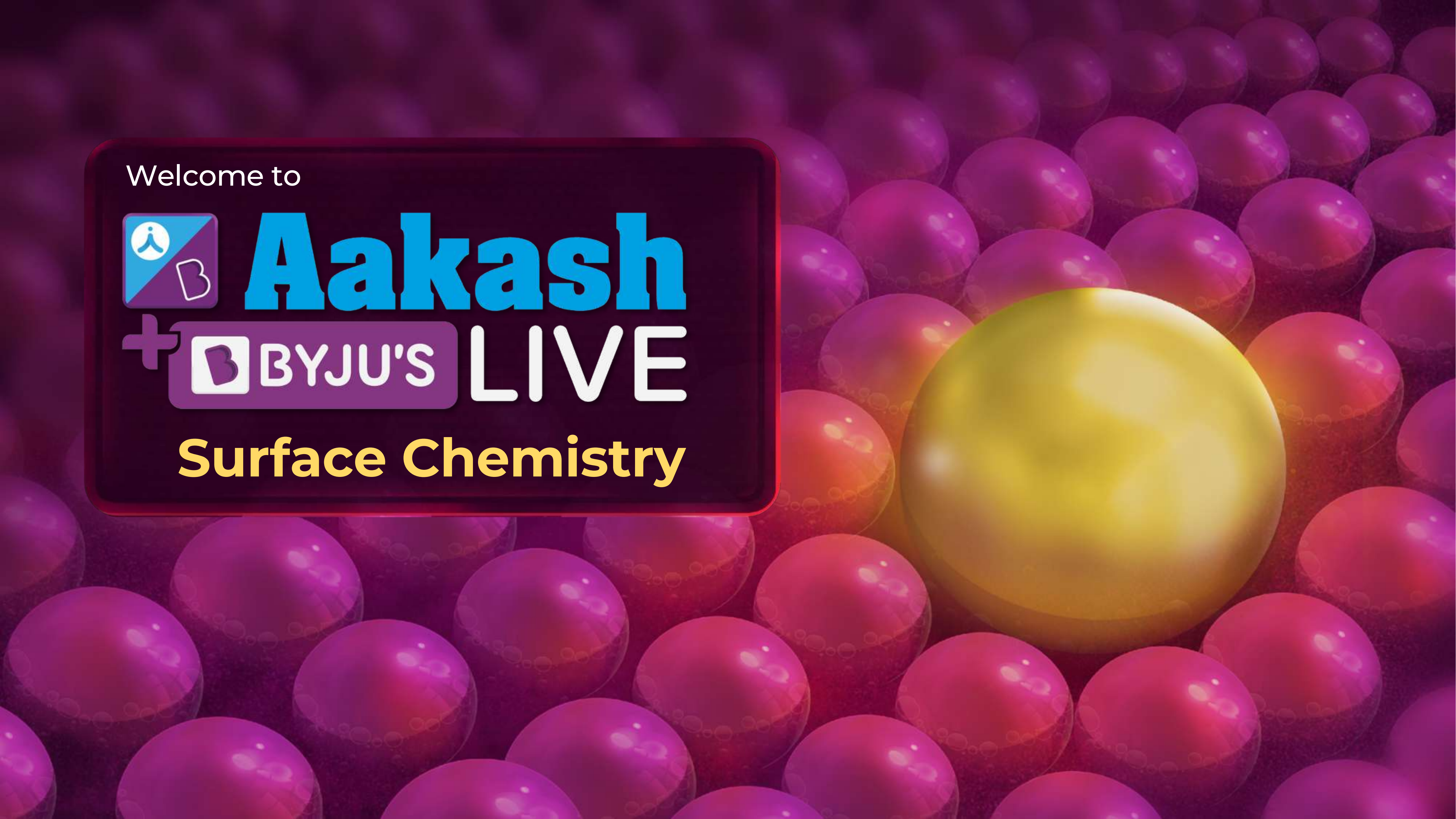
Welcome to

Aakash + BYJU'S LIVE

Surface Chemistry

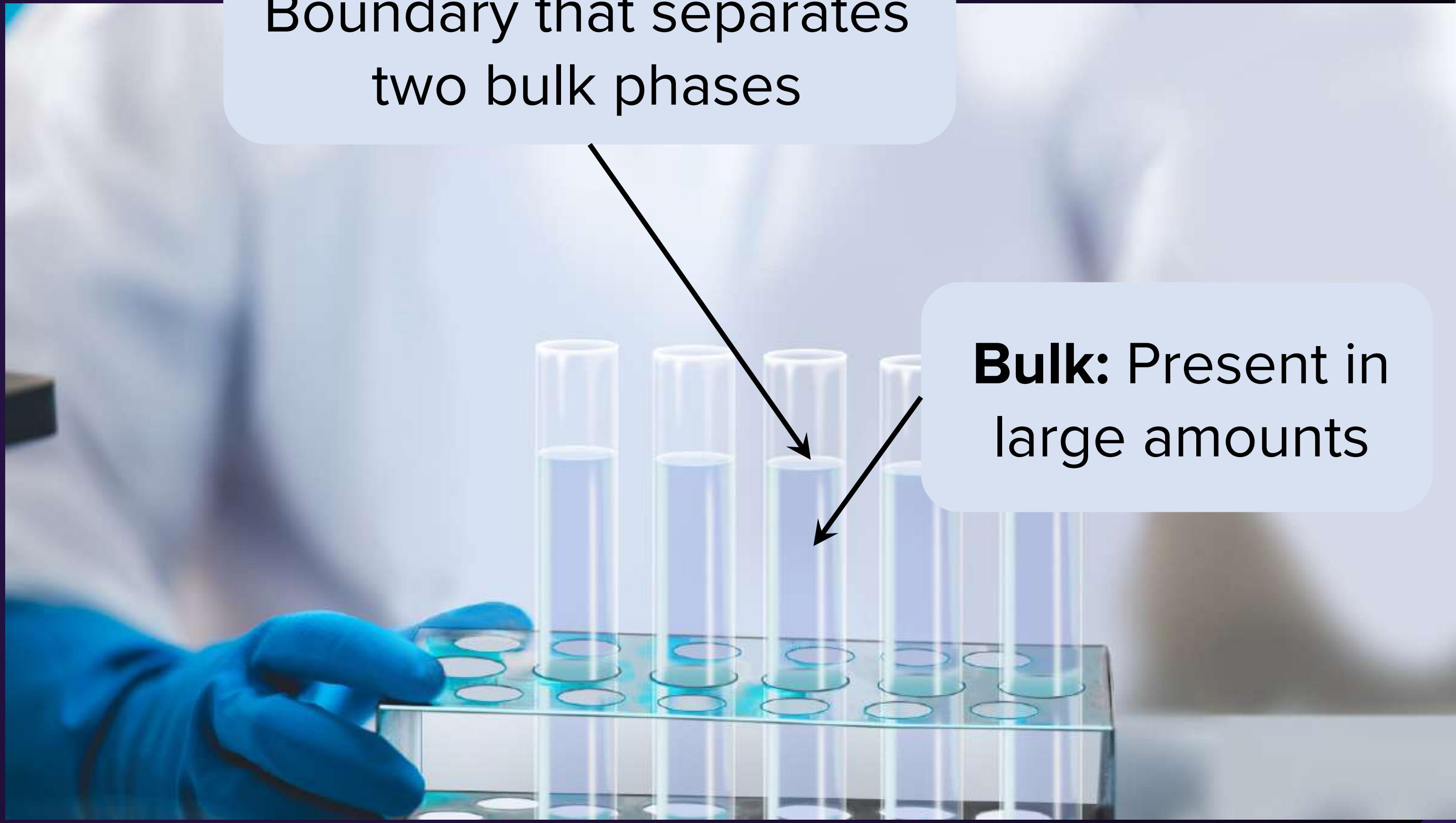


Surface Chemistry

It deals with the phenomena that occurs at **surfaces or interfaces**

Surface or interface is represented by separating the **bulk** phases by a hyphen or a slash.
E.g., solid-gas or solid/gas

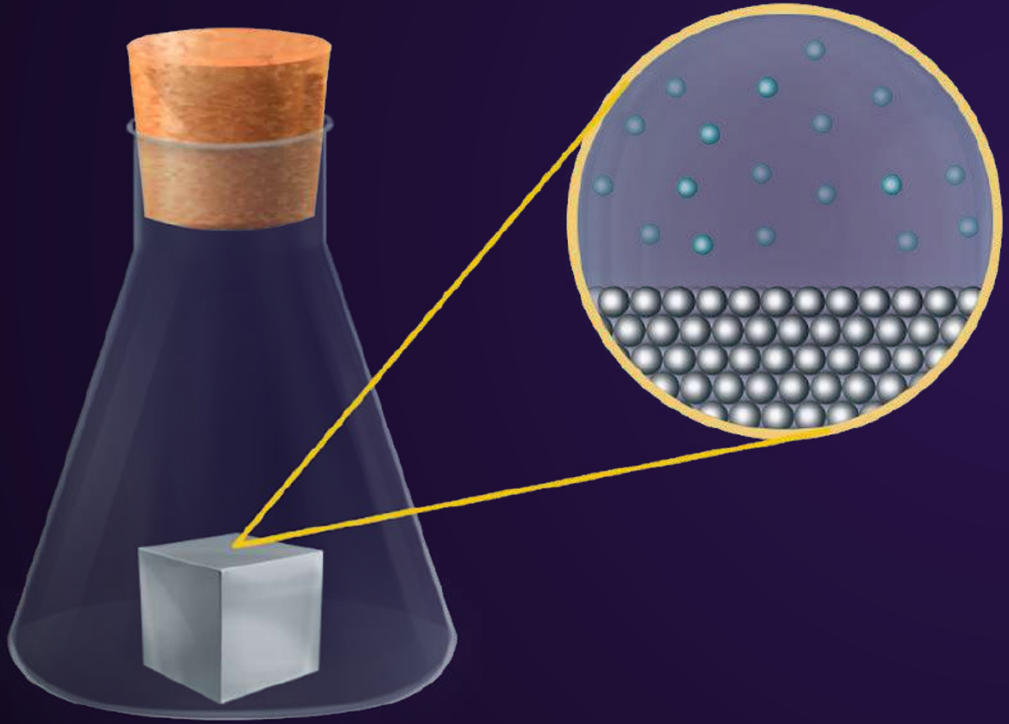
The bulk phases that we come across in surface chemistry may be **pure compounds or solutions**.



Surface/Interface: Boundary that separates two bulk phases

Bulk: Present in large amounts

Solid-gas
(solid/gas)



Liquid-liquid
(liquid/liquid)

Surface/Interface

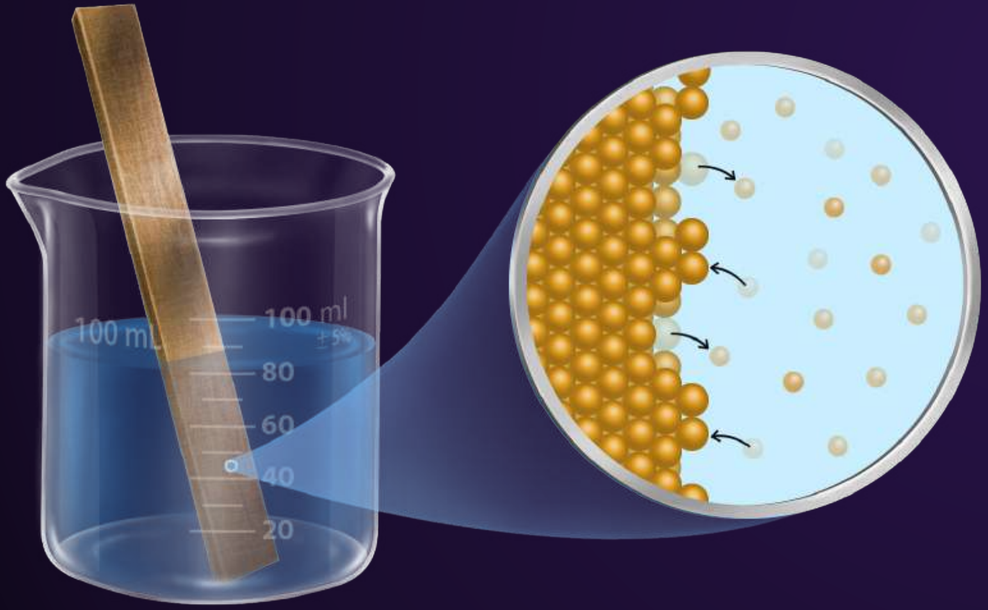
There is **no interface** between gases, due to complete **miscibility**

The surface/ interface is normally a **few molecules thick**.

Its **area** depends on the **size** of the particles of **bulk** phases.

Applications

Surface chemistry finds many applications in **industry, analytical work, and daily-life situations**.



Electrochemical equilibrium at solid liquid interface

Corrosion

Clean Surfaces

Every surface can't be considered to conduct surface studies meticulously.

Ultra clean surfaces are required to conduct the surface studies.

Such metal surfaces are obtained under very **high vacuum** (10^{-8} to 10^{-9} Pa)

Need to be **stored in vacuum** otherwise they interact with air (e.g.: O_2, N_2, etc.)

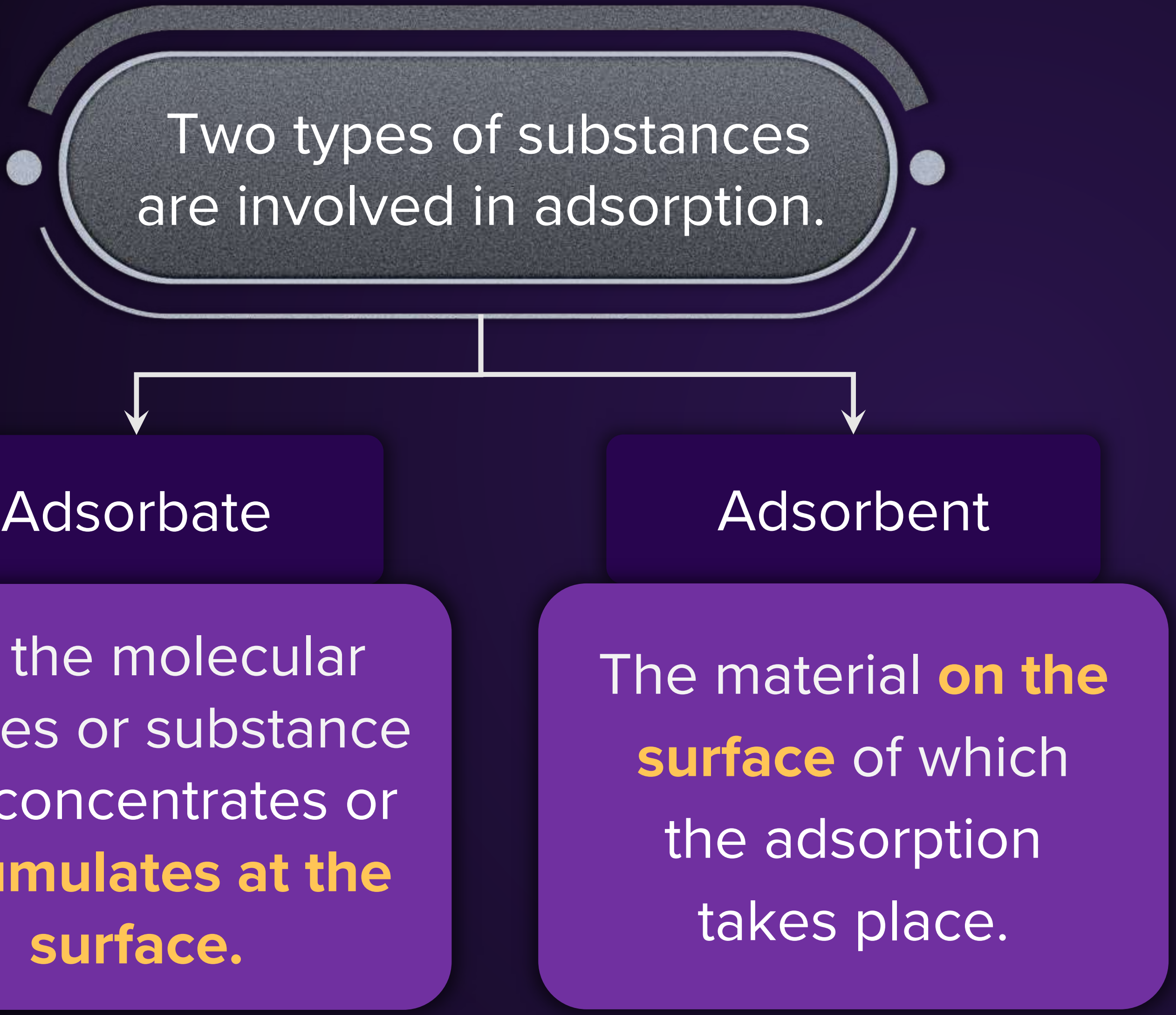
Adsorption

Solid surface has tendency to **attract and retain** other phase particles.

Such particles **remain at surface** without moving deep into the bulk.

It is the **accumulation** of molecular species at the **surface** rather than in the bulk of a solid or liquid.

Adsorption



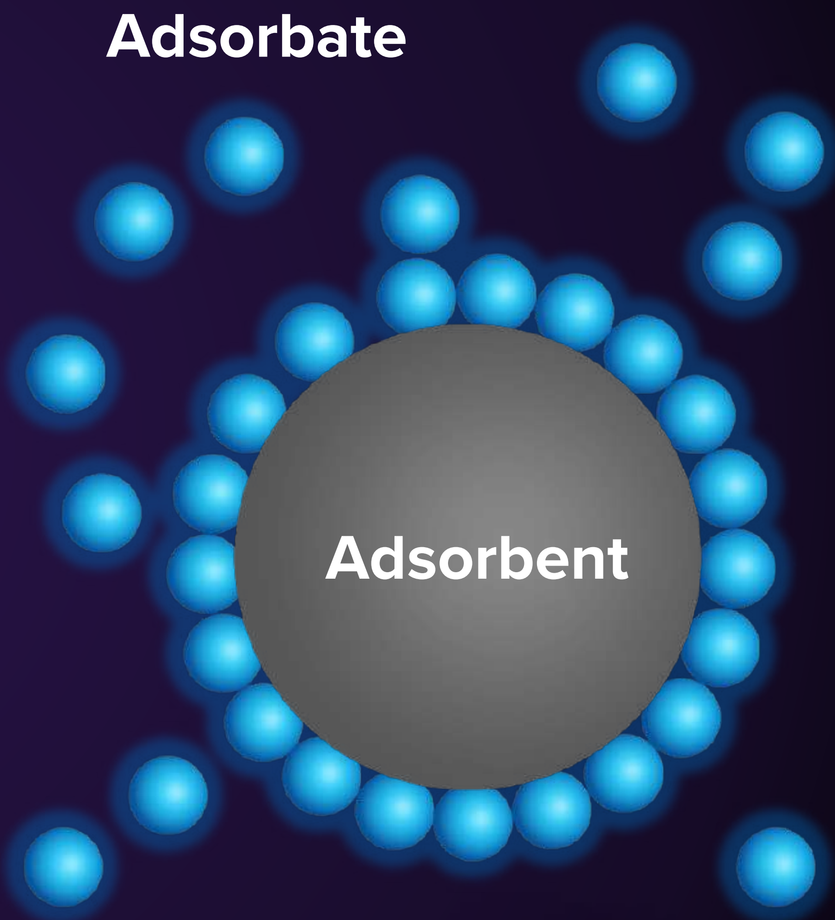
Two types of substances are involved in adsorption.

Adsorbate

It is the molecular species or substance that concentrates or **accumulates at the surface.**

Adsorbent

The material **on the surface** of which the adsorption takes place.



Adsorption

Adsorption is essentially a **surface phenomenon**.

↓

Solids, particularly in **finely divided** state have **large** surface area.

↓

Therefore, charcoal, silica gel, alumina gel, clay, etc. act as **good adsorbents**.

Examples

Gases like O_2, H_2, CO, Cl_2, NH_3, or SO_2 are taken in a closed vessel containing **charcoal**

The **air** becomes **dry** in the presence of **silica gel**.

Desorption

Desorption

The process of **removing** an adsorbed substance (**adsorbate**) from a surface on which it is adsorbed (**adsorbent**).

Absorption

The phenomenon in which the particles of gas or liquid get **uniformly distributed** throughout the **body** of the solid.

Example

Anhydrous $CaCl_2$

Absorption vs Adsorption

Absorption	Adsorption
The substance is **uniformly distributed** throughout the **bulk** of the solid.	The substance is concentrated only **at the surface** and does not penetrate through the surface to the bulk of the adsorbent.
The **concentration is uniform** throughout the **bulk** of the material.	The **concentration** of the adsorbate **increases** only **at the surface** of the adsorbent.

Absorption vs Adsorption

Absorption	**Adsorption**
It is a **bulk** phenomenon.	It is a **surface** phenomenon.
Absorption occurs at a **uniform** rate.	Adsorption is **rapid** in the beginning and its rate slowly decreases.
It is a **slow** process.	It is a **fast** process.
E.g.: Water vapours are absorbed by anhydrous calcium chloride.	E.g.: Water vapours are adsorbed by silica gel.

Remember!

When absorption and adsorption of the **same substance** take place simultaneously, it is known as **sorption**.

For example, dyes get adsorbed as well as absorbed in cotton fibre.

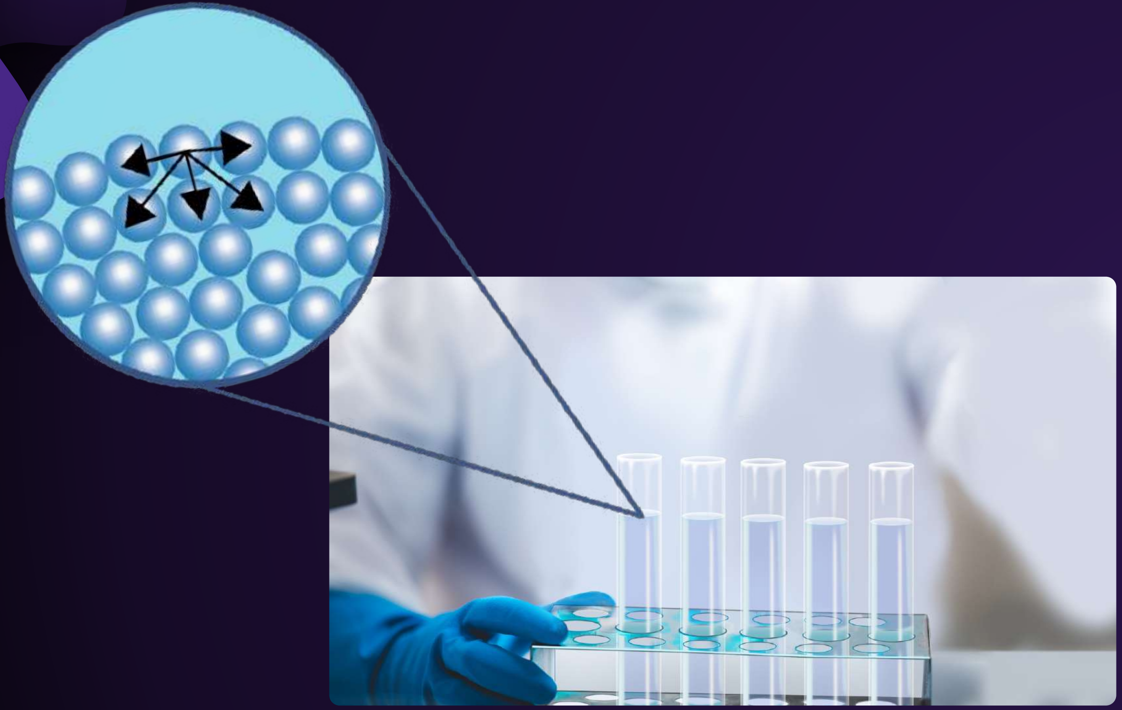
Mechanism of Adsorption

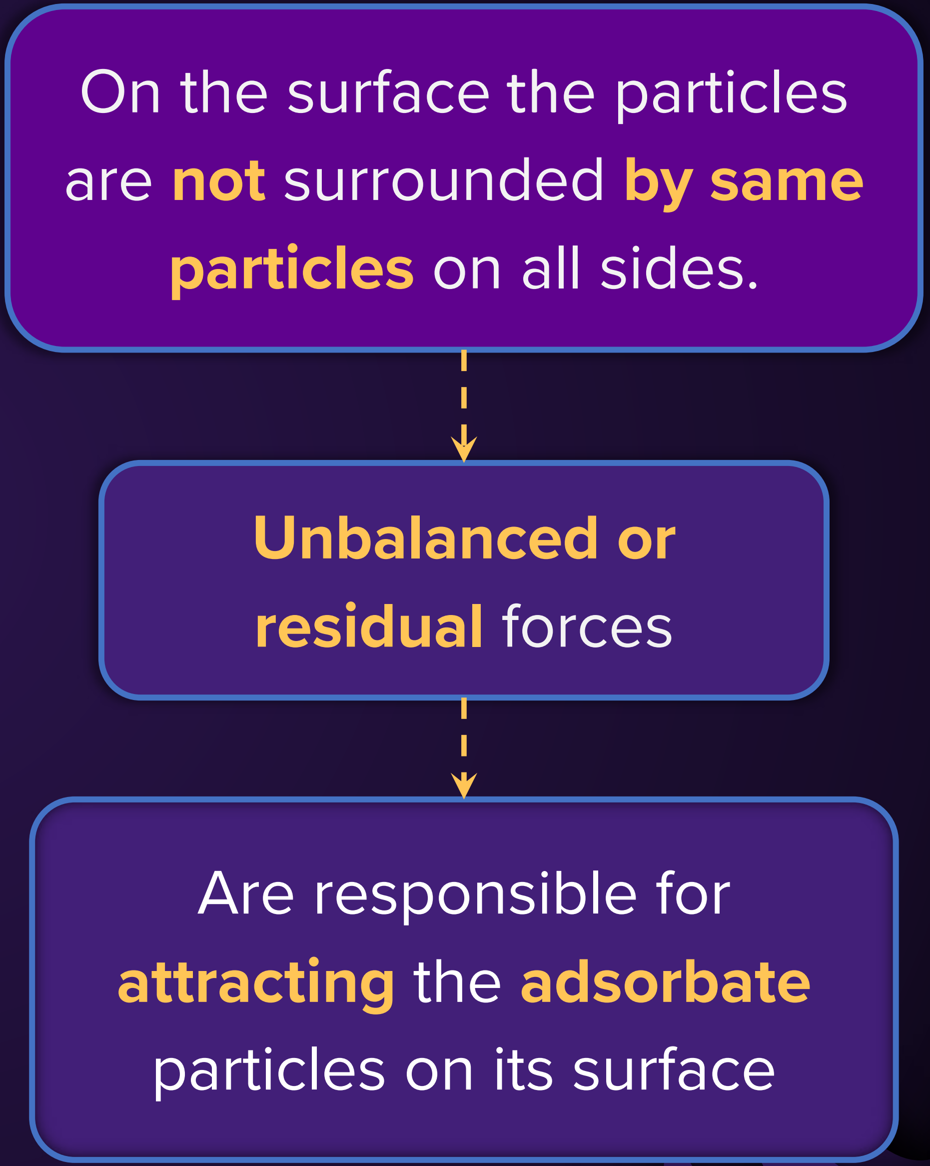
Surface particles of the adsorbent are **not in the same environment** as the particles inside the **bulk**.

Inside the adsorbent

All the forces acting between the particles are mutually **balanced**.

Mechanism of Adsorption





On the surface the particles are **not** surrounded **by same particles** on all sides.

Unbalanced or residual forces

Are responsible for **attracting** the **adsorbate** particles on its surface

Thermodynamics of Adsorption

1

Adsorption involves **a decrease** in **residual** forces or **surface energy**.

Energy is released, so the **heat of adsorption** is negative.

Adsorption is always **exothermic.**

$\Delta H < 0$

2

The **freedom of movement** of gaseous adsorbate particles is **restricted** due to adsorption.

Entropy **decreases**

$\Delta S < 0$

Thermodynamics of Adsorption

3

For a process to be spontaneous,

$\Delta G < 0$

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

We know, $\Delta H < 0$ $\Delta S < 0$

Initially, if ΔH is **sufficiently negative** in an adsorption process

Then combination of these two factors make **ΔG negative**.

As adsorption proceeds, ΔH becomes **less and less negative**.

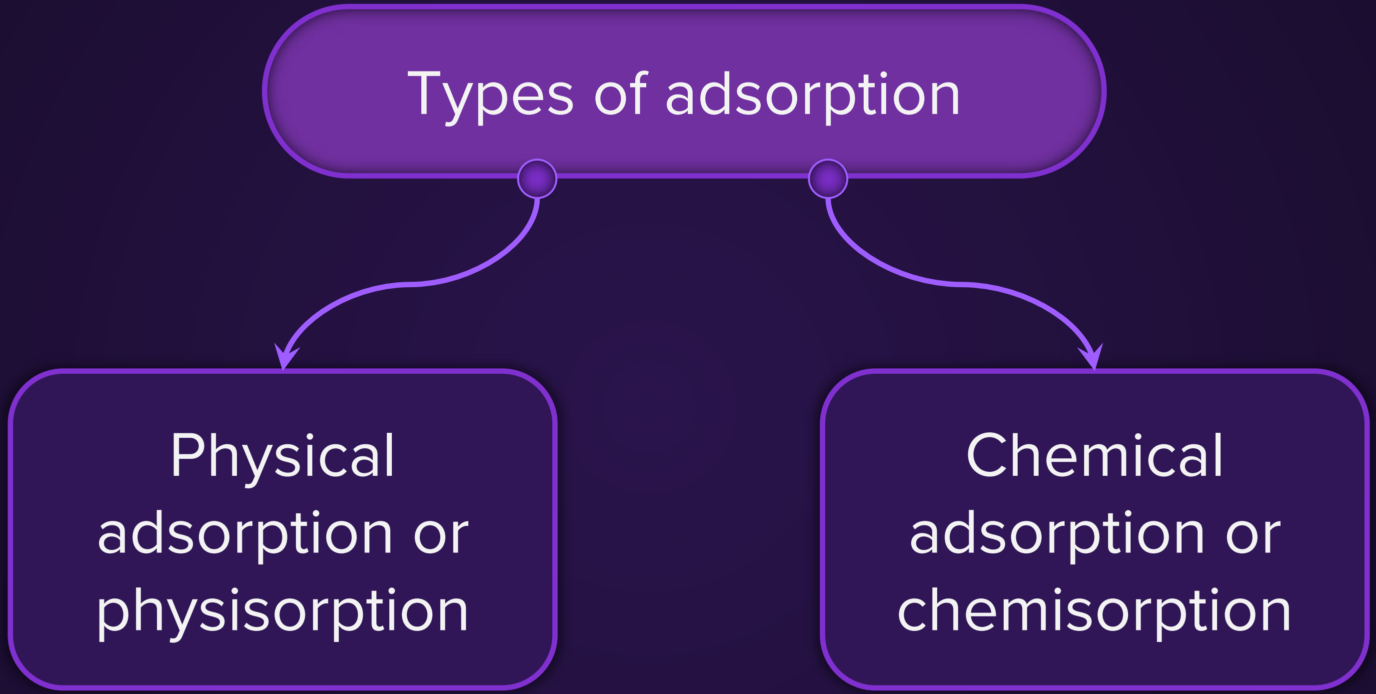
Hence, ΔH becomes equal to $T\Delta S$ and ΔG becomes **zero**.

