General Characteristics of enzyme Catalysis ⇒

Enzymes are Complex protein Substances produced by living Cells. They can Catalyzed numerous Chemical reaction occuring in animal and plant bodies. Some of the Common ~~Characterized~~ characteristics of enzyme reactions are given below:

i) Enzymes are highly specific and each enzyme Catalyzed a particular reaction.

e.g. Invertase (enzyme) Can break up Sucrose but fails to break up maltose.

Maltase Can break up maltose.

ii) For enzyme reaction there exists an optimum temperature at which its efficiency is maximum. Above this temperature enzyme gets denatured and losses its activity.

iii) Enzyme reactions are much sensitive to Catalytic poisons. Some typical Catalytic poisons are HCN, H_2S, CS_2 etc.

iv) In certain [redacted] cases the activity of an enzyme depends upon certain non-protein Substances Called Co-enzyme.

v) Enzyme losses their activity in presence of electrolytes or when exposed to UV light.

vi) The effect of pH on the rate of enzyme reaction is very Complex. The rate is usually passes through a maxima as the pH increased and then decreases.

Kinetics of Enzyme Catalysis ⇒

$$E + S \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} ES$$

$$ES \xrightarrow{k_2} P + E$$

E → Enzyme molecule

S → Substrate

ES → enzyme-substrate Complex

P → Product

The rate of formation of products (P),

$$\frac{d[P]}{dt} = k_2[ES] \quad \text{---------} (1)$$

On applying the steady-state approximation to ES, we get

$$\frac{d[ES]}{dt} = 0 = k_1[E][S] - k_{-1}[ES] - k_2[ES]$$

$$\text{or, } [ES](k_{-1} + k_2) = k_1[E][S]$$

$$\text{or, } [ES] = \frac{k_1[E][S]}{k_{-1} + k_2} \quad -(2)$$

Now, $[S]_0$ = Initial Concentration of Substrate

$[E]_0$ = Initial Concentration of Enzyme

Then, $[E] = [E]_0 - [ES]$

and $[S] \simeq [S]_0$

(Assuming that $[S]_0 \gg [E]_0$ so, $[ES]$ is negligible compared to $[S]_0$)

Hence, $[ES] = \frac{k_1([E]_0 - [ES])[S]_0}{k_1 + k_2}$

$$\text{or, } (k_{-1} + k_2)[ES] = k_1[E]_0[S]_0 - k_1[ES][S]_0$$

$$\text{or, } [ES] = \frac{K_1 [E]_0 [S]_0}{K_{-1} + K_2 + K_1 [S]_0}$$

$$\therefore = \frac{[E]_0 [S]_0}{\frac{K_{-1} + K_2}{K_1} + [S]_0}$$

$$= \frac{[E]_0 [S]_0}{K_m + [S]_0} \quad \text{—— (3)}$$

Where, $K_m = \frac{K_{-1} + K_2}{K_1}$, is known as Michaelis-Menten Constant.

$$\left(\frac{d[P]}{dt}\right)_{t=0} = \frac{K_2 [E]_0 [S]_0}{K_m + [S]_0}$$

$$\boxed{r_0 = \frac{K_2 [E]_0 [S]_0}{K_m + [S]_0}} \quad \text{—— (4)}$$

r_0 = Initial rate of the reaction.

Case-I

Low substrate Concentration ⇒

$$K_m + [S]_0 \simeq K_m$$

Then, $r_0 = \frac{K_2 [E]_0 [S]_0}{K_m}$

∴ Initial rate of the enzyme Catalyzed reaction is first order w.r.t each enzyme and substrate.

Case-II

High Substrate Concentration ⇒

$$K_m + [S]_0 \simeq [S]_0$$

Then, $$r_0 = \frac{K_2 [E]_0 [S]_0}{[S]_0} = K_2 [E]_0$$

Now the initial rate is independent of the concentration of substrate, i.e. zero order wrt to substrate.

Note:- This is the maximum possible rate by enzyme catalysed reaction at a given initial concentration of enzyme.

Then we have

$$r_{max} = K_2 [E]_0 \quad \text{——— (5)}$$

↳ Maximum turnover number of the enzyme catalysed reaction

Turnover number : No. of molecules converted in unit time by one molecule of the enzyme.

