

Chapter - Surface Chemistry



Topic-1: Adsorption



1 MCQs with One Correct Answer

- Methylene blue, from its aqueous solution, is adsorbed on activated charcoal at 25°C. For this process, the correct statement is [Adv. 2013]
 - The adsorption requires activation at 25°C
 - The adsorption is accompanied by a decrease in enthalpy
 - The adsorption increases with increase of temperature
 - The adsorption is irreversible
- Adsorption of gases on solid surface is generally exothermic because [2004S]
 - enthalpy is positive
 - entropy decreases
 - entropy increases
 - free energy increases
- Rate of physisorption increases with [2003S]
 - decrease in temperature
 - increase in temperature
 - decrease in pressure
 - decrease in surface area



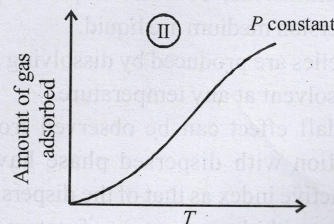
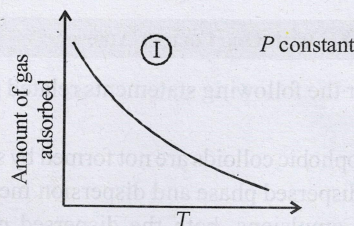
2 Integer Value Answer

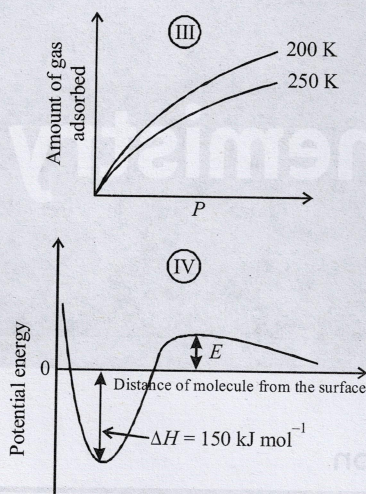
- To form a complete monolayer of acetic acid on 1g of charcoal, 100 mL of 0.5 M acetic acid was used. Some of the acetic acid remained unadsorbed. To neutralize the unadsorbed acetic acid, 40 mL of 1 M NaOH solution was required. If each molecule of acetic acid occupies $P \times 10^{-23} \text{ m}^2$ surface area on charcoal, the value of P is [Adv. 2024]
 [Use given data: Surface area of charcoal = $1.5 \times 10^2 \text{ m}^2 \text{ g}^{-1}$; Avogadro's number (N_A) = $6.0 \times 10^{23} \text{ mol}^{-1}$]
- 20% of surface sites are occupied by N_2 molecules. The density of surface site is $6.023 \times 10^{14} \text{ cm}^{-2}$ and total surface area is 1000 cm^2 . The catalyst is heated to 300 K while N_2 is completely desorbed into a pressure of 0.001 atm and volume of 2.46 cm^3 . Find the number of active sites occupied by each N_2 molecule. [2005 - 4 Marks]



6 MCQs with One or More than One Correct Answer

- The correct option(s) related to adsorption processes is(are) [Adv. 2022]
 - Chemisorption results in a unimolecular layer.
 - The enthalpy change during physisorption is in the range of 100 to 140 kJ mol^{-1} .
 - Chemisorption is an endothermic process.
 - Lowering the temperature favors physisorption processes.
- When O_2 is adsorbed on a metallic surface, electron transfer occurs from the metal to O_2 . The true statement(s) regarding this adsorption is(are) [Adv. 2015]
 - O_2 is physisorbed
 - Heat is released
 - Occupancy of $\pi^* 2p$ of O_2 is increased
 - Bond length of O_2 is increased
- The given graphs/data I, II, III and IV represent general trends observed for different physisorption and chemisorption processes under mild conditions of temperature and pressure. Which of the following choice(s) about I, II, III and IV is (are) correct? [2012]





- (a) I is physisorption and II is chemisorption
 (b) I is physisorption and III is chemisorption
 (c) IV is chemisorption and II is chemisorption
 (d) IV is chemisorption and III is chemisorption

9. The correct statement(s) pertaining to the adsorption of a gas on a solid surface is (are) [2011]
 (a) Adsorption is always exothermic
 (b) Physisorption may transform into chemisorption at high temperature
 (c) Physisorption increases with increasing temperature but chemisorption decreases with increasing temperature
 (d) Chemisorption is more exothermic than physisorption, however it is very slow due to higher energy of activation



