caused by spraying salt over clouds. The colloidal water particles of the clouds get neutralised by the oppositely charged ions of the salt and coagulated to bigger water droplets causing artificial rain.

(*c*) When a beam of light is passed through a colloidal solution the path of beam gets illuminated with visible light. This is due to scattering of light by the colloidal particles.

Q16. (*a*) Which will adsorb more gas, a lump of charcoal or its powder, and why?

(*b*) Describe the preparation of the following colloidal solutions. Name the method used in each case.

(*i*) Silver sol (*ii*) Sulphur sol.

[*CBSE Delhi* 2013 C]

Ans. (*a*) A lump of charcoal will adsorb more gas than its powder. This is because penetration of gas through particles in powder form is difficult and this will obstruct the process of adsorption.

(*b*) (*i*) **By reduction:** Silver sol is obtained by the reduction of dilute silver chloride solution with stannous chloride.

$$2AgCl + SnCl_2 \longrightarrow \underset{\text{Silver sol}}{2Ag} + SnCl_4$$

(*ii*) **By oxidation:** Sulphur sol is obtained by passing H_2S gas through an oxidising agent like bromine water.

$$H_2S + Br_2(aq) \longrightarrow \underset{\text{Sulphur sol}}{S} + 2HBr$$

Q17. How do size of particles of adsorbent, pressure of a gas and prevailing temperature influence the extent of adsorption of a gas on a solid?

[*AI* 2005]

Ans. (*i*) **Effect of size of the particles of adsorbent:** Greater the specific area of the solid available for adsorption of adsorbent, greater would be its adsorbing power. That is why porous or finely divided forms of adsorbents adsorb more strongly. However, the size of pores should be large enough to allow the diffusion of gas molecules.

(*ii*) **Effect of pressure:** Increase in pressure initially increases the adsorption which later attains equilibrium at high pressure.

$$\frac{x}{m} = kP^{1/n} (n > 1)$$

(*iii*) **Effect of temperature:** Adsorption being an exothermic process, decreases with increase in temperature. This is true for physical adsorption. However, in chemical adsorption, the extent of adsorption first increases and then decreases with the increase in temperature.

Q18. What are the two classes of emulsions? Give one example of each class. State one activity to test the type of an emulsion. [*CBSE* 2005]

Ans. The two types of emulsions are:

(*i*) **Oil-in-water type:** In this type, small droplets of oil are dispersed in water. For example: milk, cod liver oil.

(*ii*) **Water-in-oil type:** In this type, water droplets are dispersed in oil or fat as a medium. For example, butter.

Dye test: Some oil soluble dye is added to the emulsion. If the background becomes coloured, the emulsion is water-in-oil type and if the colour of droplets are seen then the emulsion is oil-in-water type.

Q19. Differentiate between soaps and detergents. [*CBSE* 2005]

Ans.

Soaps	Detergents
(*i*) Soaps are sodium salts of long chain fatty acids.	(*i*) Detergents are sodium salts of long chain alkyl sulphates or long chain alkyl benzene sulphonates.
(*ii*) They cannot be used in acidic solutions.	(*ii*) They can even be used in acidic solutions.
(*iii*) They cannot be used in hard water as they produce precipitate with Ca^{2+} and Mg^{2+} ions.	(*iii*) They can be used even in hard water as they do not form insoluble precipitate with Ca^{2+} or Mg^{2+} ions.
(*iv*) Soaps are biodegradable, so they do not cause any pollution.	(*iv*) Some of the synthetic detergents are non-biodegradable so they pollute river and lake water.

Q20. Illustrate with examples.

(*i*) Lyophilic and Lyophobic sols

(*ii*) Homogeneous and Heterogeneous catalysis. [*CBSE* 2005, 17]

Ans. (*i*) The substances such as proteins, starch, rubber, *etc.* directly passes into the colloidal state when brought in contact with the solvent. Such colloids are known as lyophilic sols.

The substances like metals, their sulphides, hydroxides, *etc.* do not form colloidal sol readily when mixed with dispersion medium. The colloidal sols can only be prepared by some special methods. Such sols are called lyophobic sols.