Equilibrium is attained.

Enthalpy of Adsorption ($\Delta H_{Adsorption}$)

It is the amount of **heat released** when **1 mole** of an adsorbate gets adsorbed on a particular adsorbent at adsorption **equilibrium**.

It depends on the nature of both **adsorbent** and **adsorbate**.



Types of adsorption

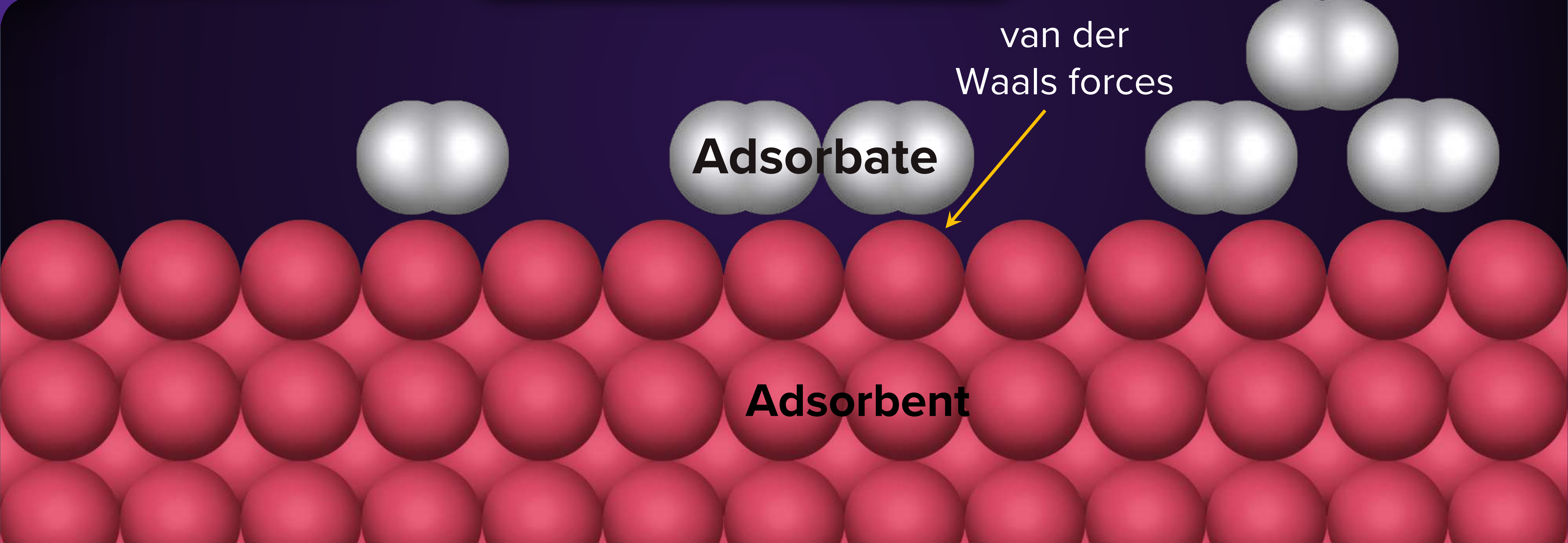
Physical adsorption or physisorption

Chemical adsorption or chemisorption

Physical Adsorption

If **accumulation** of a **gas** on the surface of a **solid**,

Force of attraction:
van der Waals’ forces.
Temperature favoured: **Low**
Layer: **Multilayered**



Characteristics of Physisorption

Characteristics

- Lack of specificity
- Nature of adsorbate
- Reversible nature
- Surface area of adsorbent
- Enthalpy of adsorption

Lack of Specificity

A given surface of an adsorbent

Does not show any **preference** for a particular gas as the van der Waals' forces are **universal**

Nature of Adsorbate

Having **higher** critical temperatures (T_C)

Generally,

Easily liquefiable gases are readily adsorbed.

As van der Waals forces are **stronger** for gases having **higher T_C**

Example

As, $T_C\ (SO_2) = 630\ K$ & $T_C\ (CH_4) = 190\ K$

1 g of activated charcoal adsorbs more sulphur dioxide than methane.

Reversible Nature

Physical adsorption of a gas by a solid is generally **reversible**.

$$\text{Solid} + \text{Gas} \rightleftharpoons \text{Gas/Solid} + \text{Heat}$$

Effect of change in pressure/volume

When the **pressure** of a gas is **increased** (volume is decreased),

More gas is **adsorbed** on the solid surface.

Le Chatelier's principle

Also, the **gas** can be **desorbed**/ removed from surface by **decreasing** pressure.

Reversible Nature

Solid + Gas ⇌ Gas/Solid + Heat

Effect of change in temperature

Le Chatelier's principle

The adsorption process is **exothermic**.

↓

With **increase** in temperature

↓

Physical adsorption **decreases** or the gas is removed from the surface.

Surface Area of Adsorbent

The extent of physisorption **increases** with the **increase** in **surface area** of the adsorbent

Thus, **finely divided** metals and **porous** substances having large surface areas are **good adsorbents**

Enthalpy of Adsorption

Physical adsorption is an **exothermic** process but enthalpy of adsorption is **very low.**

(20−40) kJ mol^{-1}

Reason

As **weak physical forces** like van der Waals' forces are involved, the **attraction** between the adsorbate and the adsorbent is **low**.

Chemical Adsorption

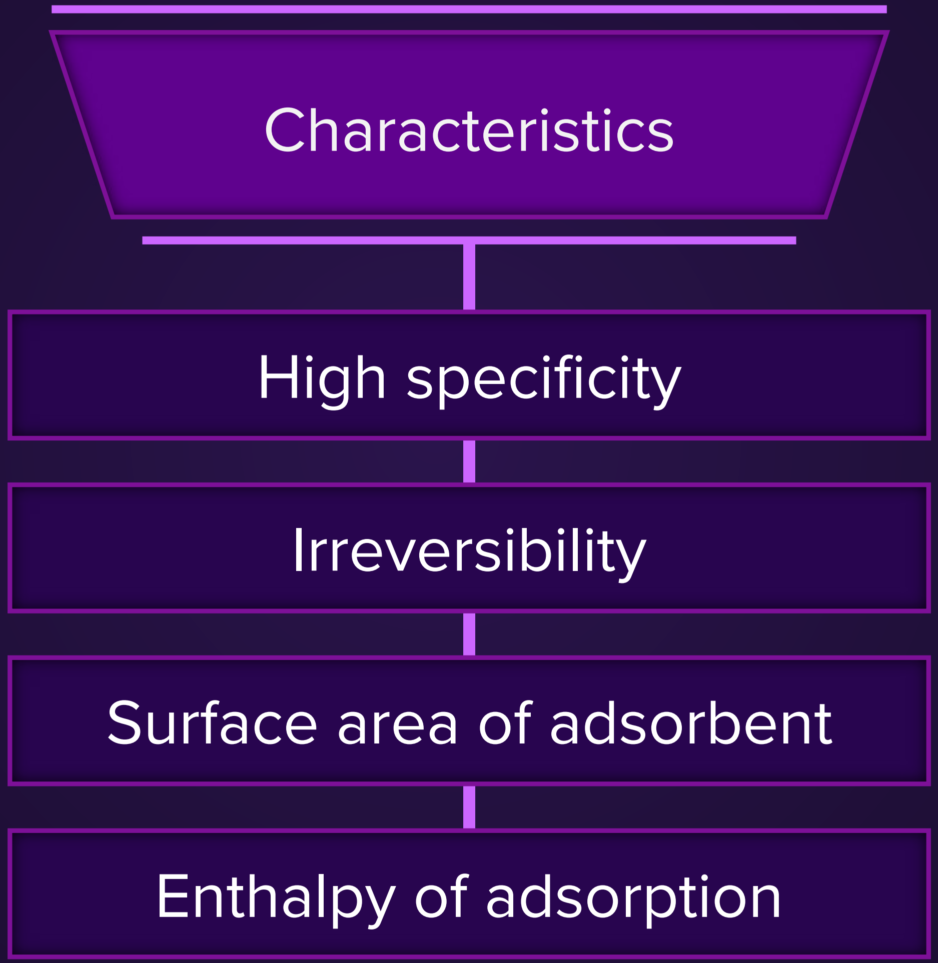
The adsorption in which gas **molecules or atoms** of the adsorbate are **held** to the solid surface of the adsorbent by the **chemical bonds**.

Chemical **bonds** may be **covalent or ionic** in nature

Generally, occurs at **high temperature** and is **monolayer** adsorption

Chemisorption involves a **high activation** energy, often referred to as **activated adsorption.**

Characteristics of Chemisorption



Characteristics

High specificity

Irreversibility

Surface area of adsorbent

Enthalpy of adsorption

High Specificity

Chemisorption occurs **only** if there is a possibility of **chemical bonding** between adsorbent and adsorbate

Example

1. **Oxygen** is adsorbed on **metals** by virtue of **oxide** formation.
2. **Hydrogen** is adsorbed by **transition metals** due to **hydride** formation.

Irreversibility

As chemisorption involves **compound formation.** It is usually **irreversible** in nature.

Effect of change in temperature

Although chemisorption is an **exothermic** process, it is **very slow** at **low temperature** due to **high activation energy**.

Effect of change in pressure

Usually, **high** pressure is **favourable** for chemisorption.

Surface Area of Adsorbent

Chemisorption also **increases** with an increase in the surface area of the adsorbent.

Enthalpy of Adsorption

As **chemical bond** formation is involved, enthalpy of adsorption is **high**

(80–240) kJ mol^{-1}

Physisorption vs Chemisorption

Property	Physisorption	Chemisorption
Nature of adsorption	**Weak** (van der Waals' forces)	**Strong** (Chemical bond formation)
Specificity of adsorption	Not specific	Highly specific
Reversibility of adsorption	Reversible	Irreversible
Temperature at which adsorption is more pronounced	**Low** temperature	**High** temperature
Effect of change in temperature	**Decreases** with rise in temperature	**Increases** with rise in temperature
Enthalpy of adsorption	**Low** (20-40 kJ mol^{-1})	**High** (80-240 kJ mol^{-1})

Physisorption vs Chemisorption

Property	Physisorption	Chemisorption
Nature of adsorbate layer	**Multi-layered** (at high pressure)	**Mono-layered**
Energy of activation	**Low**	Significantly **high**
Rate	Rapid/Fast	Slow
Ease of desorption	**Easy**, since van der Waals forces are involved	**Not easy**, since chemical forces are involved
Nature of gas	More **easily liquifiable** gases are adsorbed readily	Gases which can **react** with the **adsorbent** show chemisorption

Remember

A physisorption, at low temperature, may **pass into** chemisorption, as the temperature is **increased**.

As **temperature** increases

Physisorption

Dihydrogen is first adsorbed on nickel by **van der Waals’** force.

Chemisorption

Molecules of hydrogen then **dissociate** to form hydrogen **atoms** which are held on the surface.

Competitive Adsorption

When an adsorbent is in contact with **more than one** species

▷

There will be **competition** amongst them **to get adsorbed** on the surface of the adsorbent.

Factor Affecting Adsorption of Gases on Solids

- Nature of gases (adsorbate)
- Nature of adsorbent
- Effect of temperature
- Effect of pressure

Remember!

Extent of adsorption $\propto$ Ease of liquefaction $\propto$ Critical temperature of gas

Nature of Adsorbent

Extent of adsorption $\propto$ **Surface area** of solid

So, **finely divided** adsorbents are **more efficient** than normal one.

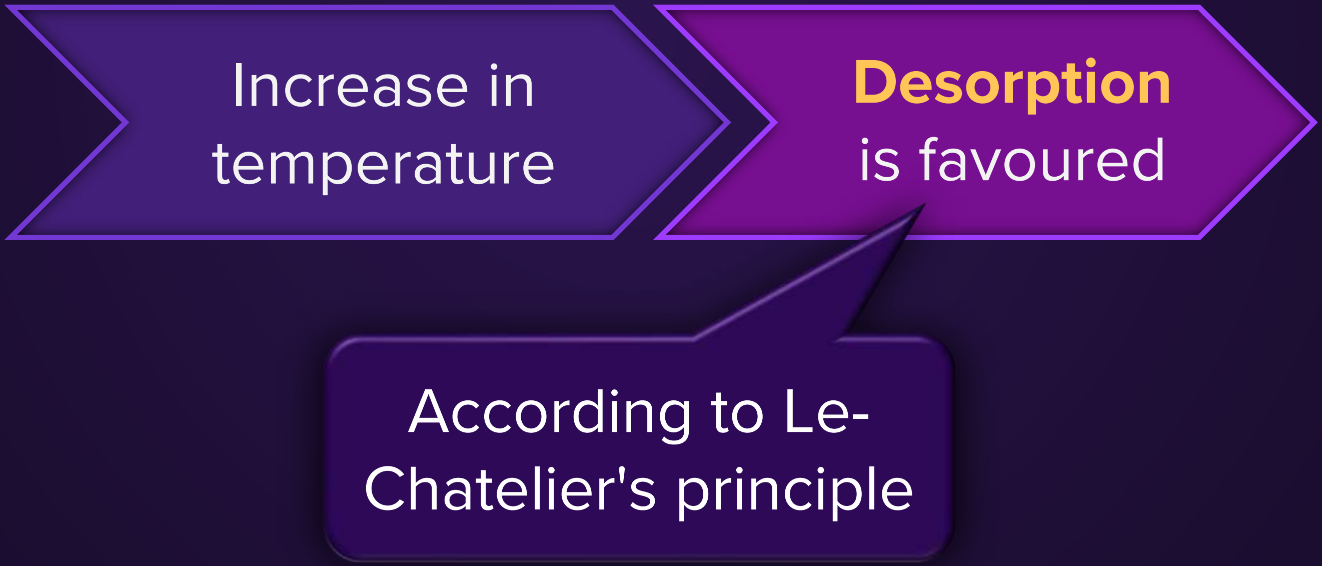
Activated charcoal, clay etc., can adsorb gases which are **easily liquified.**

Gases such as H_2, N_2 and O_2 are generally adsorbed on **finely divided transition metals** Ni and Co.

Effect of Temperature

We know,

Adsorbent (s) + Adsorbate (g) $\rightleftharpoons$ [Adsorbent---Adsorbate] + ΔH



Increase in temperature

Desorption is favoured

According to Le-Chatelier's principle

Adsorption Isobar

At constant pressure,

The variation in the **amount of gas adsorbed** by the **adsorbent** with **temperature** can be expressed by a curve termed as **adsorption isobar**

At constant pressure, P

x → Mass of gas adsorbed

m → Mass of adsorbent

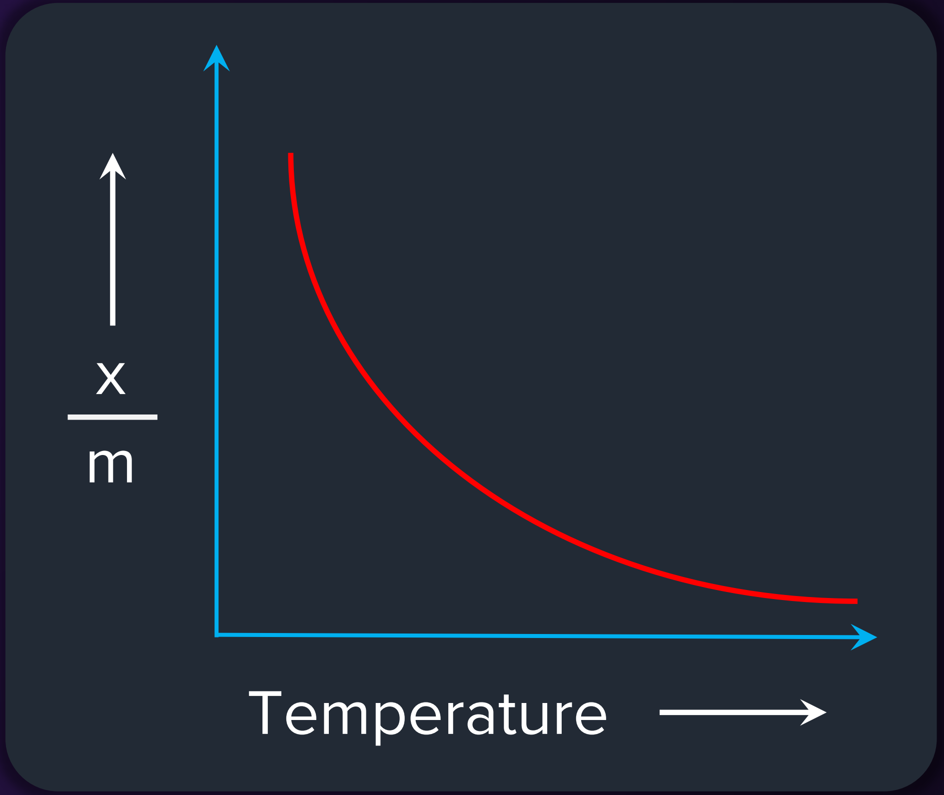
$\frac{x}{m}$ → Amount of gas adsorbed per unit mass of adsorbent

Extent of adsorption

Adsorption Isobar for Physisorption

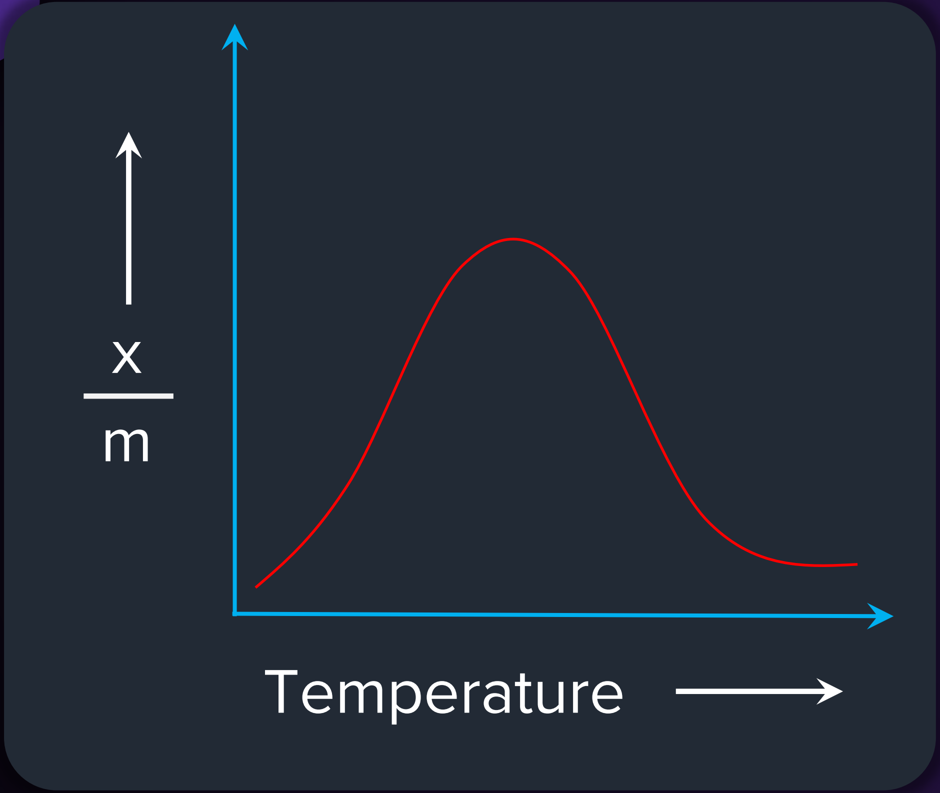
With **increase** in temperature, physical adsorption **decreases** continuously

Extent of adsorption vs temperature



Adsorption Isobar for Chemisorption

Extent of adsorption
vs temperature



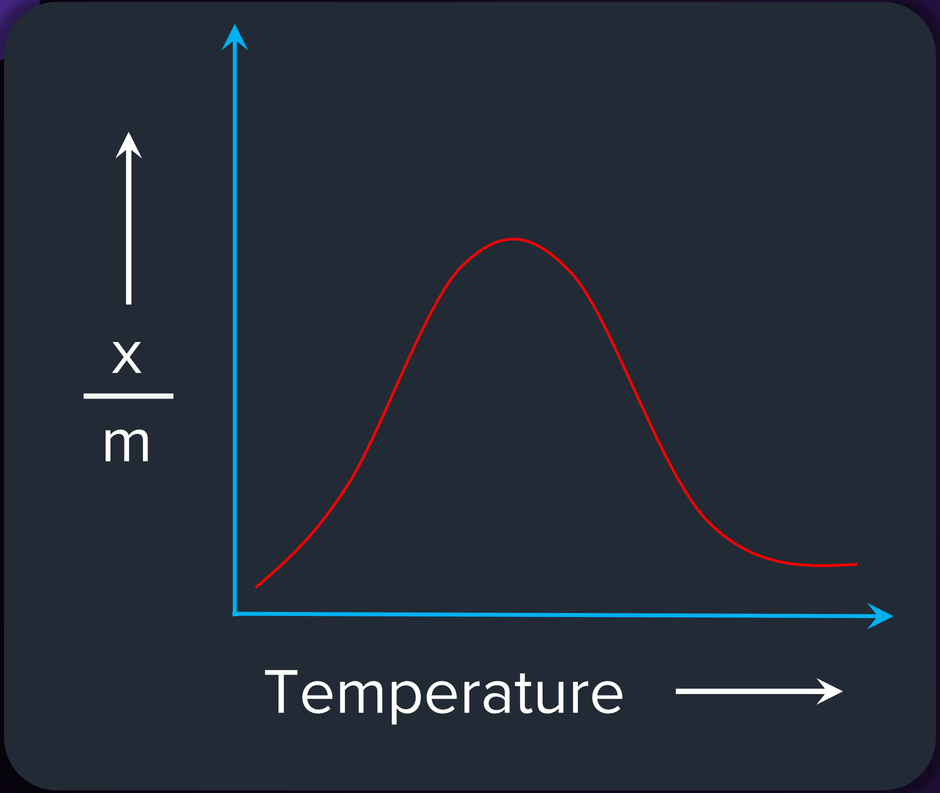
Chemical adsorption **increases initially** with temperature

Reaches a **maximum**

Then **decreases continuously.**

Adsorption Isobar for Chemisorption

Extent of adsorption
vs temperature



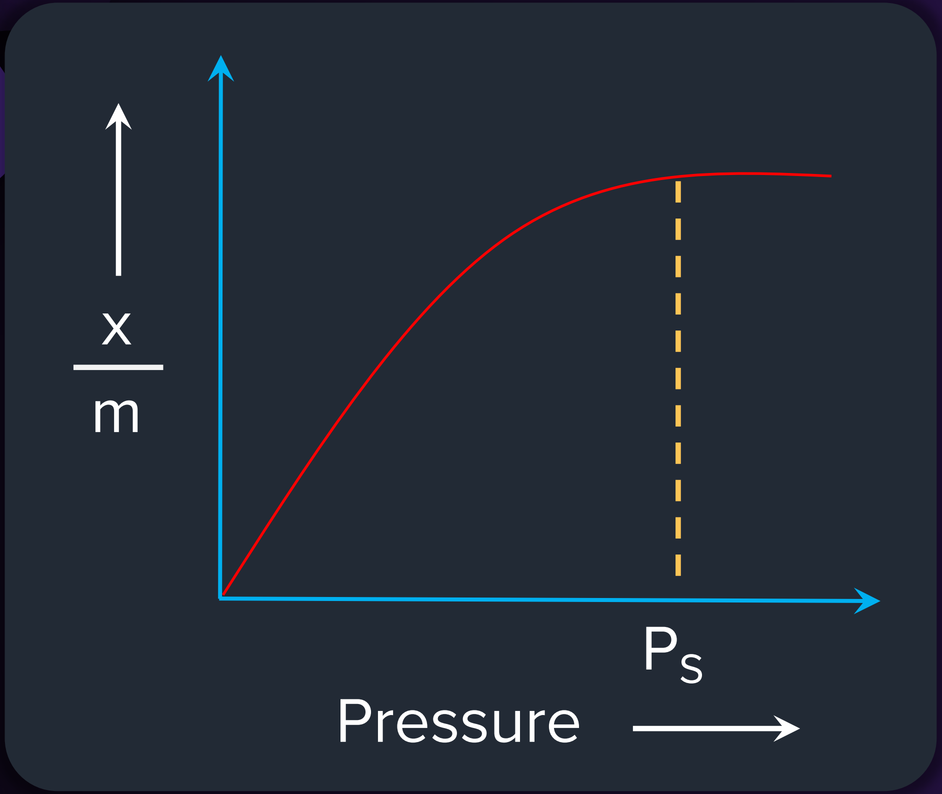
There is an increase in the chemisorption initially because **activation energy** is required to **initiate** the process

So, chemical adsorption is also known as '**activated adsorption**'

Effect of Pressure

The extent of adsorption of a gas (**x/m**) depends upon the **pressure of the gas**.

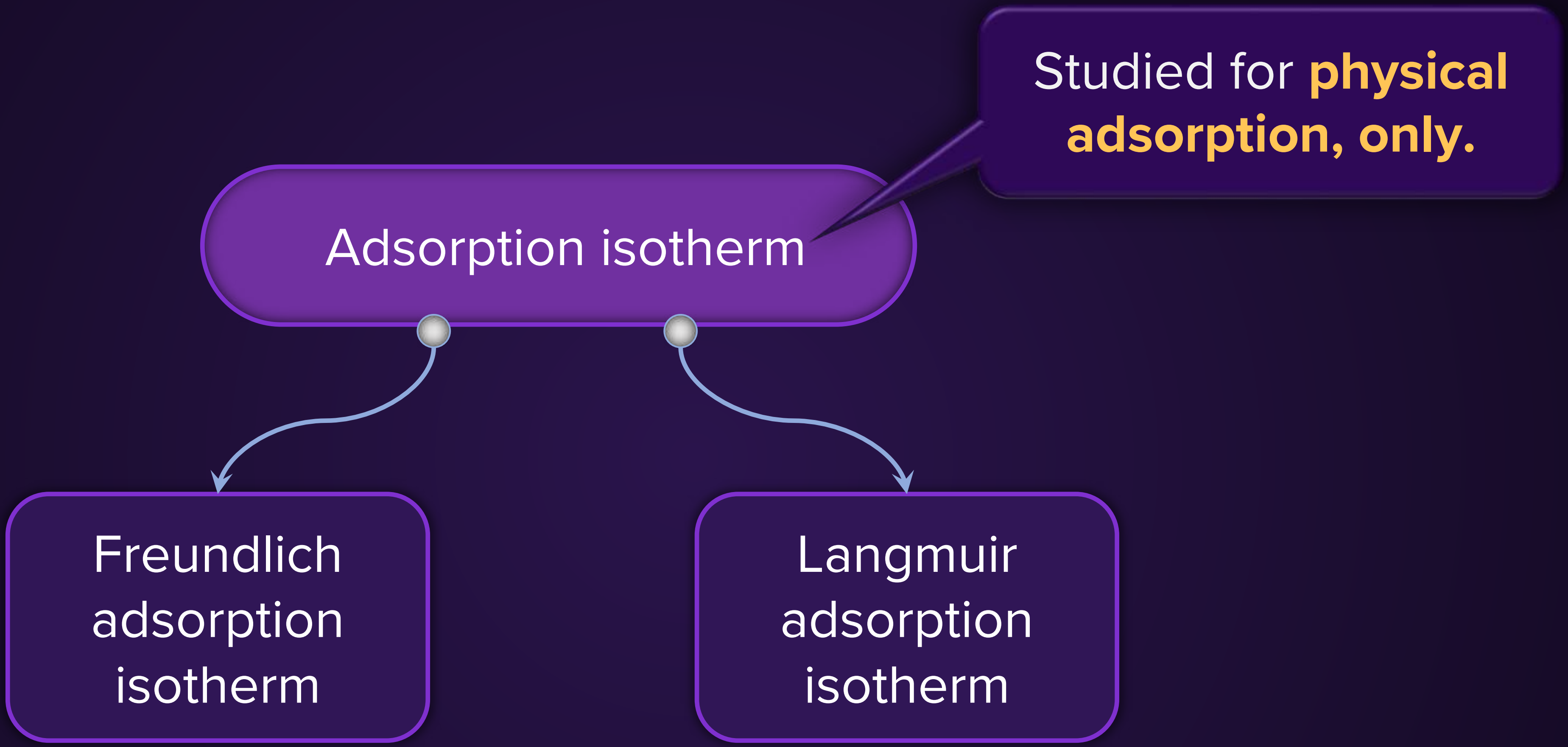
Adsorption Isotherm



At constant temperature,

Adsorption isotherm is a curve representing variation in the **amount of gas adsorbed** by the adsorbent with pressure

Extent of adsorption (**x/m**) increases with pressure, it becomes **maximum** corresponding to a pressure P_s, called **saturation pressure**



Adsorption isotherm

Studied for **physical adsorption, only.**

Freundlich adsorption isotherm

Langmuir adsorption isotherm

Freundlich Adsorption Isotherm

Freundlich gave an **empirical relationship** between the extent of adsorption(**x/m**) and **pressure**, at a particular temperature.

