

# SURFACE CHEMISTRY

## CHAPTER 05

### INTRODUCTION

- **ADSORPTION**- Adsorption is the process where molecules or particles stick to the surface of another substance. It occurs due to attractive forces between the adsorbate and adsorbent. Unlike absorption, adsorbate remains on the surface without entering the interior. It has various applications in purification, separation, and environmental remediation.
- **CAUSE**-Adsorption occurs due to attractive forces like Van der Waals forces, electrostatic forces, and chemical bonding between the adsorbate and adsorbent.
- **CHARACTERISTICS**-Adsorbents possess characteristics such as porosity, high surface area, selectivity, regeneration capability, stability, cost-effectiveness, and compatibility with the system.

|   | <b>Physical Adsorption</b>                       | <b>Chemical Adsorption</b>                               |
|---|--|--|
| <b>Interactions</b>   | Weak van der Waals forces                        | Strong chemical bonds                                    |
| <b>Energy Requirement</b>                                   | Low  | High   |
| <b>Temperature</b>  | Low  | High   |
| <b>Reversibility</b>  | Reversible                                       | Irreversible   |
| <b>Specificity</b>  | Non-specific                                     | Specific   |
| <b>Adsorbate-Adsorbent Interactions</b>                     | Weaker forces (London dispersion, dipole-dipole) | Stronger forces (covalent bonding, coordination bonding) |
| <b>Surface Coverage</b>                                     | Lower capacity                                   | Higher capacity  |
| <b>Influence of Temperature, Pressure, and Surface Area</b> | Significant influence                            | Less influence   |
| <b>Examples</b>   | Physisorption on activated carbon, zeolites      | Chemisorption in catalytic reactions, surface reactions  |

## APPLICATION OF ADSORPTION

An adsorption isotherm is a relationship that describes the equilibrium between the concentration of an adsorbate (molecules or particles being adsorbed) and the amount of adsorbate adsorbed onto an adsorbent surface at a given temperature. In other words, it relates the adsorption capacity of the adsorbent to the concentration of the adsorbate in the surrounding environment.

**Freundlich Isotherm:** The Freundlich isotherm is an empirical equation that describes multilayer adsorption and assumes that adsorption occurs on heterogeneous surfaces. It allows for a variable adsorption capacity and considers interactions between adsorbate molecules.

$$\frac{x}{m} = k \cdot P^{1/n}$$

Where  $x$  is the mass of gas adsorbed,  $m$  is the mass of adsorbent,  $P$  is the pressure of gas and  $k, n$  are constants. Another form of equations is,  $\log \frac{x}{m} = \log k + \frac{1}{n} \log P$

This is an equation of straight line. The slope of straight line gives the value of  $\frac{1}{n}$  and the intercept on the  $y$ -

|                       | Colloids                           | Suspensions  | True Solutions                  |
|-----------------------|------------------------------------|--|---------------------------------|
| <b>Particle Size</b>  | Intermediate (1 - 1000 nanometers) | Larger particles (>1000 nanometers)                | Individual molecules or ions    |
| <b>Stability</b>      | Stable                             | Require continuous agitation                       | Stable                          |
| <b>Settling</b>       | Do not settle                      | Settle over time                                   | Do not settle                   |
| <b>Transparency</b>   | Translucent/opaque                 | Opaque/turbid                                      | Transparent                     |
| <b>Tyndall Effect</b> | Exhibit                            | Do not exhibit                                     | Do not exhibit                  |
| <b>Examples</b>       | Milk, mayonnaise, ink, fog         | Muddy water, orange juice with pulp, sand in water | Saltwater, sugar water, ethanol |

In addition to colloids and suspensions, true solutions consist of individual molecules or ions uniformly dispersed in a solvent. True solutions are characterized by their transparency, stability, lack of settling, and the absence of the Tyndall effect. Examples of true solutions include saltwater, sugar water, and ethanol solutions.

### Classification of colloids.

Colloids can be classified as follows:

- (1) State of appearance i.e. rigid appearance (called gels) or fluid like appearance (called sols).

| Dispersed phase | Dispersion medium | Name       | Examples  |
|-----------------|-------------------|------------|---|
| Solid           | Solid             | Solid sol  | Some coloured glasses, precious stones, alloys, minerals, pearls. |
| Solid           | Liquid            | Sol        | Some paints, muddy water.   |
| Solid           | Gas               | Aerosol    | Smoke, dust, dust storm, volcanic dust                            |
| Liquid          | Solid             | Gel        | Cheese, butter, jellies, curd, boot-polish                        |
| Liquid          | Liquid            | Emulsion   | Milk, hair cream, emulsions                                       |
| Liquid          | Gas               | Aerosol    | Fog, mist, cloud  |
| Gas             | Solid             | Solid foam | Pumice stone, foam rubber, bread, styrene foam.                   |
| Gas             | Liquid            | Foam       | Froth, whipped cream.   |