(*ii*) ***Homogeneous catalysis*:** Here the reactants and catalyst are present in the same phase. For example, lead chamber process for the manufacture of H_2SO_4.

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

***Heterogeneous catalysis*:** Here the reactants and catalyst are present in different phases. For example, contact process for the manufacture of H_2SO_4.

$$2SO_2(g) + O_2(g) \xrightarrow{V_2O_5(s)} 2SO_3(g)$$

Q21. What do you understand by activity and selectivity of catalysts? Describe some features of catalysis by zeolites. [*AI* 2004]

Ans. **Activity of a catalyst:** The ability of a catalyst to increase the rate of a chemical reaction is called its activity. For example: Hydrogen and oxygen do not react at room temperature but this reaction is explosive in the presence of platinum catalyst.

Selectivity of a catalyst: It is the ability of a catalyst to direct a reaction to give a particular product. For example, CO + H_2 combine to form CH_4, when Ni is used as the catalyst and methanol is obtained when Cr_2O_3 is catalysed.

Zeolites: Zeolites are porous alumino silicates with general formula

$Mn[(Al\ O_2)_n\ (Si\ O_2)_4]_m H_2O$

Where n = valency of cation.

Their pore size varies from 260 pm to 740 pm. Only those molecules which can be adsorbed on those pores are catalysed, *i.e.* they are selective molecular sizes and selective catalyst. An important zeolite used in petroleum industry is ZSM–5 (zeolite sizes of molecular porosity 5). It converts alcohol into petrol (gasoline).

$$x\text{H}-\underset{\text{H}}{\overset{\text{H}}{\text{C}}}-\text{OH} \xrightarrow{\text{ZMS-5}} \underset{\text{Gasoline}}{(CH_2)_x} + H_2O$$

Q22. Explain the following terms:

(*i*) Peptisation

(*ii*) Dialysis

(*iii*) Hardy-Schulze rule. [*AI* 2004]

Ans. (*i*) **Peptisation:** It is defined as the process of converting a precipitate into a colloidal sol by shaking it with a dispersion medium in the presence of a small amount of electrolyte. The electrolyte used is called the peptising agent.

(*ii*) **Dialysis:** It is a method in which a bag made of parchment paper or cellophane is filled with a colloidal solution is suspended in fresh water. The impurities of electrolyte particles passes out leaving behind the colloidal sol.

(*iii*) **Hardy-Schulze rule:** According to this rule:

(*a*) The ions carrying the charge opposite to that of the sol particles are effective in causing the coagulation of the sol.

(*b*) Coagulation power of an electrolyte is directly proportional to the fourth power of the valency of the ions, causing coagulation.

Q23. Explain the following terms giving an example in each case:

(*i*) Emulsification

(*ii*) Coagulation

(*iii*) Electrophoresis

[*AI* 2004, *Delhi* 2012]

Ans. (*i*) **Emulsification:** The process of making an emulsion is called emulsification. An emulsion can be made by vigorously shaking or churning the two liquids in a homogeniser. An emulsifier is added to stabilise an emulsion. Milk is an emulsion of fat in water.

(*ii*) **Coagulation:** The process of aggregation of colloidal particles into an insoluble particle by the addition of some suitable electrolyte is known as coagulation. For example, when river water containing colloidal clay flows into the sea, electrolytes present in brine of sea water causes coagulation.

(*iii*) **Electrophoresis:** The movement of charged colloidal particles under the influence of an electric field is called electrophoresis, For example, when electric field is applied across As_2S_3 sol, its particles are collected near the anode, indicating the negative charge on its particles.

Q24. How are the colloids classified on the basis of the nature of interactions between dispersed phase and dispersion medium? Describe an important characteristic of each class. Which of these sols need stabilising agents of preservation? [*CBSE* 2004]

Ans. Depending upon the nature of interactions between the dispersed phase and dispersion medium, colloids are divided into two categories:

(*i*) **Lyophilic sols:** The colloids in which particles of the dispersed phase have a strong affinity for the dispersion medium are called lyophilic sols. These colloidal solutions even if precipitated, changes back to the colloidal form simply by adding the dispersion medium. So, lyophillic sols are reversible in nature, *e.g.* glue, starch, rubber.

