A number of reactions go through an intermediate

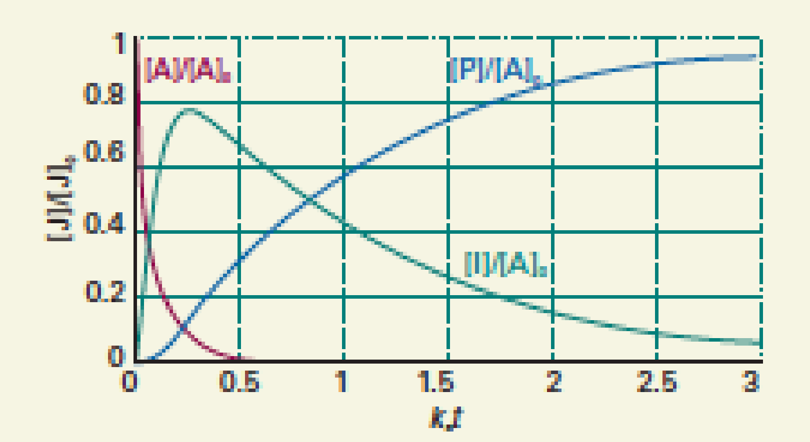
$$\mathrm{A} \xrightarrow{k_1} \mathrm{I} \xrightarrow{k_2} \mathrm{P}$$

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

$$\frac{\mathrm{d}I}{\mathrm{d}t} = k_1[\mathrm{A}] - k_2[\mathrm{I}]$$

$$\frac{\mathrm{d}P}{\mathrm{d}t} = k_1[\mathrm{I}]$$

Analytical solutions exist for consecutive reactions



Analytical solutions exist for consecutive reactions

Solutions are:

$$[\mathrm{A}] = [\mathrm{A}]_0 \mathrm{e}^{-k_1 t}$$

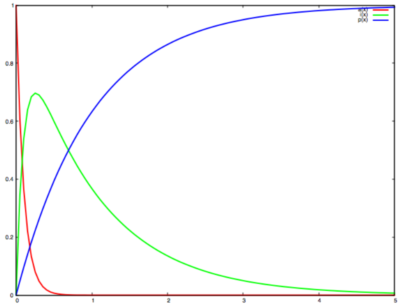
$$[\mathrm{I}] = \frac{k_1}{k_2 - k_1} [\mathrm{A}]_0 \left(\mathrm{e}^{-k_1 t} - \mathrm{e}^{-k_2 t} \right)$$

Notice that

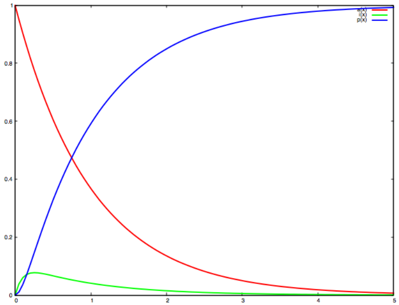
$$\frac{\mathrm{d}[\mathrm{A}]}{\mathrm{d}t} + \frac{\mathrm{d}[\mathrm{I}]}{\mathrm{d}t} + \frac{\mathrm{d}[\mathrm{P}]}{\mathrm{d}t} = 0$$