|                          | <b>Lyophilic Colloids</b>   | <b>Lyophobic Colloids</b>   |
|--------------------------|---|---|
| Affinity                 | Strong affinity between dispersed particles and dispersing medium                               | Little to no affinity between dispersed particles and dispersing medium   |
| Stability                | Typically stable, less prone to coagulation or precipitation                                    | Less stable, more prone to coagulation or precipitation   |
| Examples                 | Starch-water, protein-water, gum-water colloidal systems  | Metal sulfides in water, metal oxides in water, certain polymer particles in water                                    |
| Preparation              | Direct mixing of dispersed particles with the dispersing medium                                 | Condensation, precipitation, or dispersion techniques to reduce particle solubility in the dispersing medium          |
| Particle Interaction     | Physical adsorption, solvation, or chemical bonding between particles and the dispersing medium | Minimal interaction with the dispersing medium, stabilization through steric hindrance or electrostatic stabilization |
| Surface Charge           | Often have charged surfaces due to adsorbed ions or molecules                                   | Lack significant surface charge, making them less stable  |
| Reversibility            | Easily dispersed and reformed upon changes in temperature, concentration, or pH                 | Generally irreversible, challenging to disperse back into a colloidal state   |
| Versatility              | Can disperse in a wide range of solvents or dispersing media                                    | Require specific solvents or dispersing media to reduce particle solubility and provide stabilization                 |
| Formation of Multilayers | Can form multiple layers on particle surfaces due to strong affinity                            | Tend to form aggregates or clusters due to lack of particle-particle interaction with the dispersing medium           |

(2) Affinity for dispersion medium.

(3) Size i.e. macromolecular or associated or multimolecular.

|                                  | <b>Multi-Molecular Colloids</b>   | <b>Macromolecular Colloids</b>  | <b>Associated Colloids</b>  |
|----------------------------------|---|---|---|
| <b>Nature of Dispersed Phase</b> | Small-sized particles or molecules dispersed in the dispersing medium                           | Large-sized molecules or polymers dispersed in the dispersing medium                    | Aggregates or clusters of molecules or particles dispersed in the dispersing medium   |
| <b>Particle Size</b>             | Small particle size, typically ranging from 1 to 1000 nanometers                                | Large particle size, often exceeding 1000 nanometers                                    | Variable particle size, ranging from small aggregates to larger clusters  |
| <b>Formation Mechanism</b>       | Formed through the association of several small particles or molecules in the dispersing medium | Formed by the presence of large macromolecules or polymers in the dispersing medium     | Formed by the aggregation or clustering of molecules or particles in the dispersing medium                                      |
| <b>Stability</b>                 | Relatively unstable, prone to coagulation or precipitation                                      | Generally stable due to the entanglement or cross-linking of macromolecules or polymers | May exhibit varying stability depending on the strength and nature of the intermolecular forces holding the associates together |
| <b>Examples</b>                  | Gold sol, sulfur sol, ferric hydroxide sol  | Protein solutions, cellulose solutions, synthetic polymer solutions                     | Micelles, vesicles, reverse micelles, liquid crystals   |

### Preparation of colloidal solutions.

#### (1) Preparation of Lyophilic sols:

Colloidal solutions of lyophilic colloids, such as starch and gelatin, can be easily prepared by dissolving these substances in water. The affinity between the colloidal particles and the dispersing medium allows for their spontaneous dispersion and formation of a stable sol.

#### (2) Preparation of Lyophobic sols:

Lyophobic sols can be prepared using different methods, including dispersion and condensation methods.

### (i) Dispersion methods:

(a) Mechanical disintegration: A colloidal mill is used to grind the substance to a size comparable to colloidal particles, resulting in their dispersion in the medium.

(b) Ultrasonic dispersion: Ultrasonic vibrations with frequencies higher than the audible range are applied to coarse suspensions or liquids, such as oil or mercury, to disperse them into the colloidal range.

(c) Bredig's arc method: This method is used to prepare colloidal solutions of metals. Electric current is passed through electrodes made of the metals, leading to the formation of an electric arc and the conversion of the metal into colloidal form. For example, a colloidal solution of gold known as "Purple of Cassius" can be obtained using this method.

(d) Peptization: This method involves converting freshly prepared precipitates into colloidal form. The precipitate is treated with a suitable peptizing agent, such as an electrolyte or a surfactant, which disrupts the precipitate structure and promotes its dispersion as colloidal particles in the medium.

These methods provide different ways to prepare colloidal solutions, both for lyophilic colloids that readily dissolve in the dispersing medium and for lyophobic colloids that require dispersion techniques or condensation methods to achieve colloidal stability.

Peptisation can be achieved as follows:

- *By adding excess electrolyte* to freshly prepared precipitates.



- *By adding another colloid.* For example, Lamp black is peptised by adding gums.
- *By washing precipitate.* For example,  $\text{CuS}$  and  $\text{BaSO}_4$  washing continuously pass into colloidal form.
- *By adding organic solvents.* For example, a colloidal solution of cellulose nitrate is prepared in ethyl alcohol and ether. The product so obtained is commercially known as colloidion.

### (ii) Condensation methods:

Colloidal solutions can also be prepared using condensation methods, which involve the exchange of solvent or cooling techniques.

(a) Change of physical state: Colloidal solutions of certain elements like mercury and sulfur can be obtained by passing their vapor through cold water containing a stabilizer. The vapor condenses in the cold water, leading to the formation of colloidal particles dispersed in the medium. The addition of a stabilizer helps to maintain the stability and prevent the particles from aggregating.

These condensation methods provide alternative approaches to prepare colloidal solutions, where the physical state of the substance is changed to facilitate the formation of colloidal particles. The solvent exchange and cooling processes play a crucial role in achieving the desired dispersion and stability.

