Chapter 18: Surface Catalysis in Heterogeneous Reactions

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Abstract

In this chapter, the author focuses on the issue of surface catalysis and the role of this subject in heterogeneous reactions with specific reference to industrial chemistry applications. The reactions during the heterogeneous catalysis can be described by the difference in the phase of the catalyst and reaction phase, where the solid catalyst is used in contact with gaseous or liquid reactants. The chapter explains the manner in which surface reactions take place, including the adsorption of reactants, surface reaction, and product desorption. Examples of how surface catalysis may be used to enhance reaction rate, selectivity, and efficiency include important industrial systems (such as the Haber process to make ammonia). The use of catalysts in the petrochemical industries, including hydrogenation process, cracking and reforming, is discussed. Strong aspects of surface catalysis, such as surface area, pore framework, temperature and pressure, are cited to depict optimization of processes. The chapter is actually a mixture of theoretical information and practical examples, which show how the interaction of molecules on the surface can regulate reactions on an industrial scale. Issues such as catalyst deactivation, sintering, catalyst poisoning and catalyst regeneration are explained, and provision of measures to improve the life and sustainability of catalysts is noted. The chapter combines principles and mechanisms and industrial significance that offer students the knowledge needed in the employment of catalysis research, chemical engineering and industrial process development.

Keywords: Surface catalysis, Heterogeneous reactions, Haber process, Petrochemical industry, Adsorption, Reaction mechanism, Industrial applications.

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18.1.Introduction

Catalysis is at the heart of industrial chemistry since it allows chemical reactions to reach higher speeds, be more selective and even work under conditions that are less harsh than otherwise. All these types of catalysis, heterogeneous catalysis in which the catalyst is in a distinct phase with the reactants has become the most commonly practiced in large-scale industrial processes. The reagents are usually gases or liquids and the catalyst is a solid. The most important characteristic that determines the efficiency of the heterogeneous catalytic reaction is the interfacial interaction between the catalyst surface which is solid and the reacting species. Heterogeneous catalysis is also prevalent throughout the petrochemical industry, with which the majority of petroleum refining processes are based. Catalytic processes including catalytic cracking, reforming, isomerization as well as hydrogenation processes are significantly dependent on solid catalysts like zeolites, alumina-supported metals and metal oxides. These catalysts also assist in the processing of heavy hydrocarbon into lighter and more valuable fuels and petrochemical feeds as well as enhancing quality of the fuel by increasing the octane number and decreasing the level of sulfur. Modern fuel production on such scale would not be technically or economically viable without the presence of heterogeneous catalysts. Heterogeneous catalysis is a decisive factor in the production of ammonia by the Haber-Bosch reaction in the process of fertilizer production. Since nitrogen and hydrogen are rather inert molecules, an iron-based solid catalyst can be used to enable them to react under high pressure and temperature.

Deep Science Publishing, 2026
https://doi.org/10.70593/978-93-7185-430-6_18