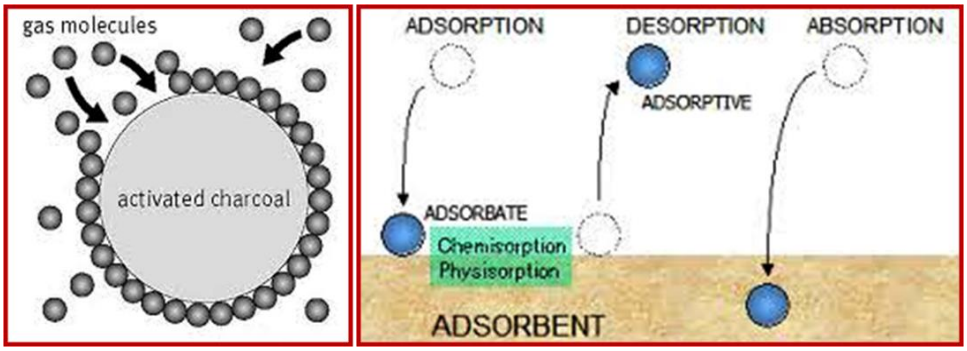
Adsorption

Definition:

Adsorption is the adhesion of atoms, ions or molecules from a gas, liquid or dissolved solid to a surface. This process creates a film of the adsorbate on the surface of the adsorbent.



Sl. No.	Absorption	Adsorption
1	Assimilation of molecular species throughout the bulk of the solid or liquid is termed as absorption.	Accumulation of the molecular species at the surface rather than in the bulk of the solid or liquid is termed as adsorption.
2	It is a bulk phenomenon	It is a surface phenomenon
3	Endothermic process	Exothermic process
4	It is not affected by temperature	It is favoured by low temperature
5	It occurs at a uniform rate	It steadily increases and reaches equilibrium
6	It is same throughout the material	Concentration on the surface of adsorbent is different from that in the bulk

Adsorbate:

The substance which is being adsorbed on the surface of another substance is called adsorbate.

Adsorbent:

The substance present in bulk, on the surface of which adsorption is taking place is called adsorbent.

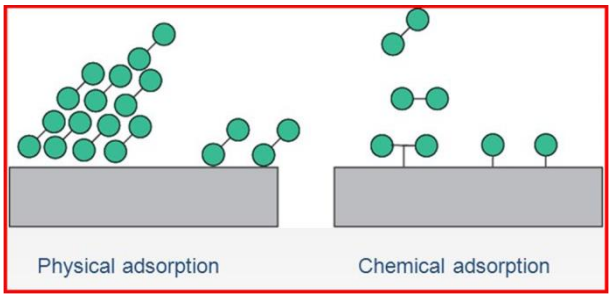
Ex: Ammonia is adsorbed by charcoal.

- Ammonia = Adsorbate and charcoal = Adsorbent

- Common examples of adsorbents are clay, silica gel, colloids, metals etc.
- If a gas gets adsorbed on to the surface of a solid, then the gas is termed as the adsorbate.

Types of Adsorption

There are two types of Adsorption – Physical Adsorption or Physisorption and Chemical Adsorption or Chemisorption.



Physical Adsorption:

It involves adsorption of gases on solid surface via weak van der Waal's forces.

Characteristics of Physical Adsorption:

- Physisorption forces involved are very weak, a small rise in temperature will cause desorption.
- Physical adsorption is reversible in nature.
- It characterized by low heat of adsorption.
- It may involve mono or multilayer formation.

Ex: Adsorption of gases on charcoal.

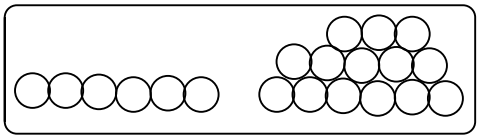
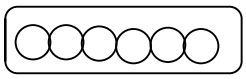
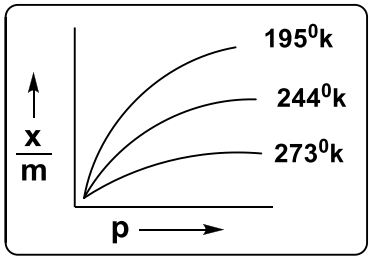
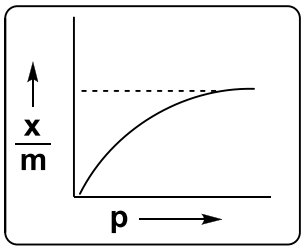
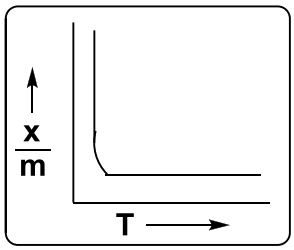
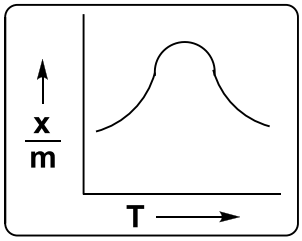
Chemical Adsorption

