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

Soln: The surface phenomenon of crowding up of molecules of a substance at the base surface rather than in the mass (bulk) of a solid or liquid is called Adsorption. Adsorbate is the substance that gets adsorbed and the adsorbent is the substance on whose surface the adsorption takes place. Here, the concentration of the adsorbate on the surface of the adsorbent increases. The concentration of the substance remains at the surface only in the case of adsorption. It does not penetrate through the surface to the bulk of the solid or liquid. For example, on dipping a chalk stick into an ink solution, there is only a color change on its surface and it will be found to be white from inside when the chalk stick is broken.

On the other hand, the process of absorption is a bulk phenomenon. In absorption, the substance gets uniformly distributed throughout the bulk of the solid or liquid.

Question 5.2: What is the difference between physisorption and chemisorption?

Soln:

Physisorption		Chemisorption
1	In this type of adsorption, the adsorbateand the adsorbent are attached to each other with weak van der Waal's forces of attraction.	In this type of adsorption, the adsorbate and the surface of the adsorbent are bonded with strong chemical bonds.
2.	No new compound is formed in the process.	The process results in the formation of new compounds at the surface of the adsorbent.
3.	It is generally found to be reversible in nature.	It is usually irreversible in nature.
4.	Weak van der Waal's forces of attraction causes low Enthalpy of adsorption. The values lie in the range of 20- 40 kJ/mol.	Enthalpy of adsorption is high as chemical bonds are formed. The values lie in the range of 40-400 kJ mol-1.
5.	Low temperature conditions are favorable.	It is favored by high temperature conditions.
6.	It is an example of multi-layer adsorption.	It is an example of mono-layer adsorption.

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

Soln: Adsorption is directly proportional to the surface area as adsorption is surface phenomenon. A finely divided substance behaves like a good adsorbent because it has a large surface area. Both physisorption and chemisorption increase with an increase in the surface area.

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

Soln: Rate of adsorption of a gas on a solid surface depends on various factors:

(1) Nature of the gas:

There is a strong Van der Waal's forces in easily liquefiable gases hence, easily liquefiable gases such as NH_3, HCl etc. are adsorbed to a great extent in comparison to gases such as H_2, O_2 etc.

(2) Surface area of the solid

The adsorption rate of a gas on the solid surface increases with the increase in the surface area of the adsorbent.

(3) Effect of pressure

Adsorption increases with an increase in pressure and, as a result adsorption is a reversible process and is accompanied by a decrease in pressure

(4) Effect of temperature

Adsorption is an exothermic process. Thus, in accordance with Le-Chatelier's principle, the magnitude of adsorption decreases with an increase in temperature.

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

Soln:

The adsorption isotherm is the plot between the extent of adsorption $\left(\frac{x}{m}\right)$ against the pressure of gas (P) at constant temperature (T).

Freundlich adsorption isotherm:

An empirical relationship between the quantity of gas adsorbed by the unit mass of solid adsorbent and pressure at a specific temperature is given by Freundlich adsorption isotherm.

$\frac{x}{m}$ reaches the maximum value at pressure P_S, observed from the given plot. P_S is called the saturation pressure. Three cases arise from the graph now.

Case I- At low pressure:

The pressure in the straight and sloping plot is directly proportional to

$\frac{x}{m}$ i.e. $\frac{x}{m} \alpha P$ $\frac{x}{m}$ = kP (k is constant)

Case II- At high pressure:

$\frac{x}{m}$ becomes independent of P values when pressure exceeds the saturated pressure,

$\frac{x}{m} \alpha P^o$ $\frac{x}{m}$ = kP^o

Case III – At intermediate pressure:

$\frac{x}{m}$ depends on P raised to the powers between 0 and 1, at intermediate pressure. This relationship is known as the Freundlich adsorption isotherm.

$\frac{x}{m} \alpha P^{\frac{1}{n}}$ $\frac{x}{m} \alpha P^{\frac{1}{n}}$ = K $P^{\frac{1}{n}}$ n > 1

Now, taking log:

$$\log \frac{x}{m} = \log k + \frac{1}{n} \log P$$

On plotting the graph between $\log\left(\frac{x}{m}\right)$ and log P, a straight line is obtained with the slope equal to $\frac{1}{n}$

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

Soln: Increasing the adsorbing power of the adsorbent is known as activating an adsorbent.

Adsorbents are activated by the following ways:

(i) The surface area of the adsorbent can be increased. Breaking it into smaller pieces or powdering it, is one way of doing it.

(ii) Activation of the adsorbent can be done by some specific treatments. For example, wood charcoal's activated is done by heating it between 650 K and 1330 K in vacuum or air. It expels all the gases absorbed or adsorbed and thus, creates a space for adsorption of gases.

Question 5.7: What role does adsorption play in heterogeneous catalysis?

