Chapter: Surface Chemistry

Intext Questions

Question 5.1:

Write any two characteristics of Chemisorption.

Answer

1. Chemisorption is highly specific in nature and it occurs only if there is a possibility of chemical bonding between the adsorbate and the adsorbent.

2. Just like physisorption, chemisorption also increases with an increase in the surface area of the adsorbent.

Question 5.2:

Why does physisorption decrease with the increase of temperature?

Answer

Physisorption is generally exothermic in nature. Thus, in accordance with Le-Chateliere's principle, it decreases with an increase in temperature. It means that physisorption takes place more readily at a lower temperature.

Question 5.3:

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

Answer

Powdered substances are usually more effective adsorbents than their crystalline forms because when a substance is powdered, its surface area increases and physisorption is directly proportional to the surface area of the adsorbent.

Question 5.4:

Why is it necessary to remove CO when ammonia is obtained by Haber's process?

Answer

It is important to remove CO in the synthesis of ammonia as CO adversely affects the activity of the iron catalyst, used in Haber's process.

Question 5.5:

Why is the ester hydrolysis slow in the beginning and becomes faster after sometime?

Answer

Ester hydrolysis can be denoted as:

$$\text{Ester} + \text{Water} \rightarrow \text{Acid} + \text{Alcohol}$$

The acid produced in the above reaction acts as a catalyst and makes the reaction faster. Substances that act as catalysts in the same reaction in which they are obtained as products are called autocatalysts.

Question 5.6:

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

Answer

The role of desorption in the process of catalysis is to make the surface of the solid catalyst free for the fresh adsorption of the reactants on the surface.

Question 5.7:

What modification can you suggest in the Hardy-Schulze law?

Answer

Hardy-Schulze law states that: "The greater the valence of the flocculating ion added, the greater is its power to cause precipitation." This law considers only the charge carried by an ion, not its size. The smaller the size of an ion, the more will be its polarising power. Therefore, Hardy-Schulze law can be modified in terms of the polarising power of the flocculating ion. So, the modified Hardy-Schulze law can be stated as "The greater the polarising power of the flocculating ion added, the greater is its power to cause precipitation."

Question 5.8:

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

Answer

Whenever a substance gets precipitated, some ions that combine to form the precipitate get adsorbed on the surface of the precipitate. Thus, it becomes important to wash the precipitate before estimating it quantitatively to remove these adsorbed ions or other such impurities.

Exercise

Question 5.1:

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

Answer

The surface phenomenon of accumulation of molecules of a substance at the surface rather than in the bulk of a solid or liquid is known as adsorption. Adsorbate is the substance that gets adsorbed and adsorbent is the substance on whose surface the adsorption takes place. In this, the concentration of the adsorbate on the surface of the adsorbent increases. The substance gets concentrated at the surface only in adsorption. It does not penetrate through the surface to the bulk of the solid or liquid. For example, if we dip a chalk into ink solution, only its surface becomes coloured. If we break the chalk stick, it will be white from inside. The process of absorption is a bulk phenomenon. The substance gets uniformly distributed throughout the bulk of the solid or liquid in absorption.

Question 5.2:

What is the difference between physisorption and chemisorption?

Answer

	Physisorption	Chemisorption
1.	The adsorbate is attached to the surface of the adsorbent with weak vander Waal's forces of attraction.	Strong chemical bonds are formed between the adsorbate and the surface of the adsorbent.
2.	No new compound is formed.	New compounds are formed at the surface of the adsorbent.
3.	It is reversible in nature.	It is generally irreversible in nature.
4.	The enthalpy of adsorption is low as weak vander Waal's forces of attraction are involved. The values lie in between $20-40\ kJ\ mol^{-1}$.	The enthalpy of adsorption is high as chemical bonds are formed. The values lie in between $40-400\ kJ\ mol^{-1}$.
5.	This type of adsorption is favoured by low temperature conditions.	This type of adsorption is favoured by high temperature conditions.
6.	This is an example of multi-layer adsorption.	This is an example of mono-layer adsorption.

Question 5.3:

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

Answer

Adsorption is generally a surface phenomenon. So, it is directly proportional to the surface area. A finely divided substance usually has a large surface area. Physisorption and chemisorption increase with an increase in the surface area. Thus, a finely divided substance behaves as a good adsorbent.

Question 5.4:

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

Answer

There are different factors which affect the rate of adsorption of a gas on a solid surface.