10 Subjective Problems

10. 1 g of charcoal adsorbs 100 mL 0.5 M CH_3COOH to form a monolayer, and thereby the molarity of CH_3COOH reduces to 0.49. Calculate the surface area of the charcoal adsorbed by each molecule of acetic acid. Surface area of charcoal = $3.01 \times 10^2 \text{ m}^2/\text{g}$. [2003 - 2 Marks]



Topic-2: Catalysis and Theories of Catalysis



1 MCQs with One Correct Answer

1. Identify the correct statement regarding enzymes [2004]
 (a) Enzymes are specific biological catalysts that cannot be poisoned

- (b) Enzymes are normally heterogeneous catalysts that are very specific in their action
 (c) Enzymes are specific biological catalysts that can normally function at very high temperatures ($T \sim 1000\text{K}$)
 (d) Enzymes are specific biological catalysts that possess well-defined active sites



Topic-3: Colloids and Emulsions



1 MCQs with One Correct Answer

1. Consider the following statements related to colloids. [Adv. 2023]
 (I) Lyophobic colloids are not formed by simple mixing of dispersed phase and dispersion medium.
 (II) For emulsions, both the dispersed phase and the dispersion medium are liquid.
 (III) Micelles are produced by dissolving a surfactant in any solvent at any temperature.
 (IV) Tyndall effect can be observed from a colloidal solution with dispersed phase having the same refractive index as that of the dispersion medium.
 The option with the correct set of statements is
 (a) (I) and (II) (b) (II) and (III)
 (c) (III) and (IV) (d) (II) and (IV)

2. Among the electrolytes Na_2SO_4 , CaCl_2 , $\text{Al}_2(\text{SO}_4)_3$ and NH_4Cl , the most effective coagulating agent for Sb_2S_3 sol is [2009S]
 (a) Na_2SO_4 (b) CaCl_2
 (c) $\text{Al}_2(\text{SO}_4)_3$ (d) NH_4Cl
 3. Among the following, the surfactant that will form micelles in aqueous solution at the lowest molar concentration at ambient condition is : [2008S]
 (a) $\text{CH}_3(\text{CH}_2)_{15}\text{N}^+(\text{CH}_3)_3\text{Br}^-$
 (b) $\text{CH}_3(\text{CH}_2)_{11}\text{OSO}_3^- \text{Na}^+$
 (c) $\text{CH}_3(\text{CH}_2)_6\text{COO}^- \text{Na}^+$
 (d) $\text{CH}_3(\text{CH}_2)_{11}\text{N}^+(\text{CH}_3)_3\text{Br}^-$

4. Lyophilic sols are [2005S]
 (a) Irreversible sols
 (b) They are prepared from inorganic compound
 (c) Coagulated by adding electrolytes
 (d) Self-stabilizing
5. The correct statement(s) related to colloids is(are) [Adv. 2021]
 (a) The process of precipitating colloidal sol by an electrolyte is called peptization.
 (b) Colloidal solution freezes at higher temperature than the true solution at the same concentration.
 (c) Surfactants form micelle above critical micelle concentration (CMC). CMC depends on temperature.
 (d) Micelles are macromolecular colloids.
6. The correct statement(s) about surface properties is (are) [Adv. 2017]
 (a) Adsorption is accompanied by decrease in enthalpy and decrease in entropy of the system
 (b) The critical temperatures of ethane and nitrogen are 563 K and 126 K, respectively. The adsorption of ethane will be more than that of nitrogen on same amount of activated charcoal at a given temperature
 (c) Cloud is an emulsion type of colloid in which liquid is dispersed phase and gas is dispersion medium
 (d) Brownian motion of colloidal particles does not depend on the size of the particles but depends on viscosity of the solution.
7. Choose the correct reason(s) for the stability of the lyophobic colloidal particles. [2012]
 (a) Preferential adsorption of ions on their surface from the solution.
 (b) Preferential adsorption of solvent on their surface from the solution.
 (c) Attraction between different particles having opposite charges on their surface.
 (d) Potential difference between the fixed layer and the diffused layer of opposite charges around the colloidal particles.



6 MCQs with One or More than One Correct Answer



9 Assertion and Reason Statement Type Questions

Each question contains **STATEMENT-1 (Assertion)** and **STATEMENT-2 (Reason)**. Each question has 4 choices (a), (b), (c) and (d) out of which **ONLY ONE** is correct. Mark your answer as

- (a) If both Statement -1 and Statement -2 are correct, and Statement -2 is the correct explanation of the Statement -2.
 (b) If both Statement -1 and Statement -2 are correct, but Statement -2 is not the correct explanation of the Statement -1.
 (c) If Statement -1 is correct but Statement -2 is incorrect.
 (d) If Statement -1 is incorrect but Statement -2 is correct.