**(b) By chemical methods:**

- *By double decomposition:*  $As_2O_3 + 3H_2S \rightarrow As_2S_3 + 3H_2O$   
(Colloidal sol.)
- *By reduction:*  $2AuCl_3 + 3SnCl_2 \rightarrow 2Au + 3SnCl_4$   
(Gold sol) (Classius purple)
- *By oxidation:*  $Br_2 + H_2S \rightarrow 2HBr + S$   
(Colloidal sol)
- *By hydrolysis:*  $FeCl_3 + 3H_2O \rightarrow Fe(OH)_3 + 3HCl$   
(Ferric hydroxide sol)

### Purification of colloidal solution

**Dialysis:** Dialysis is a method used to separate soluble impurities from a colloidal solution based on their different rates of diffusion through a semipermeable membrane, often made of parchment paper. The membrane has tiny pores that allow small molecular or ionic species to pass (diffuse) through, while larger colloidal particles are unable to pass through these pores. As a result, the impurities are effectively separated from the colloidal particles. In the case of Dialysis serves as a reliable purification technique for colloidal solutions, capitalizing on the differential diffusion rates of substances through a semipermeable membrane to selectively remove impurities and retain the colloidal particles of interest.

### Properties of colloidal solution.

Colloidal solutions exhibit several unique properties that distinguish them from true solutions and suspensions. Here are some important properties of colloidal solutions:

- 1. Particle Size:** Colloidal particles have intermediate sizes between true solutions and suspensions. They typically range from 1 to 1000 nanometers in diameter, making them larger than individual molecules but smaller than visible particles.
- 2. Brownian Motion:** Colloidal particles undergo random, zigzag motion known as Brownian motion due to collisions with solvent molecules. This motion helps prevent their rapid settling or sedimentation.
- 3. Tyndall Effect:** When a beam of light passes through a colloidal solution, it scatters off the colloidal particles, resulting in the Tyndall effect. This scattering of light makes the path of the beam visible and gives the solution a milky or hazy appearance.

**4. Surface Area:** Colloidal particles have a high surface area to volume ratio, providing a large surface area for interaction with the surrounding medium or other particles. This high surface area contributes to their unique chemical and physical properties.

**5. Heterogeneity:** Colloidal solutions are heterogeneous systems due to the presence of dispersed particles within the dispersing medium. The particles are not uniformly distributed and may form aggregates or clusters.

**6. Stability:** Colloidal solutions can exhibit varying degrees of stability. Lyophilic colloids tend to be more stable than lyophobic colloids. Stability is influenced by factors such as the nature of the particles, surface charges, and the presence of stabilizing agents.

**7. Coagulation and Flocculation:** Colloidal particles can undergo coagulation or flocculation, leading to their aggregation and precipitation. Coagulation refers to the irreversible aggregation of particles, while flocculation refers to the reversible formation of loose aggregates.

**8. Diffusion and Sedimentation:** Colloidal particles exhibit slow sedimentation rates due to their small size and Brownian motion. They diffuse and settle more slowly compared to larger particles, resulting in long-term stability of colloidal solutions.

**9. Osmotic Pressure:** Colloidal solutions can exhibit osmotic pressure due to the presence of a concentration gradient between the colloidal particles and the surrounding medium. This pressure contributes to their behavior in osmotic processes.

**10. Specific Properties:** Colloidal solutions may display specific properties depending on the nature of the particles and the dispersing medium. These properties include electrical conductivity, catalytic activity, optical properties, and unique interactions with external fields (e.g., magnetic or electric fields).

### Gold number.

The gold number is a measure of the effectiveness of a protective colloid in preventing the coagulation or flocculation of colloidal particles. It quantifies the minimum amount of protective colloid required to maintain the stability of a colloidal solution. A higher gold number indicates stronger protection, while a lower gold number indicates weaker protection. It is commonly used to assess the stabilizing power of colloidal systems in various industries.

The number of milligrams of the protective colloid which just prevent the coagulation of 10 ml of standard red gold sol when 1 ml of 10% solution of sodium chloride is added to it. Smaller the gold number of the protective colloid greater is its protecting power.

|             |              |               |      |
|-------------|--------------|---------------|------|
| Gum Arabic  | 0.15 – 0.25  | Potato starch | 25   |
| Gelatin     | 0.005 – 0.01 | Caseinate     | 0.01 |
| Egg albumin | 0.15 – 0.25  | Haemoglobin   | 0.03 |

## Emulsions.:

Emulsion is a colloidal solution of two immiscible liquids in which one liquid acts as the dispersed phase while the other liquid acts as the dispersion medium. There are two types of emulsions i.e.,

- Oil in water – Examples: milk, cream, face cream, etc.
- Water in oil – Examples: butter, cold cream etc.,

## Catalysis.

Catalysis is a process in which a substance, called a catalyst, speeds up the rate of a chemical reaction without being consumed or permanently changed in the process. It enables the reaction to proceed more rapidly or under milder conditions compared to the uncatalyzed reaction.

Catalysts work by providing an alternative pathway with lower activation energy for the reaction to occur. They facilitate the formation of intermediate species, which then undergo further reactions to yield the desired products. Catalysts increase the reaction rate by lowering the energy barrier that needs to be overcome for the reactants to transform into products. Key characteristics of catalysis include:

1. Catalysts are not consumed in the reaction and can be used repeatedly.
2. They do not change the overall energy difference between reactants and products.
3. Catalysts can work in small amounts, often in trace quantities, making them highly efficient.
4. They can be specific to certain reactions or operate as general catalysts, promoting multiple reactions.
5. Catalysts can be homogeneous (in the same phase as reactants) or heterogeneous (in a different phase, often as a solid catalyst in a liquid or gas reaction).