It is a chemical process in which the gas molecules interact with the surface of the solid to form a chemical compounds.

Characteristics of Chemical Adsorption:

- The forces involved are very strong.
- Chemical adsorption is irreversible.
- Physical adsorption is an exothermic process.
- It characterized by high heat of adsorption.
- It involves only monolayer formation.

Ex: Adsorption of O_2 on metals.

Sl. No.	Physisorption	Chemisorption
1	It involves weak van der Waal's forces.	It involves strong chemical bond.
2	Involves low heat of adsorption (<40 KJ)	Involves high heat of adsorption (40-400 KJ)
3	Occurs at ordinary temperature.	Occurs at high temperature.
4	It involves no compound formation	It involves compound formation
5	Involves no appreciable activation energy.	Involves significant activation energy.
6	Reversible and the heat gas are desorbed by slight heating.	Irreversible and the heat gas are desorbed by high temperature.
7	Non – specific. Any gas would be adsorbed on any solid.	Highly specific. A gas is adsorbed only on those solids with which it can react.
8	Involves mono or multilayer formation 	Involves only a monolayer. 
9	The magnitude of adsorption increases continuously with pressure. 	The magnitude of adsorption increases with pressure and reaches a limiting value. 
10	The magnitude of adsorption decreases continuously with temperature. 	The magnitude of adsorption increases and then decreases with temperature. 

Factors influencing adsorption

1. Nature of the gas
2. Nature of the solid
3. Surface area of the solid adsorbent
4. Effect of temperature
5. Effect of pressure

1. Nature of the gas

In general, easily liquefiable gases e.g., CO_2, NH_3, Cl_2 and SO_2 etc. are adsorbed to a greater extent than the elemental gases e.g. H_2, O_2, N_2, He etc...

2. Nature of the solid

Porous and finely powdered solid e.g. charcoal, fullers earth, adsorb more as compared to the hard non-porous materials. Due to this property powdered charcoal is used in gas masks.

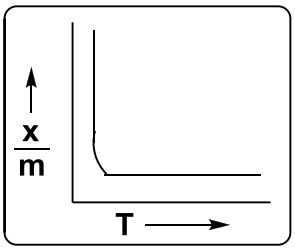
3. Surface area of the solid adsorbent

The extent of adsorption depends directly upon the surface area of the adsorbent, i.e. larger the surface area of the adsorbent, greater is the extent of adsorption. Surface area of a powdered solid adsorbent depends upon its particle size. Smaller the particle size, greater is its surface area.

4. Effect of temperature

Physorption occurs rapidly at low temperature and decrease with increase of temperature. One the other hand chemisorption occurs at all temperature and increase with increase temperature.

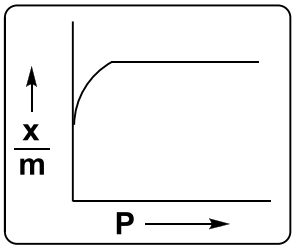
Fig: Adsorption isobar



5. Effect of pressure

The extent of physorption increase with increase of pressure. Change of pressure has no such effects on chemisorption.

Fig: Adsorption isotherm



Adsorption Isotherms

A mathematical equation, which describes the relationship between pressure (p) of the gaseous adsorbate and the extent of adsorption at any fixed temperature, is called adsorption isotherms. The extent of adsorption is expressed as mass of the adsorbate adsorbed on one unit mass of the adsorbent. Thus, if x g of an adsorbate is adsorbed on m g of the adsorbent, then

$$\text{Extent of adsorption} = \frac{x}{m}$$

Various adsorption isotherms are commonly employed in describing the adsorption data.