(*ii*) **Lyophobic sols:** The colloids in which particles of the dispersed phase have no or very little affinity for the dispersion medium are called lyophobic sols. These are irreversible in nature.

Once precipitated, they have little tendency to get back into the colloidal form or simply by adding the dispersion medium, *e.g.* As_2S_3 sol. Lyophobic sols need stabilising agents for their preservation.

Q25. What are detergents? Give their scheme of classification. Why are the detergents preferred over soaps?

[*AI* 2004]

Ans. A detergent is a surface active agent which is used for cleaning the dirty surfaces. It contains a non-polar hydrocarbon chain (hydrophobic part) and a polar group (hydrophilic part) within the molecules and thus shows adsorption and micellization.

On the basis of charge on polar part, detergents are classified as follows:

(*i*) **Anionic detergents:** In these type, large part of molecules acts as anions, *e.g.* alkyl benzene sulphonates.

(*ii*) **Cationic detergents:** These are mostly acetates or chlorides of the quaternary a ammonium salts, *e.g.* cetyltrimethyl ammonium chloride.

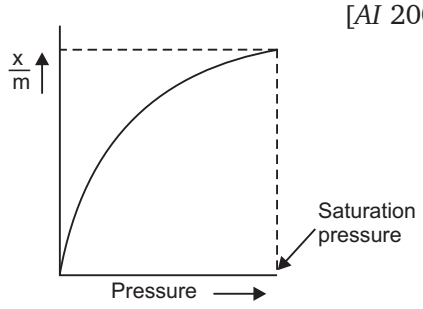
(*iii*) **Non-ionic detergents:** Like esters of high molecular mass formed by the reaction between polyethylene glycol and stearic acid.

Detergents are preferred over soaps as they work even in hard water and acidic medium where soaps become insoluble. They have a powerful cleansing action.

Q26. Explain Brownian Movement. [*CBSE* 2004]

Ans. When colloidal particles are observed under the ultramicroscope, the particles are seen to be in constant motion in a zig-zag path. This zig-zag motion of the dispersed phase particles is called Brownian movement.

Q27. What is adsorption? How does adsorption of a gas on a solid surface vary with pressure? Illustrate with the help of an appropriate graph. [*AI* 2003]



Ans. Adsorption is the phenomenon of attracting and retaining the molecules of a substance on the surface of a liquid or a solid, resulting in higher concentration of the molecules on the surface.

Effect of pressure: At constant temperature, the adsorption of gas increases with increase of pressure of the gas. At low pressure, it increases rapidly. At an equilibrium pressure, the extent of adsorption (x/m) reaches its maximum value after which adsorption is independent of pressure.

$$\frac{x}{m} = kP^{1/n}$$

Q28. How are the following sols prepared?

(*a*) Sulphur sol (*b*) Collodion [*CBSE* 2003]

Ans. (*a*) Sulphur sol is obtained by bubbling H_2S through an oxidising agents like bromine water:

$$H_2S + Br_2 \longrightarrow \underset{\text{(colloidal sol)}}{2HBr} + S$$

(*b*) Cellulose nitrate colloid can be prepared by dispersing it in a mixture of ethyl alcohol and ether. It is commercially known as collodion.

Q29. What are emulsions? What are their different types? Give one example of each type. [*CBSE* 2014]

Ans. An emulsion is a colloidal dispersion in which both the dispersed phase and the dispersion medium are liquids and the two liquids involved are otherwise immiscible.

(*a*) Oil in water type, in which oil is a dispersed phase and water is the dispersion medium. For example: milk is as emulsion of liquid fat dispersed in water.

(*b*) Water in oil type, in which water is the dispersed phase and oil is the dispersion medium. For example: cod liver oil is an emulsion of water in oil in which water is the dispersed phase and oil is the dispersion medium.

Q30. What is the reason for the stability of colloidal sols? [*CBSE* 2016]

Ans. Reasons for the stability of colloidal sols are:

(*a*) Coagulation of the colloidal sol is prevented because of the presence of equal and similar charges on the colloidal particles.

(*b*) Colloidal particles are covered by a sheath of liquid in which they are extensively solvated because of which they acquire stability.

