

# Comparative Analysis of Homogeneous and Heterogeneous Catalysis

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**ABSTRACT:** *The chemical industry has often favored heterogeneous catalysis, but the development of better catalysts has been hindered by the presence of numerous kinds of active sites and also by the low concentration of active sites. These elements have blocked a levelheaded change of these frameworks, consequently the observational idea of heterogeneous catalysis. Catalysis is principally an atomic marvel, and it must include all around characterized surface organometallic intermediates and additionally progress states. In this manner, one must have the capacity to build a very much characterized dynamic site, test its reactant execution, and survey a structure movement relationship, which will be utilized, thus as in homogeneous catalysis to configuration better catalysts.*

*Different new ways to deal with heterogeneous catalysis can convey sub-atomic understanding to the outline of new impetuses and even permit the disclosure of new. After over an era of presence, heterogeneous catalysis can even now be enhanced and will assume an essential part in taking care of current issues. It offers a response to sparing and natural issues looked by industry in the generation of particles.*

**Keywords :** *Chemistry, homogeneous, heterogeneous, catalytic.*

## INTRODUCTION

The term “catalysis” was first employed by Berzelius in 1836 to identify a new entity capable of promoting the occurrence of a chemical reaction by a “catalytic contact”. In his view, the catalyst was seen as something that is added to the reaction to speed up the rate of the reaction (catalytic force) without being consumed or produced in the process. It is important to recognize that the catalysis can be traced back to ancient terms if we consider for example the fermentation processes, which are examples of biocatalysis. As for the industrial catalytic processes, catalytic production of sulfuric acid, i.e. lead chamber process, where oxidation of sulfur dioxide ( $\text{SO}_2$ ) to sulfur trioxide ( $2 \text{SO}_3$ ) was performed in the presence of a mixture of nitric oxides ( $\text{NO}/\text{NO}_2$ ) as catalyst, back to eighteenth century. However, catalysis started to play a major impact on the chemical industry starting from the beginning of the twentieth century, nowadays more than 95% of chemicals being produced via a process that includes at least one catalytic step.

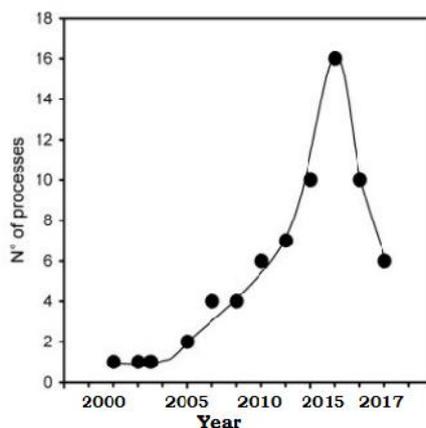


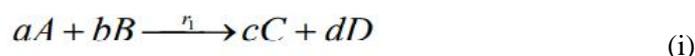
Fig 1: historical development of major industrial catalytic processes

The volcano-like shape reported in Figure 1, which illustrates the introduction of major industrial catalytic processes as a function of time, could suggest that catalysis could be considered to be a mature technology, where major developments have already been achieved. However, an overview of the catalytic technology that has been introduced on the US market in the 1990s, reported over 130 examples of new catalysts or catalyst improvements for operating processes indicating the vital role of the catalytic technology to many industrial processes. In summary, catalysis nowadays plays a key role in the production of chemicals and materials.

Catalysis plays a vital role in the chemical industry by contributing to both its economical success and environmental sustainability. More than 75% of all industrial chemical transformations employ catalysts in areas as diverse as polymers, pharmaceuticals, agrochemicals, and petrochemicals. In fact, 90% of newly developed processes involve the use of catalysts [1]. In addition, the growing focus on environmental conservation relies heavily on developments in the field of catalysis. Heterogeneous catalysis is widely used in industrial applications because of the facile separation, which often results in lower operating costs. On the other hand, homogeneous catalysis has limited industrial applications due to the difficult and costly catalyst separation and recovery.

### Catalyzed Vs Non-Catalyzed Reaction

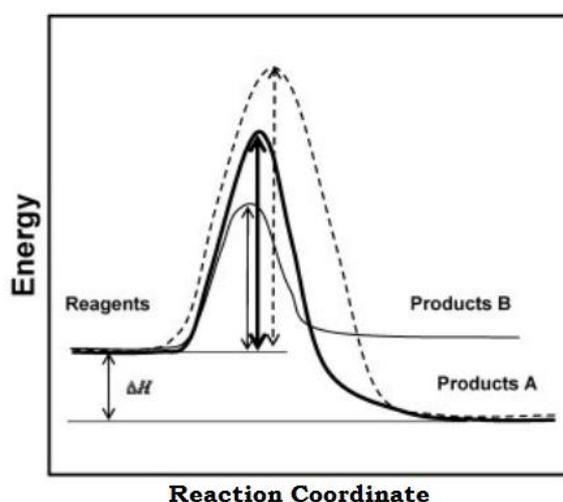
From a chemical point of view, the concept of catalyst is intimately linked to the mechanism of the chemical reaction. The catalyst is capable of accelerating the reaction rate or to change the selectivity of the reaction towards different products with respect to the situation when the reaction occurs in the absence of the catalyst. To explain these concepts, let us consider a general chemical reaction which is described by the following equation :



where A , B and C , D represent respectively the reagents and the products and the terms a b , , and c d , , represent the stoichiometric coefficients of the reaction.. For such a reaction we can define the reaction rate as:

$$r = -\frac{1}{a} \times \frac{d[A]}{dt} = -\frac{1}{b} \times \frac{d[B]}{dt} = \frac{1}{c} \times \frac{d[C]}{dt} = \frac{1}{d} \times \frac{d[D]}{dt} \quad (ii)$$

where the use of square brackets is conventionally employed to indicate the concentration of the different species in mol L<sup>-1</sup>.