The relationship can be expressed as,

$$\frac{x}{m} \propto p^{\frac{1}{n}}$$

$n > 1$

$$\frac{x}{m} = k\,p^{\frac{1}{n}} \quad \text{...(1)}$$

At a particular T

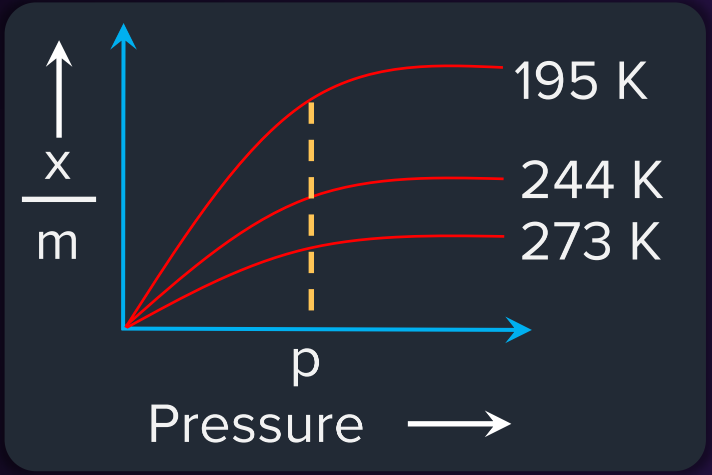
Where,
k and n: Constants
x: Mass of gas adsorbed
m: Mass of adsorbent

Depends on the **nature of gas** and **adsorbent**

Freundlich Adsorption Isotherm

$\frac{x}{m}$ vs pressure

(at different temperatures)



At a fixed pressure, there is a **decrease** in physical adsorption with **increase** in temperature.

The curves at **different temperatures** approach saturation at **high pressure**.

Freundlich Adsorption Isotherm

$$\frac{x}{m} = k\,p^{\frac{1}{n}}$$

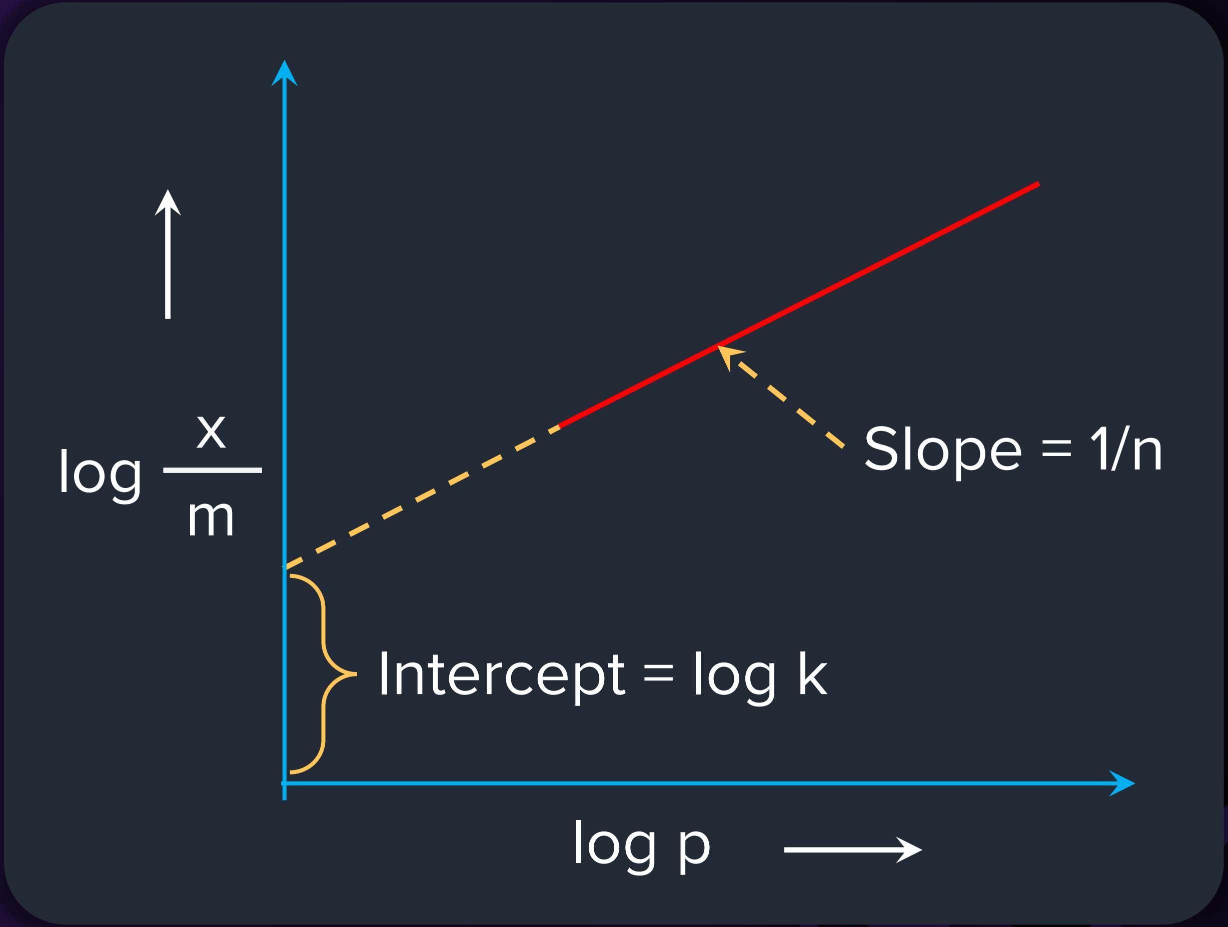
Taking log on both sides,

$$\log \frac{x}{m} = \log kp^{\frac{1}{n}}$$

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

$$\log \frac{x}{m} = (1/n) \log p + \log k$$

Compare with straight line equation, y = mx + c



Freundlich Adsorption Isotherm

Freundlich isotherm is **valid** if the plot is a **straight line.**

It explains the behavior of adsorption in an **approximate** manner.

Probable range is 0.1 to 0.5

The factor (1/n) can have values between

0 to 1

Freundlich isotherm **holds** good over a **limited range** of pressure.

Adsorption Isotherm Under Different Pressure Ranges

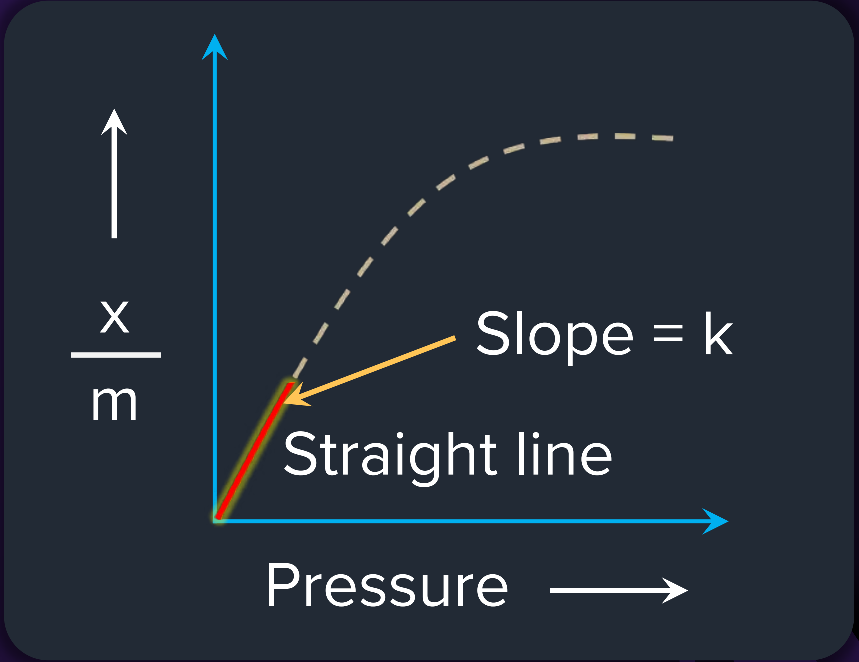
1 At low pressure

n = 1

$$\frac{1}{n} = 1$$

So, $$\frac{x}{m} = kp$$

$\frac{x}{m}$ vs P → Linearly dependent on pressure



Adsorption Isotherm Under Different Pressure Ranges

2 At intermediate pressure

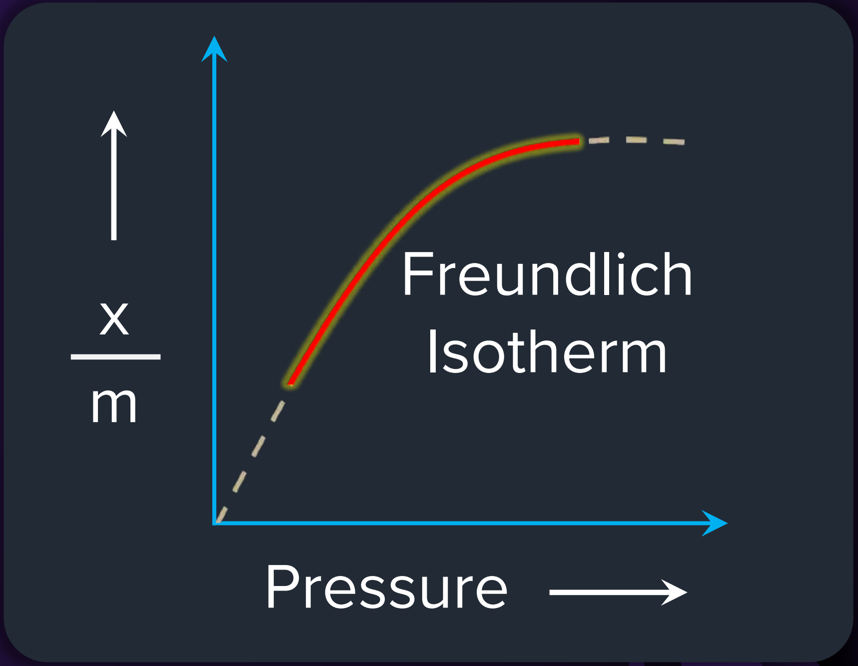
$$0 < \frac{1}{n} < 1$$

$$\frac{x}{m} = kp^{\frac{1}{n}}$$

Freundlich isotherm

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

Power of pressure (n value)



Adsorption Isotherm Under Different Pressure Ranges

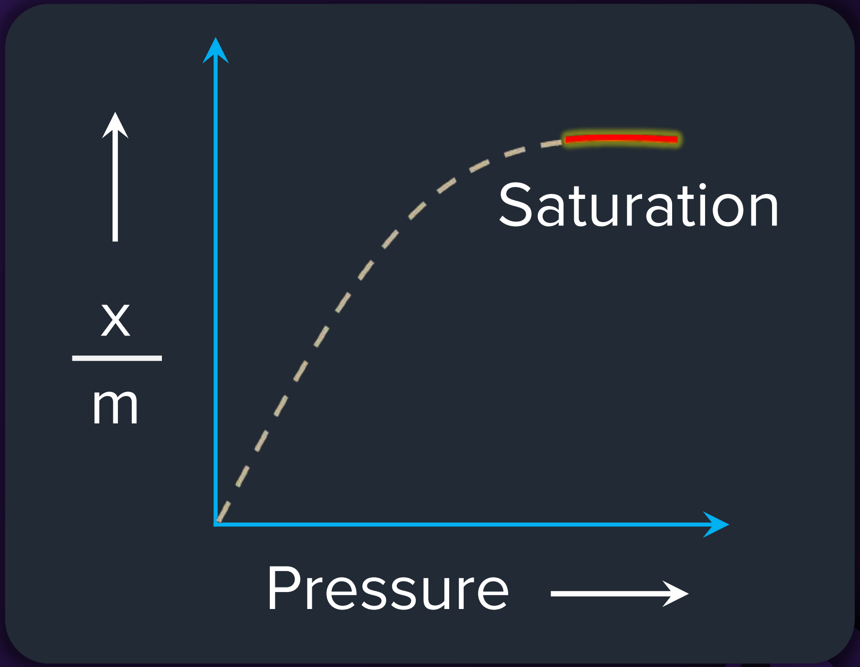
3 At high pressure

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

Independent of pressure

$$\frac{1}{n} = 0$$

So, $$\frac{x}{m} = k$$



Drawbacks of Freundlich Adsorption Isotherm

1 It **holds** good for a **limited range** of pressure of the gas, but generally, fails at **high pressure**.

Saturation at high pressure

2 The isotherm is **applicable** when the adsorbate forms a **unimolecular layer** on the adsorbent surface.

Assumptions of Langmuir Adsorption Isotherm

1. The adsorbed **gas** is considered to behave **ideally.**
2. A **solid surface** is considered as **homogenous** but contains a **fixed** number of **adsorption sites** on surface.
3. Each site adsorbs a **single** molecule i.e., adsorption is **monomolecular.**
4. Rate of **adsorption** = Rate of **desorption**
5. There is **no lateral overlap** between adsorbed molecules.

Langmuir Adsorption Isotherm

Rate of adsorption $\propto$ Fraction of surface available for adsorption

Rate of adsorption $\propto$ Pressure of gas (P)

$$\frac{\text{Sites occupied}}{\text{Total available sites}}$$

θ --→ **Fraction** of surface covered

For a **reversible** physisorption process,

$$\text{Adsorbent + Gas} \underset{k_d}{\overset{k_a}{\rightleftharpoons}} \text{Gas/adsorbent}$$

Rate of adsorption $\propto$ $P(1 - \theta)$

Rate of adsorption $=$ $k_a\, P(1 - \theta)$

k_a: Adsorption rate constant

Langmuir Adsorption Isotherm

We know,

Rate of adsorption = Rate of desorption

$$k_a P(1 - \theta) = k_d \theta$$

$$\theta = \frac{\frac{k_a}{k_d} P}{1 + \frac{k_a}{k_d} P}$$

$$\theta = \frac{KP}{1 + KP}$$

Where, $K = \frac{k_a}{k_d}$

Langmuir Adsorption Isotherm

According to Langmuir,
extent of adsorption is
proportional to ϴ

$$\frac{x}{m} \propto \theta$$

$$\frac{x}{m} = K_1 \times \frac{KP}{1 + KP}$$

K_1 is a proportionality constant

$$\frac{x}{m} = \frac{aP}{1 + bP} \quad \ldots (1)$$

a, b are Langmuir parameters

$$a = K_1 \times K = K_1 \times \frac{k_a}{k_d}$$

$$b = K = \frac{k_a}{k_d}$$

Langmuir Adsorption Isotherm

At high pressure,

$$1 + bP \approx bP$$

$$\frac{x}{m} = \frac{aP}{bP} = \frac{a}{b}$$

x/m becomes **independent** of pressure i.e., the **surface is fully covered** and change in pressure has **no effect** on further adsorption.

At low pressure,

$$1 + bP \approx 1$$

$$\frac{x}{m} = \frac{aP}{1} = aP$$

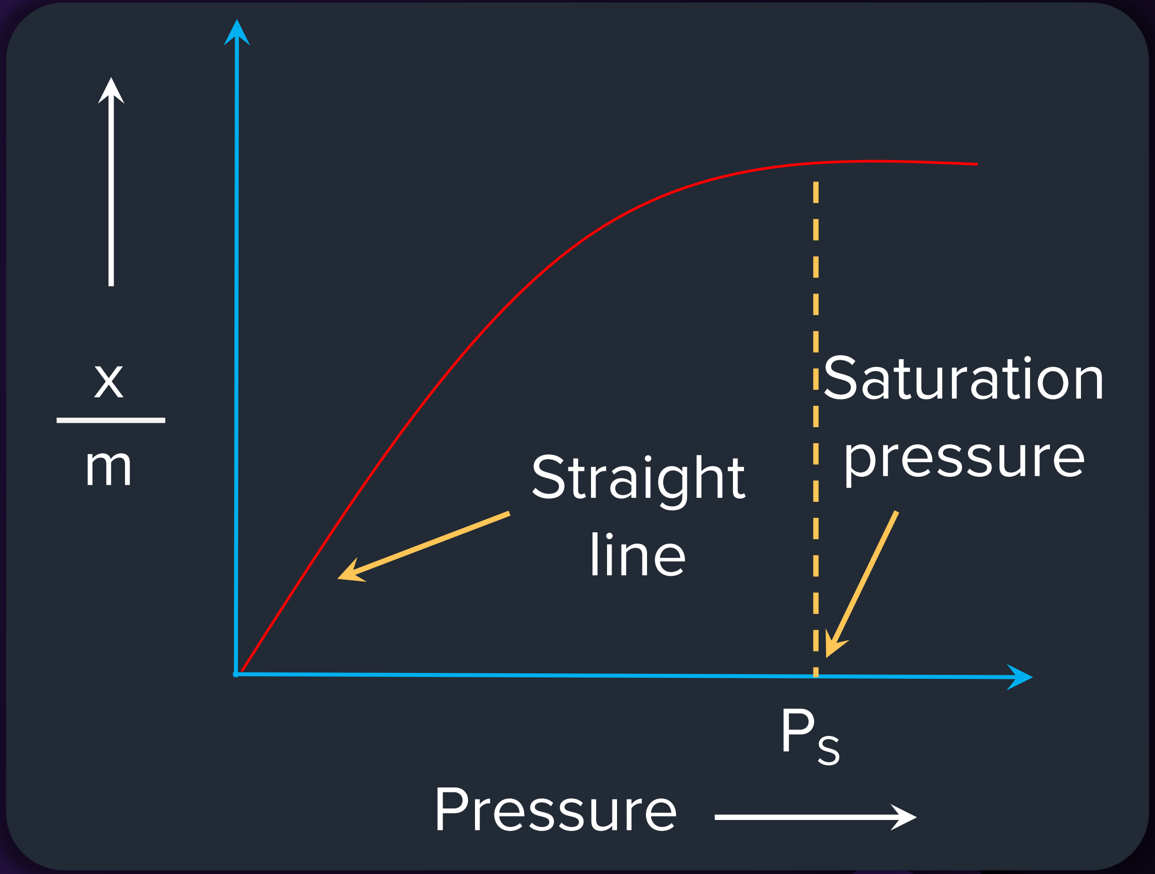
x/m **increases linearly** with pressure

Langmuir Adsorption Isotherm

Low pressure, $\frac{x}{m} = aP$

High pressure, $\frac{x}{m} = \frac{a}{b}$

We know, for adsorption isotherm



Determination of Values of a and b

We know,

$$\frac{x}{m} = \frac{aP}{1 + bP}$$

Inverse form,

$$\frac{m}{x} = \frac{1 + bP}{aP}$$

$$\frac{m}{x} = \frac{1}{aP} + \frac{b}{a}$$

Plot of (m/x) vs (1/P)

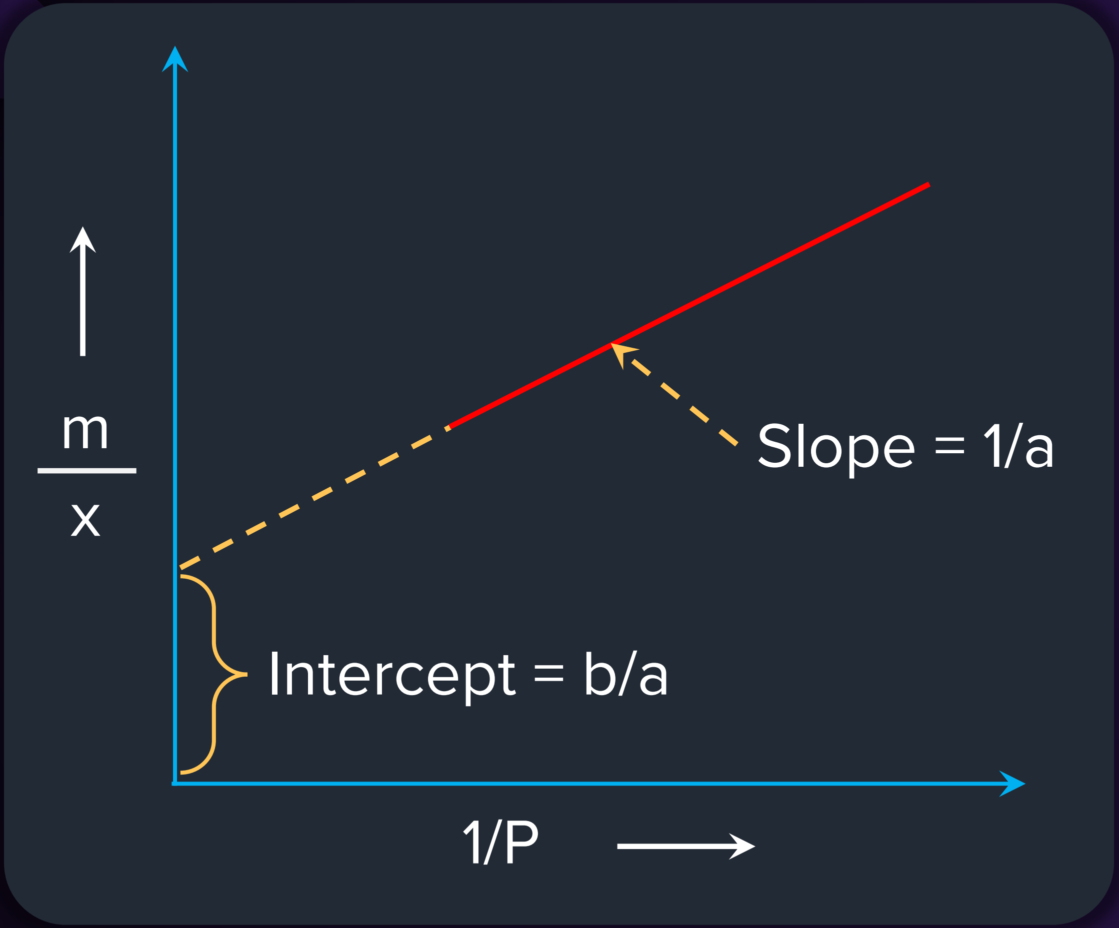
Straight line

Where,

Slope = 1/a

Intercept = b/a

Determination of Values of a and b



Values of a and b can be determined using the **slope** and **intercept** of the m/x vs 1/P curve

Adsorption from Solution Phase

Solids can adsorb solutes **from a solution.**

Example:

A solution of **acetic acid in water** is shaken with **charcoal.**

A part of the **acid is adsorbed** by the charcoal, and the **concentration** of the acid **decreases.**

Characteristics of Adsorption from Solution Phase

1. The **extent** of adsorption **increases** with **increase** in the **surface area** of adsorbent.
2. The **extent** of adsorption **decreases** with **increase** in **temperature**.
3. The **extent** of adsorption **depends** on the **concentration** of the **solute** in solution.
4. The **extent** of adsorption **depends** on the **nature** of the **adsorbent** and the **adsorbate**.

Characteristics of Adsorption from Solution Phase

Freundlich's equation approximately describes the **behaviour of adsorption** from the solution.

But for the solution phase, **concentration** of the solution is taken in account **instead of pressure**.

$$\frac{x}{m} = kC^{\frac{1}{n}} \quad \text{... (1)}$$

C : The equilibrium concentration of solute

k : Constant

n : Constant, $(n > 1)$

(x/m) : Extent of adsorption

Freundlich Adsorption Isotherm

$$\frac{x}{m} = k\,C^{\frac{1}{n}}$$

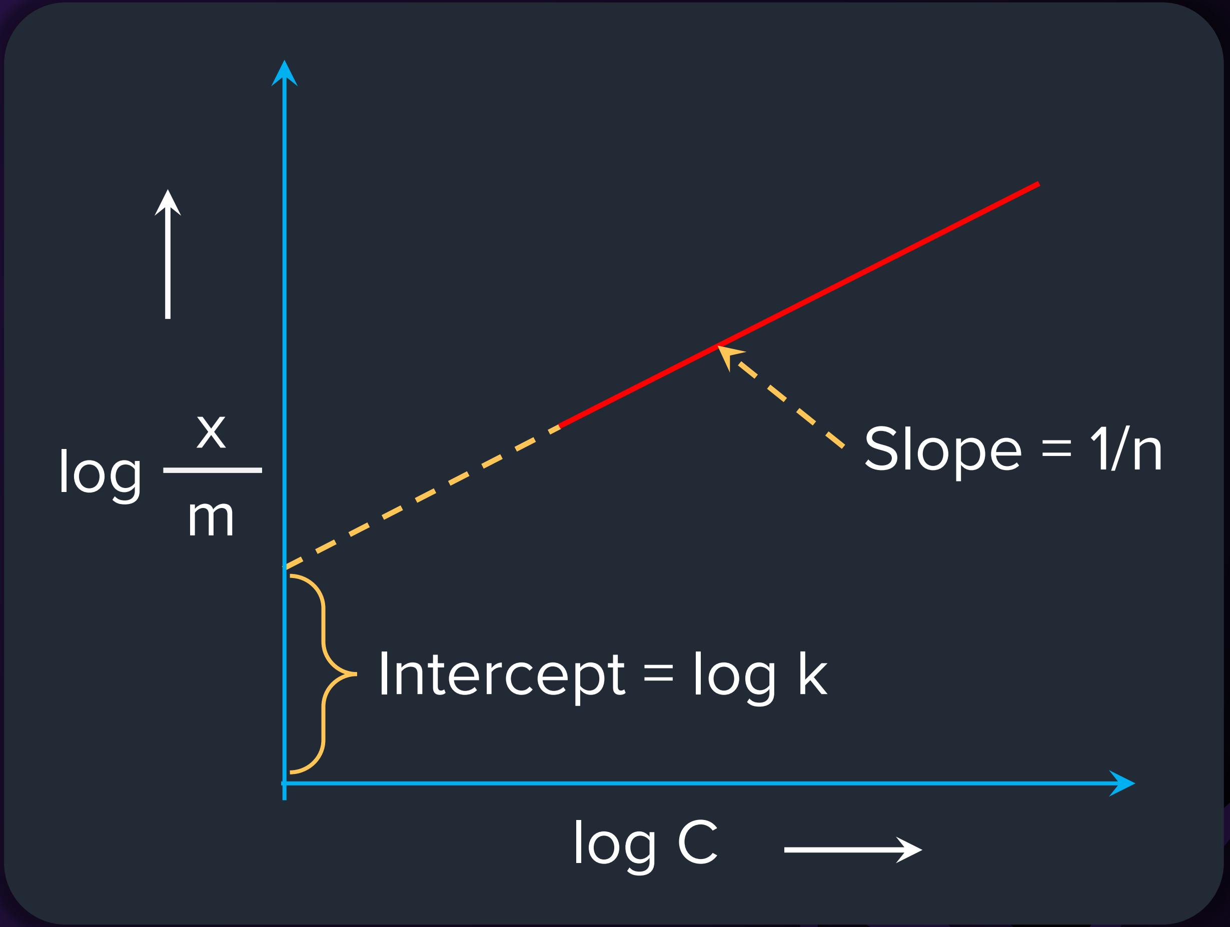
Taking log on both sides,

$$\log\frac{x}{m} = \log kC^{\frac{1}{n}}$$

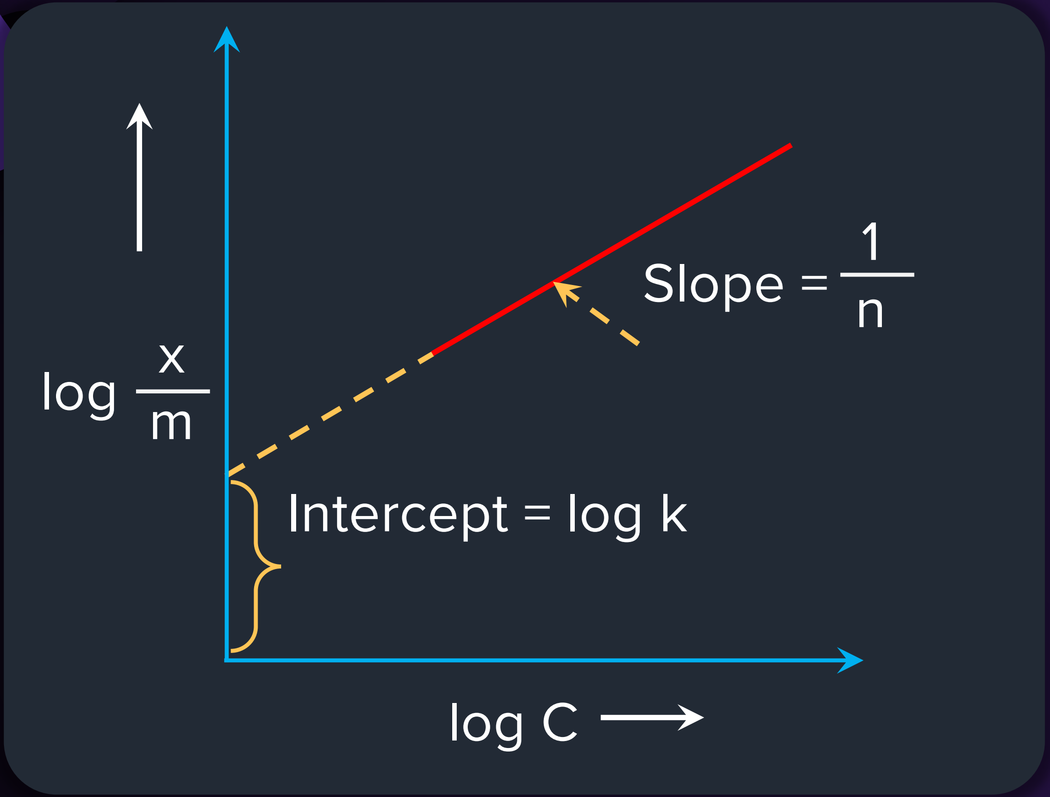
$$\log\frac{x}{m} = \log C^{\frac{1}{n}} + \log k$$

$$\log\frac{x}{m} = (1/n)\log C + \log k$$

Compare with straight line equation, y = mx + c



Characteristics of Adsorption from Solution Phase



Validity of Freundlich isotherm can be established if plot of log x/m vs log C is a straight line.