Catalysis finds extensive applications in various fields, including industrial chemical production, environmental processes, energy conversion, and biological systems. It plays a vital role in improving reaction efficiency, reducing energy consumption, and enabling the synthesis of desired products.

## TYPES OF CATALYSIS:

Catalysis can be classified into several types based on different criteria. Here are some common types of catalysis:

1. **Homogeneous Catalysis:** In homogeneous catalysis, the catalyst and the reactants are in the same phase, typically as a liquid or gas. The catalyst molecules interact directly with the reactants, facilitating the reaction. Examples include the use of transition metal complexes in organic synthesis.
2. **Heterogeneous Catalysis:** Heterogeneous catalysis involves a catalyst that exists in a different phase than the reactants, often as a solid catalyst in a liquid or gas reaction. The reactants adsorb onto the catalyst surface, where the reaction takes place. Examples include the use of metal catalysts like platinum or palladium in automotive catalytic converters.

**3. Enzymatic Catalysis:** Enzymes are biological catalysts that facilitate biochemical reactions in living organisms. Enzymatic catalysis occurs in aqueous environments and is highly specific to particular substrates. Enzymes play a critical role in various biological processes, such as digestion, metabolism, and DNA replication.

**4. Acid-Base Catalysis:** Acid-base catalysis involves the use of acids or bases as catalysts to facilitate reactions by donating or accepting protons. Acid catalysis involves the generation of a proton, while base catalysis involves the removal of a proton. Acid-base catalysis is common in organic chemistry reactions, such as ester hydrolysis or aldol condensation.

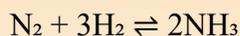
**5. Photocatalysis:** Photocatalysis utilizes light energy to drive catalytic reactions. Photocatalysts absorb photons and generate excited states that can interact with reactants to initiate chemical transformations. This type of catalysis finds applications in environmental remediation, water splitting, and organic synthesis.

**6. Biocatalysis:** Bio catalysis involves the use of whole cells or isolated enzymes to catalyze chemical reactions. Biocatalysts offer high selectivity and specificity for certain reactions and are used in various industrial processes, including pharmaceutical synthesis and biofuel production.

### HABER'S PROCESS

The Haber's process, also known as the Haber-Bosch process, is a significant industrial chemical process used to synthesize ammonia ( $\text{NH}_3$ ) from nitrogen gas ( $\text{N}_2$ ) and hydrogen gas ( $\text{H}_2$ ). It was developed by the German chemist Fritz Haber in the early 20th century.

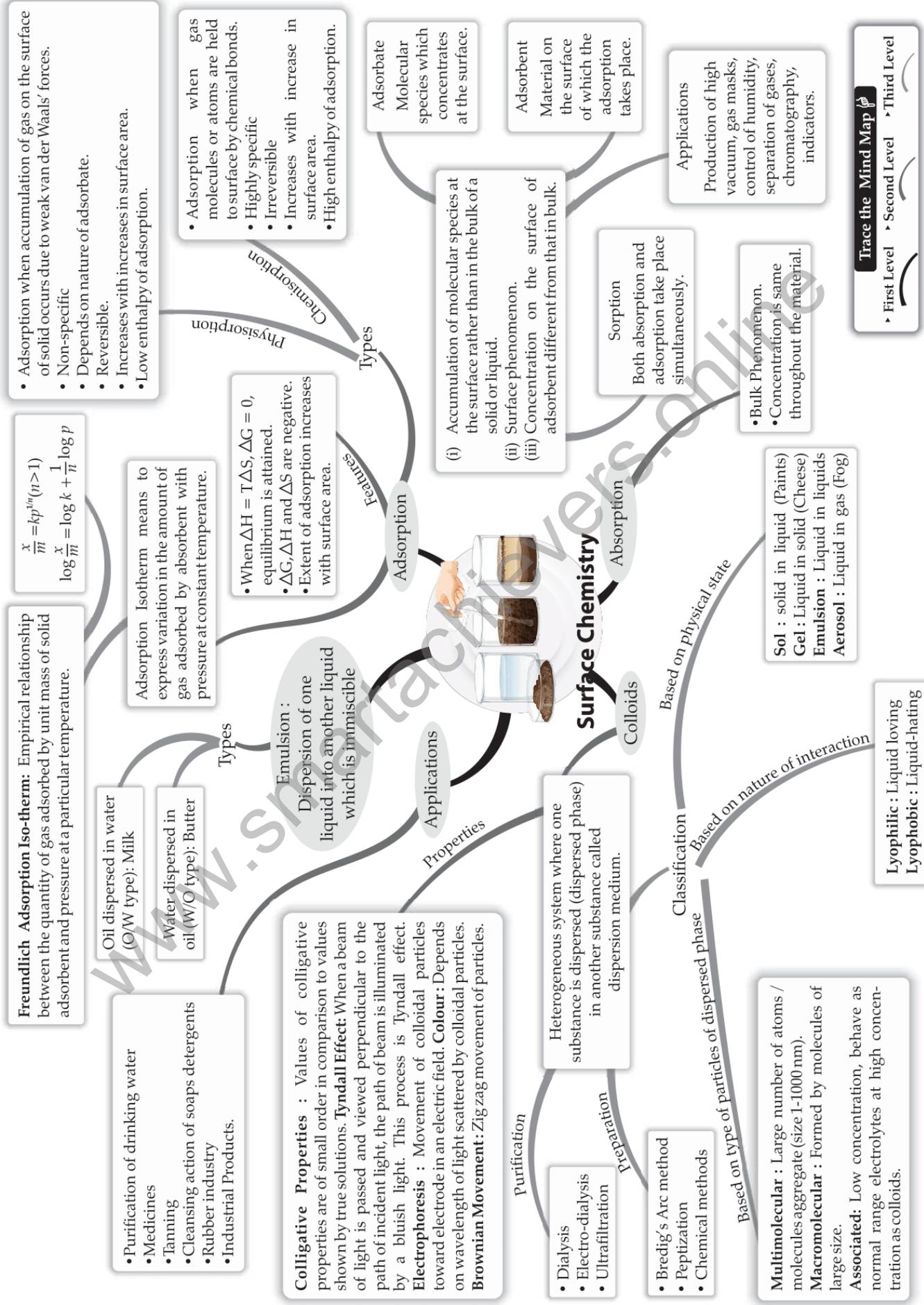
The process takes place under high pressure and elevated temperature, typically around 200-300 degrees Celsius and pressures of 150-200 atmospheres. Several catalysts are used to facilitate the reaction, with iron being the most commonly employed catalyst. The overall reaction for the Haber's process can be represented as follows:



The reactants, nitrogen gas and hydrogen gas, are introduced into a reaction vessel. The gases are compressed to high pressures using compressors and then heated to the reaction temperature. The gases are passed over a catalyst bed, where the ammonia synthesis occurs. The presence of the catalyst helps to lower the activation energy for the reaction, allowing it to proceed at a faster rate.

The ammonia produced in the reaction is usually in the gaseous state and is separated from unreacted nitrogen and hydrogen gases by cooling and condensation. The ammonia can then be collected as a liquid or used directly in downstream industrial processes.

The Haber's process is of great significance in the production of ammonia, which serves as a key precursor for the production of fertilizers, explosives, and various other chemicals. It revolutionized the agricultural industry by enabling the large-scale production of ammonia-based fertilizers, leading to increased crop yields and improved food production worldwide.



## PRACTICE QUESTIONS

- Which of the following is an example of a lyophilic sol?
  - Starch solution
  - Sand suspension
  - Oil-in-water emulsion
  - Gold sol
- The process of adsorption is accompanied by:
  - Decrease in surface area
  - Increase in pressure
  - Release of heat
  - Increase in volume
- The phenomenon of adsorption is most influenced by:
  - Temperature
  - Pressure
  - Concentration of the adsorbate
  - Surface area of the adsorbent
- A substance that adsorbs gases on its surface is called a/an:
  - Adsorbate
  - Adsorbent
  - Catalyst
  - Solvent
- Which of the following is an example of chemisorption?
  - Physisorption of gas on charcoal
  - Adsorption of a dye molecule on fabric
  - Absorption of liquid in a sponge
  - Reaction of hydrogen with a metal surface
- The Freundlich equation is used to describe:
  - Langmuir adsorption isotherm
  - Heterogeneous catalysis
  - Enzymatic activity
  - Heterogeneous equilibrium
- The process of the formation of a colloidal solution from a precipitate is called:
  - Peptization
  - Emulsification
  - Sedimentation
  - Coagulation

8. The Tyndall effect is observed in colloidal solutions due to:
- Reflection of light by the particles
  - Refraction of light by the particles
  - Scattering of light by the particles
  - Absorption of light by the particles
9. Which of the following is an example of a protective colloid?
- Gelatin
  - Sand
  - Oil
  - Salt
10. The process of separating colloidal particles from a solution by the difference in their rates of diffusion is called:
- Dialysis
  - Electrodialysis
  - Ultrafiltration
  - Centrifugation
11. The process of precipitation of colloidal particles due to the addition of an electrolyte is called:
- Coagulation
  - Peptization
  - Flocculation
  - Sedimentation
12. The property of a catalyst that enables it to selectively promote certain reactions is called:
- Activation energy
  - Specificity
  - Surface area
  - Reactivity
13. Which of the following is an example of a heterogeneous catalyst?
- Enzyme
  - Homogeneous catalyst
  - Zeolite catalyst
  - Acid catalyst
14. The process in which a catalyst is poisoned or deactivated by a substance that binds to its active sites is called:
- Inhibition
  - Promotion
  - Poisoning
  - Auto-catalysis
15. The process of catalytic cracking is used in the production of:
- Fertilizers
  - Polymers
  - Petroleum products
  - Pharmaceuticals

16. Which type of catalysis involves the formation of an intermediate complex between the catalyst and the reactants?

- a) Acid-base catalysis
- b) Enzymatic catalysis
- c) Homogeneous catalysis
- d) Heterogeneous catalysis

17. The catalyst used in the Haber's process for the production of ammonia is:

- a) Platinum
- b) Palladium
- c) Iron
- d) Nickel

18. Photocatalysis involves the use of:

- a) Light energy
- b) High pressure
- c) Temperature
- d) Catalysts

19. The process of purifying a colloidal solution by removing impurities through a semipermeable membrane is called:

- a) Dialysis
- b) Ultrafiltration
- c) Coagulation
- d) Sedimentation

20. Which of the following is an example of an anionic surfactant?

- a) Sodium dodecyl sulfate
- b) Cetyltrimethylammonium bromide
- c) Polyethylene glycol
- d) Polyvinyl alcohol

21. Which of the following characteristics is not correct for physical adsorption?

- a) Adsorption on solids is reversible
- b) Adsorption increases with increase in temperature
- c) Adsorption is spontaneous
- d) Both enthalpy and entropy of adsorption are negative