Soln: **Heterogeneous catalysis:** It is catalytic process which involves the presence of catalyst and reactants in different phases. The adsorption theory explains this type of heterogeneous catalytic action. The mechanism of catalysis involves the following steps:

(i) The reactant molecules are adsorbed on the catalyst surface.

(ii) The formation of an intermediate is caused by occurrence of a chemical reaction.

(iii) The products are desorped from the catalyst surface

(iv) The products are diffused away from the catalyst surface.

In this process, the catalyst is present in the solid state and the reactants are usually present in the gaseous state. Gaseous molecules are then adsorbed on the surface of the catalyst. The rate of reaction increases when the concentration of reactants on the surface of the catalyst increases. In such reactions, the products have very less affinity for the catalyst and are quickly desorbed, thereby making the surface free for other reactants.

Question 5.8: Why is adsorption always exothermic ?

Soln: Adsorption is always exothermic. This statement can be explained in two ways.

(i) The residual forces on the surface of the adsorbent are decreased due to adsorption. As a result, the surface energy of the adsorbent is also reduced. Therefore, adsorption is always exothermic.

(ii) ΔH of adsorption is always negative. The movement of a gas is restricted when it is adsorbed on a solid surface. This leads to a decrease in the entropy of the gas i.e., ΔS is negative. Now for a process to be spontaneous, ΔG should be negative.

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

Since, ΔS is negative, ΔH has to be negative to make ΔG negative. Hence, adsorption is always exothermic.

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

Soln: One of the criteria of classifying colloids is the physical state of the dispersed phase and dispersion medium. Depending upon the type of the dispersed phase and dispersion medium (solid, liquid, or gas), there can be eight types of colloidal systems.

	Dispersed phase	Dispersion medium	Type of colloid	Example
1.	Solid	Solid	Solid Sol	Gemstone
2.	Solid	Liquid	Sol	Paint
3.	Solid	Gas	Aerosol	Smoke
4.	Liquid	Solid	Gel	Cheese
5.	Liquid	Liquid	Emulsion	Milk
6.	Liquid	Gas	Aerosol	Fog
7.	Gas	Solid	Solid foam	Pumice stone
8.	Gas	Liquid	Foam	Froth

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

Soln: **Effect of pressure:**

Adsorption increases with an increase in pressure, since adsorption is a reversible process and is accompanied by a decrease in pressure.

Effect of temperature:

In accordance with Le-Chatelier's principle, the magnitude of adsorption decreases with an increase in temperature. Thus, adsorption is an exothermic process.

Question 5.11: What are lyophilic and lyophobic sols? Give one example of each type. Why are hydrophobic sols easily coagulated ?

Soln: **(i) Lyophilic sols:** Lyophilic sols are colloidal sols that are formed by mixing substances such as gum, gelatin, starch, etc. with a suitable liquid (dispersion medium). These sols are reversible in nature i.e., if two constituents of a sol are separated by any process, such as evaporation, then the sol can be prepared again simply by shaking the mixture of dispersion medium and dispersion phase.

(ii) Lyophobic sols: Colloidal sols are not formed, when substances such as metals and their sulphides are mixed with the dispersion medium. Only special methods are used to prepare their colloidal sols. Such sols are called lyophobic sols. These sols are irreversible in nature. For example: sols of metals.

Now, two things determine the stability of hydrophilic sols – the salvation of a colloidal particle and the presence of a gas.

At the same time, the presence of a charge determines the stability of a hydrophobic sol. Therefore, the former is much more stable than the latter. If the charge of hydrophobic sols is removed (by addition of electrolytes), then the particles present in them come closer and form aggregates, leading to precipitation.

Question 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?

Soln: (i) **In multi-molecular colloids**, the colloidal particles are an aggregate of atoms or small molecules with a diameter of less than 1 nm. Van der Waal's forces of attraction are responsible to hold together the molecules in the aggregate. Examples of such colloids include gold sol and sulphur sol.

(ii) **In macro-molecular colloids**, Large molecules having colloidal dimensions is the shape of the colloidal particles. These particles have a high molecular mass. Sol is obtained on dissolving these particles in a liquid. For example: starch, nylon, cellulose, etc.

(iii) At low concentrations certain substances tend to behave like normal electrolytes. However, at higher concentrations, due to the formation of aggregated particles these substances behave like colloidal solutions. Such colloids are called aggregated colloids.

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

Soln: Protein molecules of high molecular masses are termed as enzymes. Colloidal solutions are formed when these are dissolved in water. These are complex, nitrogenous organic compounds produced by living plants and animals. Enzymes are also called 'biochemical catalysts'.

