Michaelis-Menten Kinetics

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Chemical Reaction Engineering

Enzyme are proteins that speeds up biological reactions without being used up

- **Catalyzer** - substances that speeds up reactions without being used up
- **Enzyme** - proteins that catalyzes reactions
  - E.g. Sucrase - digestive enzyme that breaks down sucrose into glucose

Michaelis-Menten kinetics describes simple enzymatic reactions

- Overall reaction
  - $\mathrm{S} \xrightarrow{\mathrm{E}} \mathrm{P}$
- Reaction mechanism
  - $\mathrm{S} + \mathrm{E} \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} \mathrm{ES}$
  - $\mathrm{ES} \xrightarrow{k_2} \mathrm{P} + \mathrm{E}$

Michaelis-Menten kinetics can be derived with pseudo-steady-state approximation

Ex. Derive the rate of production r_{P} described by Michaelis-Menten and determine $V_{\max}$ and K_M:

$$\boxed{r_{\mathrm{P}} = \frac{V_{\max}[\mathrm{S}]}{K_M + [\mathrm{S}]}}$$

- Rate expression of rate of production

- Rate expression of rate of production of intermediate
  - **Pseudo-steady-state approximation** - intermediates are immediately consumed after production, so the net rate of intermediate is zero

Michaelis-Menten kinetics relates rate of production with substrate concentration

- Enzyme balance - total amount of enzyme is constant

- Solve for $[\mathrm{ES}]$

- Solve for r_{P}

Michaelis-Menten parameters describes reaction properties

- Simplify r_{P} with
  - **Maximum rate** of reaction
    - $V_{\max} = k_2[\mathrm{E_T}]$
  - **Michaelis-Menten constant** - attraction of enzyme of its substrate
    - $K_M = \dfrac{k_2 + k_{-1}}{k_1}$
  - **Turnover number** - # substrates converted to product per unit time on one enzyme at saturation
    - $k_{\mathrm{cat}} = k_2$

- Given Michaelis-Menten parameters, we can know $r_{\mathrm{P}}([\mathrm{S}])$ by Michaelis-Menten eqn:

$$\boxed{r_{\mathrm{P}} = \frac{V_{\max}[\mathrm{S}]}{K_M + [\mathrm{S}]}}$$

Michaelis-Menten parameters can be found by linearizing the Michaelis-Menten eqn

$$\boxed{r_{\mathrm{P}} = \frac{V_{\max}[\mathrm{S}]}{K_M + [\mathrm{S}]}}$$

- **Lineweaver-Burk equation**
  - $\dfrac{1}{r_{\mathrm{P}}} = \dfrac{K_M}{V_{\max}} \dfrac{1}{[\mathrm{S}]} + \dfrac{1}{V_{\max}}$
- Eadie-Hofstee equation
  - $r_{\mathrm{P}} = V_{\max} - K_M \dfrac{r_{\mathrm{P}}}{[\mathrm{S}]}$
- Hanes-Woolf equation
  - $\dfrac{[\mathrm{S}]}{r_{\mathrm{P}}} = \dfrac{K_M}{V_{\max}} + \dfrac{1}{V_{\max}}[\mathrm{S}]$