**Fig 2: Effect of catalyst on the reaction profile**

For the sake of simplicity, we will consider the reaction rate for a process occurring in a single homogeneous phase. This case can be described by a kinetic law, which is measured experimentally and represents the relationship between the reaction rate and the reactant concentration:

$$r_1 = k_1[A]^m[B]^n \quad (\text{iii})$$

where A is the geometric factor, R the universal gas constant (8.32 J mol<sup>-1</sup> K<sup>-1</sup>), T reaction temperature (K) and E<sub>a</sub> is the activation energy (J mol<sup>-1</sup>) for the reaction.

It is important to realize that the presence of a catalyst can modify also the product distribution as illustrated in Figure for a hypothetical catalyst offering a new reaction pathway leading to products B.

### Homogeneous vs. Heterogeneous Catalysts

In Homogeneous catalysis, the catalyst and reactants are in the same phase, usually liquid.

Examples are:

- transition metal ions
- transition metal complexes
- inorganic acids and bases
- enzymes

In heterogeneous catalysis, Catalyst and reactants are in different phases, either

- **reactants:** gases

**catalyst:** solid

- **reactants:** organic liquids or aqueous solutions

**catalyst:** solid

Examples are:

- ammonia
- fuel cell
- catalytic convertor
- hydrogenation
- Friedel Crafts

Traditionally catalysts were distinguished into homogeneous and heterogeneous; subsequently, heterogenized catalysts were also introduced. This distinction is linked to the fact that the catalyst operates respectively in the same phase where the reaction occurs (homogeneous catalysts) or in a different phase (heterogeneous or heterogenized catalysts). In principle, there is no limitation on the phase to be considered, as a matter of fact the first industrial catalyzed reaction (1750) was the oxidation of SO to 2 SO using 3 NO as a homogeneous catalyst, which occurs in the gaseous phase. On the other hand, most of the processes using homogeneous catalysts occur in a liquid phase whereas for the heterogeneous catalysts, the catalyst is usually in a solid form, and the reaction occurs either in the liquid or gaseous phase. The fact that the catalysts is in a distinct phase with respect to the reaction medium, accounts for the major advantage of the heterogeneous catalysts over the homogenous as it makes the separation e reutilization of heterogeneous catalysts simple and cheap compared to the homogenous catalysts. A great variety of homogeneous catalysts used in organic synthesis, metal complexes, metals ions, organometallic complexes, organic molecules up to biocatalysts.

The major advantages/disadvantages of heterogeneous vs. homogeneous catalysts are summarized in Table 1. As a general picture, the main difference is the fact that in the case of homogeneous catalysts, every single catalytic entity can act as a single active site. This makes homogeneous catalysts intrinsically more active and selective compared to traditional heterogeneous catalysts such as oxides or supported metal particles. The heterogeneity of the surface sites is, in fact, a common feature of the heterogeneous catalysts.

Table 1 compares homogeneous and heterogeneous catalysis in terms of catalytic effectiveness, catalyst properties, and catalyst separation [1]. Homogeneous catalysts offers improved selectivity, increased activity, and avoid mass transfer limitations, which may permit lower temperatures.

**Table 1: Comparison between Homogeneous and Heterogeneous Catalysis**

	<b>Homogeneous</b>	<b>Heterogeneous</b>
<b>Active Centers</b>	All atoms	Only surface atoms
<b>Selectivity</b>	High	Low
<b>Mass Transfer Limitations</b>	Very rare	Can be severe
<b>Structure/Mechanism</b>	Defined	Undefined
<b>Catalyst Separation</b>	Tedious/Expensive (extraction or distillation)	Easy
<b>Applicability</b>	Limited	Wide
<b>Cost of Catalyst Losses</b>	High	Low

## CONCLUSIONS

The objective of this paper has been to study the best resource of heterogeneous catalysis simplicity of detachment and reuse for homogeneous reactions, which bring a large group of extra preferences, in absence of mass exchange impediments, in expanded rate, or more all in the particularly improved selectivity. The acknowledgment of these natural constraints of the homogeneous catalyst prompted a prospering movement endeavoring to heterogenize homogeneous catalysts. The point is that of joining the upsides of the homogenous impetus with the office of the heterogeneous frameworks to reuse the catalyst. A few courses to grapple or typify the homogenous, beneath examined, were recommended, nonetheless, it must be underlined that a noteworthy downside of the heterogenized impetus is the draining of the impetus amid its utilization and reuse, prompting deactivation.

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