Freundlich Adsorption Isotherm

To represent the variation of adsorption with pressure at a given temperature Freundlich proposed the equation.

$$\frac{x}{m} = KP^{1/n} \longrightarrow (1)$$

Where,

x = amount of gas adsorbed, m = amount of adsorbent
P = equilibrium pressure, K and n = constant

Equation 1 is known as **Freundlich adsorption isotherm**.

This relation is represented in the form of a curve by plotting the amount of gas adsorbed per unit mass of adsorbent (x/m) against equilibrium pressure (P). Taking logarithms on both sides, equation 1 becomes,

$$\log \frac{x}{m} = {}^{1/n} \log P + \log K$$

Compare with the equation for a straight line, **y = mx + c**

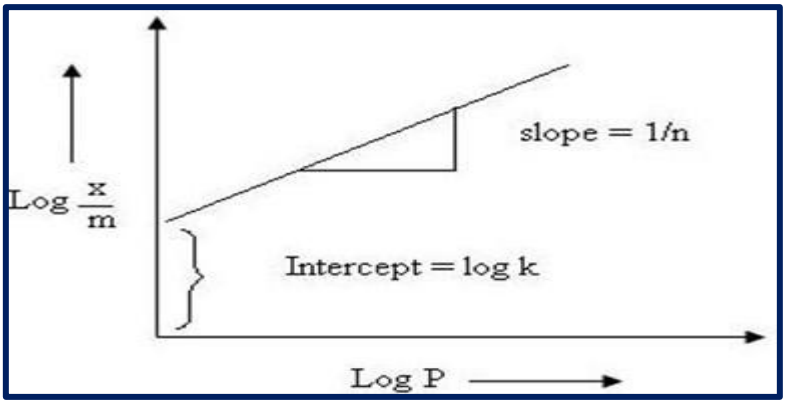


Fig: Freundlich Isotherm Plot

- On plotting log x/m against log P, a straight line should be obtained.
- When plotting with the experimental values, a straight line is got as expected, thus proving the validity of Freundlich isotherm.

Limitation:

- It is obeyed at low pressure of the adsorbate and it fails if the pressure of the adsorbate is too high.

Langmuir Adsorption Isotherm

Assuming that the adsorbed gas molecules form a unimolecular layer, Langmuir derived an expression relating the amount of gas adsorbed and the equilibrium pressure of the gas at constant temperature.

Where,

x = amount of gas adsorbed, m = amount of adsorbent,

P = equilibrium pressure, K and n = constant

Equation 2 is known as **Langmuir adsorption isotherm**.

$$\frac{x}{m} = \frac{k_1 Kp}{1+Kp} \longrightarrow (2)$$

$$\frac{1}{x/m} = \frac{1+kp}{k_1 Kp} = \frac{1}{k_1 Kp} + \frac{1}{k_1}$$

Multiplying both sides of the above equation with P,

$$\frac{P}{x/m} = \frac{1}{k_1 K} + \frac{p}{k_1} \longrightarrow (3)$$

Equation 3 is another form of Langmuir adsorption isotherm.

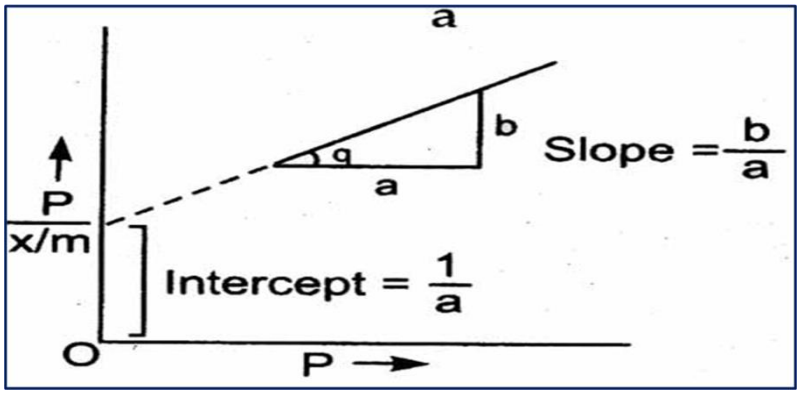


Fig: Verification of Langmuir Isotherm

- On plotting log P/x/m against P, a straight line should be obtained.
- In most cases, a straight line is got, thus proving the validity of Langmuir isotherm.

Limitation:

- Langmuir`s theory is restricted to the formation of a unimolecular layer of gas molecules on the solid surface and it does not consider the possibility of multilayer formation.

~~~~~~
~~~~~~