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THEORY AND BASIC CONCEPTS OF ADSORPTION

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ABSTRACT

Adsorption is the attachment 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. This process differs from absorption. Adsorption is a surface-based process while absorption involves the whole volume of the material. The term sorption means both processes, while desorption is the opposite of it. Adsorption is a surface phenomenon. It occurs or exists in natural, physical, biological, and chemical systems, and is widely used in industrial applications such as activated charcoal, capturing and using waste heat to provide cold water for air conditioning and other process requirements (adsorption chillers), synthetic resins, increase storage capacity of carbide-derived carbons, and water purification. Through this article we reviewed and threw some light on various basic aspects and prospects of adsorption phenomenon which occurring and dealing with chemical or medical sciences. In addition to this it also includes various applications which provide fruitful results in the field of pharmaceuticals and environmental related studies.

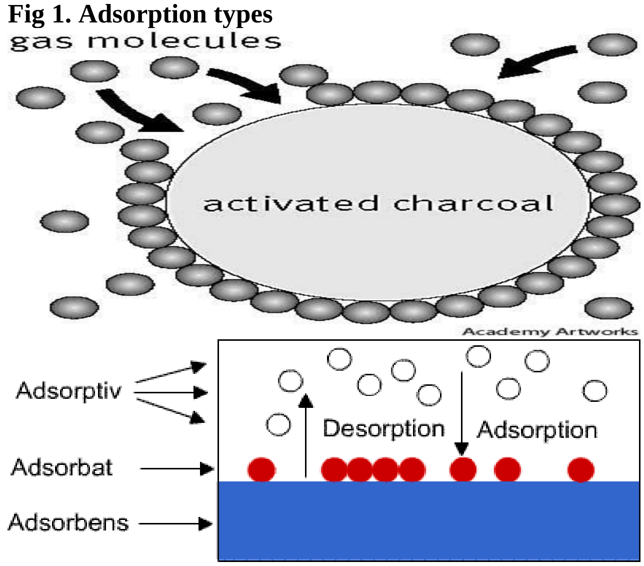
Keywords: Adsorption theory, characteristics of adsorption, types of adsorptions, chemisorptions, physisorption, adsorption isotherm, application of adsorption.

INTRODUCTION

It is a process that occurs when a molecule of gas or liquid (adsorbate) attached on the surface of a solid or a liquid (adsorbent) and forms a molecular or atomic film of the adsorbate on the substance. Kinetic Energy loses in the process of adsorption by this; it makes adsorption an exothermic process. While the process of desorption is an endothermic process. In this process, the separation of the adsorbate from the adsorbent must need heat supply for separation. In simple words, it is the removal of adsorbed molecule from the surface. We can also say that, desorption is an opposite process takes place by vaporisation of the adsorbate [1,2]

Adsorption process is completely differs from absorption process, in which a particle of gas or liquid (solute) dissolved throughout the solvent (body of the solid/liquid) to form a solution. The term sorption encompasses (include) both processes, Adsorption is operative in For the most natural physical, biological, and chemical systems the mechanism of adsorption is important, and this mechanism is widely used in industrial applications such as activated charcoal, water purification and synthetic resins. The principle on which the process of adsorption works is adhesion or accumulation [3,4].

Fig 1. Adsorption types



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TYPES OF ADSORPTION

There are generally two types of adsorption following below

Physisorption also known as physical adsorption is a type of adsorption in which the adsorbate attached to the surface (adsorbent) only through Van der Waals attractive forces (weak intermolecular forces) interactions, the behaviour of real gases is non-ideal due to the Van der Waals forces. The characteristic feature of physical adsorption is the adsorption at low heat and the heat ranges from 10 to 20 kJ/mol.

Chemisorption also known as chemical adsorption is a type of adsorption in which the adsorbate molecule attached to a surface by the formation of a chemical bond such as covalent or ionic bond, as reverse to the Van der Waals forces which cause physisorption. The feature of chemical adsorption is the adsorption at high heat of four times greater than that of physical adsorption [3,4].

