

Rate equation for single- substrate enzyme -catalyzed reaction

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Abstract: The aim of this article is to establish a rate equation for single- substrate enzyme -catalyzed reaction. [Madhukar. C. **Rate equation for single- substrate enzyme -catalyzed reaction.** *Rep Opinion* 2012;4(12):37-38]. (ISSN: 1553-9873). <http://www.sciencepub.net/report>. 7

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In 1913, the German biochemist Leonor Michaelis and the Canadian physician Maud Menten proposed a mathematical model of the Single-substrate Enzyme Catalyzed reaction. It involves an enzyme E reversibly binding to a substrate S to form a complex ES, which in turn is converted into a product P and the enzyme E is regenerated. This may be represented schematically as



For which the Michaelis constant K_m is given by

$$\frac{K_m = [E] [S] / [ES]}{K_m [ES] / [E] = [S]} \quad (1)$$

Let the initial concentration of the substrate be $[S_0]$ mole/ dm³. Let $[X]$ mole/ dm³ decompose in t seconds. The undecomposed concentration of the substrate is $\{[S_0] - [X]\}$ mole/ dm³. The undecomposed substrate can either be free (unbound) S or in complex with enzyme (ES).

Therefore,

$$[S_0] - [X] = [ES] + [S] \quad (2)$$

Substituting Eq. (1) into Eq. (2) we obtain

$$[S_0] - [X] = [ES] + (K_m [ES] / [E]) \quad (3)$$

Degree of substrate reactivity = $[X] / [S_0]$
It is represented by the symbol α .

$$[X] = \alpha [S_0]$$

Substituting this into Equation (3) yields

$$[S_0] - \alpha [S_0] = [ES] + (K_m [ES] / [E])$$

Or $[S_0] (1 - \alpha) = [ES] + (K_m [ES] / [E])$

On rearrangement this leads to

$$[ES] = [E] [S_0] (1 - \alpha) / (K_m + [E]) \quad (4)$$

Discussion:

1. If the concentration of E is small or K_m is relatively large, then $[E] \ll K_m$ and the Eq. (4) is simplified to

$$K_m [ES] = [E] [S_0] (1 - \alpha)$$

However, here $K_m [ES] = [E] [S]$. Hence

$$\begin{aligned} [S] &= [S_0] (1 - \alpha) \\ [S] + \alpha [S_0] &= [S_0] \\ [S] + [X] &= [S_0] \end{aligned}$$

This means: $[ES] = 0$

2. If the concentration of E is large or K_m is relatively small, then $[E] \gg K_m$ and the Eq. (4) reduces to

$$\begin{aligned} [ES] &= [S_0] (1 - \alpha) \\ [ES] &= [S_0] - [X] \\ [ES] + [X] &= [S_0] \end{aligned}$$

This means: $[S] = 0$

3. Substituting $[E]$ for K_m in Eq. (4) yields

$$\begin{aligned} 2 [ES] &= [S_0] (1 - \alpha) \\ [ES] + [ES] + [X] &= [S_0] \\ \text{This means: } [ES] &= [S] \end{aligned}$$

4. The rate of product formation is given by $V = K_c [ES]$ (K_c = catalytic constant)

When solved for $[ES]$

$$V = K_c [E] [S_0] (1 - \alpha) / (K_m + [E])$$

However, here $[E] = [E_0] (1 - Y)$. Hence

$$V = K_c [E_0] (1 - Y) [S_0] (1 - \alpha) / \{K_m + [E_0] (1 - Y)\}$$

(Y = fractional saturation of enzyme)

On rearrangement this leads to

$$\{K_m / K_c (1 - Y) [E_0] [S_0]\} + \{1 / K_c [S_0]\} = (1 - \alpha) / V$$

However, here

$$K_c / K_m = K \text{ (Catalytic Efficiency).}$$

Hence

$$\{1 / K (1 - Y) [E_0] [S_0]\} + \{1 / K_c [S_0]\} = (1 - \alpha) / V$$

A plot of $(1 - \alpha) / V$ versus $1 / (1 - Y)$ will yield $1 / K_c [S_0]$ at the intercept with y axis and the slope is $1 / K [E_0] [S_0]$.

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