Catalyst

A chemical substance that can **alter** the **rate** of a reaction, by providing an **alternative** pathway.

Example:

$$2KClO_3 \xrightarrow{MnO_2} 2KCl + 3O_2$$

Normally, $KClO_3$ is heated to **high** temperature

653–873 K

When catalyst **MnO_2** is used, reaction occurs at a **low** temperature and **rapidly**

473–633 K

Types of catalysts

- On the basis of phases
  - Homogeneous catalyst
  - Heterogeneous catalyst
- On the basis of impact on rate of reaction
  - Positive catalyst
  - Negative catalyst (inhibitor)

Homogeneous Catalyst

The process in which the catalysts and reactants are in the **same phase** process is called as **homogeneous catalysis**.

The catalyst is called a **homogeneous catalyst**.

Example:

Hydrolysis of ester (acidic medium)

(i) $CH_3COOC_2H_5\ (\ell) + H_2O\ (\ell) \xrightarrow{HCl\ (\ell)} CH_3COOH\ (aq) + C_2H_5OH\ (aq)$

Oxidation of sulphur dioxide

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

Heterogeneous Catalyst

The process in which the catalysts and reactants are in **different phase** process is called as **heterogeneous catalysis**.

The catalyst is called a **heterogeneous catalyst**.

Example:

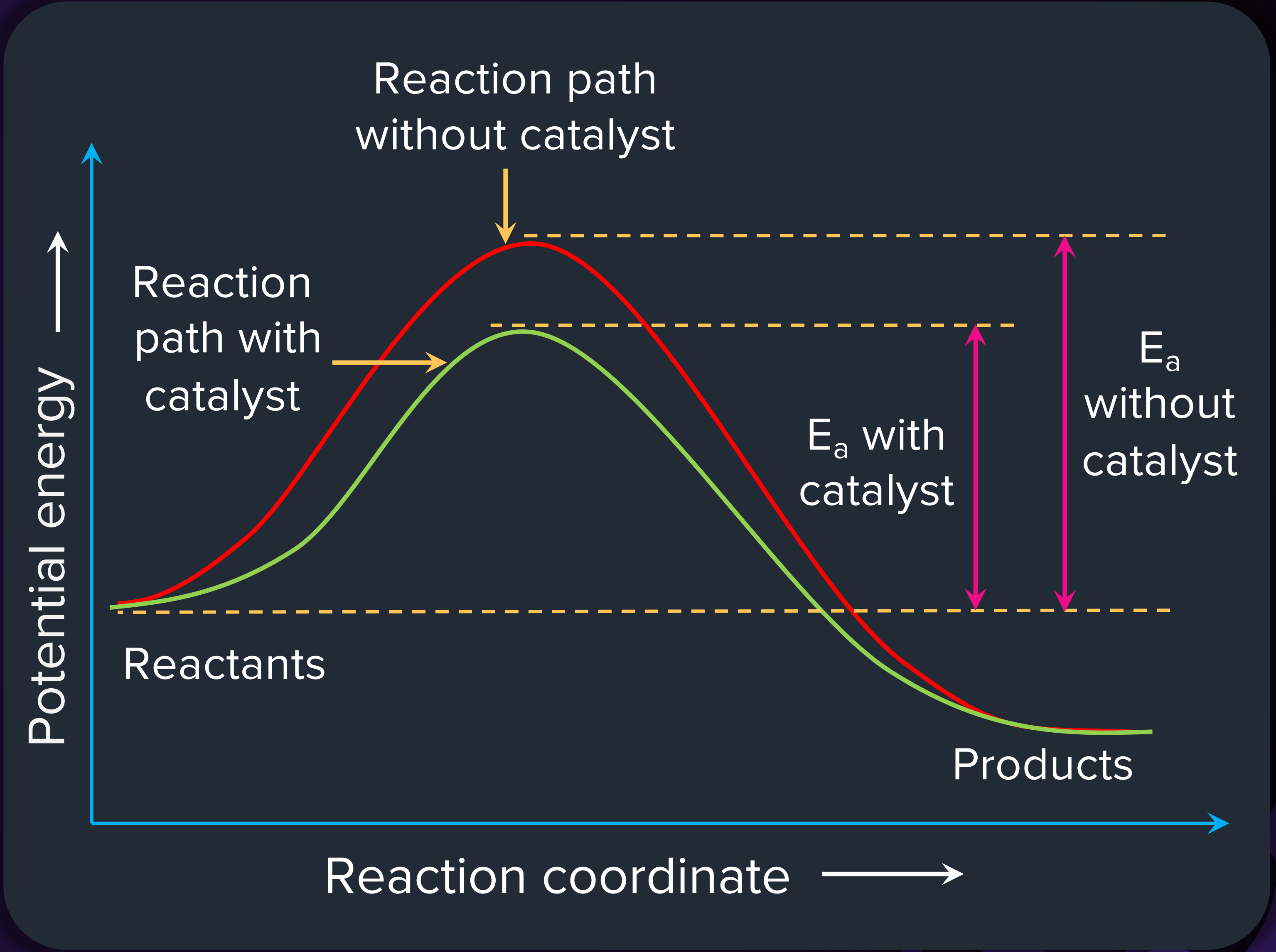
Decomposition of H_2O_2

$$2H_2O_2\ (\ell) \xrightarrow{MnO_2\ (s)} H_2O\ (\ell) + O_2\ (g)$$

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

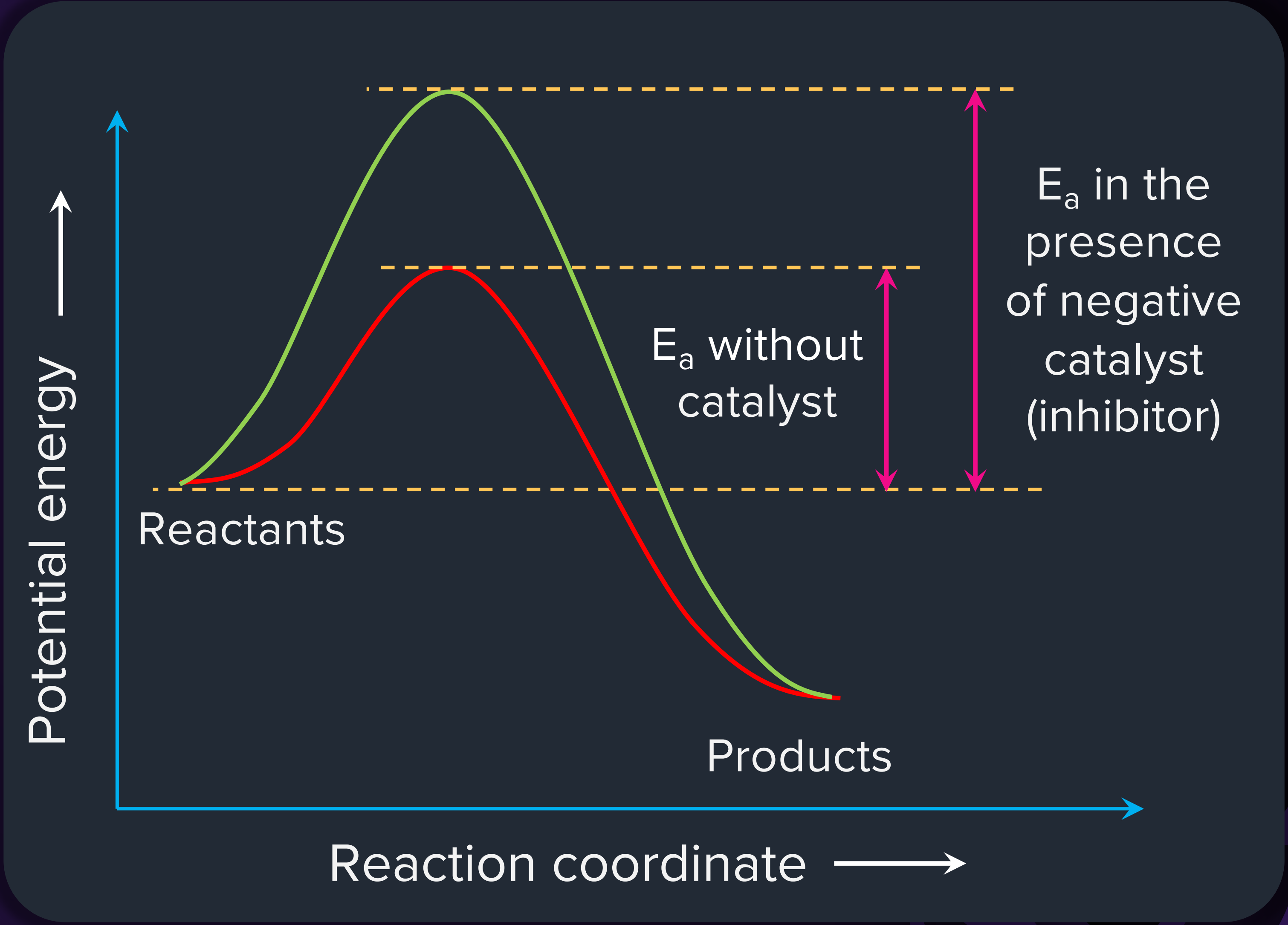
Positive Catalyst

A positive catalyst **increases** the reaction rate by **reducing** the activation energy **barrier.**

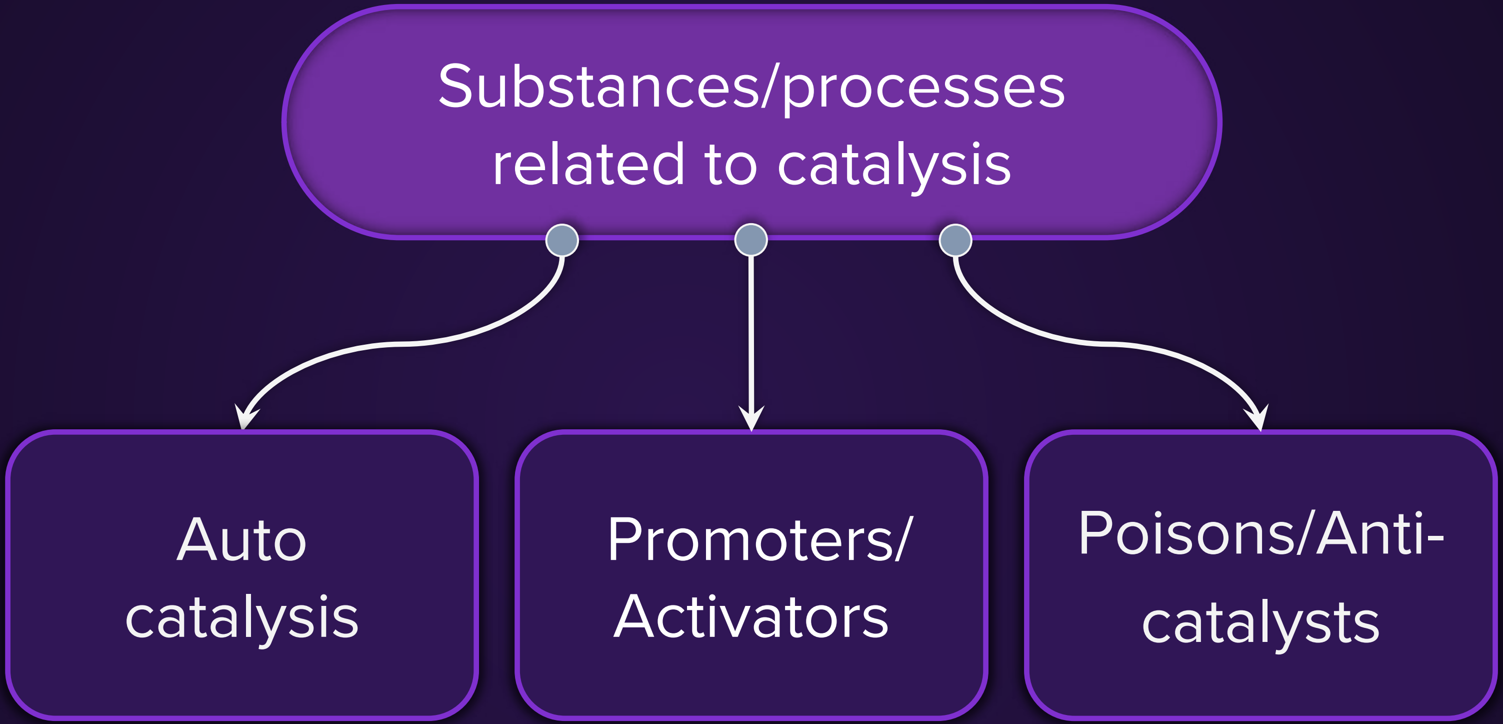


Negative Catalyst

A negative catalyst **decreases** the reaction rate by **increasing** the activation energy **barrier**.



Other Important Terms



Substances/processes related to catalysis

Auto catalysis

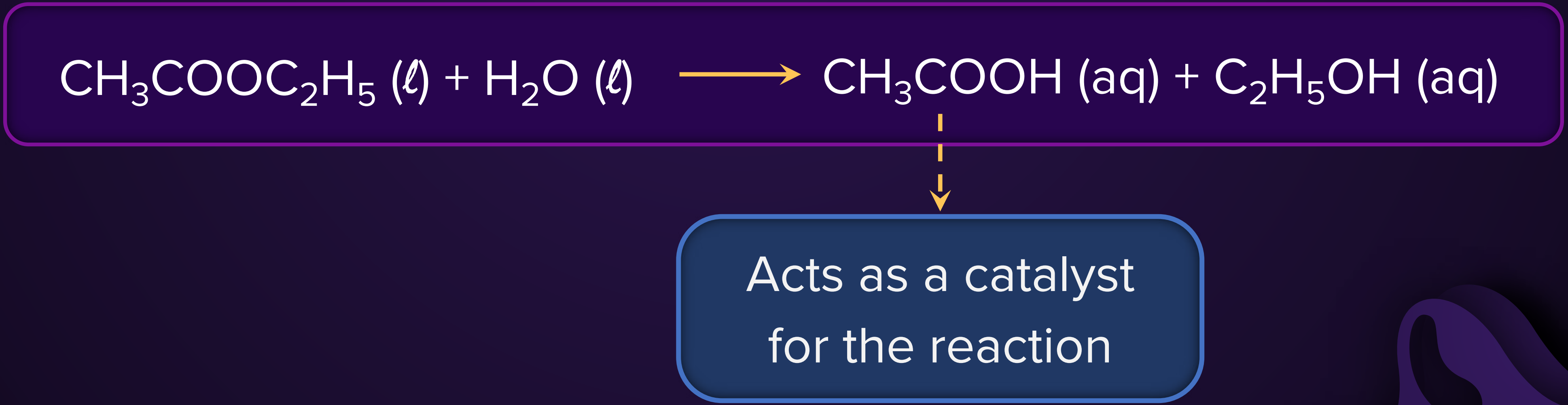
Promoters/ Activators

Poisons/Anti-catalysts

Auto Catalysis

When one of the **products** of a reaction behaves as a **catalyst** for that reaction and **increases** the rate of reaction

Example:



$$CH_3COOC_2H_5\ (\ell) + H_2O\ (\ell) \longrightarrow CH_3COOH\ (aq) + C_2H_5OH\ (aq)$$

Acts as a catalyst for the reaction

Promoters/Activators

Substances that are **not catalysts** themselves

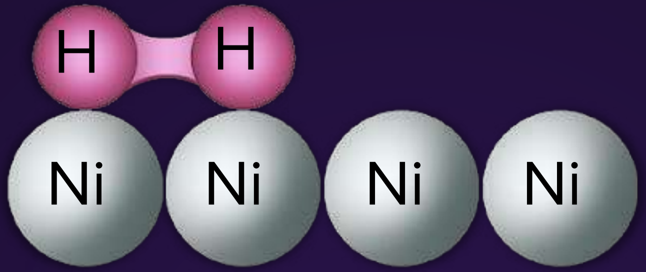
But their presence can **increase** the catalytic **activity** of a catalyst.

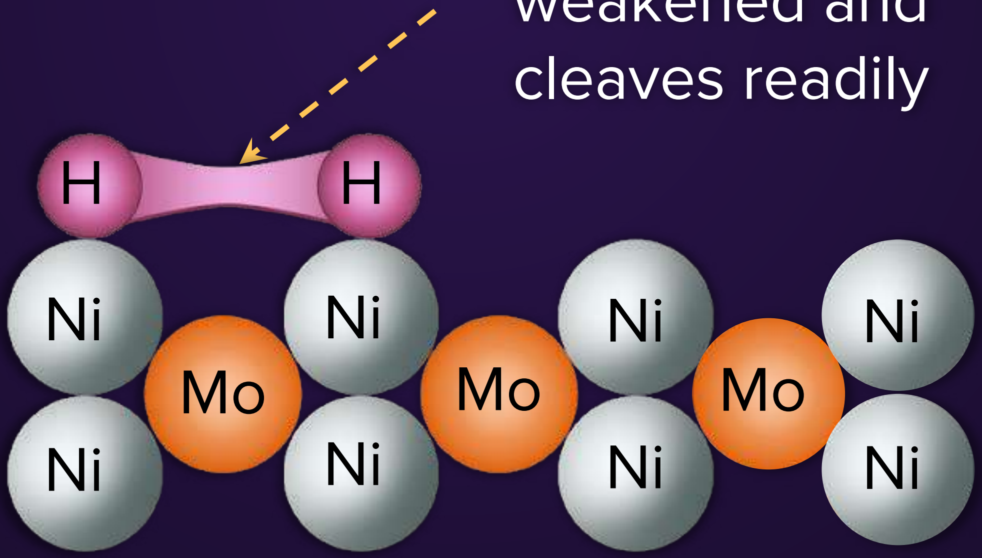
Example:

(i) $\text{Vegetable oils } (\ell) + H_2\text{ (g)} \xrightarrow[\text{Cu (promoter)}]{\text{Ni (catalyst)}} \text{Vegetable ghee (s)}$

(ii) $N_2\text{ (g)} + 3H_2\text{ (g)} \xrightarrow[\text{Mo (promoter)}]{\text{Fe (catalyst)}} 2NH_3\text{ (g)}$

Promoters/Activators





Covalent bond much weakened and cleaves readily

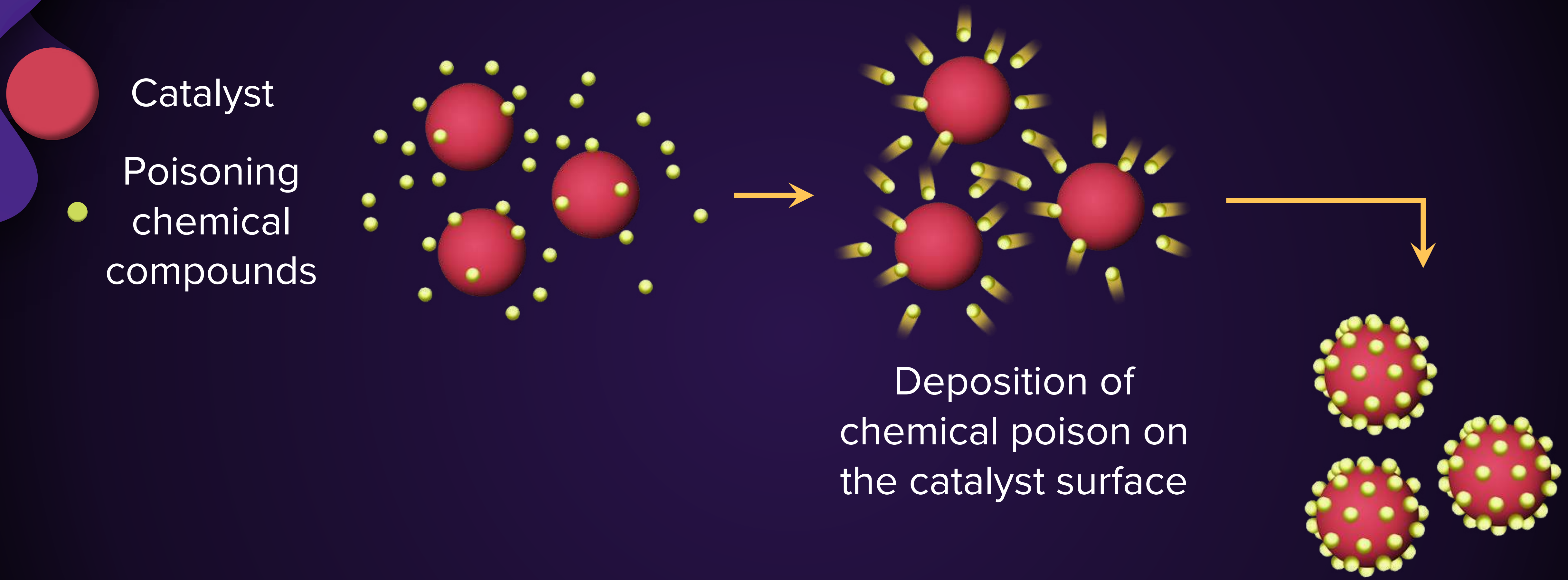
Catalytic Poisons/Anti-Catalysts

Substances that are **not catalysts** themselves

But their presence **decreases** the **activity** of a catalyst

Poisoning is due to **preferential adsorption** of poison on the surface of the catalyst.

Catalytic Poisons/Anti-Catalysts



Catalyst

Poisoning chemical compounds

Deposition of chemical poison on the catalyst surface

Deactivation of catalyst

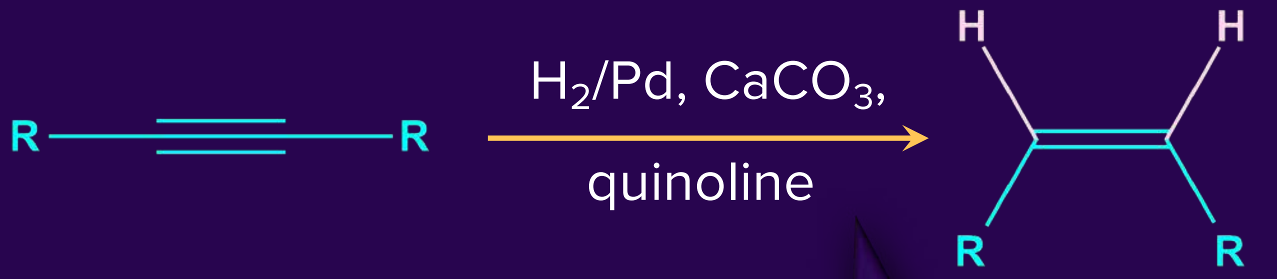
Catalytic Poisons/Anti-Catalysts

Example

(i)

$$N_2\ (g) + 3H_2\ (g) \xrightarrow[\text{Co/H}_2\text{S (Poison)}]{\text{Fe (Catalyst)}} 2NH_3\ (g)$$

(ii)



H_2/Pd, $CaCO_3$,

quinoline

Lindlar's Catalyst

Adsorption Theory of Heterogeneous Catalysis

Modern adsorption theory, a combination of

- Old adsorption theory/Adsorption theory of catalysis
- Intermediate compound formation theory

Old Adsorption Theory

The **reactants** in gaseous state or in solution, are **adsorbed** on the surface of the **solid catalyst**.

The **increase** in concentration of the **reactants** on the surface **increases** the **rate** of reaction.

The **heat** of adsorption (exothermic process) is utilized in **enhancing** the **rate** of the reaction.

Intermediate Compound Formation Theory

A catalyst forms **temporary bonds** with the reactants resulting in an **intermediate complex**.

This exists for a **short time** and decomposes to **yield products** and the catalyst.

Mechanism of Heterogeneous Catalysis

The **surface** of the catalyst, unlike the inner part of the bulk, has **free valancies** that provide the seat for chemical forces of attraction.

Gas molecules are held up on the surface due to **loose chemical combination**.

↓

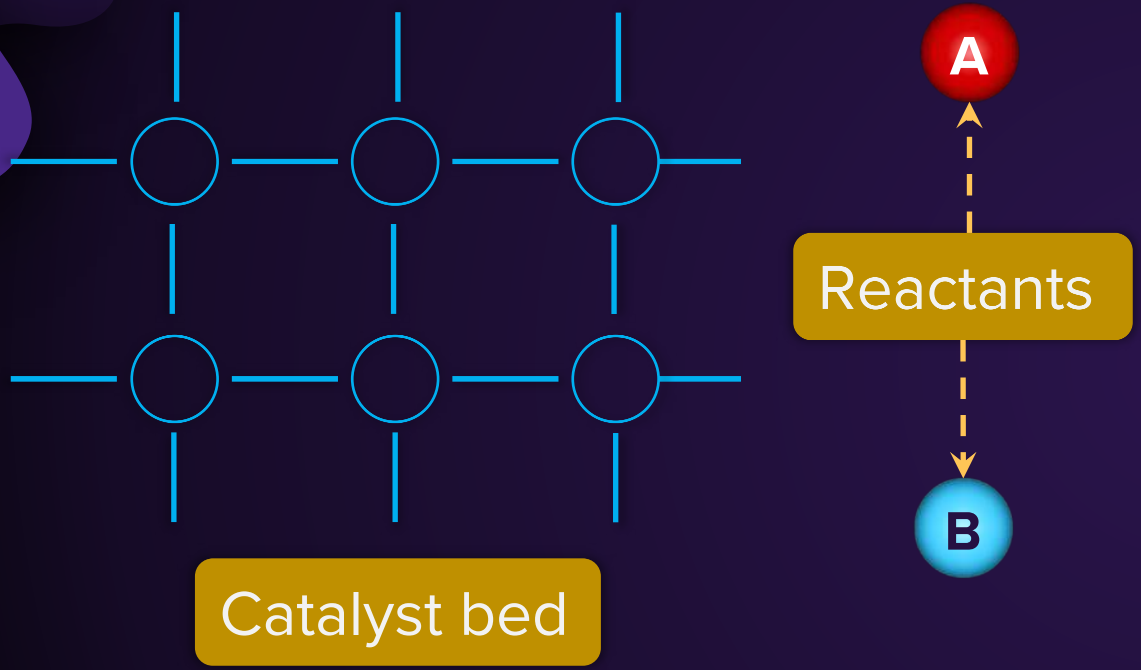
Different molecules are **adsorbed** side by side and **react with each other** forming **new molecules**.

↓

The **formed** product molecules may **evaporate,** leaving the surface for the **fresh reactant** molecules.

Mechanism of Heterogeneous Catalysis

Step 1

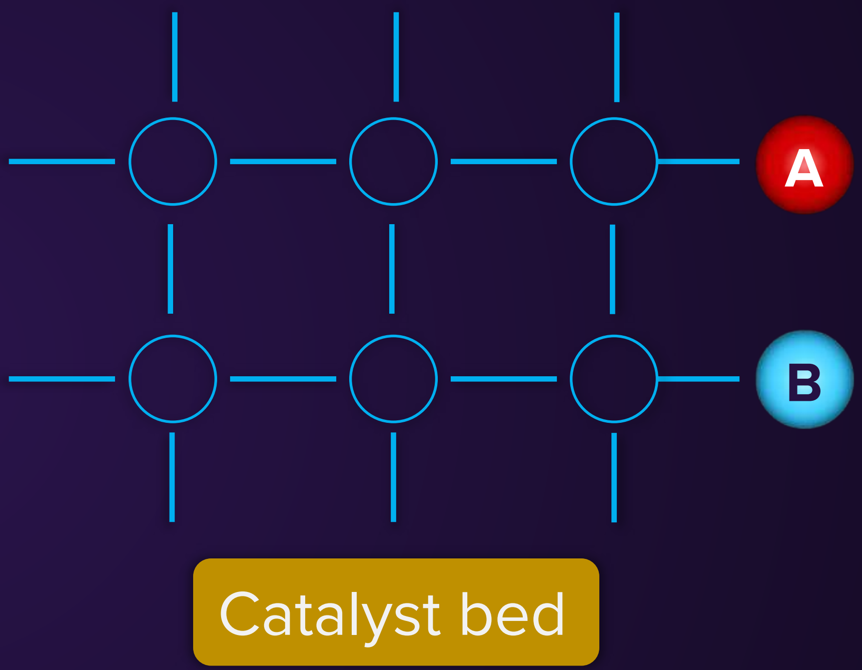


Reactants

Catalyst bed

Diffusion of **reactant(s)** to the **surface** of the catalyst.

Step 2

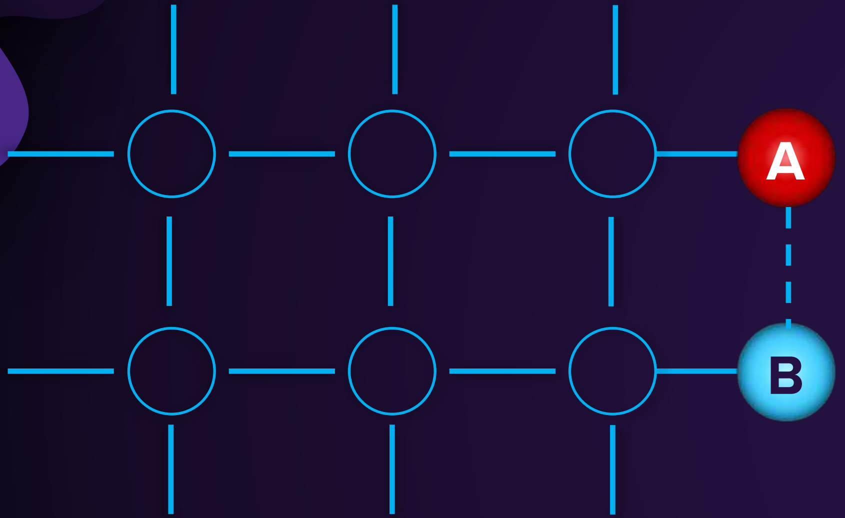


Catalyst bed

Adsorption of reactant molecules on the surface of the catalyst.

