Adsorption isotherms describe how molecules interact with solid surfaces and reach equilibrium at constant temperature

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Abstract

Adsorption isotherms are mathematical models that describe how molecules distribute between a liquid or gas phase and a solid surface at equilibrium and constant temperature. These models are essential for understanding adsorption capacity, surface characteristics, and interaction mechanisms in systems used for catalysis, wastewater treatment, gas storage, and separation processes. Common isotherm models such as Langmuir, Freundlich, and Temkin provide insights into adsorption behavior and surface heterogeneity. This article discusses the principles, types, and applications of adsorption isotherms in chemical science.

Keywords: Adsorption isotherms, Langmuir model, Freundlich model, Surface adsorption, Equilibrium studies, Adsorbents, Wastewater treatment, Surface heterogeneity, Physical chemistry, Separation processes

Introduction

Adsorption is a surface phenomenon in which molecules from a fluid phase accumulate on the surface of a solid, forming an adsorbed layer that reaches equilibrium over time [1]. Understanding how much of a substance can be adsorbed under specific conditions is crucial for designing systems used in purification, catalysis, and environmental remediation. Adsorption isotherms provide the mathematical relationship between the amount of adsorbate on the surface and its concentration in the surrounding phase at constant temperature.The Langmuir isotherm model assumes monolayer adsorption on a homogeneous surface with a finite number of identical sites. It is widely used to describe systems where adsorption occurs without interaction between adsorbed molecules [2]. In contrast, the Freundlich isotherm accounts for heterogeneous surface energies and multilayer adsorption, making it suitable for complex surfaces such as activated carbon and natural adsorbents.The Temkin isotherm introduces the effect of adsorbate–adsorbent interactions by considering how adsorption energy changes with surface coverage. These models collectively help chemists interpret experimental data and understand the nature of adsorption processes [3]. By fitting experimental results to these models, parameters such as adsorption capacity and binding strength can be determined.Adsorption isotherms are extensively applied in wastewater treatment,

where pollutants such as dyes, heavy metals, and organic compounds are removed using solid adsorbents. Knowledge of isotherm behavior helps in selecting appropriate materials and optimizing operating conditions [4]. In gas storage and separation technologies, adsorption isotherms guide the design of materials capable of selectively capturing gases like carbon dioxide and methane. Surface characteristics such as porosity, surface area, and functional groups significantly influence adsorption behavior. Advances in nanomaterials and surface modification techniques have improved adsorption efficiency, making isotherm studies more relevant in modern material design [5].

Conclusion

Adsorption isotherms offer essential insights into how molecules interact with solid surfaces and reach equilibrium at constant temperature. By applying models such as Langmuir, Freundlich, and Temkin, chemists can analyze adsorption behavior and design efficient systems for purification and separation. Continued research in advanced adsorbent materials will further enhance the importance of adsorption isotherm studies in chemical science.

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