

ADSORPTION AND SURFACE PHENOMENA: EXTENDED PRINCIPLES AND MEDICAL IMPORTANCE

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Abstract: This extended article provides a comprehensive explanation of adsorption and surface phenomena and their medical importance. Additional sections, expanded discussions, and new tables are included. Adsorption plays a key role in detoxification, hemodialysis, drug delivery, biomaterials, diagnostics, and nanotechnology.

1. Introduction

Adsorption refers to the accumulation of molecules on the surface of solids or liquids. Unlike absorption, where molecules penetrate the bulk of a material, adsorption is a surface-based process. In medical science, adsorption is important in drug delivery, poisoning treatment, dialysis, biosensors, and implant material engineering. The advantages of the adsorption techniques for enzyme immobilization are the following:

1. Adsorption of enzymes to the matrices is very easy and capable of high enzyme loading.
2. It is possible to separate and purify the enzymes while being immobilized.
3. The active sites of the adsorbed enzymes are usually unaffected, and the enzymes are not usually deactivated by adsorption.
4. Easy removal of the enzyme from the support is possible, as adsorption is a reversible process. However, adsorption methods for enzyme immobilization also have several disadvantages:
5. Desorption of enzymes is a common problem that limits immobilization efficiency.
6. The state of immobilization is very sensitive to pH, ionic strength, and temperature of the solution.
7. The amount of enzymes loaded on a support particle is usually low due to the weak interactive force.

Keywords: Adsorption, Surface Phenomena, Medicine, Biomaterials, Drug Delivery, Activated Carbon, Biosensors, Nanomaterials, Physisorption, Chemisorption

2. Classification and Mechanisms

- Physical Adsorption (Physisorption): Weak forces, reversible
- Chemical Adsorption (Chemisorption): Strong bonds, often irreversible
- Ion Exchange Adsorption: Important in dialysis
- Molecular Adsorption: Used in biosensors

3. Additional Factors

Factors include pore size, surface roughness, electrostatic interaction, hydrophobicity, pH, and temperature. These parameters influence the behavior of medical implants and drug delivery systems

5. Medical Case Studies

- Activated charcoal detoxifies toxins
- Dialysis membranes adsorb metabolic wastes
- Implants depend on protein adsorption regulation
- Nanoparticles use adsorption for controlled drug release

7. Discussion

Adsorption influences pharmacokinetics, toxicology, biosensor development, nanomedicine, and biomaterial compatibility. In modern medicine, adsorption-based technologies enhance drug efficiency, diagnostic accuracy, and implant safety.

8. Equilibria and Kinetics of Adsorption

The fundamental principles of adsorption are well known and have been well reported in standard textbooks (Ruthven, 1984). Therefore, only information pertaining to wastewater

treatment is discussed here. The design of the adsorption process in wastewater treatment involves understanding of sorption equilibria and kinetics apart from other aspects for commercial viability. The equilibrium capacity gives the maximum theoretical capacity that can be obtained, while in real-world operations, more useful terminologies such as operating capacity and breakthrough capacity are commonly used. The mathematical models for equilibrium and kinetics are most useful for designing wastewater systems, and it is convenient to have the maximum possible information through appropriate models for accurate design, scale-up, and physical understanding of the phenomenon so that it can be extended to similar systems.

9. Conclusion

Adsorption and surface phenomena are foundational processes in medicine.

With growing advancements in biomaterials, sensors, and nanotechnology, adsorption continues to play a significant role in diagnostics, therapy, and biomedical engineering. Finally, an extensive overview of selected industrial applications of these technologies is provided, which is divided into general applications, food production applications, and the recovery of valuable bio- and technofunctional compounds from the byproducts of plant food processing, which may be used as natural food additives or for their potential health-beneficial effects in functional or enriched foods and nutraceuticals.

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