Mechanism of Heterogeneous Catalysis

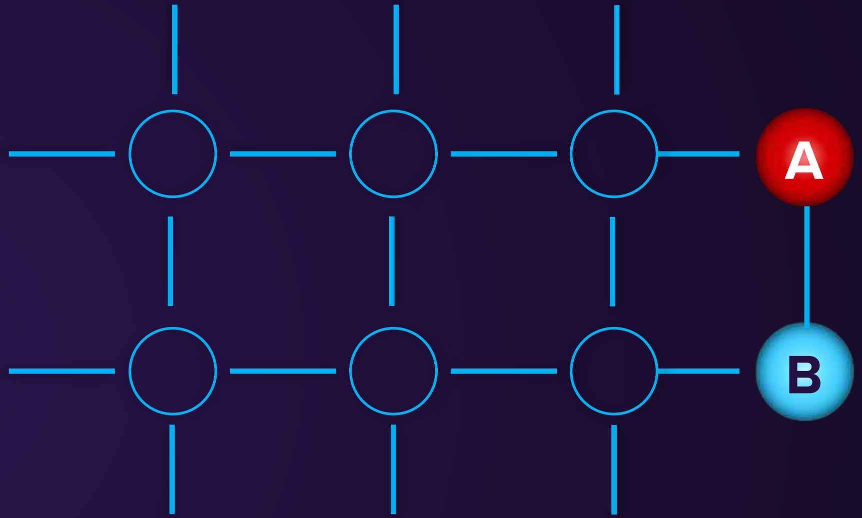
Step 3



Catalyst bed

Occurrence of **chemical reaction** on the catalyst's surface through the formation of an **intermediate.**

Step 4

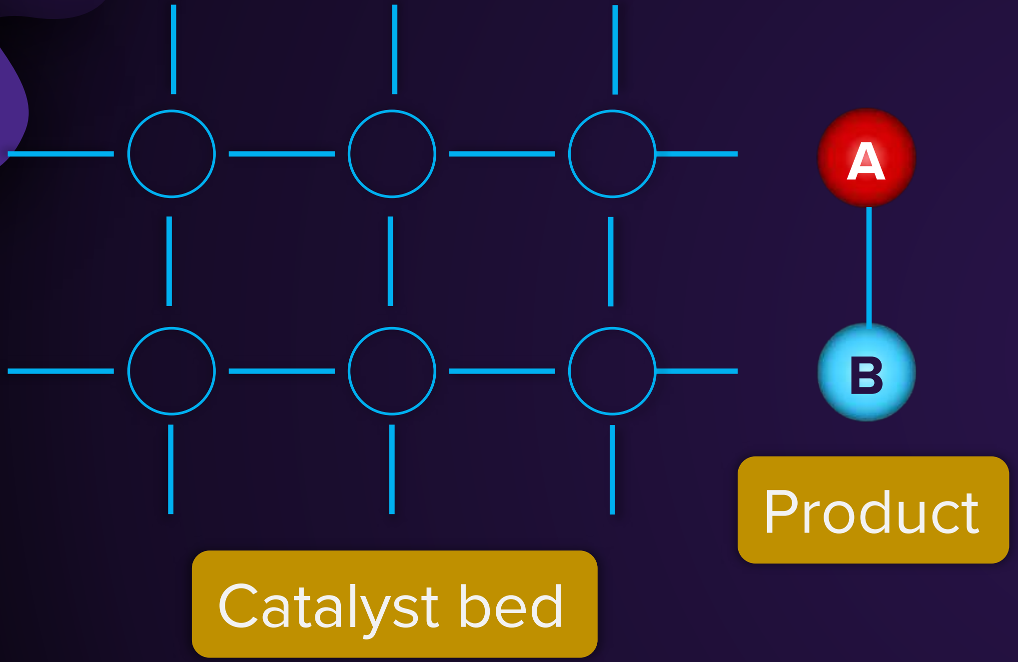


Catalyst bed

Desorption of reaction **products** from the catalyst surface, making the **surface available again** for more reaction to occur.

Mechanism of Heterogeneous Catalysis

Step 5



Diffusion of reaction **products away** from the catalyst's surface.

Example

The addition of H_2 gas to **ethylene** (C_2H_4) in the presence of **Ni** catalyst.

Modern Adsorption Theory

This theory **explains** why the catalyst remains **unchanged** in mass and chemical composition at the end of the reaction

It is effective even in small quantities

But **does not explain** the **action** of catalytic promoters and catalyst poisons

Important Features of Solid Catalysts

Important features of solid catalysts

- Activity
- Selectivity

Activity

The **activity** of a catalyst depends upon the **strength of chemisorption** to a large extent.

Reactants must get adsorbed **reasonably** strongly on to the catalyst to become **active.**

However, adsorption shouldn't be **so** strong that reactants are **immobilised.**

No space on surface for further reactants

Activity

Example

For **hydrogenation** reaction,

The catalytic activity **increases** from group 5 to group 11 metals

The **maximum** activity is shown by groups **7–9** elements

$$2H_2\ (g) + O_2\ (g) \xrightarrow{Pt(s)} 2H_2O\ (\ell)$$

Selectivity

The ability of a catalyst to **direct** a reaction to yield a **particular product** selectively, under the **same** reaction conditions, **different products** are possible.

The action of a catalyst is **highly selective** in nature.

A substance that acts as a catalyst in **one** reaction may **fail** to catalyse **another** reaction.

Selectivity

Example

$$CO + H_2 \xrightarrow{\text{Ni surface}} CH_4 + H_2O$$

$$CO + H_2 \xrightarrow{\text{Cu surface}} HCHO$$

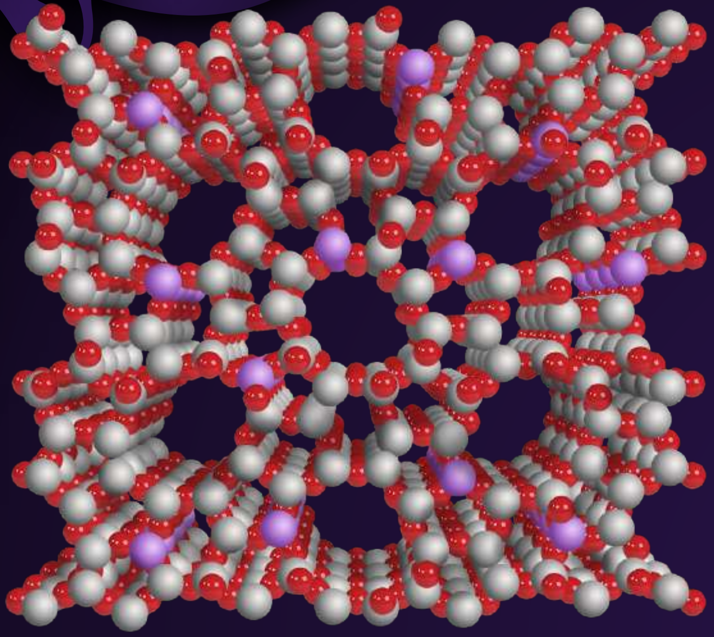
$$CO + H_2 \xrightarrow{\text{ZnO surface}} CH_3OH$$

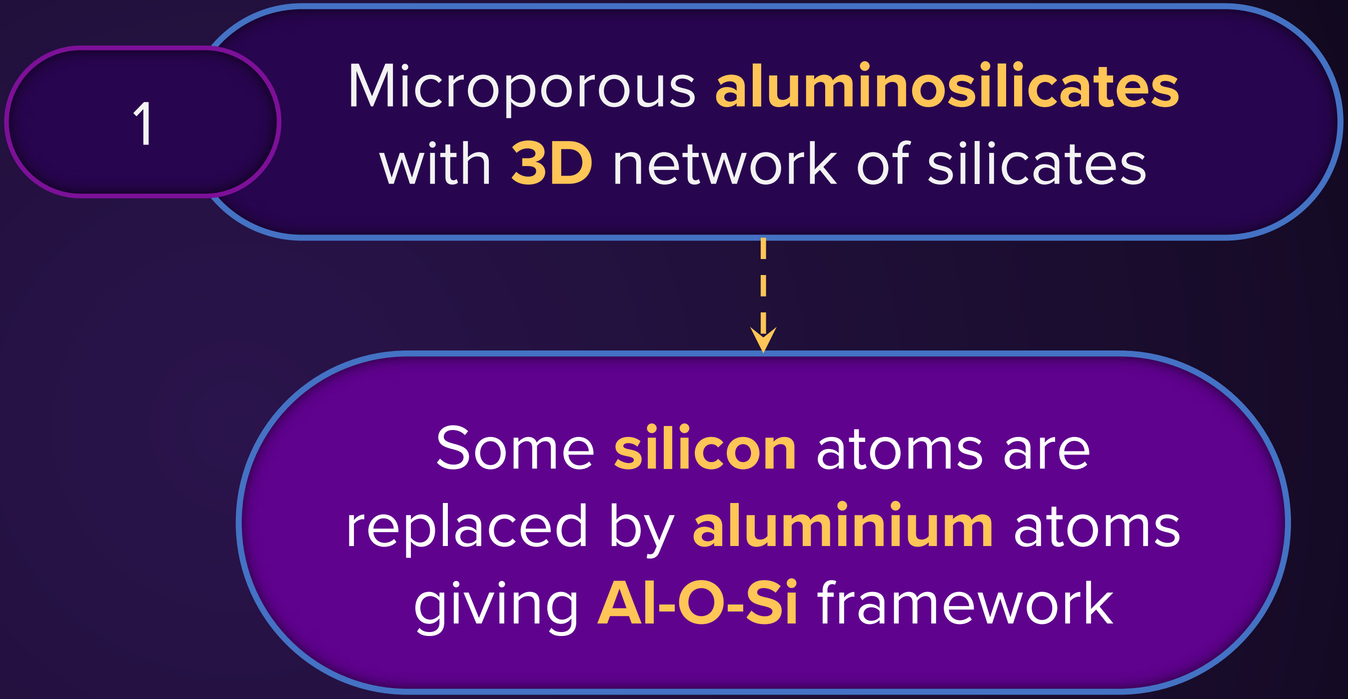
Shape Selective Catalysis

The catalytic reaction that depends upon the **pore structure** of the catalyst and the **size** of the **reactant** and **product** molecules.

Zeolites are good shape-selective catalysts because of their **honeycomb-like** structures.

Zeolites





1

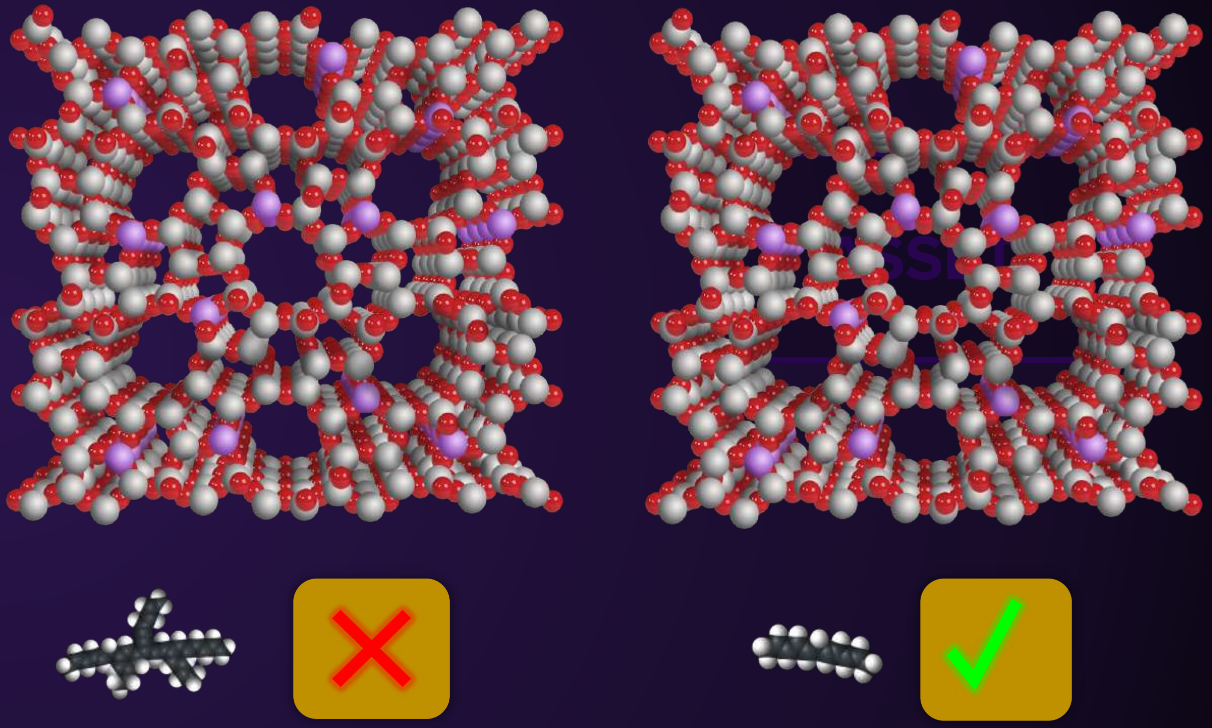
Microporous **aluminosilicates** with **3D** network of silicates

Some **silicon** atoms are replaced by **aluminium** atoms giving **Al-O-Si** framework

Zeolites

2 The pore size of zeolites

260–270 pm



Uses of Zeolites

1

Used as a catalyst in petroleum industries for **cracking of hydrocarbon** and **isomerisation**

2

The catalyst **ZSM-5** converts **alcohol directly into gasoline** by dehydrating it to give a mixture of hydrocarbons.

R-OH ⟶ Hydrocarbon mixture

Enzyme Catalysis

Complex nitrogenous organic compounds which are produced by **living plants and animals**

They are actually **protein molecules** of **high** molecular mass and **form colloidal solutions** in water.

Enzyme Catalysis

Numerous reactions that occur in the **bodies** of animals and plants to **maintain** the life process are catalysed by **enzymes.**

The enzymes are, thus, termed as

Biochemical catalysts

And the phenomenon is known as

Biochemical catalysis

Example of Enzyme–Catalysed Reactions

Inversion of cane sugar

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}\,(aq)} + \underset{\text{Water}}{H_2O\,(\ell)} \longrightarrow \underset{\text{Glucose}}{C_6H_{12}O_6\,(aq)} + \underset{\text{Fructose}}{C_6H_{12}O_6\,(aq)}$$

Enzyme
Invertase

Conversion of milk into curd

Milk → Curd

Enzyme
Lactobacillus

Mechanism of Enzyme Catalysis

There are a **number of cavities** present on the **surface** of enzymes.

They are usually the **active centers** on the **surface of enzyme** particles.

The reactant molecules that have **complementary shape** fit into these cavities just like a **key fits into a lock.**

The activated complex thus formed, **decomposes into products**

Steps Involved in Enzyme-Catalysed Reaction

The enzyme-catalysed reactions may be considered to proceed in **two steps.**

1

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

Where,

E: Enzyme

S: Substrate

$ES^{\ddagger}$: Activated complex

Binding of enzyme to substrate to form an activated **complex**

2

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

P: Product

Decomposition of the activated complex to form **product**

Characteristics of Enzyme Catalysis

1 Most **efficient**

One molecule of an **enzyme** may transform

One million molecules of the **reactant** per minute

2 Highly **specific** in nature

Each enzyme is **specific** for a **given reaction**

One enzyme **cannot catalyse more than one** reaction

Characteristics of Enzyme Catalysis

3

Highly **active** under **optimum** temperature

The **rate** of an enzyme reaction becomes **maximum** at a **definite** temperature.

This is known as **optimum temperature.**

On **either side** of the **optimum temperature,** the enzyme activity **decreases.**

Optimum temperature range for enzymatic activity	Human body temperature **suitable** for enzyme–catalysed reactions
298–310 K	**310 K**

Characteristics of Enzyme Catalysis

4 Highly **active** under **optimum** pH

The **rate** of an enzyme-catalysed reaction is **maximum** at a particular pH

This is known as **optimum pH**

pH range: 5–7

5 Increasing activity in the presence of **co-enzymes** and **activators**

The enzymatic activity **increases** in the presence of certain substances

known as **co-enzymes**

Non-protein organic molecules (example: vitamin)

Effect of Activators on Enzyme Activity

Activators

Generally, **metal ions**

Na^+, Mn^{2+}, Co^{2+}, Cu^{2+}, etc.

Example:
For **Amylase,** activity **increases** in presence of **Na^+** ions

Weakly bonded to enzyme molecules **increase** the catalytic activity

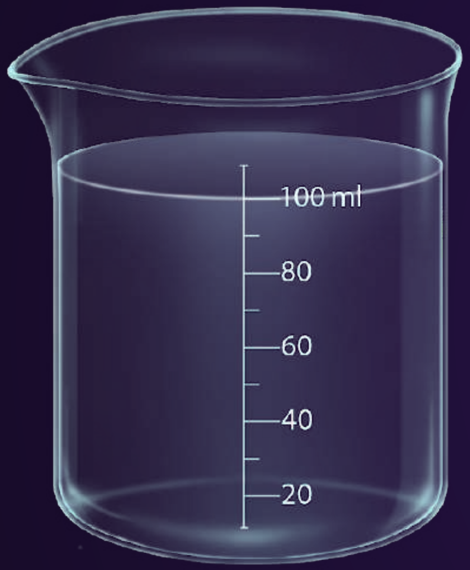
6

Influence of **inhibitors** and **poisons**

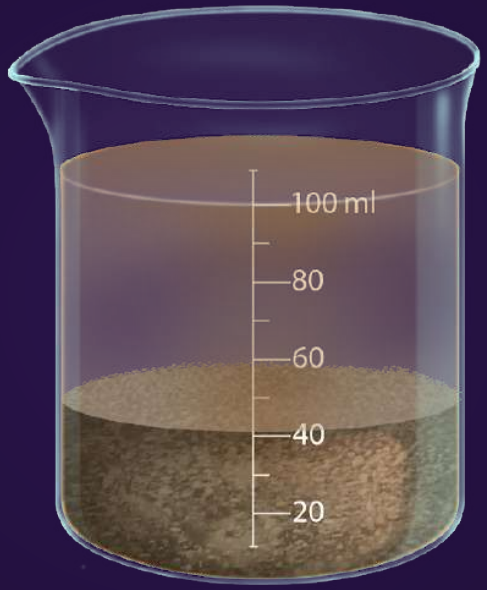
The inhibitors or poisons interact with the **active functional groups** on the enzyme surface

Often **reduce or completely destroy** the catalytic activity of the enzymes

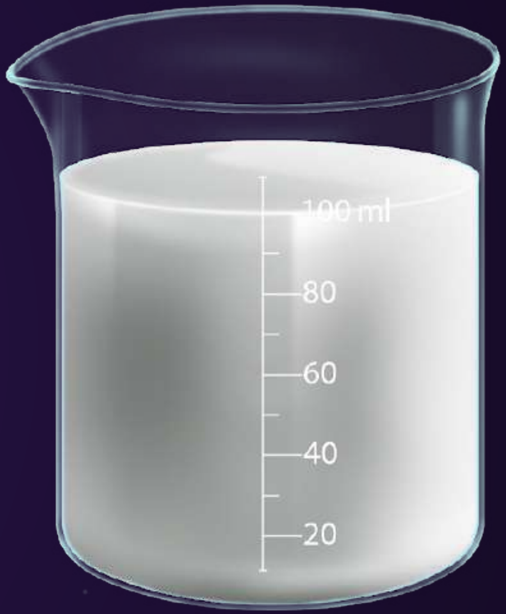
Types of Mixtures



Homogeneous
mixture: Solution
Example: Salt solution



Heterogeneous
mixture: Suspension



Colloid: Milk

Colloids

Between the two extremes of suspensions and solutions,

we come across a large group of systems called **colloidal dispersions** or simply **colloids**

Colloids consist of two parts

Dispersed phase (D.P.)

The phase that is **dispersed/present** in the form of colloidal particles

Dispersion medium (D.M.)

A **medium** in which colloidal particles are **dispersed**

Colloids

Colloid = Dispersed phase (D.P.) + Dispersion medium (D.M.)

Example: Gold sol

A colloid is a **heterogeneous** system in which one substance is dispersed (**dispersed phase**) as very fine particles in another substance called **dispersion medium.**

Solution vs Colloid

In solution

The constituent particles are **ions or small molecules**

In colloid

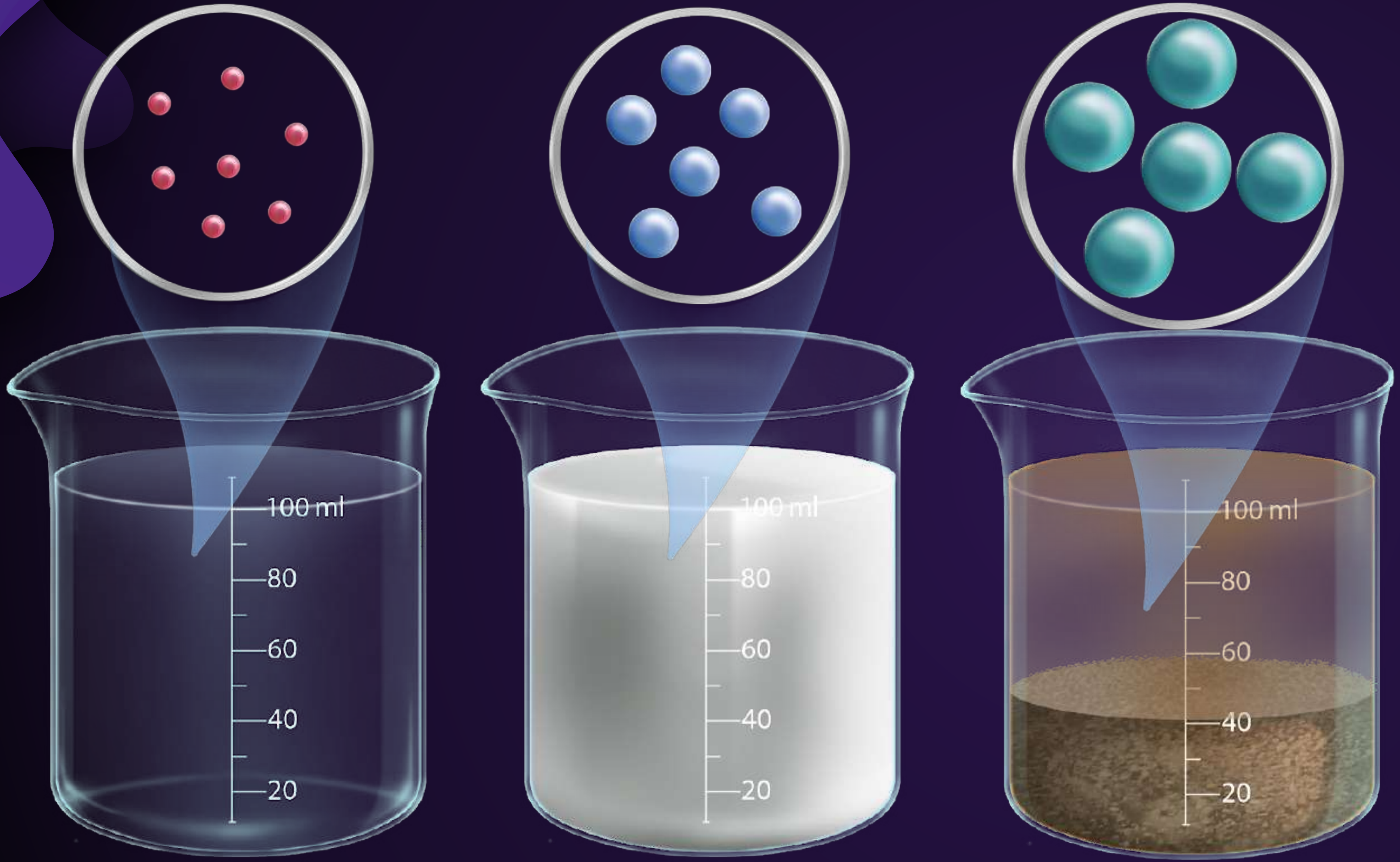
The dispersed phase may consist of particles of a **single macromolecule** or an **aggregate of many atoms, ions, or molecules**

Colloidal particles are **larger than** simple molecules but **small enough** to remain **suspended**.

Less than **1 nm**

1–1000 nm

More than **1000 nm**



Salt solution

Colloid (Milk)

Suspension (sand water)

As a result of their **small size**

Colloidal particles have an **enormous surface area** per unit mass

Leads to some special **properties of colloids**

Classification of colloids based on

- Physical state of D.P. and D.M.
- Nature of interaction between D.P. and D.M.
- Type of particles of D.P.
- Charge on particles

Classification of Colloids

Depending upon whether the dispersed phase and the dispersion medium are **solids, liquids, or gases, eight** types of colloidal systems are possible.

The mixture of a gas with another gas is **homogeneous** system, so it's **not** a colloidal system.

Dispersed phase	Dispersion medium	Name
Solid	Solid	Solid sol
	Liquid	Sol
	Gas	Aerosol
Liquid	Solid	Gel
	Liquid	Emulsion
	Gas	Aerosol
Gas	Solid	Solid sol
	Liquid	Foam

Classification of colloids based on

- Physical state of D.P. and D.M.
- Nature of interaction between D.P. and D.M.
  - Lyophilic colloids
  - Lyophobic colloids
- Type of particles of D.P.
- Charge on particles

Lyophilic Colloids and Their Characteristics

Lyophilic

"Liquid-loving"

The colloidal sol/system in which the particles of the dispersed phase

Have a **great affinity** for the dispersion medium

1. Can be **formed easily**
2. **Reversible** in nature

Reversible Nature of Lyophilic Colloids

If the dispersion medium is **separated** from the dispersed phase, the sol can be **reconstituted** by simply **remixing** with the dispersion medium.

Hence, they are known as **reversible sols.**

Examples

Glue, gelatin, starch, proteins, **egg albumin**, rubber, etc.

Lyophobic Colloids and Their Characteristics

Lyophobic **"Liquid-hating"**

The colloidal sol/system in which there is **no affinity** between particles of the dispersed phase and the dispersion medium

Prepared by special methods

1 Cannot be **formed easily**

2 **Unstable** in nature

3 **Irreversible** in nature

Irreversible Nature of Lyophobic Colloids

Once precipitated, they **do not give back** the colloidal sol

By the simple addition of the dispersion medium

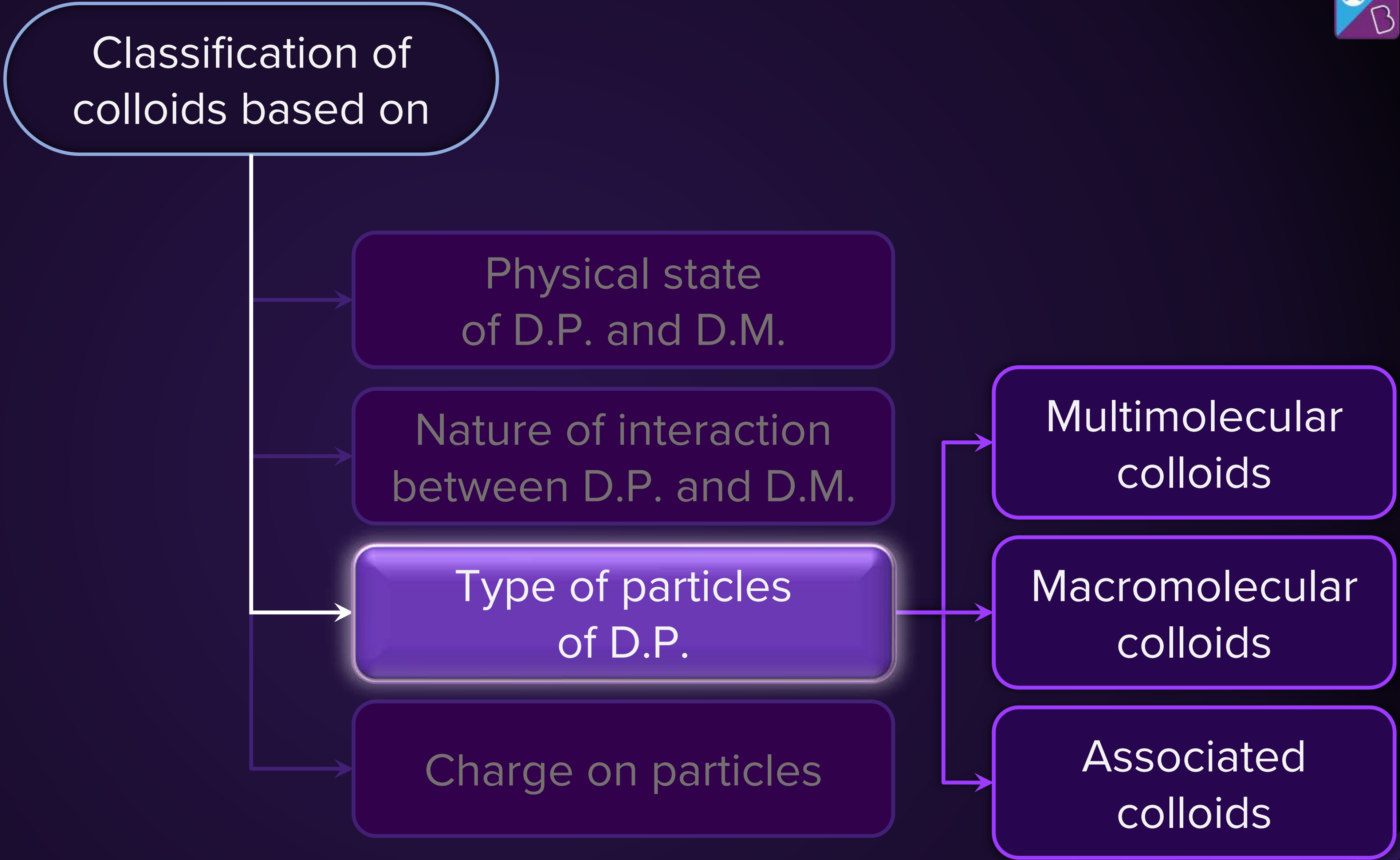
Hence, they are known as **irreversible sols.**

Hydro

If the solvent or dispersion medium → Water

Lyophilic → Hydrophilic

Lyophobic → Hydrophobic



Classification of colloids based on

Physical state of D.P. and D.M.

Nature of interaction between D.P. and D.M.

Type of particles of D.P.