Q31. Define the following terms:

(*i*) Lyophilic colloid

(*ii*) Zeta potential

(*iii*) Associated colloids [*CBSE* 2016]

Ans. (*i*) Colloidal sols are directly formed by mixing substances such as gum, gelatine, starch and rubber with a suitable liquid (the dispersion medium). Such substances are called lyophilic sols.

(*ii*) The potential difference between the fixed layer and the diffused layer of opposite charges is called the electrokinetic potential or zeta potential.

(*iii*) Substances which at lower concentration behave as a normal strong electrolyte but at higher concentration exhibit colloidal behaviour because of the formation of aggregates or micelles are known as associated colloids.

III. Long Answer Type Questions

(5 *Marks*)

Q1. (*i*) Explain the meaning of the statement, "Adsorption is a surface phenomenon".

(*ii*) State two features of chemical adsorption which are not found with physical adsorption. [*CBSE* 2006]

Ans. (*i*) **Adsorption is a surface phenomenon:** During the phenomenon of adsorption the adsorbate molecules are held on the surface of the adsorbent by weak van der Walls' or strong covalent bond forces. Therefore heat is liberated during adsorption.

It is further more clear from the fact that finely divided adsorbents are good adsorbents because free forces increases on subdivision.

(*ii*) **Two features of chemical adsorption:**

1. Unlike physical adsorption, chemical adsorption has high enthalpy of adsorption.
2. Unlike physical adsorption, chemical adsorption is specific.

Q2. (*a*) Compare physical adsorption and chemical adsorption in terms of rate and prevailing temperature.

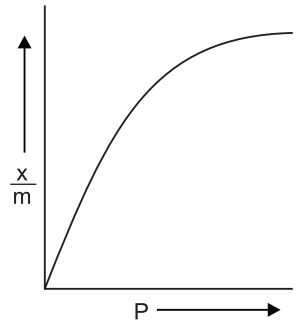
(*b*) Show graphically how the amount of gas absorbed on a solid in physical adsorption varies with (*i*) pressure and (*ii*) temperature. [*AI* 2003]

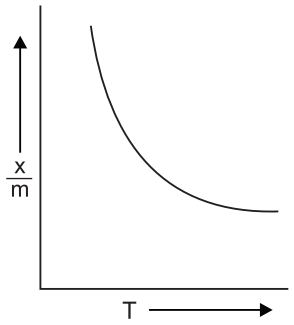
Ans. (*a*) 1. Physical adsorption takes place usually at low temperature. On the contrary chemical adsorption takes place at relatively high temperature.

2. Physical adsorption takes place with an appreciably good rate. The later decreases with rise in temperature.

The chemical adsorption takes place with a pretty good rate with rise in temperature. However, after a limit its rate decreases with rise in temperature.

(*b*)





Q3. Differentiate between physisorption and chemisorption.

Ans.

Physisorption	Chemisorption
1. It arises because of van der Waals' forces.	1. It is caused by chemical bond formation.
2. It depends on the nature of gas. More easily liquefiable gases are adsorbed readily.	2. It also depends on the nature of gas. Gases which can react with the adsorbent show chemisorption.
3. It is reversible in nature.	3. It is irreversible.
4. It is not specific in nature.	4. It is highly specific in nature.
5. Enthalpy of adsorption is low.	5. Enthalpy of adsorption is high.
6. Low temperature is favourable for adsorption. It decreases with the increase of temperature.	6. High temperature is favourable for adsorption. It decreases with increase of temperature.
7. No appreciate activation energy is needed.	7. High activation energy is sometimes needed.

Q4. Give reasons for the following:

(*a*) Enzyme catalysts are highly specific in their action.

(*b*) The path of light becomes visible when it is passed through As_2S_3 sol in water.

(*c*) The ethalpy in case of chemisorption is usually higher than that of physisorption.

Ans.

(*a*) This is because each enzyme has a specific active site on which only a particular substrate can bind.

(*b*) This is because of Tyndall effect caused due to the scattering of light by colloidal particles of As_2S_3 sol.

(*c*) Chemisorption involves the formation of a chemical bond between adsorbent and adsorbate molecule which involves high energy changes while in physisorption, the molecules of adsorbate and adsorbent are held by weak van der Waals' interactions.