FACTORS AFFECTING ADSORPTION

The most important factors affecting adsorption are as following below

Surface area of adsorbent

Extent of adsorption is generally proportional to specific surface area, specific surface area being that portion of the total surface available for adsorption. Adsorption capacity increases with increase in surface area of adsorbent pores.

Temperature

Temperature affects Adsorption. The adsorption reactions are normally exothermic, thus the extent of adsorption generally increases with decrease in temperature. Therefore, by this temperature act as inversely proportional to adsorption.

Solubility of solute (adsorbate) in liquid (waste water)

Substances slightly soluble in water will be more easily removed from water (i.e., adsorbed) than substances with high solubility {i.e., solubility is inversely proportional to the adsorption (more the solubility less the adsorption & less the solubility more the adsorption)} Also, non-polar substances will be more easily removed than polar substances since the latter have a greater affinity for water.

Polarity/Affinity of the solute for the adsorbent (carbon)

A polar solute will be strongly adsorbed from a non-polar solvent by a polar adsorbent. But a polar solvent to a non-polar adsorbent will prefer. The function of charge separation within the molecule is the Polarity of organic compounds. The surface of activated carbon is only slightly polar (water loving). Hence non-polar (water hating-hydro phobic) substances will be more easily picked up by the carbon than polar ones.

Size of the molecule with respect to size of the pores

Large molecules may be too large to enter small pores. This may reduce adsorption independently of other causes.

Degree of ionization of the adsorbate molecule

More highly ionized molecules are adsorbed to a smaller degree than neutral molecules.

pH

The degree of ionization of an acidic or basic compound or species is affects adsorption; pH governs the degree of ionization because pH affects adsorption. In general, with decreasing pH, the adsorption of typical organic pollutants from water is increased. This, in turn, PH affects adsorption.

Solute properties

In general, there is an inverse relationship exists between the extent of adsorption and water solubility can be expected to arrive. With the increasing chain length the water solubility of organic compounds within a particular chemical class will decreases, because the compound becomes more hydrocarbon-like as the number of carbon atoms becomes greater. Thus, adsorption from aqueous solution increases as a homologous series is ascended, largely because the expulsion of increasingly large hydrophobic molecules from water permits an increasing number of water-water bonds to reform [5-9].

ADSORPTION ISOTHERM

Generally isotherm means a line of equal or constant temperature drawn on a graph or chart. Adsorption isotherm is a type of mathematical model equations used to describe the relationship between the adsorbate with absorbent material [10].

The required amount of absorbent material is also determined by the use of isotherm. Adsorption is usually described through isotherms, adsorption isotherms are the division of surface covered at different pressure at a particular temperature that is, functions which adjoined the amount of adsorbate on the adsorbent, with its pressure (if gas) or concentration (if liquid) [11].

Types of Adsorption Isotherms

There are different types of adsorption isotherms to show different relationship acquired between adsorbate and adsorbent. Different adsorbates-adsorbents exhibit different types of equilibrium relationships (i.e., the function $q = f(C)$ may take different mathematical forms). The adsorption isotherm equations represent the relation between the adsorbate concentration, and the fraction which are adsorbed at constant temperature [12].

It has been found that for various conditions, following isotherms has been used
i. Langmuir isotherm
ii. Freundlich isotherm

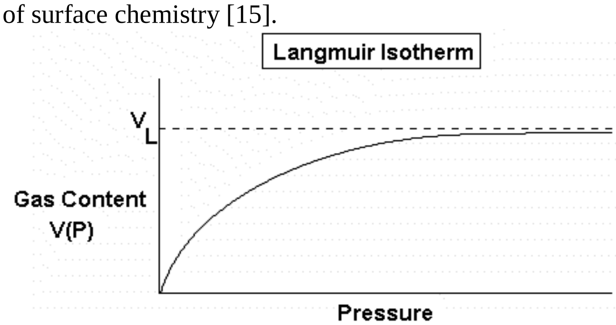
Langmuir isotherm

Irving Langmuir proposed Adsorption isotherm in 1916, which was an explanation of variation of Adsorption with pressure. On the basis of his theory, he derived an equation, which was named Langmuir Equation. It represents a relationship between the number of active sites of the surface undergoing adsorption and pressure [13].

