(18) **Today**

6.2 Kinetics

6.3 Enzyme Kinetics

Next Class (19)

6.3 Enzyme Kinetics

6.4 Enzyme Inhibition

(20) **Second Class from Today**

6.5 Enzymatic Mechanisms

Third Class from Today (21)

Chap 7: Carbohydrates

Monday office hours rescheduled to 1:10 to 2:10 from now on.

Please rework* on a separate piece of paper test 1 and hand in on Friday, March 21

Test 2 postponed to Wednesday, April 2

Kinetics: Reversible First Order Reactions

6.2.2

$$A \underset{k_2}{\overset{k_1}{\rightleftharpoons}} P \qquad A \xrightarrow{k_1} P$$

rate with respect to [A] ?

+ because this is the rate at which A is being made from P

$$\frac{d[A]}{dt} = -k_1[A] + k_2[P]$$

negative because A is being consumed

this is the rate at which a is being consumed

The values for k_1 and k_2 determine how quickly the rxn reaches its equilibrium position

The ratio of k_1 to k_2 $\left(\frac{K_1}{K_2}\right)$ determines the equilibrium constant

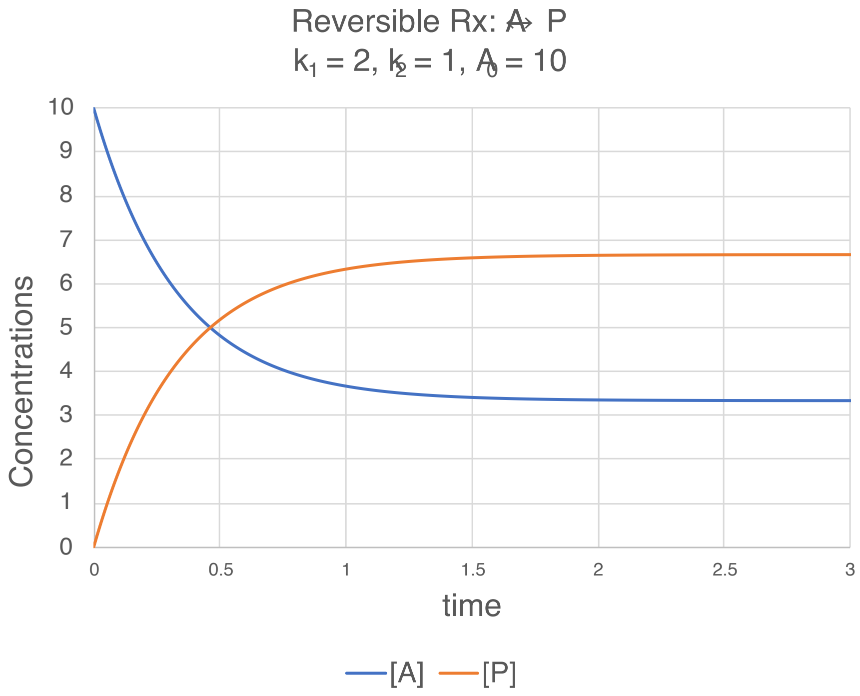
$$K = \frac{k_1}{k_2}$$

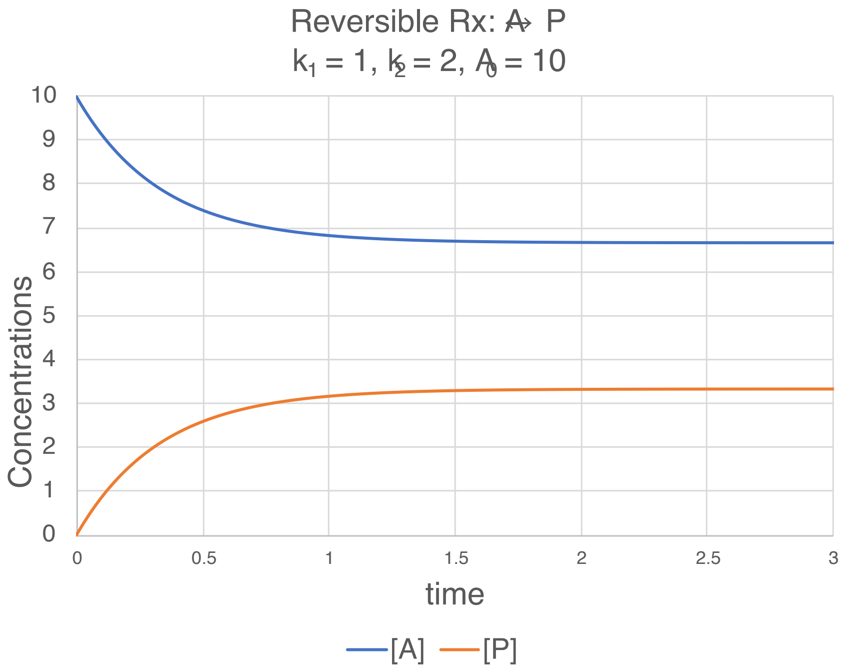
Kinetics: Kinetics: Reversible First Order Reactions