Mechanism of enzyme catalysis:

Various cavities are present with characteristic shapes, on the surface of the enzymes. Such cavities possess active groups such as $-NH_2$, $-COOH$, etc. Complementary shape of the reactant molecules fit into the cavities just like a key fits into a lock. Activated complexes are formed due to this. This complex then decomposes to give the product.

Hence,

Step 1: $E + S \rightarrow ES^+$

(Activated complex)

Step 2: $ES^+ \rightarrow E + P$

Question 5.14: How are colloids classified on the basis of
(i) physical states of components
(ii) nature of dispersed phase and
(iii) interaction between dispersed phase and dispersion medium?

Soln: Colloids can be classified on various basis:

(i) By components we mean the dispersed phase and dispersion medium i.e. the physical state of the components. Therefore, we can have eight types of colloids depending on whether the components are solids, liquids or gases..

(ii) Sols can be divided on the basis of as:

Dispersion Medium	Name of sol
Water	Aquasol or hydrosol
Alcohol	Alcosol
Benzene	Benzosol
Gases	Aerosol

(iii) The colloids can be classified as lyophilic (solvent attracting) and lyophobic (solvent repelling) on the basis of the nature of the interaction between the dispersed phase and dispersion medium.

Question 5.15: Explain what is observed
(i) when 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 a colloidal sol?

Soln:

(i) Scattering of light is observed when a beam of light is passed through a colloidal solution. This is known as the Tyndall effect. The path of the beam is illuminated in the colloidal solution with this scattering of light.

(ii) When NaCl is added to ferric oxide sol, it dissociates to give Na^+ and Cl^- ions. Ferric oxide sol particles are positively charged. Thus, when negatively charged Cl^- ions are present, ferric oxide sol particles gets coagulated.

(iii) The colloidal particles are charged and carry either a positive or negative charge. The system is made neutral when the dispersion medium carries an equal and opposite charge. The colloidal particles move towards the oppositely charged electrode when they are under the influence of an electric current. When they come in contact with the electrode, they lose their charge and coagulate.

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

Soln: Emulsion is defined as the colloidal solution in which both the dispersed phase and dispersion medium are liquids.

There are two types of emulsions:

(a) Oil in water type: Here, water is the dispersion medium while oil is the dispersed phase. For example: milk, vanishing cream, etc.

(b) Water in oil type: Here, oil is the dispersion medium while water is the dispersed phase. For example: cold cream, butter, etc.

Question 5.17: How do emulsifires stabilise emulsion? Name two emulsifiers.

Soln:

The process of decomposition of an emulsion into its constituent liquids is called demulsification. Examples of demulsifiers are surfactants, ethylene oxide, etc.

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

Soln: Emulsification and micelle formation determines the cleansing action of soap. Sodium and potassium salts of long-chain fatty acids($R\text{-}COO\text{-}Na^+$) is the basic mixture of a soap. Sodium is attached to the end of the molecule, which is polar in nature, while the alkyl-end is non- polar. Thus, a soap molecule contains both polar and non-polar part. i.e. hydrophilic and hydrophobic part respectively.

Micelle is formed when water containing dirt is mixed with soap, the molecules of soap surround the dirt particles in such a manner that the dirt molecule and the hydrophobic part gets attached and the hydrophilic parts point away from the dirt molecule. Thus, non-polar group dissolves in the dirt particle while polar group dissolves in the dirt particle. Now, a stable emulsion is formed as these micelles are negatively charged and they do not coalesce.

Question 5.19: **Give four examples of heterogeneous catalysis.**

Soln: **(i)** Sulphur trioxide is formed by the oxidation of sulphur dioxide. In this reaction, Pt acts as a catalyst.

$$2SO_{2(g)} \overset{Pt_{(s)}}{\rightarrow} 2SO_{3(g)}$$

(ii) Combination of dinitrogen and dihydrogen in the presence of finely divided iron results in the formation of ammonia.

$$N_{2(g)} + 3H_{2(g)} \overset{Fe_{(s)}}{\rightarrow} 2NH_{3(g)}$$

This process is called the Haber's process.

(iii) Oswald's process: Oxidation of ammonia to nitric oxide in the presence of platinum.

$$4NH_{3(g)} + 5O_{2(g)} \overset{Pt_{(s)}}{\rightarrow} 4NO_{(g)} + 6H_2O_{(g)}$$

(iv) Hydrogenation of vegetable oils in the presence of Ni.

$$Vegetableoil_{(l)} + H_{2(g)} \overset{Ni_s}{\rightarrow} Vegetableghee_{(s)}$$

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

Soln: **(a) Activity of a catalyst:**

The ability to increase the rate of a particular reaction is called its activity. The activity of a catalyst is decided by the main factor i.e. chemisorption. When reactants are adsorbed on the catalyst surface, the process should neither be too strong nor too weak. It should just be strong enough to make the catalyst active.

