Chapter 17: Adsorption – Types & Isotherms

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Abstract

This chapter discusses the adsorption phenomenon, its types, theoretical models, and the importance of adsorption in industries. Adsorption may be described as the sticking of molecules in a fluid phase on the surface of a solid and is used in catalysis, separation process and also in environmental applications. The chapter distinguishes between the physical adsorption (physisorption) that is formed due to weak Van der Waals forces, and the chemical adsorption (chemisorption) formed due to strong chemical bonds. It uses isotherms of adsorption that comprise the Langmuir and the Freundlich models to describe the dependence of the concentration of adsorbates and the quantity of adsorbates that was adsorbed at the equilibrium. The chapter describes the factors that affect adsorption, including the temperature, pressure, the surface area, and the nature of the adsorbent. Its use in industrial processes is stated, including gas purification, water treatment, heterogeneous catalysis, chromatography and activated carbon filters. The chapter also describes the other problems of adsorbent regeneration, the maximization of efficiency, and the scale-up of the adsorption processes. With theory, mathematical modeling and practice, students can learn not only how to design industrial processes based on adsorption, but they also learn how to approach the surface on a molecular scale. Adsorption is also a subject in the engineering and biotechnology degrees of chemical engineering, environmental science, catalysis, and materials technology.

Keywords: Adsorption, Physisorption, Chemisorption, Langmuir isotherm, Freundlich isotherm, Industrial applications, Surface phenomena.

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17.1. Introduction

Adsorption is an essential process in chemical and materials science and is defined as a process that takes place on the surface (or interfaces of) a two-phase system, where molecules, ions, or atoms (the adsorbates) cluster at an interface, most often a solid-gas or solid-liquid interface. The substance on which adsorption takes place on its surface is referred to as adsorbent. In contrast to absorption, in adsorption the penetration of substances into the bulk of a substance does not occur, but is limited to the surface region, and so is strongly dependent on factors like surface area, porosity, particle size, and surface chemistry of the adsorbent.Adsorption is a phenomenon that has been known over a number of centuries. The practical use had been observed early in the 18th and 19th centuries with scientists recording the capacity of charcoal and porous solids to take away gases, odors and coloring matter in air and liquids. One of the earliest industrial applications of adsorption was made in 1773 by Carl Wilhelm Scheele, who noticed that gas could be adsorbed by charcoal and that in 1785 Johann Tobias Lowitz discovered the decolorization of solutions using charcoal, another early adsorption process. During the early 20 th century, there was greater scientific knowledge about adsorption. In 1916, Irving Langmuir postulated the adsorption isotherm that is now called the Langmuir adsorption isotherm, and whose assumptions accounted for monolayer adsorption on a non-porous surface. This was succeeded by the Freundlich adsorption isotherm, which is an empirical theory of adsorption on nonhomogeneous surfaces. Subsequently, Brunauer, Emmett and Teller later in 1938, expanded the theory introduced by Langmuir to include multilayer adsorption and come up with the BET theory, which allowed the determination of the surface area of porous materials accurately. Adsorption is an important part of contemporary physical as well

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