$$\implies [\mathrm{A}] + [\mathrm{I}] + [\mathrm{P}] = 0$$

The intermediate concentration is small if the second rate constant is large

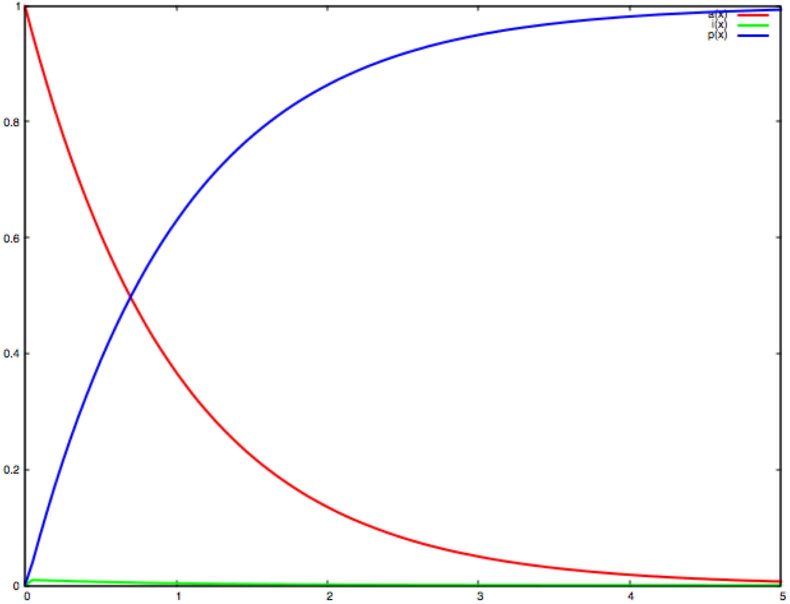


$k_1 = 10k_2$

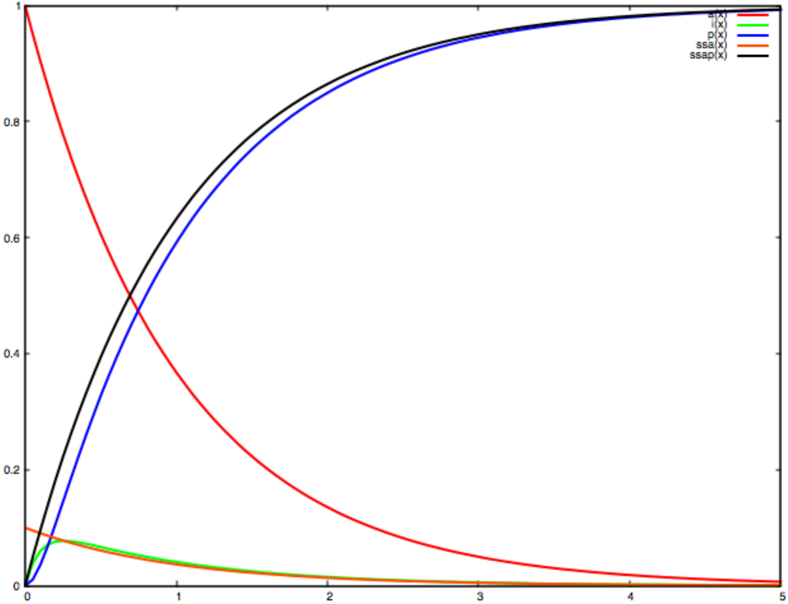


$k_2 = 10k_1$

If $k_2 \gg k_1$, $[\mathrm{I}] \approx 0$ and its rate of change is small.



The Steady State Approximation implies that $\frac{d[I]}{dt} = 0$



Can we differentiate $A \xrightarrow{k_1} I \xrightarrow{k_2} P$ from $A \xrightarrow{k_1} P$?

$$[P] = [A]_0 - [A] - [I]$$

$$[P] = [A]_0 \left\{ 1 + \frac{1}{k_1 - k_2} \left(k_2 e^{-k_1 t} - k_1 e^{-k_2 t} \right) \right\}$$

If $k_2 \ll k_1$,

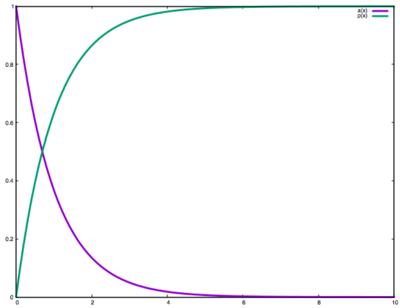
$$[A] = [A]_0 e^{-k_1 t} \qquad \text{and} \qquad [P] = [A]_0 (1 - e^{-k_2 t})$$

Time constant for A decay and P growth are different.
If $k_1 \ll k_2$,

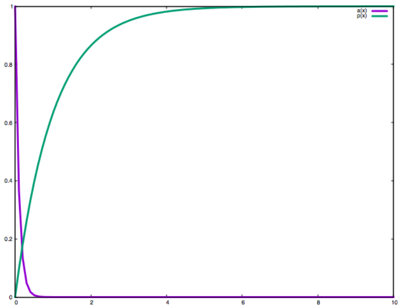
$$[A] = [A]_0 e^{-k_1 t} \qquad \text{and} \qquad [P] = [A]_0 (1 - e^{-k_1 t})$$

Time constant for A decay and P growth are same.

$A \xrightarrow{k_1} I \xrightarrow{k_2} P$ differentiated from $A \xrightarrow{k_1} P$ when $k_2 \ll k_1$?



$k_1 \ll k_2$; A decay and P build-up with same time constant.



$k_2 \ll k_1$; A decay and P build-up with different time constants.