IV. Value-Based Questions

Q1. After entering a closed coal mine area, Ravi found difficulty in breathing, also felt nausea.

(*a*) What could be the reason for this?

(*b*) How could Ravi estimate the level of the pollutant?

(*c*) As a citizen of the country what should be his course of action further?

Ans.

(*a*) In coal mines due to lack of oxygen a small percentage of carbon monoxide is formed. This carbon monoxide being poisonous is the reason for the symptoms.

(*b*) Ravi could estimate the level of CO using I_2O_5.

(*c*) Ravi should immediately inform the concerned authority about the excess of CO in the coal mine.

Q2. After cleaning the refrigerator thoroughly, Rohit closed it and kept it switched off for two days. After that on opening it, he got a foul smell. His neighbour advised him to keep a piece of charcoal in the fridge.

(*a*) As a student of chemistry explain why the neighbour suggested to keep a piece of charcoal in fridge?

(*b*) What value can be drawn from this?

Ans.

(*a*) The charcoal piece adsorbs the foul smelling gases. E.g., in a compost pit

too charcoal can be added to remove the foul smell.

(*b*) We can reduce the air-pollution of air by reducing bad smell.

Q3. Ramesh went to a Cinema theatre driving his car under foggy weather and met with an accident due to unbalanced driving with hindered beam of light.

(*a*) Define Tyndall effect.

(*b*) Which type of colloid is the fog?

(*c*) Mention the values associated with the above situation.

Ans.

(*a*) When a beam of light is passed through a colloidal solution, the path of beam is illuminated, it is called Tyndall effect.

(*b*) In fog, dispersed phase is liquid and dispersion medium is gas.

(*c*) Self awareness, critical thinking.

Q4. Your friend's father is working in coal mines and he is having asthma. In your friend's family only his father is the earning member. As a student of Chemistry what will you suggest to your friend's father?

Ans. His faster is suggested to wear a gas-mask while working. Gas mask is a device which consists of activated charcoal or a mixture of absorbents that can be used for breathing in coal mines and to absorb the poisonous gases.

V. HOTS Questions

Q1. (*a*) Heat of adsorption is greater for chemisorption than physisorption. Why?

(*b*) What is colloidion?

(*c*) Differentiate between peptization and coagulation.

Ans. (*a*) Due to the formation of chemical bond between adsorbate and Adsorbent.

(*b*) 4% solution of nitro cellulose in a mixture of alcohol and ether.

(*c*) Peptisation is the process of converting a precipitate into colloidal sol by adding an electrolyte. But coagulation is the settling of colloidal particles.

Q2. Dialysis is a method of purification of sols. But prolonged dialysis of the sol makes it unstable. Why ?

Ans. Traces of electrolytes in the sol, impart charge to the dispersed phase particles making it stable. Prolonged dialysis removes all the electrolytes, thus making the sol unstable.

Q3. Why the sun looks red at the time of setting? Explain on the basis of colloidal properties.

Ans. At the time of setting, the sun is at the horizon. The light emitted by the sun has to travel a longer distance. As a result, the blue part of the light is scattered away by the dust particles in the atmosphere. Hence the red part is visible.

Q4. SnO_2 forms a positively charged colloidal sol in acidic medium and a negatively charged sol in the basic medium. Why?

Ans. SnO_2 is amphoteric in nature. It reacts with acid, e.g. HCl to form $SnCl_4$ in the solution. The common Sn^{4+} ions are adsorbed on the surface of SnO_2 particles giving them a positive charge. SnO_2 reacts with a base e.g., NaOH to form Sodium Stannate in the solution. These stannate ions are adsorbed on the surface of SnO_2 particles giving them a negative charge.

Q5. What is meant by induced catalysis ? Give an example.

Ans. It is the phenomenon in which a chemical reaction increases the rate of another reaction which otherwise may not occur in similar conditions. For e.g., Sodium arsenite (Na_3AsO_3) is not oxidised in air but if air is blown into a solution containing Na_3AsO_3 and Na_2SO_3, then both AsO_3^{3-} and SO_3^{2-} ions are oxidised.