6.2.2

$$[A] = \frac{[A]_0\,[k_1 + k_2(e^{-(k_1 + k_2)t})]}{k_1 + k_2}$$

$$[P] = [A]_0 - \frac{[A]_0\,[k_1 + k_2(e^{-(k_1 + k_2)t})]}{k_1 + k_2}$$





https://bio.libretexts.org/Bookshelves/Biochemistry/Fundamentals_of_Biochemistry_(Jakubowski_and_Flatt)/01:_Unit_I-_Structure_and_Catalysis/06:_Enzyme_Activity/6.02:_Kinetics_without_Enzymes

Kinetics: Consecutive Irreversible First Order Reactions

$$\ominus\, A \xrightarrow{k_1} B \xrightarrow{k_2} C$$

A is being consumed

$$\frac{d[A]}{dt} = -k_1[A]$$

B is being ⊕ formed from A, but it is being ⊖ consumed to make C

$$\frac{d[B]}{dt} = k_1[A] - k_2[C]$$

$$\frac{d[C]}{dt} = k_2[B]$$

rate law is rate constant times chemical that acts as the reactant to form the product

Enzyme Kinetics

6.3.2

$$\mathrm{E} + \mathrm{S} \underset{k_2}{\overset{k_1}{\rightleftharpoons}} \mathrm{ES} \xrightarrow{k_3} \mathrm{E} + \mathrm{P}$$

?

$$\frac{d[P]}{dt} = k_3 [ES]$$

pre-equilibrium/rapid equilibrium vs steady state assumption

1. binding of substrate to enzyme is fast and reversible, and product formation k_3 is the rate limiting step. This is referred to as the pre-equilibrium condition

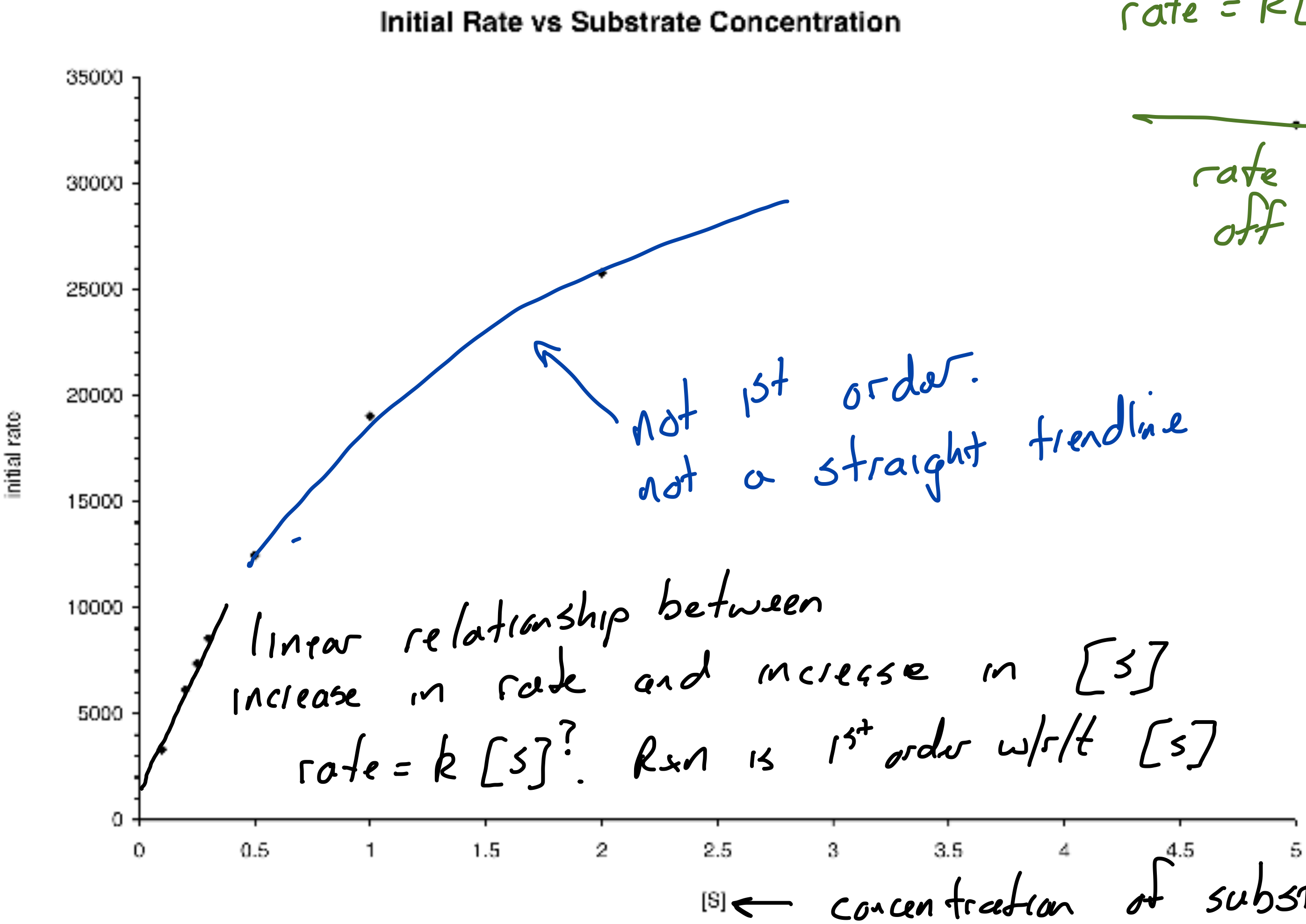
2. the rate at which the ES complex is formed is equal to the rate at which it is consumed. This is referred to as the steady state assumption.