(1) Nature of the gas:

Easily liquefiable gases like NH_3, HCl etc. are adsorbed to a great extent in comparison to gases such as H_2, O_2 etc. This is because of the fact that Van der Waal's forces are stronger in easily liquefiable gases.

(2) Surface area of the solid

The greater the surface area of the adsorbent, the greater is the adsorption of a gas on the solid surface.

(3) Effect of pressure

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

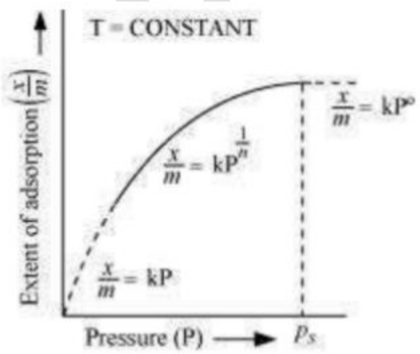
(4) Effect of temperature

Adsorption is usually an exothermic process. Therefore, 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.

Answer



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

Freundlich adsorption isotherm:

Freundlich adsorption isotherm usually gives an empirical relationship between the quantity of gas adsorbed by the unit mass of solid adsorbent and pressure at a specific temperature. From the given plot we can say that at pressure P_s, $\frac{x}{m}$ reaches the maximum valve. P_s is known as the saturation pressure. Three cases arise from the above graph.

Case I- At low pressure:

The plot is straight and sloping, which indicates that the pressure in directly proportional to $\frac{x}{m}$ i.e.

$$\frac{x}{m} \alpha P$$

$\frac{x}{m} = kP$ where k is a constant.

Case II- At high pressure:

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

$$\frac{x}{m} \alpha P^{\circ}$$

$$\frac{x}{m} = kP^{\circ}$$

Case III- At intermediate pressure:

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

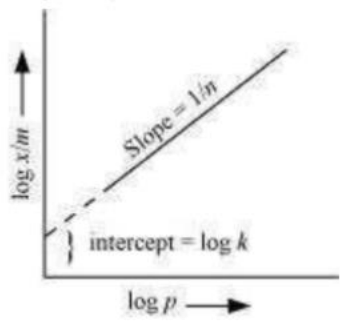
$$\frac{x}{m} \alpha P^{\frac{1}{n}}$$

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

Take logarithm on both sides:

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

On plotting the graph between $\log \frac{x}{m}$ and $\log P$, a straight line is obtained with the slope equal to $\frac{1}{n}$ and the intercept equal to $\log k$.



Question 5.6:

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

Answer

By activating an adsorbent, we increase the adsorbing power of the adsorbent.

Some of the ways to activate an adsorbent are as follows:

(i) By increasing the surface area of the adsorbent. This can be achieved by breaking it into smaller pieces or powdering it.

(ii) Some specific treatments can also lead to the activation of the adsorbent. For example, wood charcoal is activated by heating it between $650\ K$ and $1330\ K$ in vacuum or air. It expels all the gases absorbed or adsorbed and therefore, creates a space for adsorption of gases.

Question 5.7:

What role does adsorption play in heterogeneous catalysis?

Answer

Heterogeneous catalysis:

It is a catalytic process in which the catalyst and the reactants are present in different phases. This heterogeneous catalytic action can be described in terms of the adsorption theory. The mechanism of catalysis involves the below steps:

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

(ii) Occurrence of a chemical reaction through the formation of an intermediate.

(iii) De-sorption of products from the catalyst surface

(iv) Diffusion of products away from the catalyst surface.

The reactants are generally present in the gaseous state and the catalyst is present in the solid state. Gaseous molecules are adsorbed on the surface of the catalyst. As the concentration of reactants on the surface of the catalyst increases, the rate of reaction also increases. In such type of reactions, the products have very less affinity for the catalyst and are quickly desorbed, thus making the surface free for other reactants.

Question 5.8:

Why is adsorption always exothermic?

Answer

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

(i) Adsorption usually leads to a decrease in the residual forces on the surface of the adsorbent. It causes a decrease in the surface energy of the adsorbent. Thus, adsorption is always exothermic.

(ii) ΔH of adsorption is always negative. Whenever a gas is adsorbed on a solid surface, its movement is restricted leading to a decrease in the entropy of the gas i.e., ΔS is negative. For a process to be spontaneous, ΔG should be negative.

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

As ΔS is negative, ΔH should be negative to make ΔG negative. Thus, 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?

Answer

A criterion for classifying colloids is the physical state of the dispersed phase and dispersion medium. Depending upon the type of the dispersed phase and dispersion medium 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.