It is based on four hypotheses

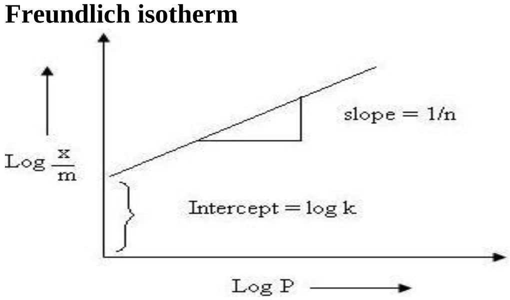
1. The total adsorption sites are equal, because the surface of the adsorbent is uniform.
2. There is no interaction between the adsorbed molecules.
3. There is same Mechanism of the occurring of all adsorptions.
4. A unilayer is formed at the maximum adsorption: there is no deposition of molecules of adsorbate on one another, already adsorbed molecules of adsorbate, present on the free surface of the adsorbent [14].

In 1932, Langmuir was awarded the Nobel Prize in chemistry for ‘his discoveries and researches in the realm of surface chemistry [15].



Here (V_L) is used for Langmuir volume parameter.

Freundlich isotherm



Log(x/m) vs. Log p graph

Freundlich gave an empirical relationship in 1909, representing the isothermal variation of Adsorption between the quantities of gas adsorbed by unit mass of solid adsorbent along with pressure at a particular temperature. This isotherm is a type of an empirical model which is used to describe the action of adsorption in aqueous systems. This type of isotherm is generally uses to explain the adsorption isotherm of the activated carbon [16].

PRACTICAL APPLICATION OF ADSORPTION

In the early ancient times of adsorption history the carbon materials which were mostly used by some rare specialist is known as charcoals Since, we know our early history where as active carbon was the first which is widely used as an adsorbent. Carbonised wood (charcoal) is in the form of its application which has been described as early as 3750 BC in an ancient Egyptian papyrus [17-19].

However, the rational use of adsorption process for industrial purposes started only at the end of the 18th century. The Swedish chemist Carl Wilhelm Scheele was the first who discover the phenomenon of adsorption of gases on charcoal in 1773 [20].

Twelve years later it was found by the Lowitz that the charcoal also act as decolourising agent when charcoal immersed in tartaric acid solution, it decolourises by adsorbing organic contaminants present in it. The discovery of this application led to the first industrial application of charcoal, where it this application was used as a decolourising agent for sugar syrup in the sugar industry in England for first time in 1794 [21].

Industrial area applications

i. Purification and separation of gas and liquid mixtures, isomers, bulk chemicals and air.
ii. Extraction of impurities from liquid and gas media before loading them into industrial system
iii. Drying liquids and gases before loading them into industrial systems.
iv. Recovery of chemicals from industrial and vent gases.
v. Purification of water selective adsorption is the way of separating gas and liquid mixtures from the certain substances [22,23].
vi. In the neutralization of waste gases and sewages are done by the help of adsorbents and it also capturing valuable components which are found in wastes at the same time, by this adsorbents play a significant role in the neutralisation process**.** Comparison to other methods, at relatively low cost adsorbents allow for the most thorough purification of raw materials [24].
vii. In the clarification of sugar, adsorbents also used in the clarification of sugar by adsorbs undesirable color present in it. It is decolorized by treating sugar solution with charcoal powder and immersed it in tartaric acid solution. We know that it was the first industrial application and it was become the decolourising agent which is also discussed above [25].

