Partial : Systems Biology

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

$$\frac{dP}{dt} = [ES]k_3$$

As $k_2 \gg k_3 \rightarrow$ steady state : $[E][S]k_1 - k_2[ES] = 0$

$$\begin{aligned}
[ES]_{produced} &= [ES]_{consumed} \\
[E][S]k_1 &= [ES]k_2 + [ES]k_3 \\
\frac{[E][S]}{[ES]} &= \frac{k_2 + k_3}{k_1} = \frac{k_2}{k_1} = K_M \text{as } k_3 \ll k_2 \\
[E_{free}] &= [E_{Tot}] - [ES] \\
\Rightarrow ([E_{Tot}] - [ES])S &= K_M[ES] \\
[E_{Tot}][S] - [ES][S] &= K_M[ES] \\
[E_{Tot}][S] &= [ES](K_M + [S]) \\
[ES] &= \frac{[E_{Tot}][S]}{K_M + [S]} \\
\text{so } \frac{dP}{dt} &= k_3 \frac{[E_{Tot}][S]}{K_M + [S]}
\end{aligned}$$