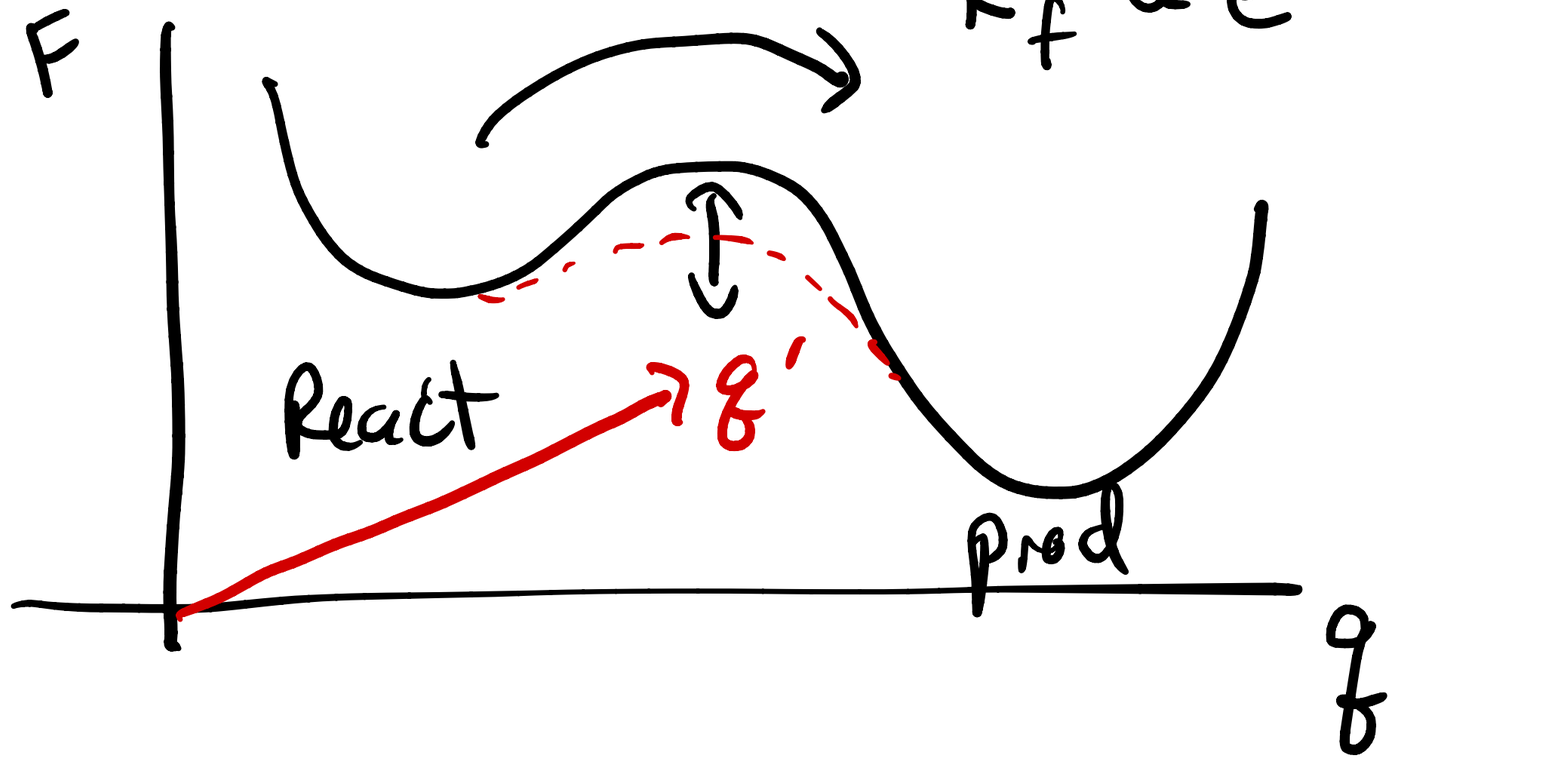
Lecture 20 - Enzymes

Catalysts:



$$R \rightleftharpoons P$$

$$R + C \rightleftharpoons P + C$$

2 kinds of catalysis

Heterogeneous ∈ Different phase

Solid catalyst, liq, gas reactant

Homogeneous ∈ same phase

Solution ← reactants

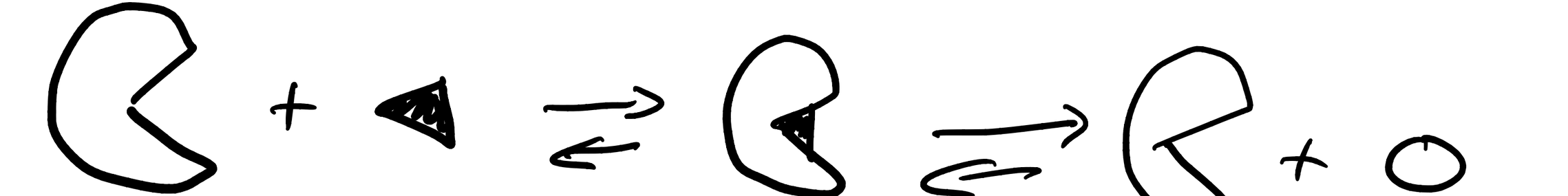
↖ catalyst

[Inorganic metals

biological enzymes

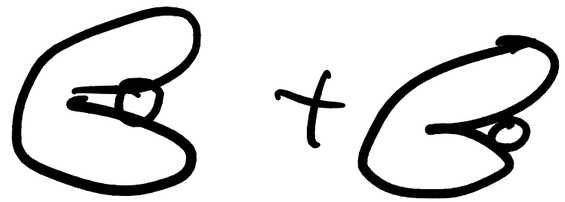
Enzymes ← passive
← "active"

Michelis - Menten Scheme



$$E + S \underset{k_b^1}{\overset{k_f^1}{\rightleftharpoons}} ES \underset{k_b^2}{\overset{k_f^2}{\rightleftharpoons}} E + P$$

Eg



G-actin

Factin

Factin

$F_{actin} + ADP + P_i$

$$E + S \rightleftarrows ES \rightleftarrows E + P$$

Total E is const $\quad [E] = [E]_0 - [ES]$

$$\frac{d[S]}{dt} = -k_f'[E][S] + k_b'[ES]$$

$$\frac{d[P]}{dt} = k_f^2[ES] - k_b^2[E][P]$$

$$\frac{d[ES]}{dt} = k_f'[E][S] + k_b^2[E][P] - k_b'[ES] - k_f^2[ES]$$

Assumption
$[S] >> [E]$
$[ES]$ complex is in S.S.

$$[ES]_{ss} = \frac{(k_f^1[S] + k_b^2[P])[E]_0}{k_f^1[S] + k_b^1 + k_b^2[P] + k_f^2}$$

$$\text{rate} = -\frac{d[S]}{dt} = k_f^1[E][S] - k_b^1[ES]$$

$$[E] = [E]_0 - [ES]$$

$$\text{rate} = \frac{(k_f^1 k_f^2[S] - k_b^1 k_b^2[P])[E]_0}{k_f^1[S] + k_b^1 + k_b^2[P] + k_f^2}$$

(at time t)

$$\text{rate} = \frac{(k_f^1 k_f^2 [S] - k_b^1 k_b^2 [P])[E]_0}{k_f^1 [S] + k_b^1 + k_b^2 [P] + k_f^2}$$

what is the initial rate of reaction:

at $t \approx 0$, $[S] = [S]_0$, $[P] = 0$

$$r_0 = \frac{k_f^1 k_f^2 [S]_0 [E]_0}{k_f^1 [S]_0 + k_b^1 + k_f^2}$$

k_{cat}

$$= k_f^2 [S]_0 [E]_0 / ([S]_0 + K_M)$$

Michaelis const

$$\frac{k_b^1 + k_f^2}{k_f^1}$$

↑ units of conc.

$$r_0 = \frac{k_{cat}\,[S]_0[E]_0}{[S]_0 + k_M} = r_{max}\left(\frac{[S]_0}{[S]_0 + k_M}\right)$$