8. **Assertion :** Micelles are formed by surfactant molecules above the critical micellar concentration (CMC).

Reason : The conductivity of a solution having surfactant molecules decreases sharply at the CMC. [2007]



Answer Key

Topic-1 : Adsorption

1. (b) 2. (b) 3. (a) 4. (2500) 5. (2) 6. (a, d) 7. (b, c, d) 8. (a, c) 9. (a, b, d)

Topic-2 : Catalysis and Theories of Catalysis

1. (d)

Topic-3 : Colloids and Emulsions

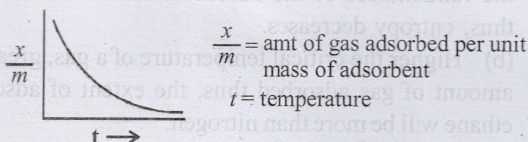
1. (a) 2. (c) 3. (b) 4. (d) 5. (b, c) 6. (a, b) 7. (a, d) 8. (b)

Hints & Solutions



Topic-1: Adsorption

- (b) The adsorption of methylene blue on activated charcoal is an example of physisorption which is exothermic, multilayer and does not have energy barrier.
- (b) When a gas is adsorbed on the surface, the freedom of movement of its molecules becomes restricted. This causes decrease in the entropy of the gas after adsorption, i.e. ΔS becomes negative. Thus, adsorption to be spontaneous, ΔH has to be negative from the equation $\Delta G = \Delta H - T\Delta S$.
- (a) Rate of physisorption increases with decrease of temperature



- (2500)
 Number of moles of unadsorbed CH_3COOH

$$= \frac{V_{\text{NaOH}} \times M_{\text{NaOH}}}{1000} = \frac{40 \times 1}{1000} = 4 \times 10^{-2} \text{ mol}$$
 Number of moles adsorbed CH_3COOH

$$= \frac{V_{\text{CH}_3\text{COOH}} \times M_{\text{CH}_3\text{COOH}}}{1000} = \frac{100 \times 0.5}{1000} = (4 \times 10^{-2})$$

$$= 10^{-2} \text{ mol}$$
 Surface area occupied by one molecular of CH_3COOH

$$= \frac{\text{Total surface area}}{\text{Number of molecules of } \text{CH}_3\text{COOH} \text{ adsorbed}}$$

$$= \frac{1.5 \times 10^2}{\frac{10^{-2} \times 6 \times 10^{23}}{6}} = \frac{150 \times 10^2 \times 10^{-23}}{6}$$

$$= 2500 \times 10^{-23} \text{ m}^2$$

$$\Rightarrow P = 2500$$

- (2) $P_{\text{N}_2} = 0.001 \text{ atm}$, $T = 300 \text{ K}$, $V = 2.46 \text{ cm}^3$
 \therefore Number of N_2 molecules

$$= \frac{PV}{RT} \times N_A = \frac{0.001 \times 2.46 \times 10^{-3}}{0.0821 \times 300} \times 6.023 \times 10^{23}$$

$$= 6.016 \times 10^{16}$$

Now, total number of surface sites = Density \times Total surface area

$$= 6.023 \times 10^{14} \times 1000 = 6.023 \times 10^{17}$$

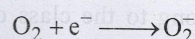
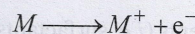
$$\text{Sites occupied by } \text{N}_2 \text{ molecules} = \frac{20}{100} \times 6.023 \times 10^{17}$$

$$= 12.04 \times 10^{16}$$

\therefore No. of sites occupied by each N_2 molecule

$$= \frac{12.04 \times 10^{16}}{6.016 \times 10^{16}} \approx 2$$

- (a, d)
 (a) Chemisorption occurs due to the chemical bond (covalent or ionic) formation between adsorbate and adsorbent. Thus, it results in a unimolecular layer.
 (b) In physisorption, the adsorbate is adsorbed on the solid surface by weak van der Waals force. So, the enthalpy of adsorption is very low, ~ 20 – 40 kJ/mol .
 (c) Chemisorption is exothermic, its enthalpy of adsorption is ~ 80 – 240 kJ/mol .
 (d) Lowering of temperature favours the physisorption over chemisorption.
- (b, c, d) Reaction on metal surface



This is an example of chemisorption.

- (c) There are 2 unpaired electrons in $\pi^* 2p$ orbital of O_2 molecule : In O_2^- the extra electron will go to $\pi^* 2p$ orbital.
 (d) This will decrease the bond order and increase the bond length.
- (a, c) Graph (I) and (III) represent physisorption because, in physisorption, the amount of adsorption decreases with the increase of temperature and increases with the increase of pressure.
 Graph (II) represent chemisorption, because in chemisorption amount of adsorption increases with the increase of temperature. Graph (IV) is showing the formation of a chemical bond, hence chemisorption.