Determination of K_m & r_{max} ⇒

we have, $$r_0 = \frac{K_2 [E]_0 [S]_0}{[S]_0 + K_M} \quad \text{(eq-4)}$$

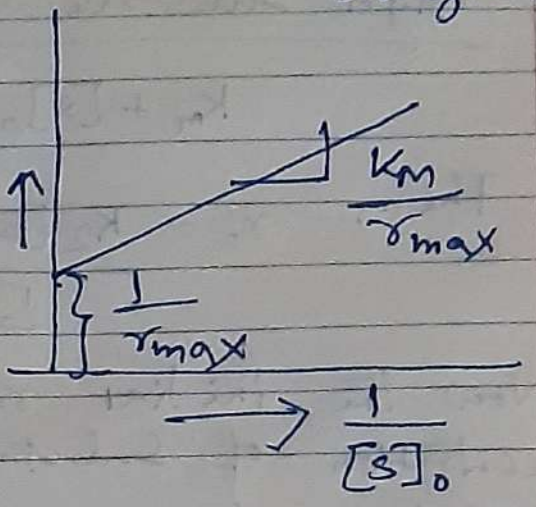
or, $$\frac{1}{r_0} = \frac{[S]_0 + K_M}{K_2 [E]_0 [S]_0} \quad \left(K_2 [E]_0 = r_{max}\right)$$

$$= \frac{1}{K_2 [E]_0} + \frac{K_M}{K_2 [E]_0 [S]_0}$$

$$= \frac{1}{r_{max}} + \frac{K_M}{r_{max} [S]_0} \quad \text{——— (6)}$$

Plot : $\frac{1}{v_0}$ Vs. $\frac{1}{[S]_0}$ $(y = mx + c)$ straight line equation

Hence, from the slope K_m & from the intercept v_{max} can be determined.



Significance of K_m ⇒

$$\frac{1}{v_0} = \frac{1}{v_{max}} + \frac{K_m}{v_{max}[S]_0} \quad \text{(from eq 6)}$$

$$\text{or, } \frac{1}{v_0} - \frac{1}{v_{max}} = \frac{K_m}{v_{max}[S]_0}$$

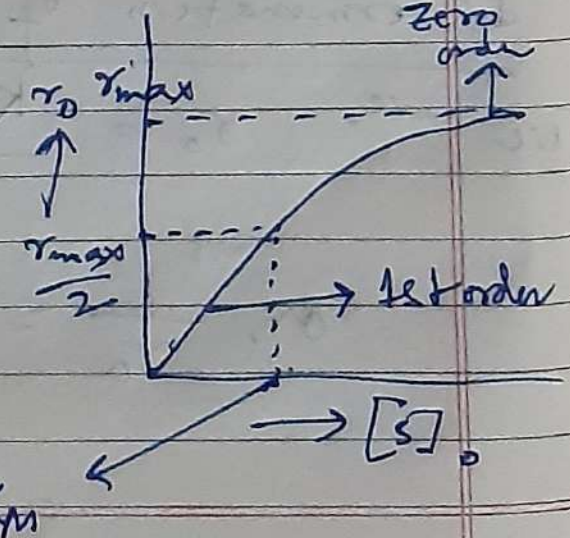
$$\text{or, } \frac{v_{max} - v_0}{v_0 v_{max}} = \frac{K_m}{v_{max}[S]_0}$$

$$\text{or, } \frac{v_{max} - v_0}{v_0} = \frac{K_m}{[S]_0} \quad \text{— (7)}$$

When, $v_0 = \frac{v_{max}}{2}$,

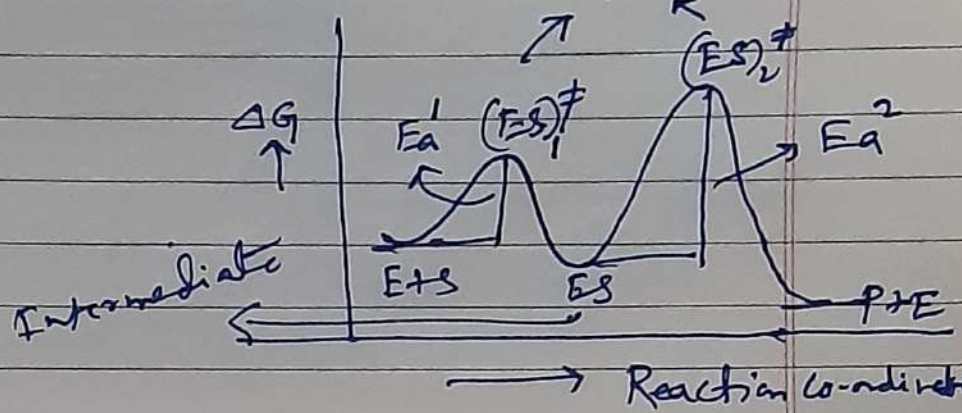
then we have

$$K_m = [S]_0$$



Energy profile diagram :-

In the case of enzyme Catalysis the 1st step is usually fast and Ea value is small. Ea value of the dissociation step has large value.



Related topic :-

1. Induced fit mechanism
2. Complementarity
3. * Difference between transition State and Intermediate state.
4. What is activation energy ?
5. Some applications.