as quickly as ES forms it is consumed

Enzyme Kinetics: Steady State Assumption

6.3.2

rate = k[S]$^{?}$ = k[S]^{0}



Initial rate of reaction

not 1st order.
not a straight trendline

rate levels off
zero order

linear relationship between increase in rate and increase in [S]
rate = k[S]$^{?}$. Rxn is 1st order w/r/t [S]

← concentration of substrate enzyme is working on

$$E + S \underset{k_2}{\overset{k_1}{\rightleftharpoons}} ES \xrightarrow{k_3} E + P$$

Enzyme Kinetics: Steady State Assumption

6.3.2

$$E + S \underset{k_2}{\overset{k_1}{\rightleftharpoons}} ES \xrightarrow{k_3} E + P$$

rate = k_3[ES]

rate of formation = rate of consumption

But what is [ES]? The ***steady state*** assumption is employed to solve for [ES]…

$$k_1[E][S] = k_3[ES] + k_2[ES]$$

rate at which ES forms

rate at which its consumed

rate at which ES is converted to P

rate at which ES is converted back to E + S

We rearrange to find [ES] in terms of things we can measure, [E] and [S]…

formed (+) consumed (-) consumed (-)

$$\frac{d[ES]}{dt} = 0 = k_1[E][S] - k_3[ES] - k_2[ES]$$

steady state means no change in conc

so rate of change is 0

$$k_2[ES]0 = k_1[E][S] - k_3[ES] - k_2[ES] + k_2[ES]$$

$$k_3[ES] + k_2[ES] = k_1[E][S] - k_3[ES] + k_3[ES]$$

$$k_3[ES] + k_2[ES] = k_1[E][S]$$

Enzyme Kinetics: Steady State Assumption

$$E + S \underset{k_2}{\overset{k_1}{\rightleftharpoons}} ES \xrightarrow{k_3} E + P$$

$$\text{rate} = k_3[ES]$$

rate of formation = rate of consumption

But what is [ES]? The ***steady state*** assumption is employed to solve for [ES]…

$$k_1[E][S] = k_3[ES] + k_2[ES]$$

rate of which its consumed

rate at which ES forms

rate at which ES is converted to P

rate at which ES is converted back to E + S

We rearrange to find [ES] in terms of things we can measure, [E] and [S]…

$$k_1[E][S] = (k_3 + k_2)[ES]$$

$$\frac{k_1}{k_2 + k_3}[E][S] = [ES]$$

Enzyme Kinetics: Steady State Assumption

6.3.2

$$E + S \underset{k_2}{\overset{k_1}{\rightleftharpoons}} ES \xrightarrow{k_3} E + P$$

$$\text{rate} = k_3[ES]$$

$$[ES] = k_1/(k_3 + k_2)\,[E][S] \Rightarrow [ES] = \frac{1}{K_m}[E][S]$$

That's a lot of k's… lets make a new term…

$$K_m = (k_3 + k_2)/k_1 \quad k_{consume}/k_{form} \qquad \frac{k_3 + k_2}{k_1}$$

OK, so now what… Well, what exactly is [E]? It's not the total amount of enzyme added…

substituting this in for this an $\frac{1}{K_m}$ in for $\frac{k_1}{k_3 + k_2}$ gives

$$\text{rate} = \frac{k_3}{K_M}[E][S] \leftarrow \text{but not consistent with data}$$