22. Which of the following statements is incorrect?

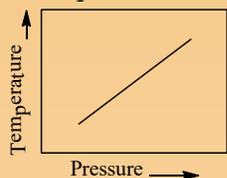
- a) Physical adsorption occurs at very low temperature and chemisorptions occur at all temperature
- b) The magnitude of chemisorption decreases with rise in temperature and physisorption increases with rise in temperature
- c) Chemisorption is irreversible and physisorption is reversible
- d) In physisorption, the activation energy of desorption is very low and in chemisorption, the activation energy of desorption is very high

23. Which of the following has maximum coagulation power with ferric hydroxide sol?  
 a) Cryolite                      b)  $K_2C_2O_4$                       c)  $K_3[Fe(CN)_6]$                       d)  $K_4[Fe(CN)_6]$
24. The critical micelle concentration (CMC) is  
 a) The concentration at which micellisation starts  
 b) The concentration at which the true solution is formed  
 c) The concentration at which one molar electrolyte is present per 1000 g of the solution  
 d) The concentration at which  $\Delta H = 0$
25. A dilute solution of litmus becomes colourless on shaking with charcoal. This is due to :  
 a) Absorption                      b) Adsorption                      c) Chemical reaction                      d) Both (a) and (b)
26. Which of the following is an example for heterogeneous catalysis reaction?  
 a)  $2SO_2(g) + O_2(g) \xrightarrow{NO(g)} 2SO_3(g)$   
 b) Hydrolysis of aqueous sucrose solution in the presence of aqueous mineral acid  
 c)  $2H_2O_2(l) \xrightarrow{Pt(s)} 2H_2O(l) + O_2(g)$   
 d) Hydrolysis of liquid in the presence of aqueous mineral acid
27. Which of the following is true in respect of adsorption?  
 a)  $\Delta G < 0; \Delta S > 0; \Delta H < 0$                       b)  $\Delta G < 0; \Delta S < 0; \Delta H < 0$   
 c)  $\Delta G > 0; \Delta S > 0; \Delta H < 0$                       d)  $\Delta G < 0; \Delta S < 0; \Delta H > 0$
28. Which is a homogeneous system?  
 a) A solution of sugar in water  
 b) Concrete  
 c) Muddy water  
 d) Bread
29. Which of the following is the most effective in the coagulation of gold sol?  
 a)  $NaNO_3$                       b)  $MgCl_2$                       c)  $Na_3PO_4$                       d)  $K_4[Fe(CN)_6]$
30. Which of the following is not a characteristic of chemisorption?  
 a)  $\Delta H$  is the order of 400 kJ                      b) Adsorption is irreversible  
 c) Adsorption may be multimolecular layer                      d) Adsorption is specific
31. Select wrong statement.  
 a) If a very small amount of  $AlCl_3$  is added to gold sol, coagulation occurs, but if a large quantity of  $AlCl_3$  is added, there is no coagulation.  
 b) Organic ions are more strongly adsorbed on charged surfaces in comparison to inorganic ions.  
 c) Both emulsifier and peptising agents stabilise colloids but their actions are different.  
 d) Colloidal solutions are thermodynamically stable.

32. The size of colloidal particles is in between  
a)  $10^{-7} - 10^{-9}$ cm    b)  $10^{-9} - 10^{-11}$ cm    c)  $10^{-5} - 10^{-7}$ cm    d)  $10^{-2} - 10^{-3}$ cm
33. The Brownian movement occurs in :  
a) Colloidal solution  
b) True solution  
c) Suspension having size  $< 500$  m $\mu$   
d) All of the above
34. Dyeing of fibre involves the process of :  
a) Adsorption    b) Absorption    c) Sorption    d) All of these
35. Which adsorption takes place at low temperature?  
a) Physical    b) Chemical    c) Both (a) and (b)    d) None of these
36. Term catalyst was given by  
a) Rutherford    b) Berzilius    c) Wohler    d) Kolbe
37. The cottrells precipitator is used to :  
a) Neutralize charge on carbon particles in air in smoke  
b) Coagulate carbon atoms of smoke  
c) Bring in cataphoresis in carbon particles  
d) All of the above
38. A catalyst is a substance which  
a) Is always in the same phase as in the reactions  
b) Alters the equilibrium in a reaction  
c) Does not participate in the reaction but alters the rate of reaction  
d) Participates in the reaction and provide an easier pathway for the same
39. Multimolecular colloids are present in  
a) Soap solution    b) Sol of proteins    c) Sol of gold    d) All of these
40. The rate of a certain biochemical reaction catalysed by an enzyme in human body is  $10^4$  times faster than when it carried out in the laboratory. The activation energy of this reaction:  
a) Is zero  
b) Is different in two cases  
c) Is the same in both the cases  
d) None of the above

41. At CMC (critical micelle concentration), the surfactant molecules undergo  
a) Dissociation      b) Micelle formation      c) Both (a) and (b)      d) None of these
42. Activated charcoal is used to remove colouring matter from pure substances. It works by  
a) Oxidation      b) Reduction      c) Bleaching      d) Adsorption
43. Lyophobic colloids are :  
a) Reversible colloids      b) Irreversible colloids      c) Protective colloids      d) Gum, proteins
44. The size of the colloid particles is :  
a) > suspension particles  
b) < suspension particles  
c) < true solution particles  
d) None of these
45. Emulsions can be destroyed by  
a) The addition of an emulsifier which tend to form an emulsion of the same type  
b) Freezing  
c) Both (a) and (b)  
d) None of the above
46. Which characteristic of adsorption is wrong?  
a) Physical adsorption in general decreases with temperature  
b) Physical adsorption in general increases with temperature  
c) Physical adsorption is a reversible process  
d) Adsorption is limited to the surface only
47. Gelatin is often used as an ingredient in the manufacture of ice-cream. The reason for this is:  
a) To prevent the formation of a colloid  
b) To stabilize the colloid and prevent crystal growth  
c) To cause the mixture to solidify  
d) To improve the flavour
48. Blood contains:  
a) Positively charged particles  
b) Negatively charged particles  
c) Neutral particles  
d) Negatively as well as positively charged particles