Answer

Effect of pressure

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

Effect of temperature

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

Question 5.11:

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

Answer

(i) Lyophilic sols:

Colloidal sols that are formed by mixing substances like gelatin, starch, gum, etc. with a suitable liquid are known as lyophilic sols. These sols are usually reversible in nature i.e., if two constituents of the sol are separated by any means (like evaporation), then the sol can be prepared again by simply mixing the dispersion medium with the dispersion phase and shaking the mixture.

(ii) Lyophobic sols:

When substances like metals and their sulphides etc. are mixed with the dispersion medium, they do not form colloidal sols. Their colloidal sols can be prepared only by some special methods. Such type of sols are known as lyophobic sols. These sols are usually irreversible in nature. For example: sols of metals.

The stability of hydrophilic sols depends on two things- the presence of a charge and the salvation of colloidal particles. The stability of hydrophobic sols is only because of the presence of a charge. Thus, the latter are much less stable than the former. If the charge of hydrophobic sols is removed, then the particles present in them get 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?

Answer

(i) In multi-molecular colloids, the colloidal particles are usually an aggregate of atoms or small molecules having a diameter of less than $1\ \text{nm}$. The molecules in the aggregate are held together by van der Waal's forces of attraction. Some examples of such colloids are gold sol and sulphur sol.

(ii) In macro-molecular colloids, the colloidal particles are usually large molecules having colloidal dimensions. These particles have a high molecular mass. When these particles are dissolved in a liquid, we get a sol. For example: nylon, cellulose, starch, etc.

(iii) Some substances tend to behave like normal electrolytes at lower concentrations. At higher concentrations, these substances behave as colloidal solutions due to the formation of aggregated particles. Such type of colloids are known as aggregated colloids.

Question 5.13:

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

Answer

Enzymes are generally protein molecules of high molecular masses. They form colloidal solutions when they are dissolved in water. They are complex, nitrogenous organic compounds produced by living plants and animals. Enzymes are also known as biochemical catalysts.

Mechanism of enzyme catalysis:

On the surface of the enzymes, some cavities are present with characteristic shapes. They possess active groups such as $-NH_2$, $-COOH$, etc. The reactant molecules having a complementary shape fit into the cavities like a key fits into a lock which leads to the formation of an activated complex. This activated 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 dispersion medium and

(iii) Interaction between dispersed phase and dispersion medium?

Answer

Colloids can be classified on various bases:

(i) On the basis of the physical state of the components i.e. the dispersed phase and dispersion medium. Depending on whether the components are solids, liquids, or gases, we have eight types of colloids.

(ii) On the basis of the dispersion medium, sols can be divided as:

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

(iii) On the basis of the nature of the interaction between the dispersed phase and dispersion medium, the colloids can be divided into lyophilic (solvent attracting) and lyophobic (solvent repelling).

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?

Answer

(i) When a beam of light is passed through a colloidal solution, then scattering of light takes place. This is called the Tyndall effect. The scattering of light illuminates the path of the beam in the colloidal solution.

(ii) When $NaCl$ is added to ferric oxide sol, it dissociates to give Na^+ and Cl^- ions. The particles of ferric oxide sol are positively charged. So, they coagulate in the presence of negatively charged Cl^- ions.

(iii) The colloidal particles are charged and they carry either a positive or negative charge. The dispersion medium carries an equal and opposite charge. It makes the whole system neutral. Under the influence of an electric current, the colloidal particles move towards the oppositely charged electrode and 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.

Answer

Emulsion is a colloidal solution in which both the dispersed phase and dispersion medium are liquids. There are two types of emulsions:

(a) Oil in water type:

Oil is the dispersed phase and water is the dispersion medium. For example: vanishing cream, milk, etc.

(b) Water in oil type:

Water is the dispersed phase and oil is the dispersion medium. For example: butter, cold cream, etc.

Question 5.17:

What is demulsification? Name two demulsifiers.

Answer

Demulsification is the process of decomposition of an emulsion into its constituent liquids.

Example: surfactants, ethylene oxide, etc.

Question 5.18:

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

Answer

The cleansing action of soap is because of emulsification and micelle formation. Soaps are generally sodium and potassium salts of long chain fatty acids, $R-COO^{-}Na^{+}$. The end of the molecule to which the sodium is attached is polar in nature and the alkyl-end is non-polar. So, a soap molecule contains a hydrophilic (polar) and a hydrophobic (nonpolar) part.