Pharmaceutical applications

i. In the pharmaceutical industry adsorbents are used for the removal and purification of vitamins, antibiotics and in the purification of anaesthetics and also in other purposes.
ii. The Adsorbents are widely applied in medicine, among others, for adsorption of poison or take up poisons which are found in living organisms and it also use in the case of some diseases of the alimentary canal (GIT-gastro intestinal tract).
iii. Recently, adsorbents have been used for purification of blood from noxious substances using the method of chemisorption.
iv. In the chromatographic analysis**,** adsorbents are also used in the chromatographic analysis for analysis and separation of mixtures with simultaneous evolution of high purity components. This technique is called chromatographic analysis. Of particular importance in laboratory practice are adsorbents used in chromatographic analysis. Adsorption gas chromatography is used in industrial laboratories for periodical inspection of technological processes and in systems of automatic control and steering of many production processes.
v. In the production of high vacuum, it is possible to obtain, create and maintain high vacuum by using adsorbents, among others, it is used in large size machinery and to ensure long and stable work of semi conducting, cooling and other equipment.
vi. Drying of gases and liquids are take place by the use of activated alumina as adsorbents [26].

Medical applications

Adsorption of proteins at solid-liquid interface Proteins adsorption at solid liquid interface is connected among others with the problem of biocompatibility of materials. In the modern medical system, the modern medicines are used which are extensively synthetic materials, ceramics and polymers. In body part replacement surgery or substitution surgery or transplantation, implantation, when surgical intervention requires to replace various body organs, vessels, bones, tissues and other transplantable body parts like by synthetic ones (i.e., artificial). This human activity brings out the light/slight problem of biocompatibility, and blood compatibility is its particular or common case [27]. Current knowledge shows that the problem of compatibility is connected with the extent of surface energy decrease due to the contact of materials with aqueous media [28]. Biocompatible materials equilibrated with liquid phase in aqueous media have to possess an optimum surface energy of approximately several mJ/m2, which allows for the prevention of adsorption on the surface of a potentially compatible material of proteins, which promotes intensively the adhesion of platelets resulting into thrombosis. At the same phase of time, the value of surface energy cannot be prevented to disperse spontaneously and, thus, to destruct of a material [29]. Work must be investigated by using blood-material contacting systems. But such type of studies is difficult to control and perform. The problem is now being solved by adsorption application of executing blood protein adsorption on synthetic materials. Example, serum albumins, results into higher reliability in blood-compatibility of potentially suitable materials in vivo. On the other hand, preferential adsorption of fibrinogen and other protein factors of blood coagulation decrease the serviceability of those materials. Therefore, the adsorption of proteins at the surface of biomedical sciences, such as implants, catheters and insulin pumps, is the first step in a complex series of biochemical/biophysical processes, which determine the biological response to a foreign material [30]. The surface of polycarbonates with adsorbed serum albumin is one of the most suitable to be used in the implant devices [31].

Environmental applications

Every aspect of human activity is closely connected with the natural environment.
i. In Flue gas treatment, there is removal of emission of SOx, NOx and mercury.
ii. Waste water treatment, for the removal of Organics, nitrogen and phosphorus,
iii. Removal and recovery of nutrients from waste water.
iv. Drinking water production and advanced treatment of waste water, etc.
v. Desiccant dehumidification technology, it involves improvement of indoor air quality and removal of air pollutants and the number of microorganisms either removed or killed by dessicants due to co-adsorption by dessicant materials.
vi. Defense applications- Removal of contaminants are used in defense tasks; extreme toxic chemical agents are present; during the Gulf War experience gained and has awareness of the need in better air purification. The systems is designed especially for the defense applications; in contrast to the solvent vapor recovery processes, defense systems have only to purify air, but both the applications are environmentally related where application of adsorption technology is used quite successfully [32-35].

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CONFLICT OF INTEREST

No interest.

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