# Catalyst

A catalyst is defined as a substance which alters the rate of a chemical reaction, itself remaining chemically unchanged at the end of the reaction. The process is called Catalysis. 17

*. A catalyst may increase or decrease the rate of reaction.

⇒ which increases rate of reaction is called Positive catalyst and process is called Positive catalysis or simply catalysis

⇒ A catalyst retards the rate of reaction is called negative catalyst and process is called negative catalysis.

## Types of catalysis

There are two main types of catalysis

(a) Homogeneous catalysis
(b) Heterogeneous Catalysis
(c) Enzyme catalysis

### (a) Homogeneous catalysis:

In homogeneous catalysis, the catalyst is in the same phase as the reactants and is evenly distributed throughout. This type of catalysis can occur in gas phase or the liquid (solution) Phase.

#### Example of Homogeneous catalysis in Gas Phase

(a) Decomposition of acetaldehyde ($CH_3CHO$) with iodine($I_2$) catalyst

$$CH_3CHO + (I_2) \longrightarrow \underset{gas}{CH_4 + CO}$$

(5) Example of homogeneous catalysis in solution Phase: (2)

Hydrolysis of cane sugar in aqueous solution in the presence of mineral acid as catalyst

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{H_2SO_4} C_6H_{12}O_6 + C_6H_{12}O_6 + [H_2SO_4]$$

## Heterogeneous catalysis.

The catalysis in which the catalyst is in a different Physical Phase from the reactant is termed Heterogeneous catalysis. In this catalysis reactants are in the gas phase while the catalyst is a solid. This process is also called contact catalysis since the reaction occurs by contact of reactant with the catalyst surface.

(1) Example of heterogeneous catalysis with gaseous reactant

combination of sulphur dioxide ($SO_2$) and oxygen in the presence of finely divided platinum or Vanadium pentoxide, $V_2O_5$

$$2SO_2 + O_2 + \underset{\text{Solid}}{[Pt]} \longrightarrow 2SO_3 + [Pt]$$

(2.) Heterogeneous catalysis with liquid reactants

The decomposition of aqueous solution of hydrogen peroxide ($H_2O_2$) is catalyzed by manganese dioxide ($MnO_2$) or Platinum in colloidal form

$$\underset{\text{liquid}}{2H_2O_2} + \underset{\text{solid}}{[Pt]} \longrightarrow 2H_2O + O_2 + [Pt]$$

(3.) Heterogeneous catalysis with Solid reactants

The decomposition of potassium chlorate ($KClO_3$) is catalyzed by manganese dioxide ($MnO_2$).

$$2KClO_3 + [MnO_2] \longrightarrow 2KCl + 3O_2 + [MnO_2]$$

# Enzyme Catalysis



Enzymes are protein molecules which act as catalyst to speed up organic reactions in living cells. The Catalysis brought about by enzymes is know as Enzyme Catalysis or biocatalysis.

e.g: Inversion of cane sugar ($C_{12}H_{22}O_{11}$) by Invertase present in yeast

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{invertase}} C_6H_{12}O_6 + C_6H_{12}O_6$$

(b) conversion of glucose into ethanol by Zymase present in yeast

$$C_6H_{12}O_6 \xrightarrow{\text{Zymase}} 2C_2H_5OH + 2CO_2$$

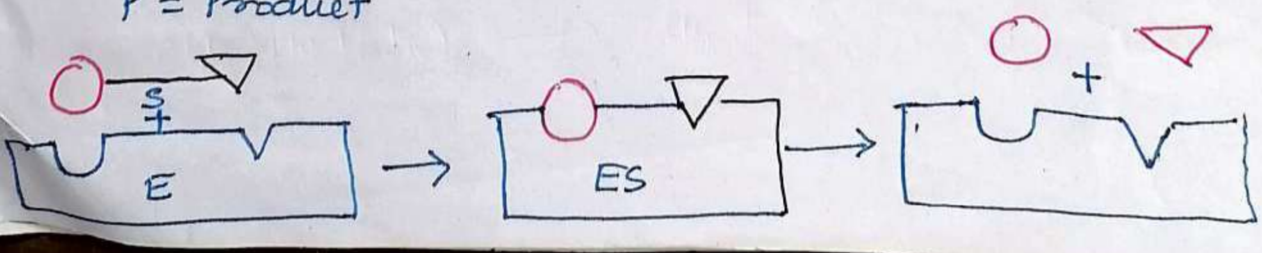
## Mechanism of Enzyme catalysis

The long chains of the enzyme (protein) molecules are coiled on each other to make a rigid colloidal particle with cavities on its surface. These cavities which are of characteristic shape and abound in active groups ($NH_2$, $COOH$, $SH$, $OH$) are termed Active centers. The molecules of substrate which have complementary shape, fit into these cavities just as key fits into lock (Lock-and-key theory). By virtue of the presence of active groups, the enzyme forms an activated complex with the substrate which at once decomposes to yield the product.