Substitute new term for [E] into equation for [ES] and solve for [ES]…

total amt of enzyme added   free enzyme + enzyme in complex

$$[E]_T = [E] + [ES]$$

$$[E] = [E]_T - [ES]$$

Enzyme Kinetics: Steady State Assumption

$$\text{rate} = k_3[\text{ES}]$$

$$[\text{ES}] = k_1/(k_3 + k_2)\ [\text{E}][\text{S}]$$

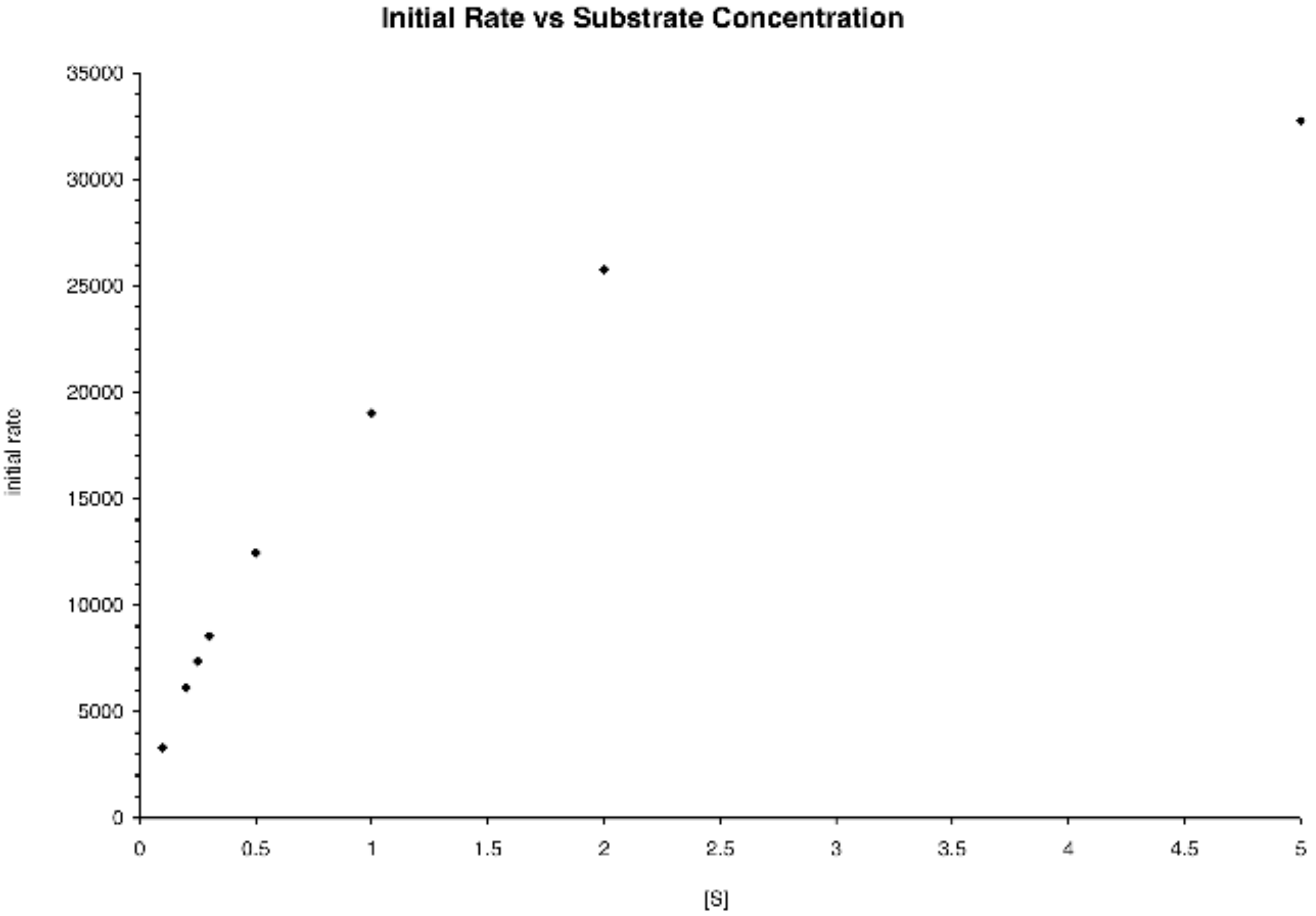
$$\text{K}_\text{m} = (k_3 + k_2)/k_1 \quad k_\text{consume}/k_\text{form}$$

$$[\text{ES}] = [\text{E}]_\text{T}\ [\text{S}]/(\text{K}_\text{m} + [\text{S}])$$

Which finally gets us to the rate law…

Enzyme Kinetics: Compare the Rate law to the Plot

$$\mathbf{rate} = k_3[\mathrm{E}]_T\,[\mathrm{S}]/(K_m + [\mathrm{S}])$$



$K_m >> [S]$	K_m similar to [S]	$K_m << [S]$
rate = $(k_3/K_m)[E]_T[S]$	rate = $k_3[E]_T\,[S]/(K_m + [S])$	rate = $k_3[E]_T$

Enzyme Kinetics: Steady State Assumption

6.3.2