49. The curve showing the variation of pressure with temperature for a given amount of adsorption is called



- a) Adsorption isobar    b) Adsorption isotherm    c) Adsorption isostere    d) Adsorption isochore

50. When white light is passed through a colloidal solution containing fine suspended particles of gold, then the scattered light seen in a direction different from that of the incident light is:

- a) Yellow coloured    b) Blue coloured    c) Green coloured    d) Red coloured

51. Emulsions of polyvinylacetate are used in:

- a) Polishes    b) Latex paints    c) Fire works    d) Rayons

52. Peptization denotes

- a) Digestion of food    b) Hydrolysis of proteins  
c) Breaking and dispersion into colloidal state    d) Precipitation of solid from colloidal dispersion

53. Which characteristic is the most important factor in giving rise to peculiar properties of colloids?

- a) Large size  
b) Small size  
c) High charge density  
d) High ratio of surface area to the volume

54. Alum helps in purifying water by:

- a) Forming Si complex with clay particles  
b) Sulphate part which combines with the dirt and removes it  
c) Aluminium which coagulates the mud particles  
d) Making mud water soluble

55. If the dispersed phase is a liquid and the dispersion medium is a solid, the colloid is known as:

- a) A sol    b) An emulsion    c) A gel    d) A foam

56. In physical adsorption gas molecules are bound on the solid surface by

- a) Chemical forces    b) Electrostatic forces    c) Graphical forces    d) Van der Waals' forces

57. On adding 1 mL solution of 10% NaCl to 10 mL gold solution in the presence of 0.25 g of starch, the coagulation is just prevented. Starch has the gold number equal to :
- a) 0.25                      b) 2.5                      c) 250                      d) 0.025
58. Hardy-Schulze rule states that :
- a) Non-electrolytes have better coagulating action on colloids than electrolytes  
b) Sols are coagulated by effective ions whose charge is opposite to that of sol and the ions of higher charge are much more effective than the ions of lower charge  
c) Charge of the ions has no effect on the coagulation of a sol  
d) Sols are coagulated only by those ions whose charge is similar to that of the sol
59. In homogeneous catalytic reactions, the rate of reaction:
- a) Depends upon the concentration of catalyst  
b) Independent of the concentration of catalyst  
c) Depends upon the free energy change  
d) Depends upon physical state of the catalyst
60. Catalysts are generally used in finely divided state because
- a) It avoids wastage of catalyst  
b) We can see its reaction  
c) It has more surface  
d) It has no effect on reaction rate

## ANSWERS

1. **(a)** Starch solution is an example of a lyophilic sol, which means it forms a stable colloidal dispersion in a suitable solvent, such as water.
2. **(c)** The process of adsorption is typically exothermic, meaning heat is released during the adsorption of molecules onto the surface of the adsorbent.
3. **(d)** The surface area of the adsorbent plays a crucial role in adsorption. A higher surface area provides more sites for adsorption and enhances the adsorption process.
4. **(b)** A substance that adsorbs gases on its surface is referred to as an adsorbent. It can be a solid material or a liquid capable of adsorbing gases.
5. **(d)** Chemisorption involves chemical bonding between the adsorbate and the adsorbent surface. The reaction of hydrogen with a metal surface is an example of chemisorption.
6. **(a)** The Freundlich equation is not specifically used to describe Langmuir adsorption isotherm. It is an empirical equation that relates the amount of adsorbate on the surface to its equilibrium concentration in the bulk phase.
7. **(a)** Peptization is the process of converting a precipitate back into a colloidal solution by the addition of a suitable peptizing agent, such as an electrolyte or an acid.
8. **(c)** The Tyndall effect is the scattering of light by the colloidal particles present in a solution, resulting in the visibility of a beam of light passing through it.
9. **(a)** Gelatin is an example of a protective colloid, which stabilizes the colloidal dispersion by forming a protective layer around the dispersed particles.
10. **(a)** Dialysis involves the separation of solute particles from a colloidal solution using a semipermeable membrane based on the difference in their rates of diffusion.
11. **(c)** Flocculation is the process of bringing together colloidal particles to form larger aggregates or flocs, resulting in the destabilization of the colloidal dispersion.
12. **(b)** Specificity refers to the property of a catalyst to selectively promote certain reactions while remaining inactive towards others.

13. (c) Zeolite catalysts are examples of heterogeneous catalysts, which are solid materials with well-defined structures that catalyze chemical reactions.

14. (c) Catalyst poisoning refers to the deactivation or inhibition of a catalyst's activity due to the presence of a substance that binds to its active sites, rendering it ineffective.

15. (c) Catalytic cracking is a process used in the petroleum industry to convert heavy hydrocarbons into lighter, more valuable petroleum products, such as gasoline and diesel.

16. (c) The formation of an intermediate complex between the catalyst and the reactants is typical of homogeneous catalysis, where the catalyst and reactants are in the same phase.