- Multimolecular colloids
- Macromolecular colloids
- Associated colloids

Charge on particles

Multimolecular Colloids

On dissolution,

A large number of atoms or smaller molecules of a substance **aggregate together.**

They **form** species having **size in the colloidal range** (1–1000 nm).

Such species are known as **multimolecular colloids.**

Examples

1 Gold sol may contain **particles of various sizes** having many atoms.

2 Sulphur sol consists of particles containing thousand or more of **S_8 sulphur molecules**.

Macromolecular Colloids

Macromolecules in **suitable solvents** form solutions in which

The **size** of the macromolecules may be in the **colloidal range.**

Such systems are known as **macromolecular colloids.**

Stability

These colloids **are quite stable** and **resemble true solutions** in many respects.

Examples

Starch, cellulose, proteins, enzymes, polythene, nylon, polystyrene, synthetic rubber, etc.

Associated Colloids

At **low** concentration

Some substances behave as **strong electrolytes.**

At **high** concentration

These substances behave as **colloidal particles**

This behaviour is due to the formation of **aggregates.**

These aggregated particles are known as **associated colloids.**

Also known as **micelles**

Examples: Soap, detergent

Micelles

Micelles are relatively **small, spherical structures** composed of a **few to some thousand** molecules.

These molecules **attract one another** to form a larger aggregate which falls in the colloidal range.

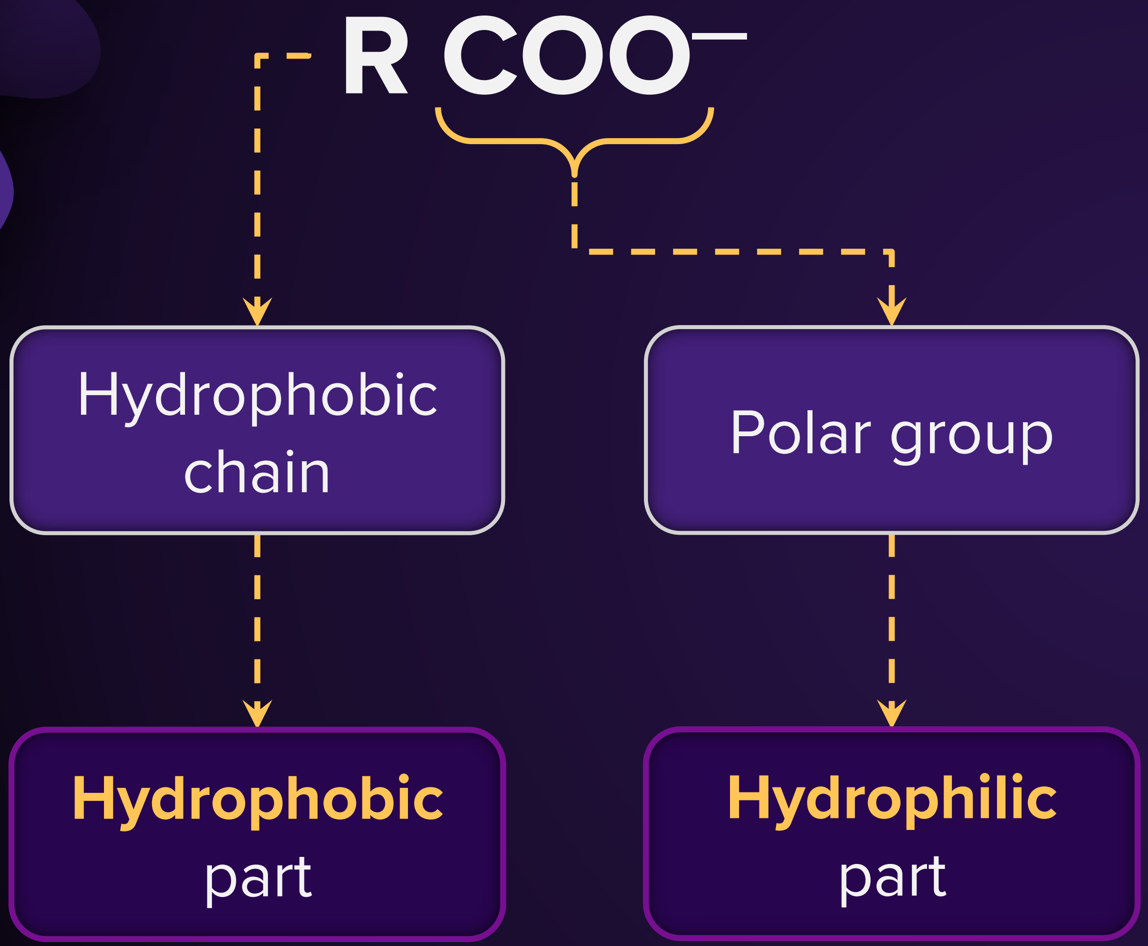
Example: Soap solution

Soap is a sodium salt of a higher fatty acid which is represented as

$RCOO^-Na^+$

Examples: Sodium stearate $CH_3(CH_2)_{16}COO^-Na^+$

Hydrophilic and Hydrophobic Ends of a Soap Ion



$R\underbrace{COO^-}$

Hydrophobic chain

Polar group

Hydrophobic part

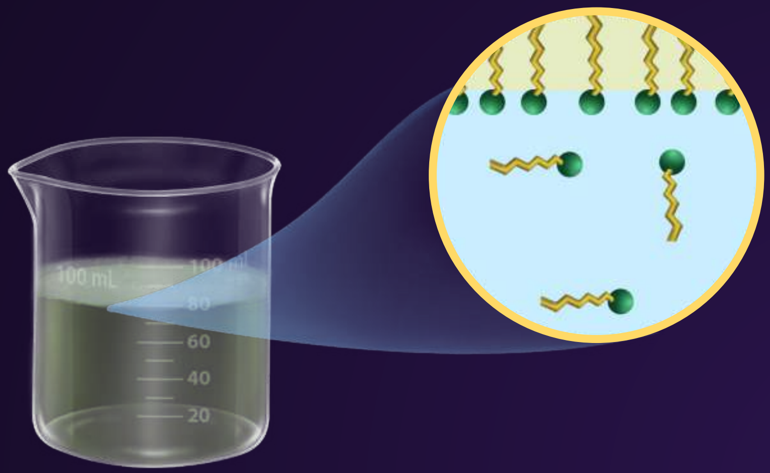
Hydrophilic part

Stearate ion
$CH_3(CH_2)_{16}COO^-$

Hydrophilic head

Hydrophobic tail

Mechanism of Micelle Formation



When sodium stearate
$\{CH_3(CH_2)_{16}COO^-Na^+\}$
is **dissolved** in water,
it **dissociates** into
$RCOO^-$ and Na^+ ions.
Where $R = CH_3(CH_2)_{16}$

So, $RCOO^-$ arranges itself in such a way that **COO^-** can be **close to water** and the **hydrocarbon** chain can stay away from it by **staying at the surface.**

Mechanism of Micelle Formation

But at higher concentration, these are **pulled into the bulk** of the solution and they aggregate in a **spherical form.**

The spherical form has the **hydrocarbon** chains pointing **towards the centre.**

The **COO^-** part remains **outward** on the surface of the sphere.

Mechanism of Micelle Formation

This aggregated form is known as **micelle,** which may contain 100 such ions.

Critical micelle concentration (CMC)

It is the **concentration above which** micelle formation takes place.

Kraft temperature (T_k)

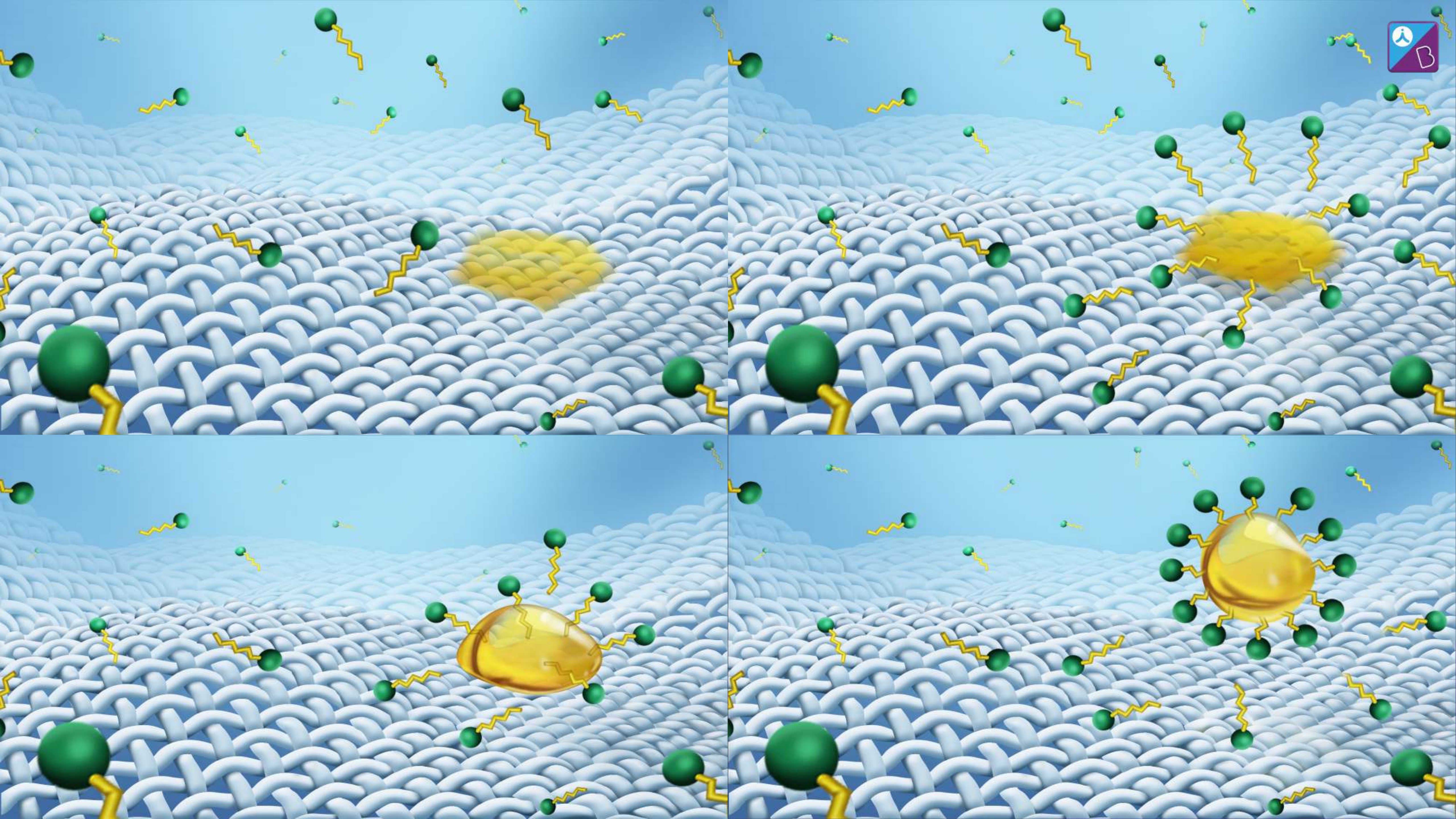
The **formation** of micelles takes place only **above** a **particular temperature.**

The Cleansing Action of Detergents

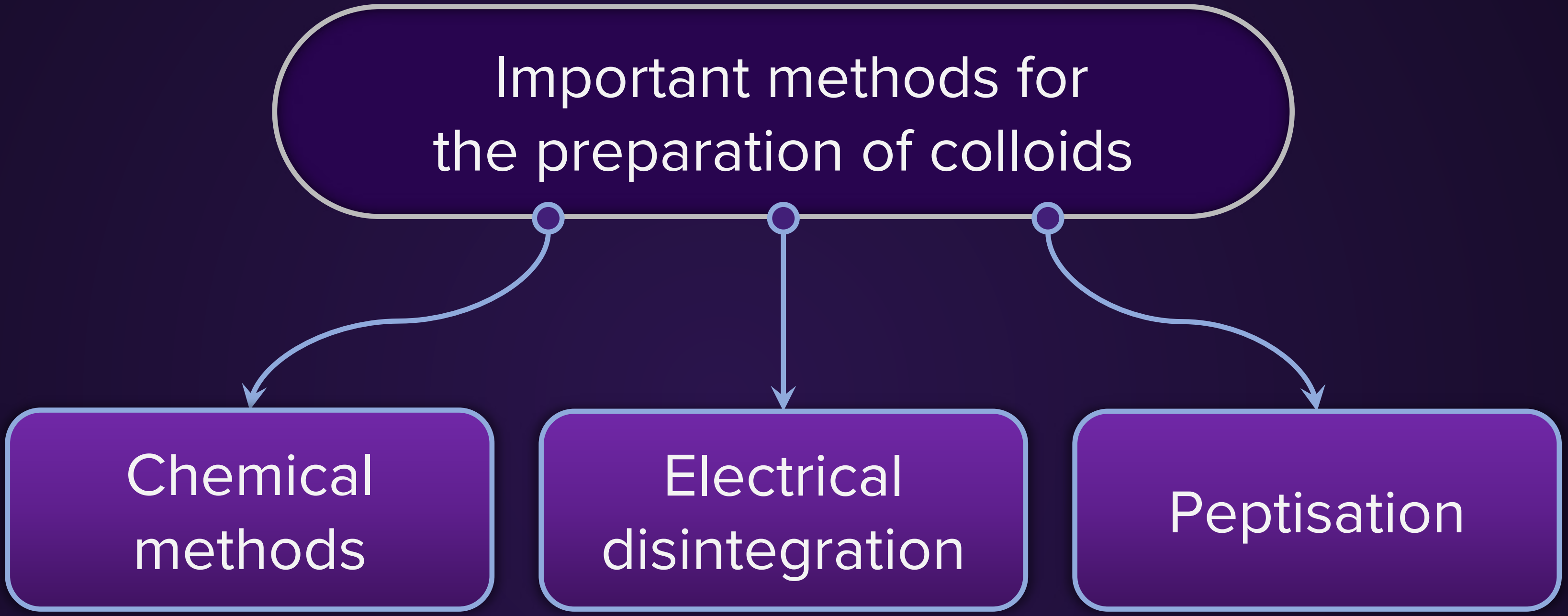
Sodium lauryl sulphate
$\{CH_3(CH_2)_{11}SO_4^{-}Na^{+}\}$

The **polar** group is **$-SO_4^{-}$** along with the long hydrocarbon chain.

So, the **mechanism** of micelle formation in detergents is the **same** as that of soaps.



Preparation of Colloids



Important methods for the preparation of colloids

- Chemical methods
- Electrical disintegration
- Peptisation

Chemical Methods

Colloids are prepared by **chemical reactions** like oxidation, reduction, etc.

The formed molecules **aggregate** and give **sols.**

$$2AuCl_3 + 3HCHO + 3H_2O \xrightarrow{\text{Reduction}} \mathbf{2Au}\ (sol) + 3HCOOH + 6HCl$$

$$As_2O_3 + 3H_2S \xrightarrow[\text{decomposition}]{\text{Double}} \mathbf{As_2S_3}\ (sol) + 3H_2O$$

$$2H_2S + SO_2 \xrightarrow{\text{Oxidation}} \mathbf{3S}\ (sol) + 2H_2O$$

$$FeCl_3 + 3H_2O \xrightarrow{\text{Hydrolysis}} \mathbf{Fe(OH)_3}\ (sol) + 3HCl$$

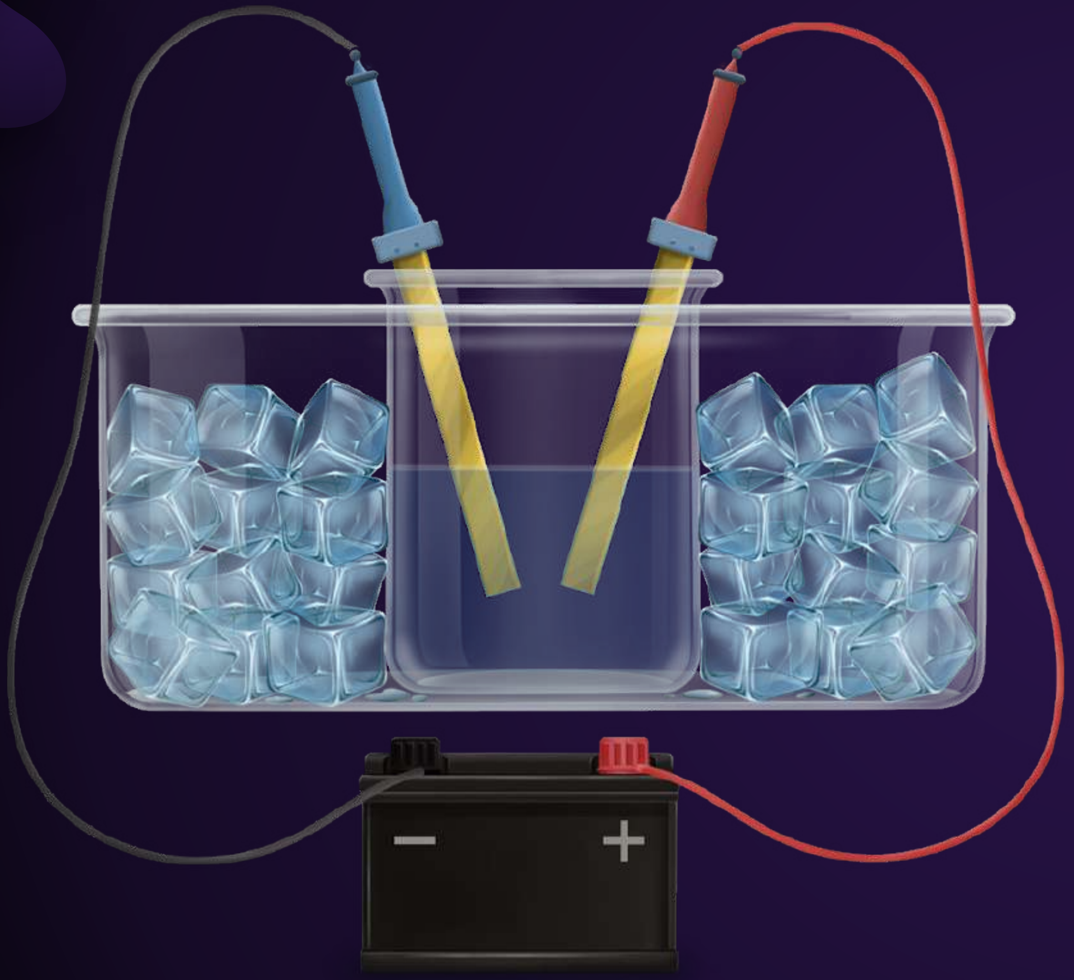
Electrical Disintegration

The process involves both **dispersion and condensation.**

It is also known as **Bredig's arc method.**

The colloidal **sols of metals** such as **gold, silver, platinum**, etc. can be prepared by this method

Mechanism of Bredig’s Arc Method



An electric arc is struck between metal **electrodes** immersed in the dispersion medium.

The intense **heat** produced **vapourises** the metal.

It then **condenses** to form particles of colloidal size.

Peptisation

The process of converting a **precipitate into colloidal sol** by **shaking** with dispersion medium in the presence of a **small amount** of **electrolyte**

Peptising agent

Generally, it is used to convert a **freshly prepared precipitate** into a **colloidal sol.**

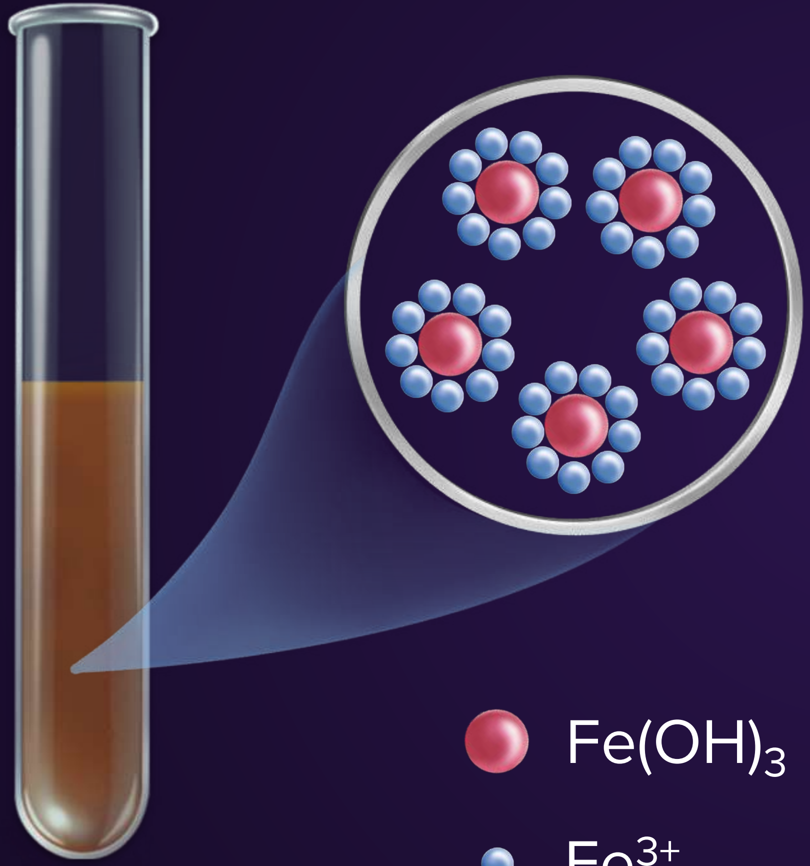
Example

Freshly precipitated **$Fe(OH)_3$** is shaken with aqueous solution of **$FeCl_3$**

Peptising agent

Peptisation

Colloidal sol formation



● $Fe(OH)_3$

● Fe^{3+}

Colloidal particles of $Fe(OH)_3$

The precipitate **adsorbs** electrolyte **ions** on its surface, this causes the **development** of positive or negative **charge** on precipitates, which ultimately **break up** into smaller particles of **colloidal size**

Purification of Colloidal Solution

Traces of electrolyte is essential for the **stability** of the colloidal solution

But larger quantities **coagulate** it

So, the impurities must be **reduced** to a requisite **minimum**.

Important methods of removal of soluble impurities

- Dialysis
- Electrodialysis
- Ultrafiltration

Dialysis

Process of **removing a dissolved substance** from a colloidal solution by means of **diffusion** through a **suitable membrane**

Membranes

Animal membrane (bladder) or parchment paper or cellophane sheet

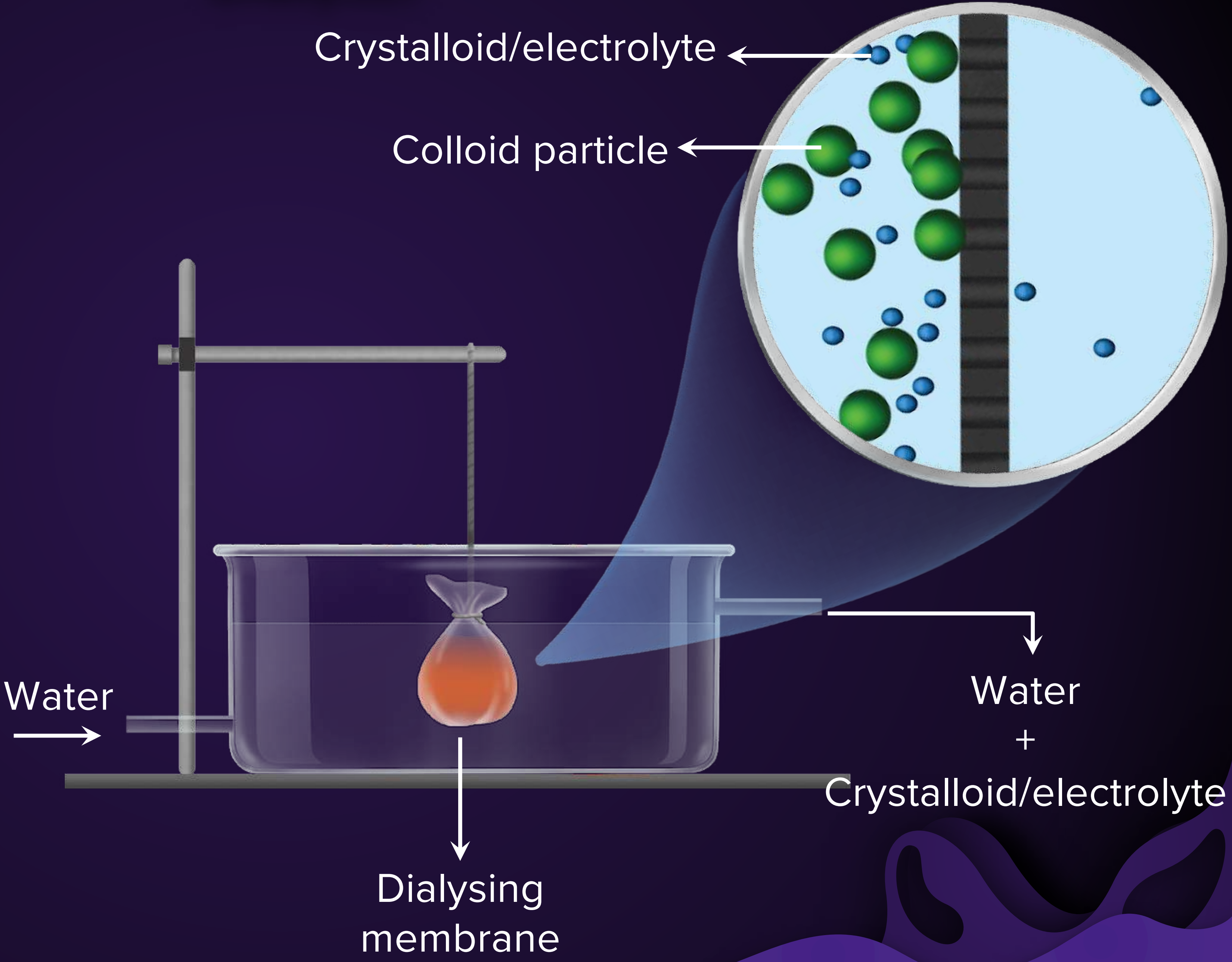
Since particles (ions or smaller molecules) in a **true solution** can **pass through** the membrane but **not the colloidal** particles

Membranes can be used for **dialysis**

Dialyser

The apparatus used for dialysis process is called as **dialyser**.

The molecules or ions in colloidal solution diffuse through dialysing membrane in running water and pure colloidal solution is left behind.



Electrodialysis

Similar to dialysis

But faster

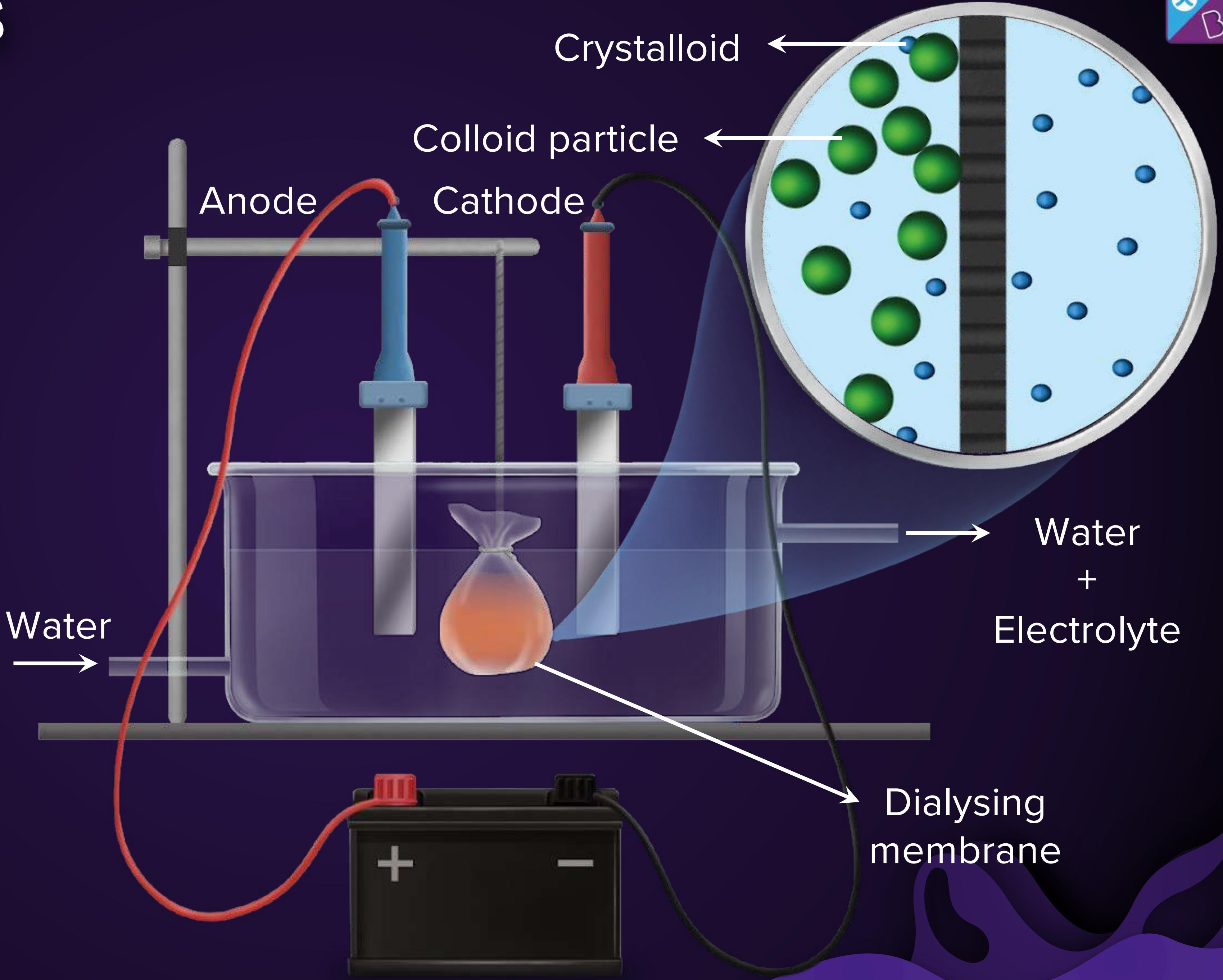
If the dissolved substance in the impure colloidal solution is **only an electrolyte**

The process can be made **faster** by **applying** an **electric field**

Important application

Purification of blood in the artificial kidney machine.