9. (a, b, d)
 (a) ΔH is negative for adsorption
 (b) Fact based
 (d) Chemical bonds are stronger than van der Waal's forces, so chemical adsorption is more exothermic.
10. Number of moles of acetic acid in 100 mL before adding charcoal = 0.05
 Number of moles of acetic acid in 100 mL after adding charcoal = 0.049
 Number of moles of acetic acid adsorbed on the surface of charcoal = 0.001
 Number of molecules of acetic acid adsorbed on the surface of charcoal = $0.001 \times 6.02 \times 10^{23} = 6.02 \times 10^{20}$
 Surface area of charcoal = $3.01 \times 10^2 \text{ m}^2$ (given)
 Area occupied by single acetic acid molecule on the surface

$$\text{of charcoal} = \frac{3.01 \times 10^2}{6.02 \times 10^{20}} = 5 \times 10^{-19} \text{ m}^2$$



Topic-2: Catalysis and Theories of Catalysis

1. (d) Enzymes are very specific biological catalysts possessing well-defined active sites



Topic-3: Colloids and Emulsions

1. (a) (III) Dissolving surfactant in a proper solvent will only form micelles at temperature above Kraft's temperature.
 (IV) For Tyndall effect there must be a large difference in refractive index between dispersed phase and dispersion medium in order to have diffraction of light.
2. (c) As Sb_2S_3 is a negative sol, so $\text{Al}_2(\text{SO}_4)_3$ will be the most effective coagulant due to higher positive charge on Al (Al^{3+}) – **Hardy-Schulze rule**.
3. (b) We know that surface acting agents (*i.e.* surfactants) such as soaps and detergents belong to the class of micelles. A micellar system when dissolved in water, dissociates to give ions. The anion consists of two parts. The polar groups such as COO^- or SO_4^{--} ion is water loving (*i.e.* hydrophilic) in nature. It is called head of the species. The hydrocarbon chain which is quite big in size is water repelling (*i.e.* hydrophobic) in nature. It is called tail of the species. The hydrocarbon chain aggregates into the micelle above the critical concentration.

It may also be noted that the critical concentration for micelle formation decreases with increase in the molecular weight of the hydrocarbon chain of surfactant.

Here, the two anions that are formed are in case of Option

(b) is $\text{CH}_3(\text{CH}_2)_{11}\text{OSO}_3^-$ and option (d) $\text{CH}_3(\text{CH}_2)_6\text{COO}^-$. The molecular weight of hydrocarbon chain is more in case of "B" so, it has lower value of critical concentration for micelle formation in aqueous solution.

4. (d) Lyophilic sols are self stabilizing because these sols are reversible and are highly hydrated in the solution.

Lyophilic sols can be coagulated by adding a suitable solvent like alcohol and an electrolyte both.

5. (b, c)

(a) Process of precipitating colloidal solution is called coagulation. Hence, this statement is wrong.

(b) Colloidal solutions exhibit colligative properties. Hence, this statement is correct.

(c) At CMC surfactant form micelles. Hence, this statement is correct.

(d) Micelles are associated colloids, not macromolecular colloids. Hence, this statement is incorrect.

6. (a, b)

(a) Since adsorption is an exothermic process, hence, enthalpy decreases during this process. On adsorption, the randomness of the adsorbate molecules decreases, thus, entropy decreases.

(b) Higher the critical temperature of a gas, greater the amount of gas adsorbed thus, the extent of adsorption ethane will be more than nitrogen.

(c) Cloud is an aerosol in which liquid is dispersed phase and gas is dispersion medium, Whereas, emulsion is liquid in liquid colloidal system.

(d) Brownian motion of colloidal particles depends on the size of the particles as well as on viscosity of the solution.

7. (a, d)

(a) When two or more ions are present in the dispersion medium, preferential adsorption of the ion common to the colloidal particle takes place.

(d) This is called zeta potential which helps in increasing the stability of the lyophobic sol.

- 8.

(b) Statement-1 is correct because the surfactant molecules aggregate to form micelles only at or above the critical micellar concentration (CMC). Although, statement-2 is also correct, *i.e.*, the conductivity of the solution having surfactant molecules decreases sharply at CMC. However, statement-2 is not the explanation for statement-1. Each micelle contains at least 100 molecules and thus, with the formation of micelles, the number of ions in solution decreases and mobility of the bulkier micelle particles decreases. This, finally leads to decrease in conductivity of the solution.