17. (c) The Haber's process for ammonia production commonly utilizes iron as a catalyst.

18. (a) Photocatalysis involves the use of light energy to initiate and drive catalytic reactions.

19. (a) Dialysis is the process of purifying a colloidal solution by separating impurities from the colloidal particles based on their different rates of diffusion through a semipermeable membrane.

20. (a) Sodium dodecyl sulfate (SDS) is an example of an anionic surfactant, which has a negatively charged hydrophilic head group

21 (b) When temperature increases, the adsorbed molecules get energy and desorption starts increasing, therefore adsorption decreases with increase in temperature

22 (b) For chemisorption, high temperature is favourable. It increases with rise in temperature. On the other hand low temperature is favourable for physisorption so it decreases with rise in temperature

23 (d) Ferric hydroxide sol is positively charged sol. It is coagulated by negative ions. Larger the charge on anion, larger is its coagulating power or smaller is its flocculation value. In  $K_4[Fe(CN)_6]$ , the anion  $[Fe(CN)_6]^{4-}$  has highest charge, therefore  $K_4[Fe(CN)_6]$  is most effective in coagulating  $Fe(OH)_3$  sol.

24 (a) CMC is the lowest concentration at which micelle formation appears

25 (b) Litmus is adsorbed by charcoal.

26 (d)  $CO(g) + 2H_2(g) \xrightarrow{Cu, ZnO - Cr_2O_3(s)} CH_3OH(l)$

In this reaction, reactants and catalyst are in different physical states, hence it is an example of heterogeneous catalysis.

27 (b) Adsorption is an exothermic process and hence,  $\Delta H$  is negative for adsorption. On the other hand the molecules of the adsorbate are held on the surface of the adsorbent and hence, they have lesser tendency to move about freely. In other words entropy decreases *i.e.*,  $\Delta S$  is negative. According to Gibbs-Helmholtz equation,  $\Delta G = \Delta H - T \cdot \Delta S$

Thus, for the process of adsorption to occur  $\Delta G$  must be negative. Hence, for adsorption  $\Delta G < 0$ ;  $\Delta S < 0$ ;  $\Delta H < 0$

- 28 (a) A homogeneous solution has number of phase = 1.
- 29 (b) Among  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$ , ions,  $\text{Mg}^{2+}$  ion has maximum valency, thus it will be the most effective in the coagulation of gold sol
- 30 (d) Activated charcoal is used for decolourizing and deodorizing sugar solution during the process of manufacture of sugar due to its adsorbing property.
- 31 (a) The phenomenon of the precipitation of a colloidal solution by the addition of the excess of an electrolyte is called coagulation. When oppositely charged sols are mixed in almost equal proportions, their charges are neutralised. So, statement (a) is wrong.
- 32 (c) The size of colloidal particles is in the range of 100 nm to 1 $\mu$ m or  $10^{-5}$  cm to  $10^{-7}$  cm.
- 33 (d) Note that pollen grains also move irregularly in water, *i.e.*, lighter and smaller suspended particles. In true solution of sugar, the sugar particles are also in motion in solution.
- 34 (d) It involves sorption. Both process of adsorption and absorption taking place simultaneously are called sorption.
- 35 (a) Physical adsorption occurs at low temperature while chemisorption occurs at higher temperature.
- 37 (d) The negatively charged carbon particles in air (smoke) are moved towards anode due to cataphoresis, where they are neutralized to left free air. The process is used to control air pollution.
- 40 (b) Enzymes decrease the activation energy to greater extent.
- 41 (b) At critical micelle concentration, the surfactant molecules associate to form micelles
- 42 (c) In case of chemisorption, adsorption only monolayered. All other option are correct about chemisorption.
- 43 (b) Lyophobic sols are irreversible. Rest all points signify for lyophilic sols.
- 44 (b) The size of the particles order in three states is :  
True solution < colloidal solution < suspension

- 45 (c) Emulsions can be broken to get the constituent liquids by heating, freezing, centrifuging or by addition of appreciable amount of electrolytes. They are also broken by destroying the emulsifying agent
- 46 (b) Physical adsorption is non-directional, reversible, multilayers exothermic process where adsorbent molecules are held on surface of adsorbent by physical forces such as van der Waals' forces.
- 47 (b) Gelatin is protective colloid.
- 48 (b) Blood is negatively charged emulsion.
- 49 (c) The plot of temperature *versus* pressure for a given amount of adsorption is called adsorption isostere
- 50 (b) Scattering of blue light is maximum because scattering  $\propto \frac{1}{\lambda^4}$ .
- 51 (b) An application in paints industry.
- 52 (c) The dispersal of a precipitated material into colloidal solution by the action of an electrolyte in solution is called peptisation and the electrolyte is called a peptising agent.
- 53 (d) Colloidal state possesses lower surface tension or increase in surface area. This provides sol to acquire peculiar properties, e. g., more adsorption power.
- 54 (c)  $\text{Al}^{3+}$  is very good coagulating agent for -ve sol (muddy water).
- 55 (c) Liquid in solid are known as gels.
- 56 (d) In physical adsorption, gas molecules over the surface of adsorbent are held by weak van der Waals' forces.
- 57 (c) Gold no. is to be reported in mg.
- 58 (b) It is the definition of rule.
- 59 (a) Catalyst forms an intermediate with reactant and thus, rate of reaction for intermediate formation depends upon concentration of catalyst.
- 60 (c) When a catalyst is present in finely divided state greater adsorption takes place hence its efficiency increases.