(b) Selectivity of the catalyst:

The selectivity of a catalyst is defined as the ability of the catalyst to direct a reaction to yield a particular product. For example, by using different catalysts, we can get different products for the reaction between H_2 and CO.

(i) $CO_{(g)} + 3H_{2(g)} \overset{Ni}{\rightarrow} CH_{4(g)} + H_2O_{(g)}$

(ii) $CO_{(g)} + 2H_{2(g)} \overset{CuZnO-CrO_3}{\rightarrow} CH_3OH_{(g)}$

(iii) $CO_{(g)} + H_{2(g)} \overset{Cu}{\rightarrow} HCHO_{(g)}$

Question 5.21: Describe some features of catalysis by zeolites.

Soln: Zeolites are alumino-silicates that are micro-porous in nature. Zeolites are also shape- selective catalysts as they have a honeycomb-like structure. Some silicon atoms are replaced by aluminium atoms in the extended 3D-network of silicates, giving them an Al–O–Si framework. The pores and cavity size of the zeolites makes the reactions very sensitve. Zeolites are commonly used in the petrochemical industry.

Question 5.22: What is shape selective catalysis?

Soln: A catalytic reaction which depends upon the product molecules and on the size of the reactant and the pore structure of the catalyst is called shape-selective catalysis. For example, catalysis by zeolites is a shape-selective catalysis. Thus, molecules having a pore size more than 260-740 pm cannot enter the zeolite and undergo the reaction.

Question 5.23: Explain the following terms:

(i)Electrophoresis

(ii) Coagulation

(iii) Dialysis

(iv)Tyndall effect

Soln: (i) Electrophoresis:

An applied electric field influences the colloidal particles to move randomly, this is known as electrophoresis. Negatively charged particles move towards the anode while, positively charged particles move to the cathode. As the particles reach oppositely charged electrodes, they become neutral and get coagulated.

(ii) Coagulation:

Conversion of a colloid into a precipitate is called coagulation, and the process of settling down of colloidal particles.

(iii) Dialysis:

When a dissolved substance is removed through a membrane from a colloidal solution by the means of diffusion is known as dialysis. Small molecules and ions can pass through animal membranes unlike colloidal particles is the main principle of this process.

(iv)Tyndall effect:

Tyndall effect is seen when a beam of light is allowed to pass through a colloidal solution, it becomes visible like a column of light. This phenomenon takes place as particles of colloidal dimensions scatter light in all directions.

Question 5.24: Give four uses of emulsions.

Soln: Uses of emulsions are:

(i) Formation of emulsions determine the cleansing action of the soap.

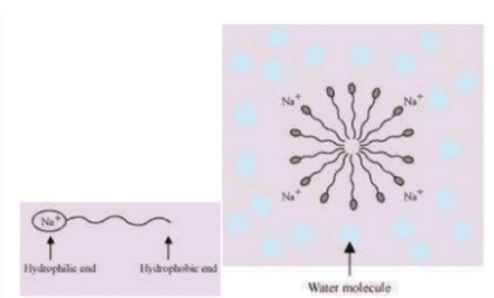
(ii) The process of emulsification is responsible for the digestion of fats in intestines.

(iii) Emulsions are formed on adding antiseptics and disinfectants to water.

(iv)Emulsification is used to make medicines.

Question 5.25: What are micelles? Give an example of a micellers system.

Soln: When soaps and detergents are dissolved in water, it forms micelle. The molecules of such substances contain a hydrophobic and a hydrophilic part. When they are present in the water, these substances arrange themselves in spherical structures in such a manner that their hydrophilic parts are pointing towards the outside, while the hydrophobic parts are present towards the centre (as shown in the given figure). This is known as micelle formation.



Question 5.26: Explain the terms with suitable examples:

(i) Alcosol

(ii) Aerosol

(iii) Hydrosol

Soln: **(i) Alcosol:**

A colloidal solution having a solid substance as the dispersed phase and alcohol as the dispersion medium is called an alcosol.

For example: colloidal sol of cellulose nitrate in ethyl alcohol is an alcosol.

(ii) Aerosol:

A colloidal solution having a solid as the dispersed phase and a gas as the dispersion medium is called an aerosol.

For example: fog

(iii) Hydrosol:

A colloidal solution having a solid as the dispersed phase and water as the dispersion medium is called a hydrosol.

For example: starch sol or gold sol

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

Soln: Common salt (a typical crystalloid in an aqueous medium) behaves as a colloid in a benzene medium. Hence, we can say that a colloidal substance does not represent a separate class of substances. When the size of the solute particle lies between 1 nm and 1000 nm, it behaves as a colloid.

Hence, we can say that colloid is not a substance but a state of the substance which is dependent on the size of the particle. A colloidal state is intermediate between a true solution and a suspension.