Electrodialysis



Ultrafiltration

The process of **separating** colloidal particles from solvent
and soluble solutes by **specially prepared filters.**

Sol particles pass through ordinary filters

The filter should be **permeable** to all substances **except** colloidal particles

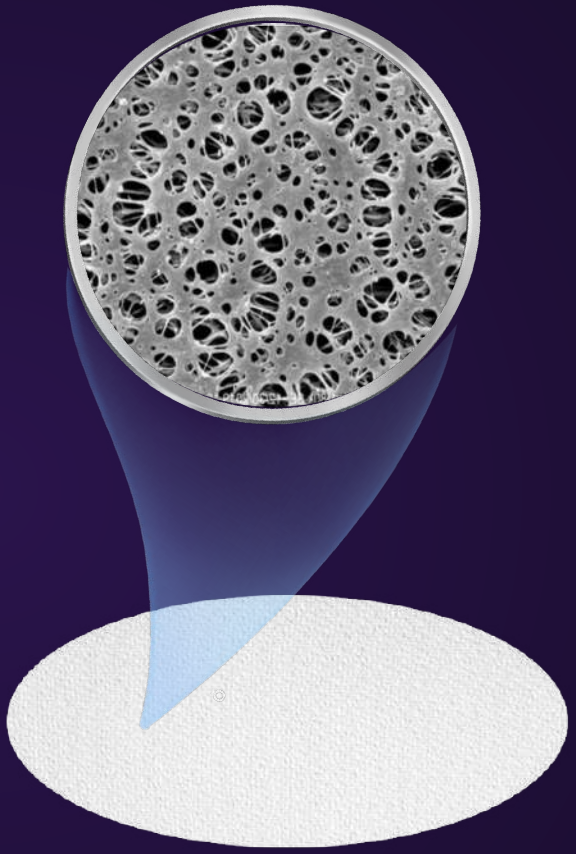
Ultrafilter paper is used for this purpose

Preparation of Ultrafilter Paper

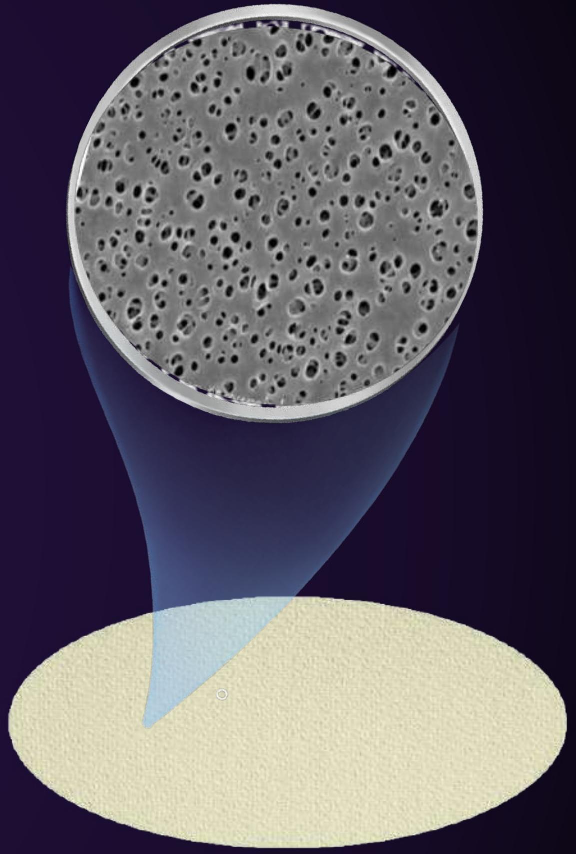
Prepared by **soaking** the filter paper in a **collodion** solution

Hardening it by formaldehyde and then **drying** it

The usual collodion is a **4% solution of nitrocellulose** in a mixture of **alcohol** and **ether**.



Normal filter paper



Ultrafilter paper

Ultrafiltration

The colloidal particles left on the ultrafilter paper are then **stirred** with **fresh** dispersion medium to get a **pure** colloidal solution.

Properties of colloidal solution

- Colligative properties
- Tyndall effect
- Colour
- Brownian movement
- Charge on colloidal particles
- Electrophoresis
- Coagulation or precipitation

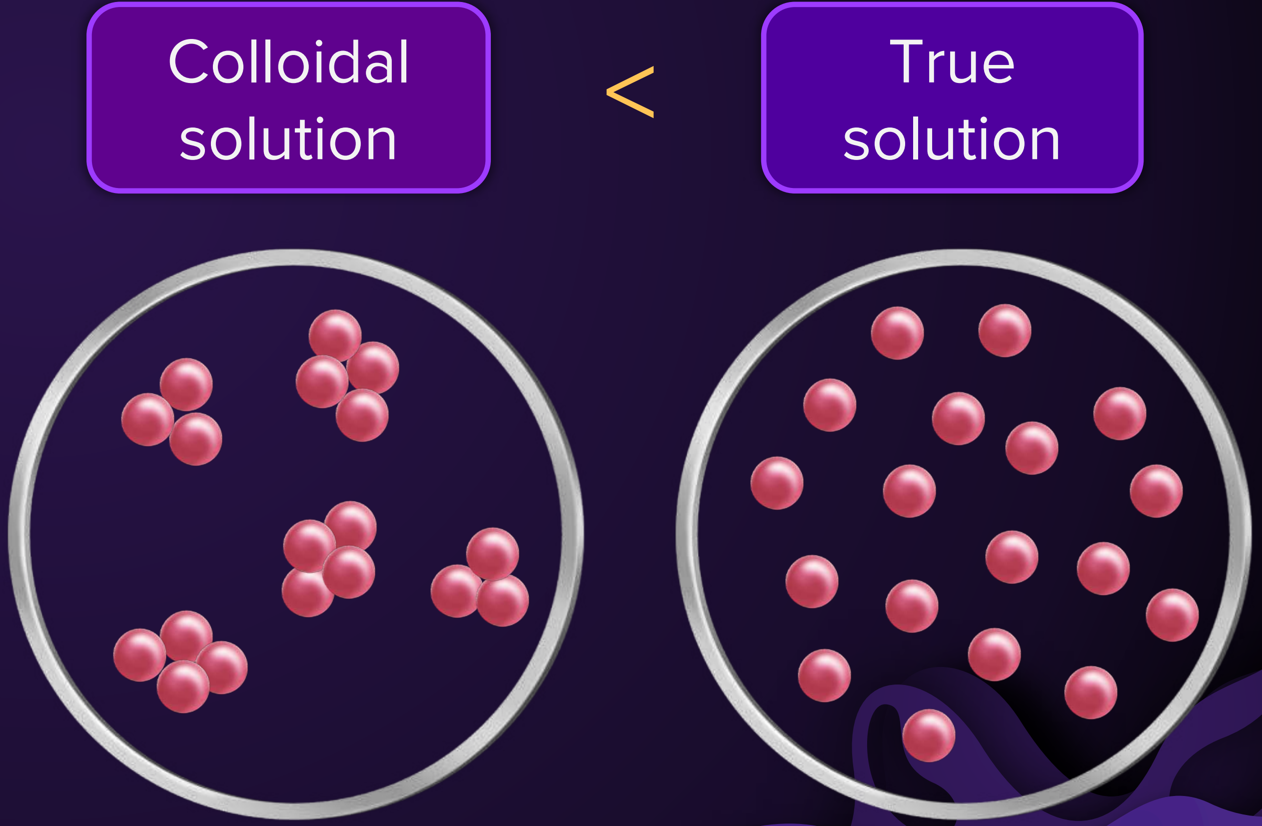
Colligative Properties

Colloidal particles are **bigger aggregates.**

The **number of particles,** per unit volume, in a colloidal solution is **small** compared to a true solution.

At the same concentration

Therefore, the **colligative property** values of



Tyndall Effect

If a strong **beam** of light is **passed** through a **colloidal sol** placed in a **dark** place

Path of the beam gets **illuminated** due to the **scattering** of light by colloidal particles.

This phenomenon is called as **Tyndall effect**

Conditions for Tyndall Effect

Condition 1

The **diameter** of the dispersed particles

Should **not** be much **smaller** than the **wavelength** of light

Condition 2

The **refractive indices** of dispersed phase and dispersion medium

Should **differ** greatly in **magnitude**

Colour

Factor 1

The **colour** of the colloidal solution **depends** on

Wavelength of light scattered by dispersed particles

Wavelength depends on **size and nature** of the **particles**

Example: Gold sol

The **finest** gold sol is **red** in colour

As the particle **size** of the sol **increases**, the colour of the sol changes

Red

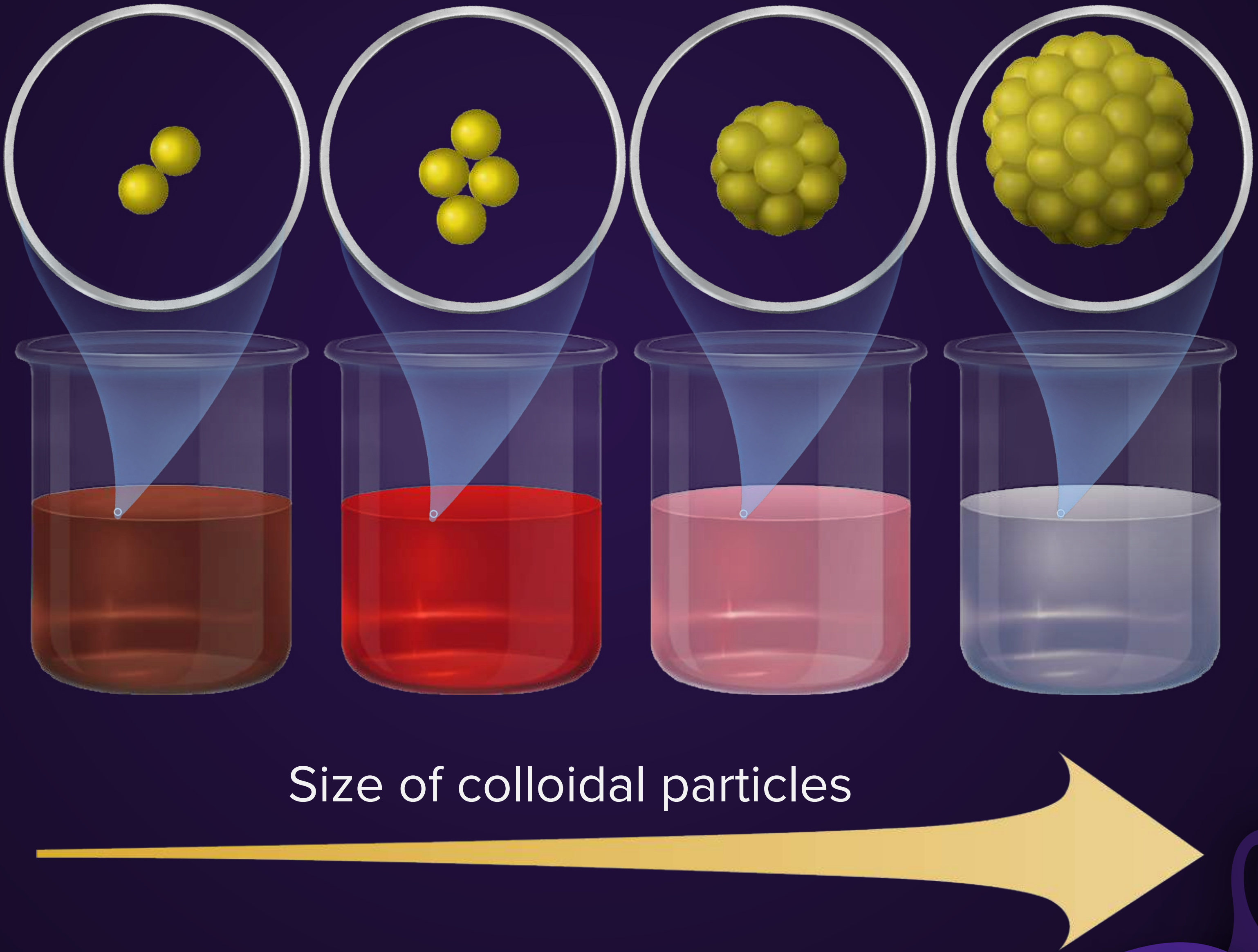
Purple

Blue

Golden

Particle size

Effect of Particle Size on Colour



Colour

Factor 2

The **colour** of the colloidal solution also **depends** on

The manner in which the **observer receives the light**

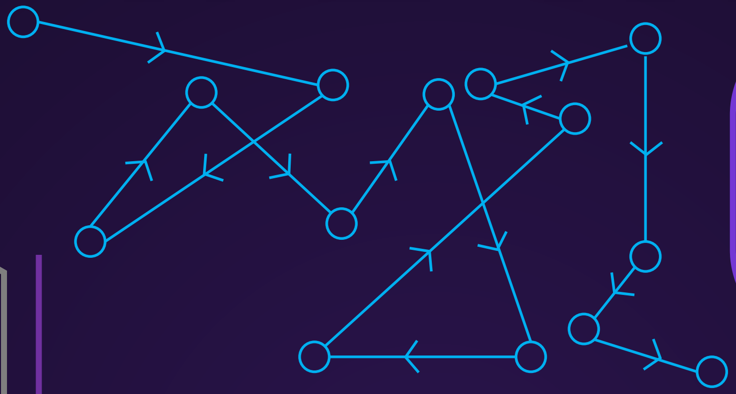
Example

A mixture of milk and water

When viewed by **reflected light** it appears **blue**

When viewed by **transmitted light** it appears **red**

Brownian Movement



When viewed under an **ultramicroscope**, colloidal particles appear to be in a continuous **zig-zag motion.**

Known as **Brownian movement**

The Brownian movement takes place

Due to the **unbalanced bombardment** of the particles

By the molecules of the dispersion medium

Brownian Movement

Factors affecting Brownian Movement

Independent of the **nature of colloid**

Depends on **size** of the colloid **particles**

Depends on the **viscosity** of the colloidal **solution**

Stability of sols

The Brownian movement has a **stirring effect**

Which **does not permit** the particles to **settle**

Thus, it is responsible for the **stability** of sols.

Charge on Colloidal Particles

Colloidal particles **always carry** an electric charge.

The **nature** of the charge is **same** on all the colloidal particles.

It may be either **positive or negative.**

Stability of sols

Presence of **equal and similar charges** on colloidal particles

Responsible in **providing stability** to the sol

Repulsion between charged particles **prevents aggregation**

Common Charged Sols

S. No.	Positively charged sols	Negatively charged sols
1	**Hydrated metallic oxides** (Examples: $Al_2O_3.xH_2O$, $Fe_2O_3.xH_2O$, etc.)	**Metals (Examples: Cu, Ag, Au sols)**
2	**Basic dye** stuffs (Examples: Methylene blue sol)	**Metallic sulphides** (Examples: As_2S_3, Sb_2S_3, CdS, etc.)
3	**Haemoglobin** (blood)	**Acid dye** stuffs (Examples: Eosin, congo red sols)
4	**Oxides** (Example: TiO_2 sol)	**Sols of starch, gum, gelatin, clay, charcoal,** etc.

Possible Reasons for Charge on Colloidal Particles

Most accepted

1 **Electron capture** by sol particles during electro dispersion of metals

2 **Preferential adsorption of ions** from solution

3 Formation of **electrical double layer**

Preferential Adsorption of Ions

When **two or more ions** are present in the dispersion medium

Preferential adsorption of the ion **common to colloidal particle** usually takes place

Preferential Adsorption of Ions

Example 1: $AgNO_3$ + KI

Case 1

Highly diluted $AgNO_3$ solution is added to **highly diluted KI** solution

Case 2

Highly diluted KI solution is added to **highly diluted $AgNO_3$** solution

$$AgNO_3\,(aq) + KI\,(aq)\,(excess) \longrightarrow AgI\downarrow\,(s) + KNO_3\,(aq)$$

$$AgNO_3\,(aq)\,(excess) + KI\,(aq) \longrightarrow AgI\downarrow\,(s) + KNO_3\,(aq)$$

The precipitated silver iodide(AgI) **adsorbs I^- ions** from the dispersion medium.

The precipitated silver iodide **adsorbs Ag^+** ions from the dispersion medium.

Preferential Adsorption of Ions

Example 2:
Charge on **ferric oxide**

Case 1

When **$FeCl_3$** is added to **excess of hot water,**

A **positively charged** sol of hydrated ferric oxide is formed.

Case 2

When **$FeCl_3$** is added to **NaOH solution,**

A **negatively charged** sol is obtained with the adsorption of OH^- ions.

Interactions Between Oppositely Charged Ions

By **selective adsorption** of a common ion on the surface, a colloidal particle **acquires** a positive or a negative **charge**.

This charged layer **attracts counter ions** from the medium to form a **second layer.**

$AgI/I^- K^+$

$AgI/Ag^+ I^-$

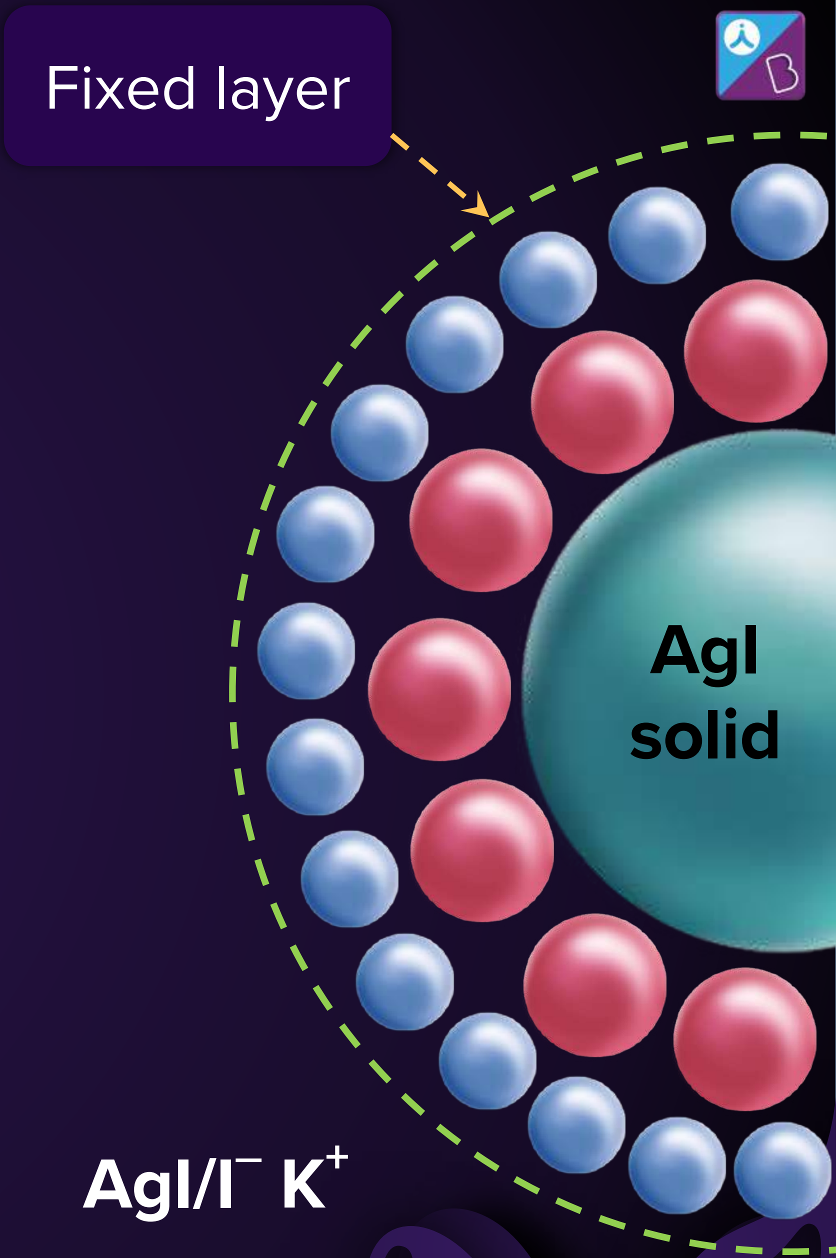
I^- ions

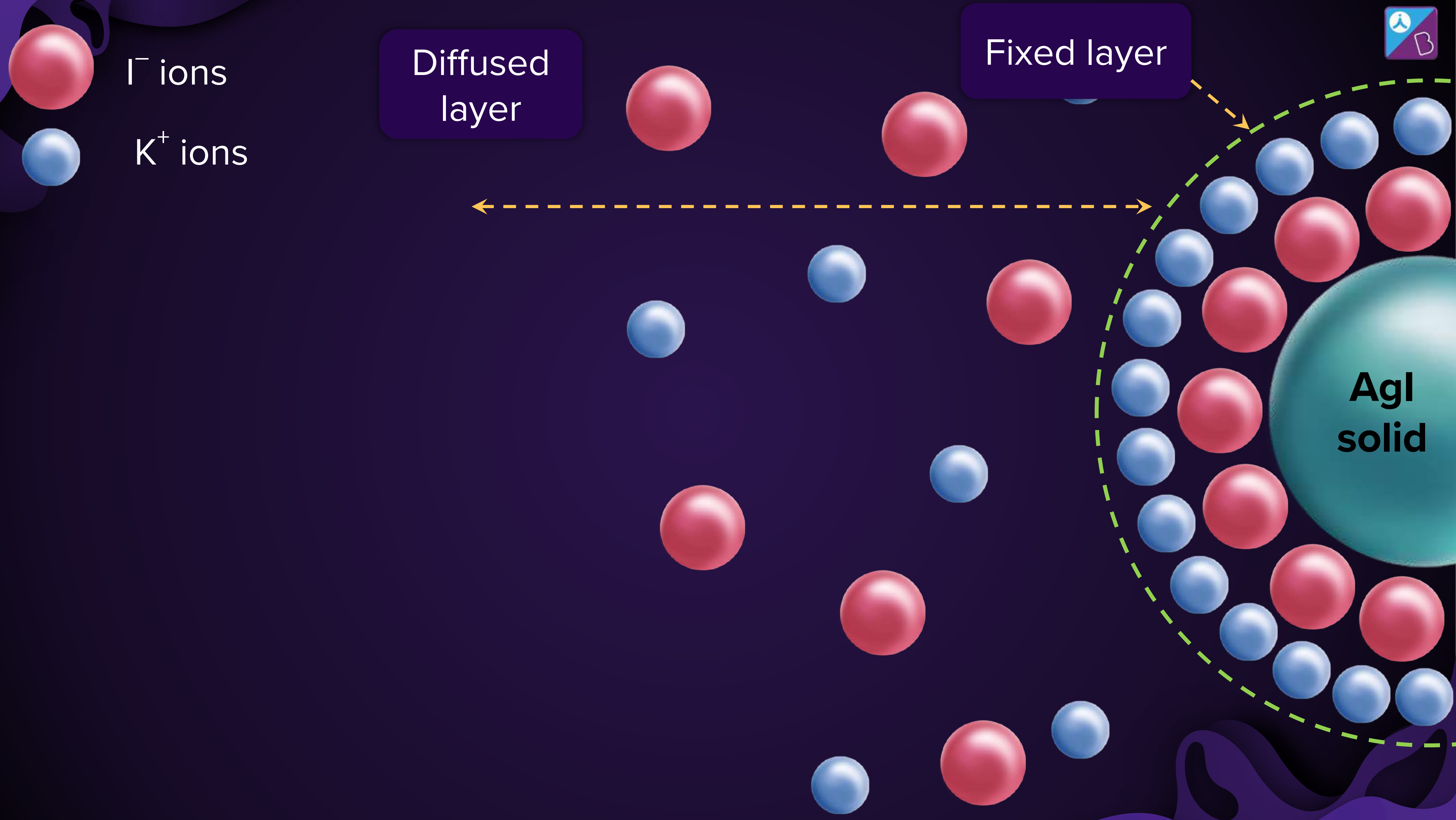
Selective adsorption of I^- ions

Formation of layer of counter (K^+) ions

● I^- ions

● K^+ ions





I^- ions

K^+ ions

Diffused layer

Fixed layer

AgI solid

Helmholtz Electrical Double Layer

The combination of the **two layers of opposite charges** around the colloidal particle is known as **Helmholtz electrical double layer.**

$AgI/I^{-}\ K^{+}$

First (inner) layer of ions → Firmly held → **Fixed** layer

Second (outer) layer of ions → Mobile → **Diffused** layer

Helmholtz Electrical Double Layer

The **opposite charges** on the fixed and the diffused layers

↓

Result in **potential difference** between the layers

↓

Called **electrokinetic potential** or **zeta potential**

Stability of sols

Presence of **double layer** (charge) on colloidal particles

↓

Responsible in **providing stability** to the sol

Electrophoresis

The **movement** of colloidal particles under an **applied potential** is known as **electrophoresis**.

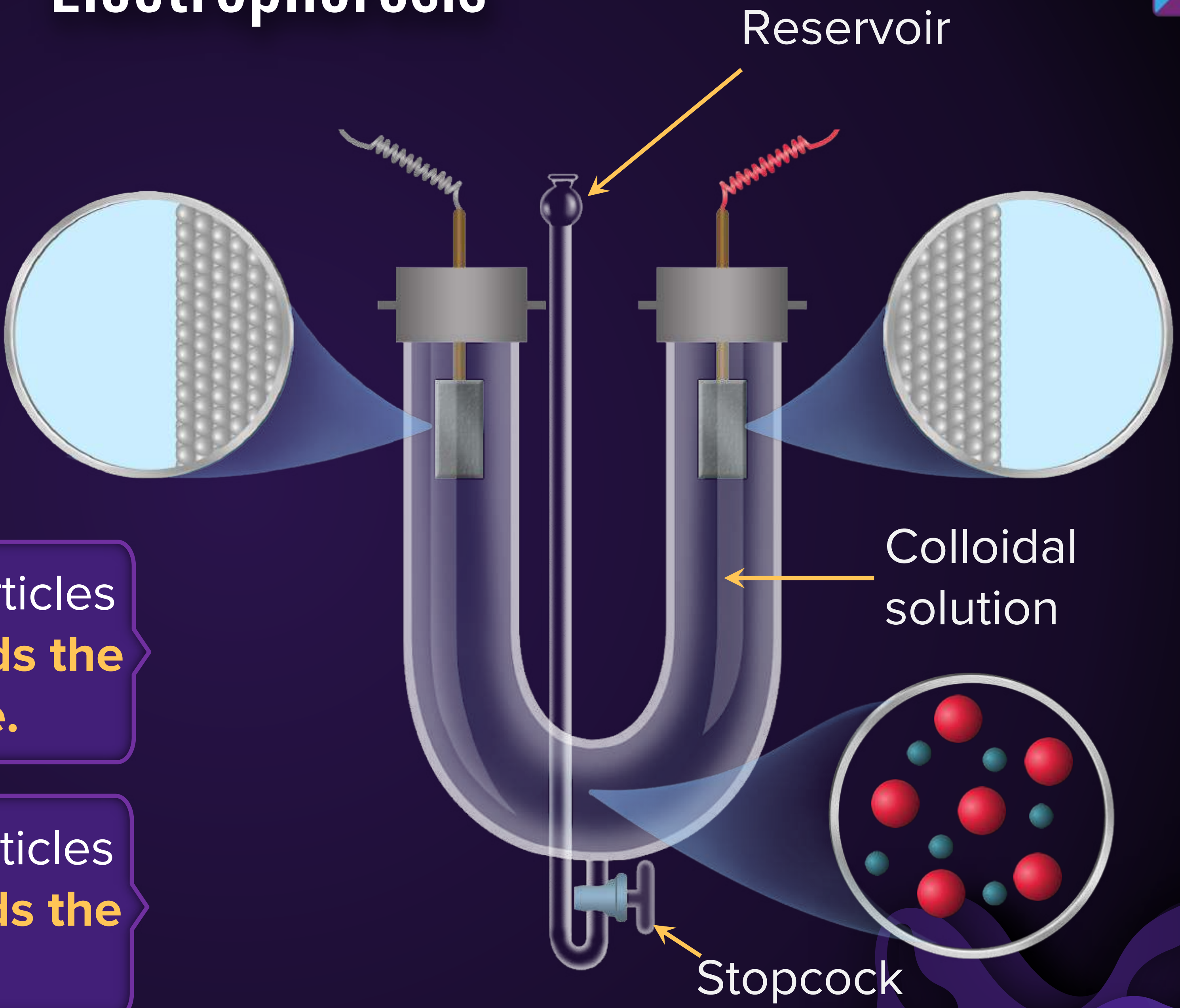
↓

It **confirms** the **existence of charge** on colloidal particles.

