

The Philosophy behind CATALYSTS!

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AS we hear about the catalysts, the thought of chemical reactions gushes into our minds. It brings a narrative of differentiating and tough reactions taking place in a complex chemical laboratory by some chemist wearing a white lab coat, protective glasses, gloves and carrying a load of risk! However, the process of catalysis can be seen in a very simplified way. If I were to say that all the enzymes are catalysts, and our body deals with these enzymes daily, hearing this becomes relaxing! This means chemical reactions are part and parcel of our lives, and so are enzymes, which are some kind of catalysts.

Enzymes are organic biocatalysts that have a high molecular weight globular protein. They alter the reaction rates and help in converting the substrate into the product. Since they are organic in nature, they contain C-H (carbon-hydrogen) and C-C (carbon-carbon) bonds. The best examples of these biocatalysts are lipase, amylase, lactase, etc. The artificial catalysts alter the rate of reaction and can be inorganic in nature. They may contain several metals, metal oxides and can be bimetallic, trimetallic, Metal Organic Frameworks (MOFs), etc. Examples are vanadium oxide, iron oxide, copper oxide, etc.

Let us understand the role played by the biological catalysts. Proteins and a few RNAs have some basic tasks, and that is to act as enzymes, which precisely means to alter the rate of reactions within the cells. There are several reactions that the body needs to sustain life, for which it needs enzymes, as these reactions cannot occur under the mild temperature and pressure conditions of the body. Here comes the role of enzymes that catalyse the reaction, not just one or two, but a million-fold. The cells may contain various types of enzymes, and each of them has different reactions to participate in getting the desired product. Enzymes follow the same philosophy as catalysts: alter the rate of reaction without their actual participation in the reaction or getting consumed in the reaction, and second, not changing the equilibrium of the reaction. When we say not changing the thermodynamics or equilibrium, it simply means that the equilibrium between the substrate and the final product is not altered by the action of the enzymes.

How is the reaction catalysed? For this, the very first concept is that of the activation energy. In very basic terms, activation energy is the minimum energy required for any reaction to occur. What if this much amount of energy is not present? The reaction cannot proceed. However, the reaction becomes highly expensive or incompatible if the activation energy required is very high. This can be understood by taking an example. Let us consider "A" as the substrate and "B" as the product. For the reaction to happen, substrate A must reach the higher energy state called the transition-state;

since this is the higher energy state, the energy required to reach it is very high. Enzymes reduce this activation energy and increase the rate of the reaction, but the rate of reaction in the forward direction equals that of the backward direction, making the thermodynamics unaffected.

This whole process happens through a certain phenomenon. This is called the mechanism of the catalysts or enzymes. Firstly, substrate "A" will be bound to the enzyme, forming a complex. This happens due to the presence of the active sites on the surface of the enzymes and the interactions through noncovalent bonding, hydrogen bonding, etc. It leads to the formation of the product on its surface, and the product thereafter separates from the surface of the catalysts, leaving behind the enzyme and the final product. This proves that enzymes or catalysts do not get consumed in the reaction and hence get recovered.

The above study basically focused on the enzymes or biocatalysts. There are several artificial catalysts, or we call them inorganic catalysts, participating in the chemical reactions in laboratories, industry, etc. They are the backbone of the chemical industry, space industry, metal industry, etc. Though all the enzymes are catalysts, not all the catalysts are enzymes.

The term "Catalysis" was proposed by Jons Jacob Berzelius in 1835, which means "down loosen." He talked about the special property imbibed within catalysts that is different from the chemical affinity and enables in production of new compounds without entering them. The first time an inorganic catalyst was used was in 1554 by Valerius Cordez by using sulphuric acid (catalyst) for converting alcohols to ethers. In further developments, the catalysts began to be classified based on their states, like liquids, gases or solids. They may be termed as homogeneous catalysts or heterogeneous catalysts. In a homogeneous catalytic system, the catalyst is in the same phase as that of the reactants, whereas in a heterogeneous catalytic system, the phases of the catalysts and the reactants are different. There are several reactions where homogeneous catalysts perform better, whereas in other reactions, the heterogeneous catalysts give better efficiency. However, the problem of separation of the product from the reaction mixture is a basic drawback of the homogeneous catalytic system.

In typical heterogeneous systems, there are various steps that take place for the reaction to occur. They are, adsorption of the reactants on the surface of the catalysts, activation and reaction of the adsorbed reactants, and finally the diffusion of the product from the catalyst's surface or also called desorption. This can be understood by understanding an example, i.e. reaction of methanol and propylene carbonate to form dimethyl carbonate and propylene glycol. In this