Michaelis and Menten proposed the following mechanism for enzyme catalysis

$$E + S \rightleftharpoons \underset{\text{Complex}}{ES} \longrightarrow P + E$$

where E = enzyme, S = Substrate (Reactant) ES = Activated complex
P = Product



## Characteristics of Enzyme catalysis

In general, enzyme behave like inorganic heterogeneous catalyst. However, they are unique in their efficiency and high degree of specificity. Some more important features of enzyme catalysis are listed below

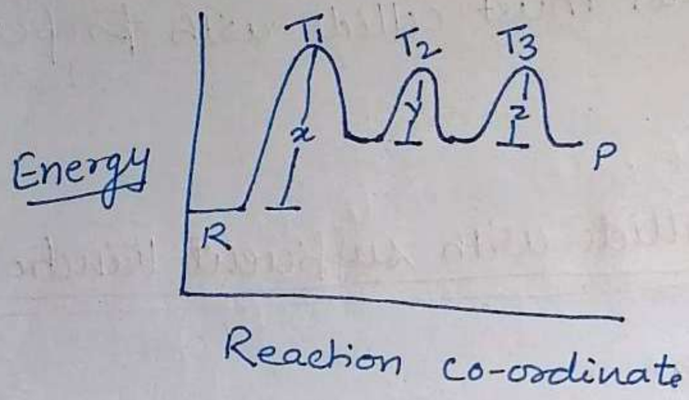
~~Characte~~

(1)

## Complex reaction:



Complex reaction proceed in a series of steps instead of a single and rate all over reaction is in accordance with stoichiometric equation for that reaction or such reaction occur in several steps where each step is elementary. Which molecularity is not defined but molecularity of each step can be defined and it's rate depends on slowest step of the reaction




$R \rightarrow P$

$R \rightarrow \cancel{A}$ → 1st step

$\cancel{A} \rightarrow \cancel{B}$ → 2nd step

$\cancel{B}$ — $P$ → 3rd step

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$R \rightarrow P$

Activation energy — step 2 $(A \rightarrow B)$ $\xrightarrow{\text{Minimum}}$ fastest

→ step I $(R \rightarrow A)$ $\xrightarrow{\text{Maximum}}$ slowest

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$\boxed{\text{Rate determining step}}$

# Theories of chemical kinetic

A/c to this theory a chemical reaction takes place only by collision between the reacting molecules. The two main conditions for a collision between the reacting molecules to be productive are:

(1.) The colliding molecules must posses sufficient kinetic energy to cause a reaction

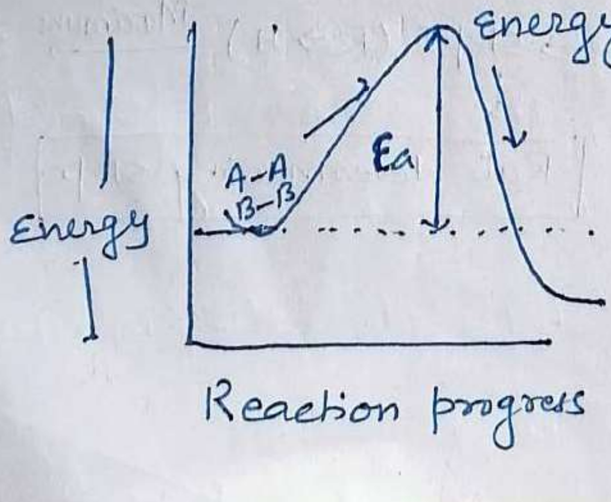
(2.) The reacting molecules must collide with proper orientation.

## (1.) The molecule must collide with sufficient kinetic energy

Let us consider a reaction

$$A-A + B-B \longrightarrow 2A-B$$

A chemical reaction occurs by breaking bonds between the atoms of the reacting molecules as forming new bonds in product molecules. The energy for the breaking of bonds comes from the kinetic energy possessed by the reacting molecules before collision.



The figure shows the activation energy, $E_a$ that is the minimum energy necessary to cause a reaction between the colliding molecules. Only the molecules colliding with kinetic energies greater than $E_a$ are able to get over the barrier and react and whoes kinetic energy less than $E_a$ fail to surmount the barrier and this type of collisions are unproductive.

## (2.) The molecule must collide with correct orientation ⇒

The reactant molecules must collide with favorable orientation. The correct orientation is that which ensure direct contact between the atoms involved in the breaking and forming of bond i.e. only the molecule colliding with kinetic energy greater than $E_a$ (activation energy) and with correct orientation can cause reaction. Let's suppose

$$A + B \rightarrow C + D$$

Then the reaction rate of elementary process is given by the expression

$$\text{rate} = f \times P \times Z$$

f = fraction of molecule which process sufficient energy to react, P = Probable fraction of collision with effective orientations and Z = collision frequency.