When soap is added to water containing dirt, the soap molecules surround the dirt particles in such a way that their hydrophobic parts attach to the dirt molecule and the hydrophilic parts point away from the dirt molecule. This is called micelle formation. So, the polar group dissolves in water while the non-polar group dissolves in the dirt particle. As these micelles are negatively charged, they do not coalesce and a stable emulsion is formed.

Question 5.19:

Give four examples of heterogeneous catalysis.

Answer

(i) Oxidation of sulphur dioxide to form sulphur trioxide. In this reaction, Pt acts as a catalyst.

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

(ii) Formation of ammonia by the combination of dinitrogen and dihydrogen in the presence of finely divided iron.

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

This process is known as Haber’s process.

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

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

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

$$\text{Vegetable oil}_{(l)} + H_{2(g)} \xrightarrow{Ni_{(s)}} \text{Vegetable ghee}_{(s)}$$

Question 5.20:

What do you mean by activity and selectivity of catalysts?

Answer

(a) Activity of a catalyst:

The activity of a catalyst is the ability of the catalyst to increase the rate of a particular reaction. Chemisorption is the main factor in deciding the activity of a catalyst. The adsorption of reactants on the catalyst surface should not be too strong nor too weak. It should be strong enough to make the catalyst active.

(b) Selectivity of the catalyst:

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

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

(ii) $CO_{(g)} + 2H_{2(g)} \xrightarrow{Cu/ZnO-CrO_3} CH_3OH_{(g)}$

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

Question 5.21:

Describe some features of catalysis by zeolites.

Answer

Zeolites are alumino-silicates that are micro-porous. They have a honeycomb- like structure, which makes them shape-selective catalysts. Zeolites have an extended $3D-$network of silicates in which some silicon atoms are replaced by aluminium atoms, giving an $Al-O-Si$ framework. The reactions taking place in them are very sensitive to the pores and cavity size of the zeolites. They are generally used in the petrochemical industry.

Question 5.22:

What is shape selective catalysis?

Answer

A catalytic reaction which depends upon the pore structure of the catalyst and on the size of the reactant and the product molecules is known as shape-selective catalysis. For example, catalysis by zeolites is a shape-selective catalysis. The pore size present in the zeolites lies between $260-740\ pm$. So, molecules having a pore size greater than this cannot enter the zeolite and undergo the reaction.

Question 5.23:

Explain the following terms: (i)

Electrophoresis (ii) Coagulation

(iii) Dialysis (iv) Tyndall effect.

Answer

(i) Electrophoresis:

The movement of colloidal particles under the influence of an applied electric field is called electrophoresis. Positively charged particles move to the cathode and the negatively charged particles move towards the anode. As the particles reach oppositely charged electrodes, they become neutral and get coagulated.

(ii) Coagulation:

Coagulation is the process of settling down of colloidal particles i.e., conversion of a colloid into a precipitate.

(iii) Dialysis

Dialysis is the process of removing a dissolved substance from a colloidal solution by the means of diffusion through a membrane. It is based on the principle that ions and small molecules can pass through animal membranes unlike colloidal particles.

(iv) Tyndall effect:

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

Question 5.24:

Give four uses of emulsions.

Answer

Four uses of emulsions:

(i) Antiseptics and disinfectants form emulsions when added to water.

(ii) Digestion of fats in intestines takes place by emulsification.

(iii) The cleansing action of soaps is based on the formation of emulsions.

(iv) Emulsification is used to make medicines.

Question 5.25:

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

Answer

Micelle formation is done by substances like soaps and detergents when dissolved in water. The molecules of such substances usually contain a hydrophobic and a hydrophilic part. When present in water, they arrange themselves in spherical structures in such a way that their hydrophobic parts are present towards the centre, while the hydrophilic parts are pointing towards the outside. This is called micelle formation.

Question 5.26:

Explain the terms with suitable examples:

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

Answer

(i) Alcosol:

Alcosol is a colloidal solution having alcohol as the dispersion medium and a solid substance as the dispersed phase.

Example: colloidal sol of cellulose nitrate in ethyl alcohol.

(ii) Aerosol:

Aerosol is a colloidal solution having a gas as the dispersion medium and a solid as the dispersed phase.

Example: fog

(iii) Hydrosol

Hydrosol is a colloidal solution having water as the dispersion medium and a solid as the dispersed phase.

Example: starch sol or gold sol

Question 5.27:

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

Answer

Common salt behaves as a colloid in a benzene medium. So, 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. So, 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.