Electrophoresis

Before electric potential is applied

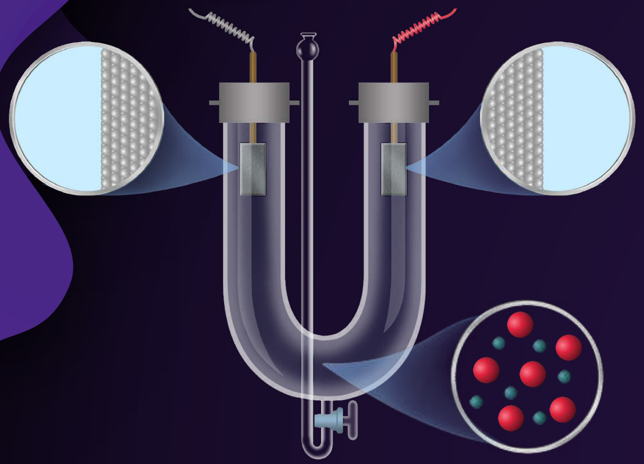
- ● Colloidal particle
- ● Dispersion medium particle



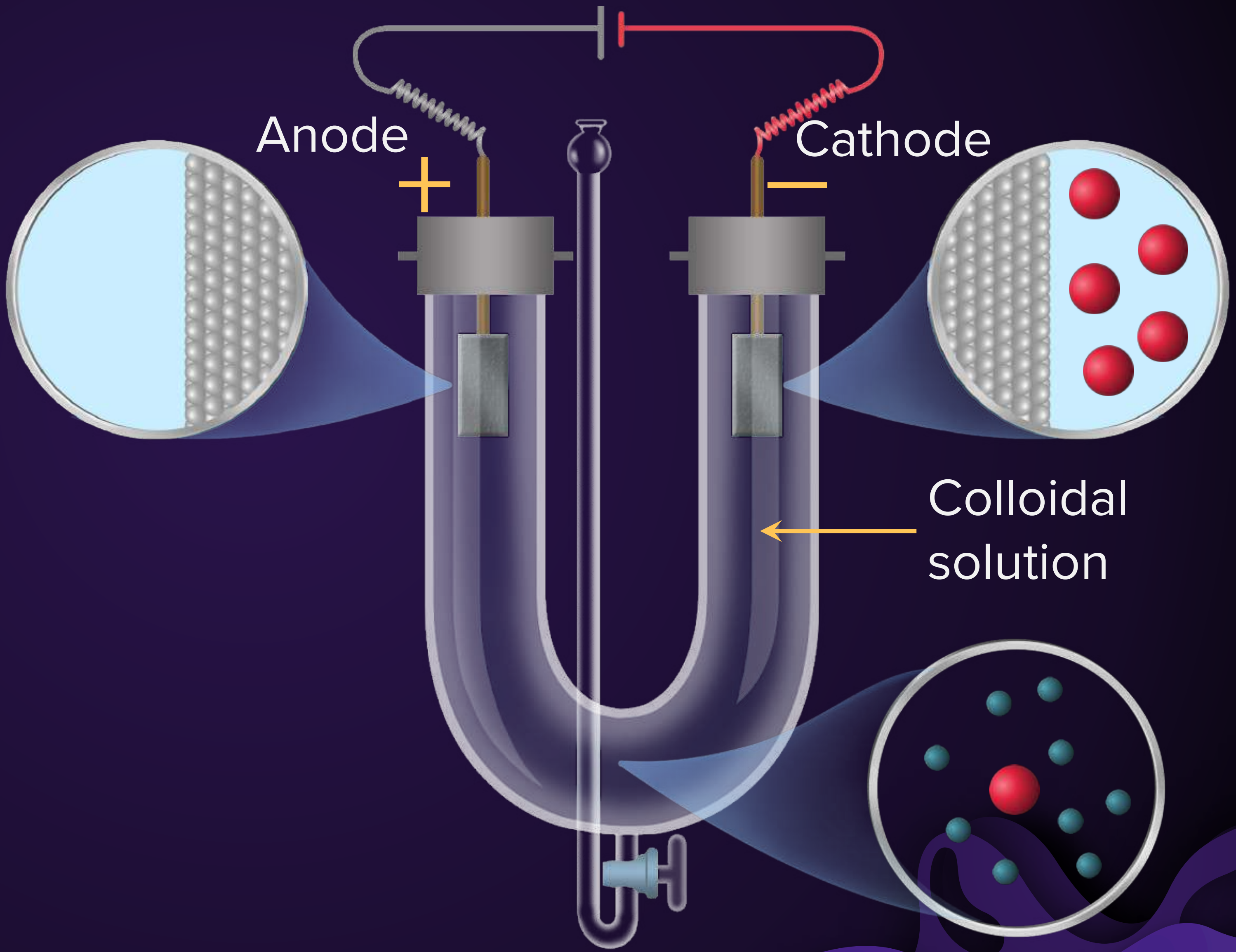
If colloidal sol is **positively charged**	Colloidal particles move **towards the cathode.**
If colloidal sol is **negatively charged**	Colloidal particles move **towards the anode.**

Electrophoresis

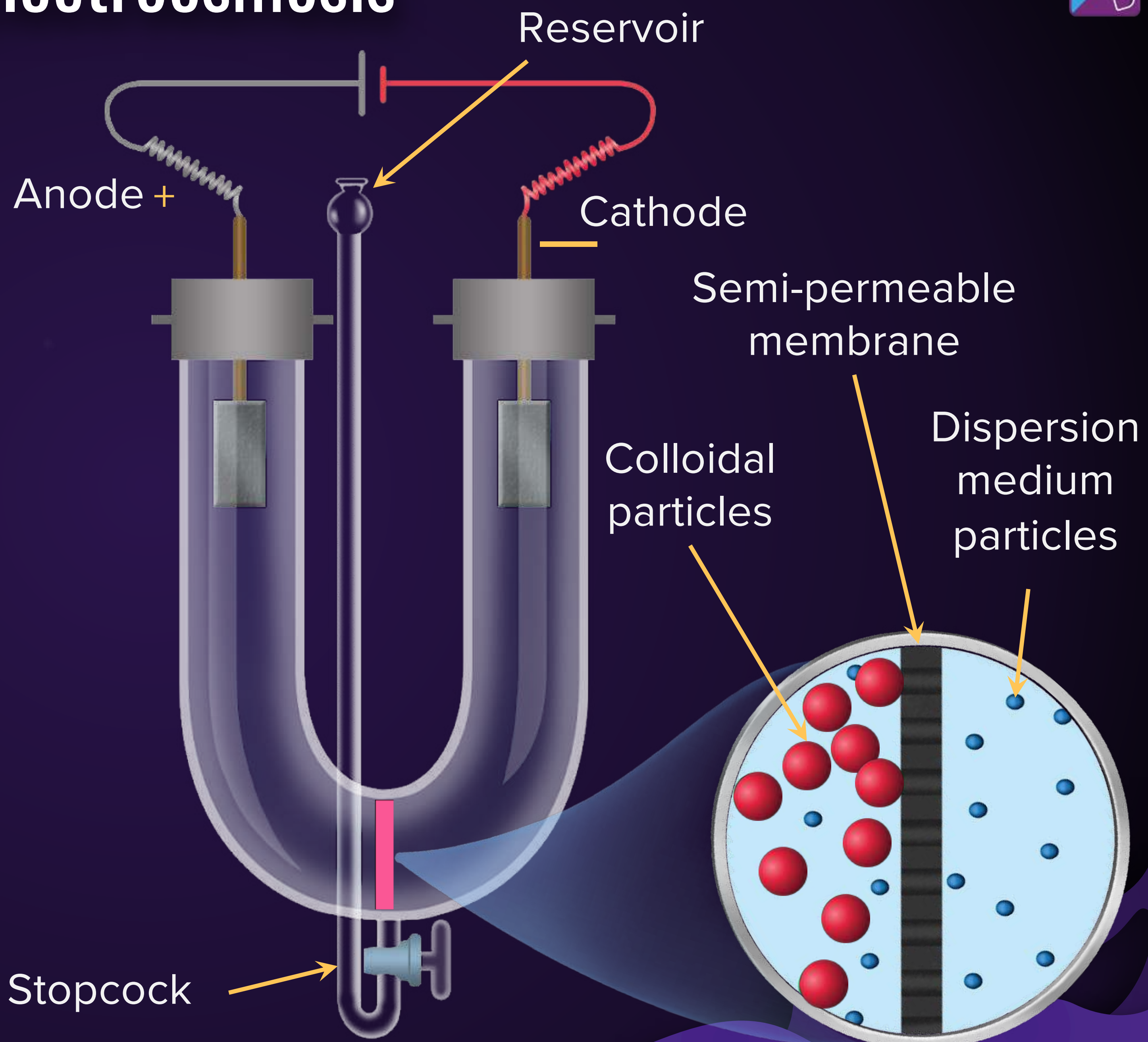
Before electric potential is applied



After electric potential is applied



Electroosmosis



Coagulation or Precipitation

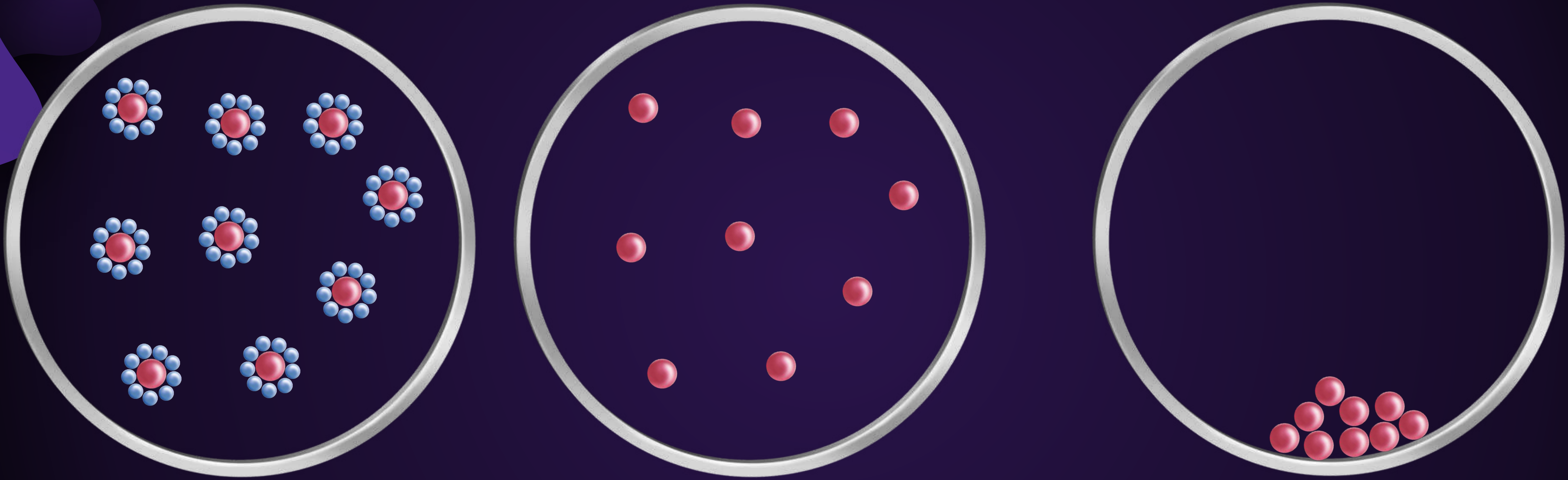
Sols are **stable** due to the presence of **charge** on particles.

If **removed,** the **uncharged** particles come close and form **aggregates.**

This process of **aggregation** of colloidal particles

Into an **insoluble precipitate** is known as **coagulation or precipitation** of the sol.

Coagulation or Precipitation



Charged colloidal particles

Uncharged colloidal particles

Coagulation/precipitation of colloidal particles

Methods for coagulation of lyophobic sols

- By electrophoresis
- By mixing two oppositely charged sols
- By boiling
- By persistent dialysis
- By addition of electrolytes

Coagulation by Electrophoresis

The **charged** colloidal particles move towards **oppositely charged** electrodes.

They get **discharged** and **precipitated**.

Coagulation by Mixing Two Oppositely Charged Sols

Oppositely charged sols, when **mixed** in **appropriate amounts**

Neutralise their charges and get **partially or completely** precipitated

This type of coagulation is known as **mutual coagulation**.

Example: Mixing of **hydrated ferric oxide** (**positive** sol) and **arsenous sulphide** (**negative** sol) brings them to their precipitated forms.

Coagulation by Boiling

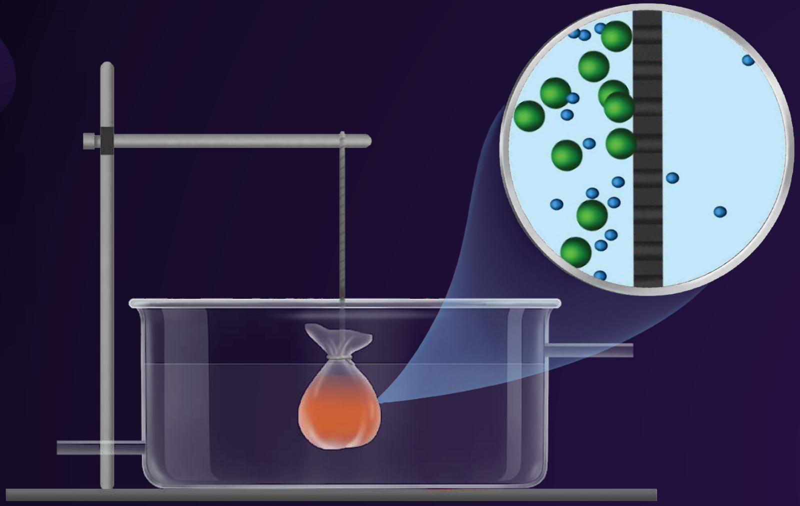
When a sol is **boiled**, the adsorbed layer is **disturbed**.

Due to **increased collisions** with the molecules of dispersion medium

The increased collisions **reduce** the **charge** on the particles.

The particles **settle down** in the form of a **precipitate**.

Coagulation by Persistent Dialysis



On **prolonged** dialysis, if **traces** of the electrolyte present in the sol are **removed completely**

The colloid becomes **unstable** and **ultimately coagulates**.

Coagulation by Addition of Electrolytes

Coagulating (flocculating) ions

Colloid particles **neutralise** by interacting with **oppositely charged ions**.

Leads to their **coagulation**

A **negative** ion causes the **precipitation** of **positively charged** sol and vice versa.

When **excess** of an electrolyte is added

The colloidal particles are **precipitated**.

Hardy-Schulze Rule

Generally,

Greater the valency of the flocculating ion added

Greater is its power to cause coagulation

Coagulating (or flocculating) power

For **positively charged** sols,

Order of coagulating power of **anions** (coagulating ions)

$[Fe(CN_6)]^{4-} > PO_4^{3-} > SO_4^{2-} > Cl^-$

For **negatively charged** sols,

Order of coagulating power of **cations** (coagulating ions)

$Al^{3+} > Ba^{2+} > Na^+$

Coagulating or Flocculating Value

The **minimum concentration** of an electrolyte **in millimoles** required to cause **coagulation of one litre** of colloidal solution

$$\text{Coagulating value} = \frac{\text{Millimoles of electrolyte}}{\text{Volume of sol in litre}}$$

Expressed in **millimoles litre^{-1}**

Coagulating or Flocculating Value

The coagulating value **decreases** with **Increase in charge** on the coagulating ion

$$\text{Coagulating power} \propto \frac{1}{\text{Coagulating value}}$$

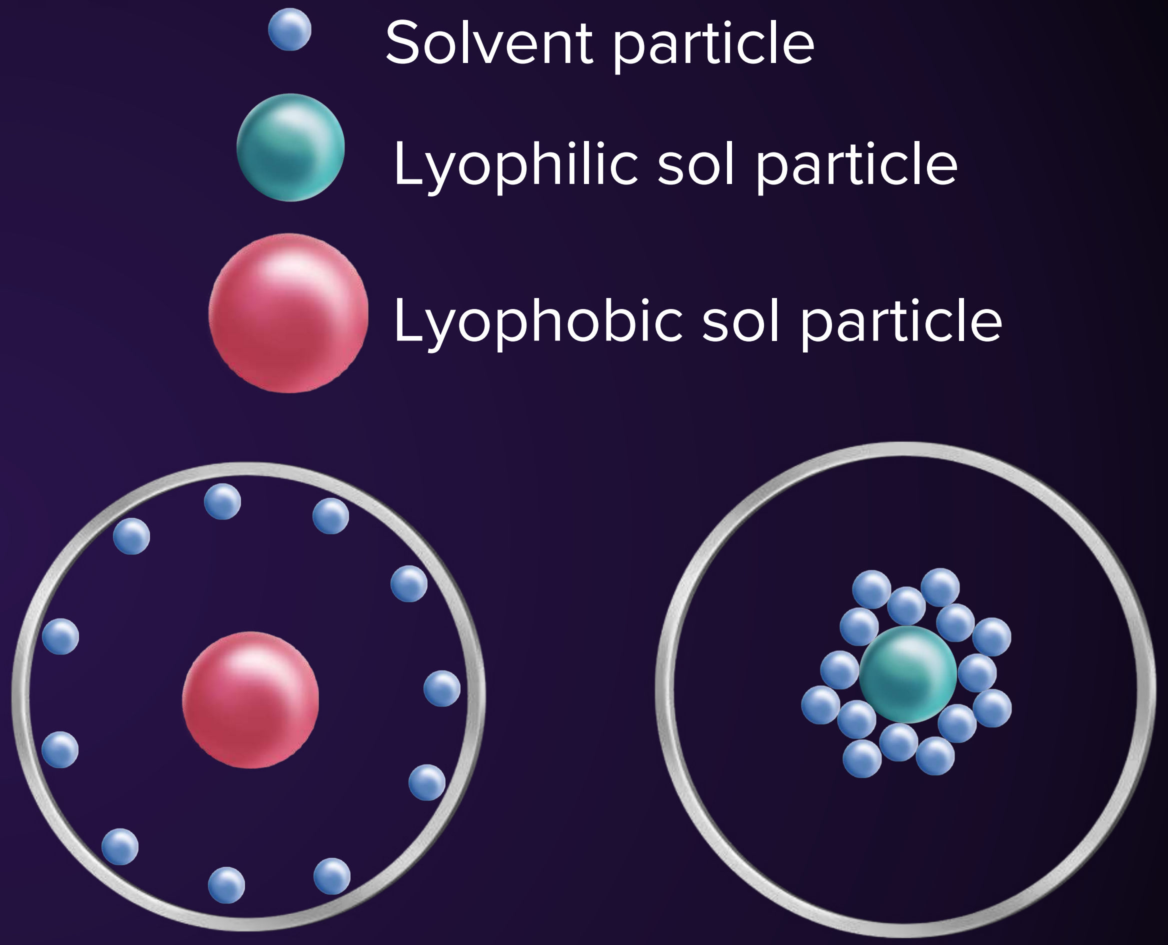
Stability of Lyophilic Sols

Lyophilic sols are **more stable** than lyophobic sols.

Reasons for stability

1 **Charge** on colloidal particles

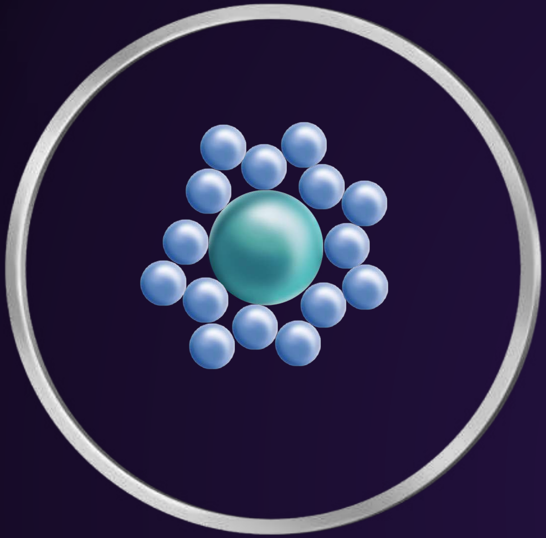
2 **Solvation** of colloidal particles



Lyophobic colloid

Lyophilic colloid

Coagulation of Lyophilic Sols



1 By adding **electrolyte**

2 By adding **suitable solvent**

Example: Alcohol and acetone are added to hydrophilic sol.

Protection of Lyophobic Colloids

Since **lyophilic** sols are **more stable** than **lyophobic** sols

Lyophilic sols have a **unique property to protect** lyophobic sols.

Lyophilic sols used for this purpose are known as **protective colloids.**

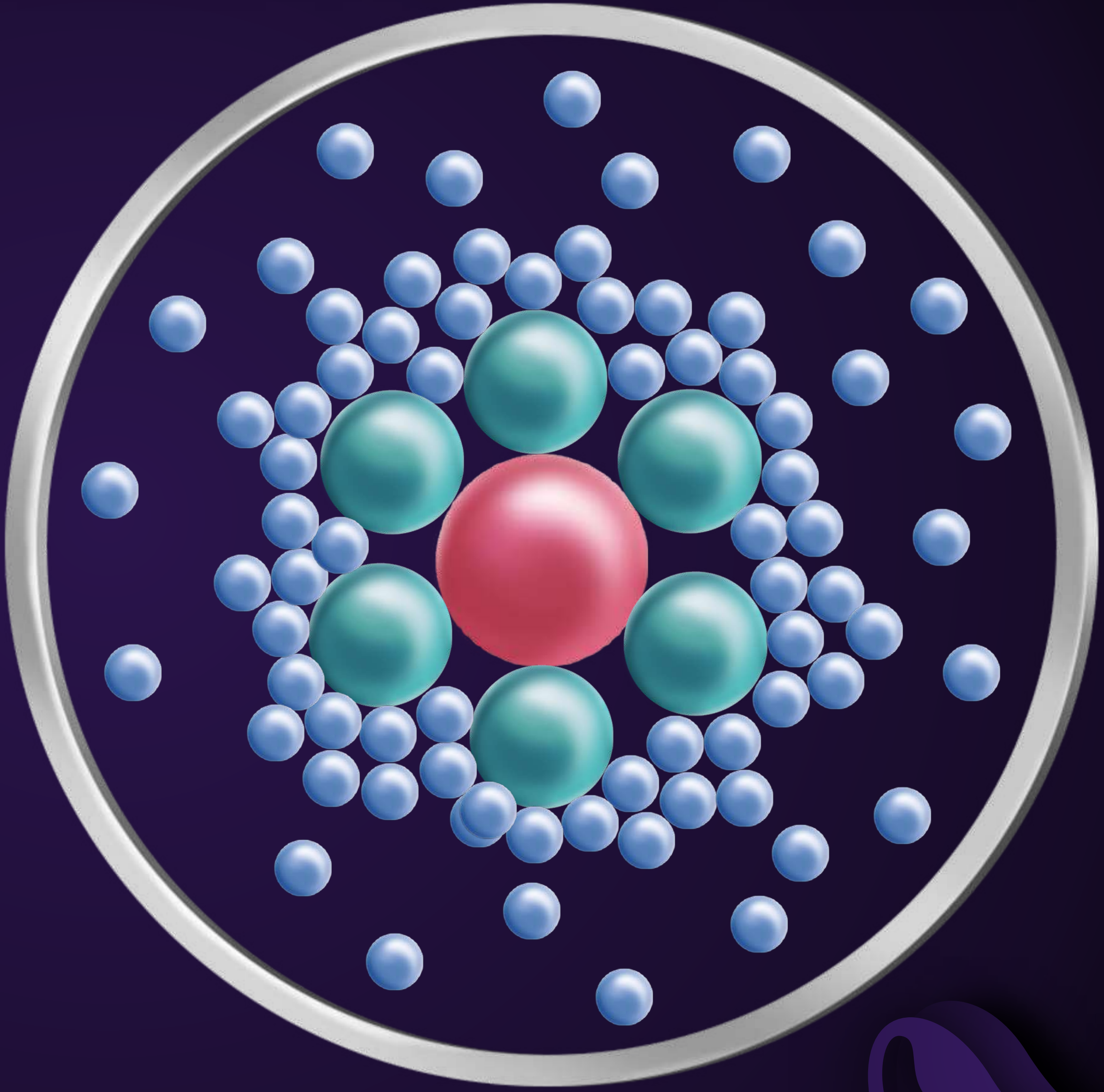
When **lyophilic** sol is **added** to **lyophobic** sol

Lyophilic particles **form a layer** around lyophobic particles.

Lyophilic particles protect lyophobic sol from electrolytes.

Protection of Lyophobic Colloids

- ● Solvent particle
- ● Lyophilic sol particle
- ● Lyophobic sol particle



Gold Number

It is the **minimum weight** in milligrams of a protective colloid required to **prevent** the **coagulation of 10 mL** of a standard **gold sol** when **1 mL of a 10% NaCl** solution is added to the sol

Smaller the gold number, **greater** will be protecting power of the protective colloid.

$$\text{Protecting power of protective colloid} \propto \frac{1}{\text{Gold number}}$$

Emulsion

Liquid–liquid colloidal system

Dispersion of finely divided **droplets** in another **liquid**

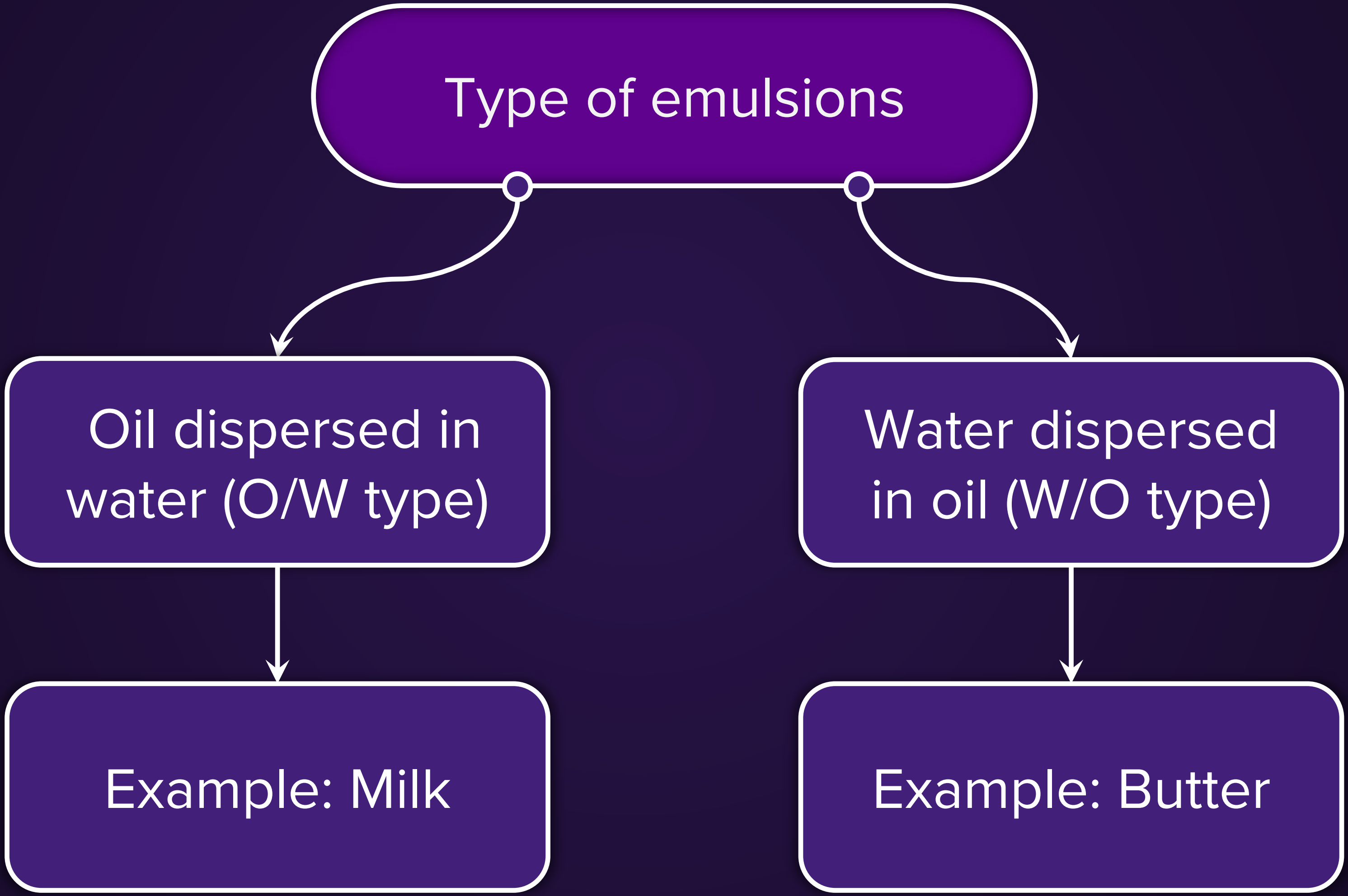
If a mixture of two **immiscible or partially miscible** liquids is **shaken**

A **coarse dispersion** of one liquid in the other is obtained.

It is called an **emulsion**.

Preparation of Emulsion

Type of Emulsions



Type of emulsions

Oil dispersed in water (O/W type)

Example: Milk

Water dispersed in oil (W/O type)

Example: Butter

Emulsions

Generally, emulsions are **unstable**.

They **separate** into two layers on standing.

A **third component** known as **emulsifying agent** is added for **stabilisation.**

It forms an **interfacial film** between suspended particles and the medium.

Demulsification

It is the **separation** of an emulsion into its **constituent liquids**.

It can be achieved by **freezing, heating, centrifugation**, etc.

Sky

Colloids Around Us

Fog or Mist

Applications of Colloids

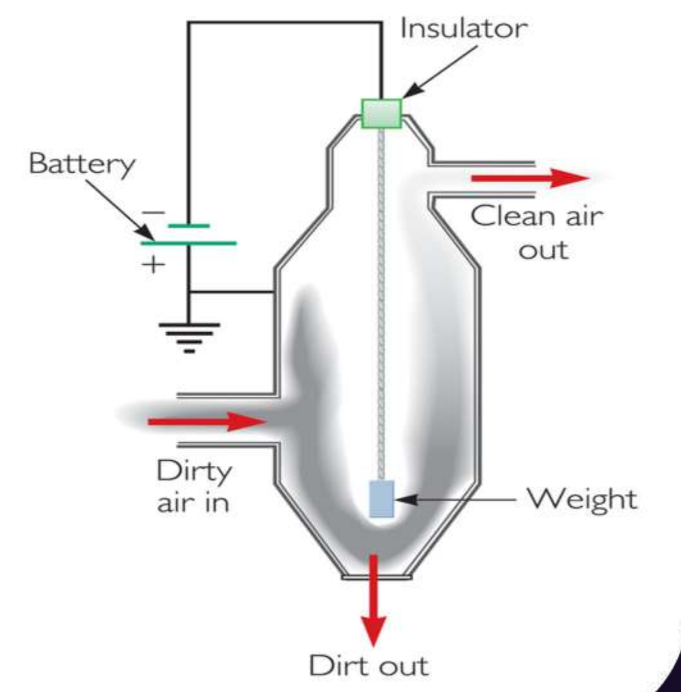
Smoke

Smoke is a colloidal solution of **solid particles**.

Such as **carbon, arsenic compounds, dust**, etc.

Schematic Diagram of an

Electrostatic Precipitator



Cottrell Smoke Precipitator

Electrical Precipitation of Smoke

Smoke is **led through** a chamber containing **weight (plate)**

The smoke particles, on coming in **contact** with the plate

Having a **charge opposite** to that carried by smoke particles

Lose their **charge** and get **precipitated**