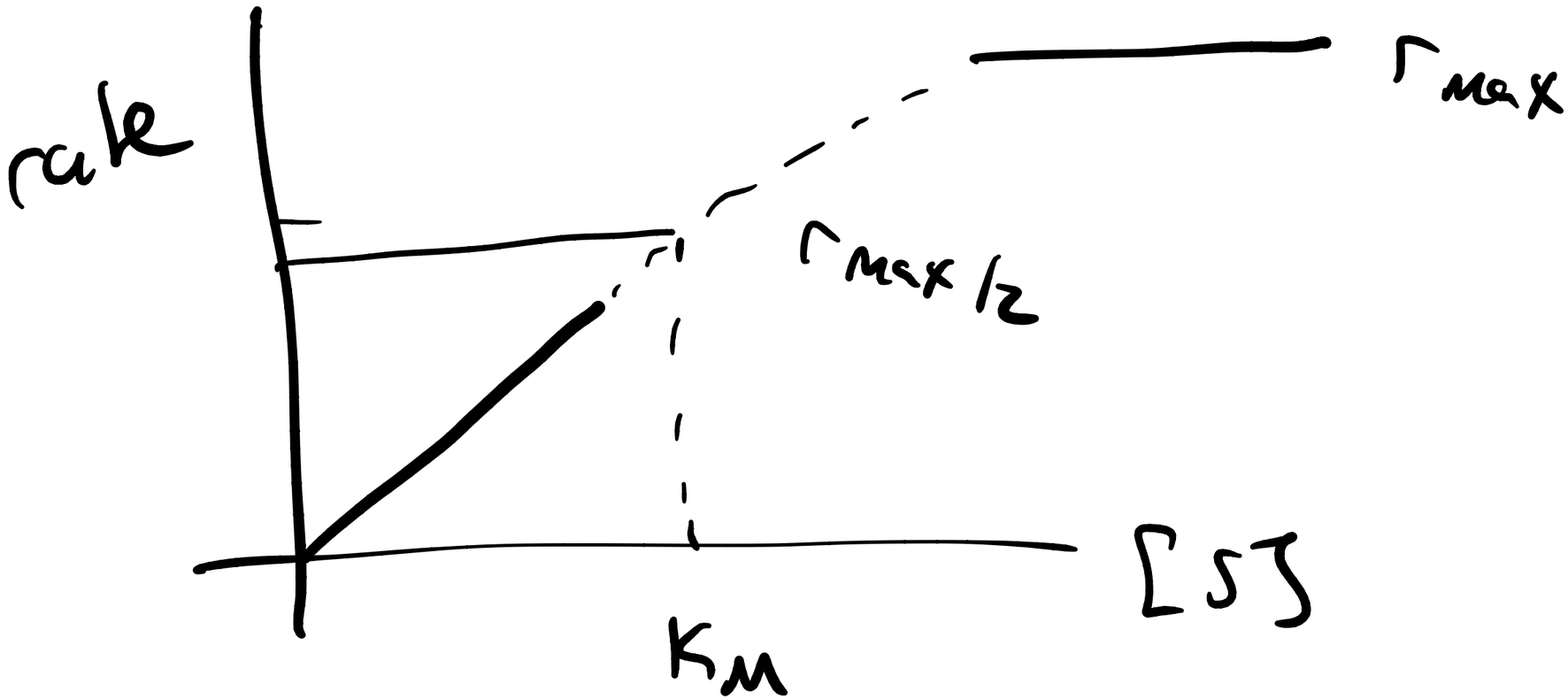
k_M "is" the concentration where $r_0 = r_{max}/2$

2 limits

$[S]_0 << k_M$, rate $\propto [S]_0$

$[S]_0 >> k_M$, rate is 0th order in $[S]_0$

$$r_{max} = k_{cat}\,[E]_0$$



Turnover #: r_{max} / [enzyme active sites]

$$\simeq \frac{k_{cat}}{\#}$$

$$[E]_0 \cdot \#$$

Catalytic efficiency

$$\epsilon = \frac{k_{cat}}{K_M}$$, units of $\frac{1}{M}$ $\frac{1}{s}$

range $10^0 - 10^{10}$ $M^{-1}s^{-1}$

$10^8 - 10^{10}$ diffusion limited

biggest when k_{cat} & k_f' are Big

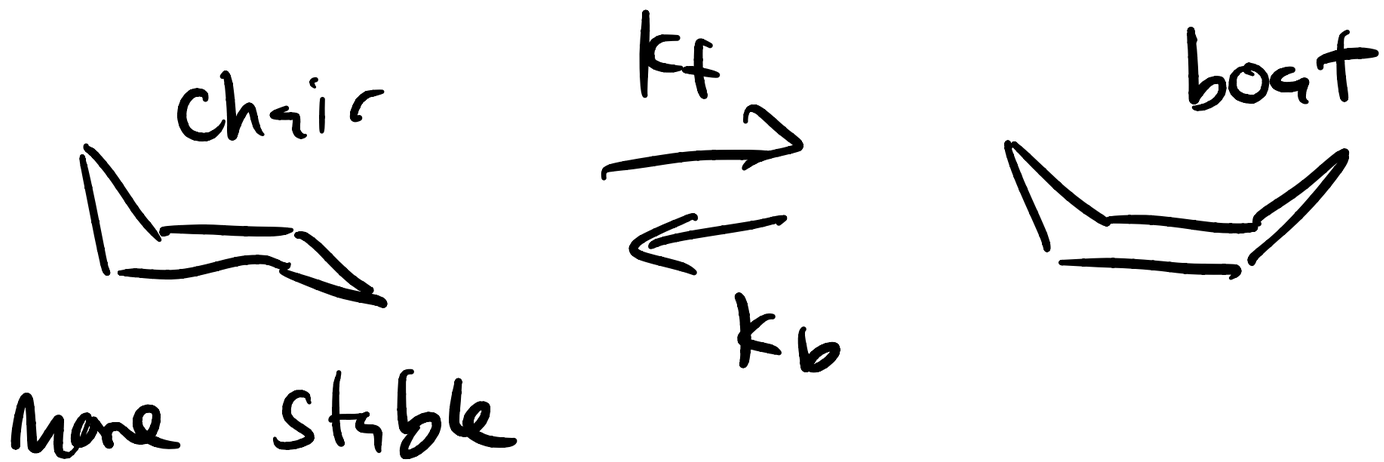
k_b' is small

Intro to Statistical thermodynamics (Ch 4 Barrick)

want: molecules → bulk properties

Key idea: properties of a bulk system
Can't depend on individual arrangements
of molecules ← has to be an average

What is going on at individual molecule level ...



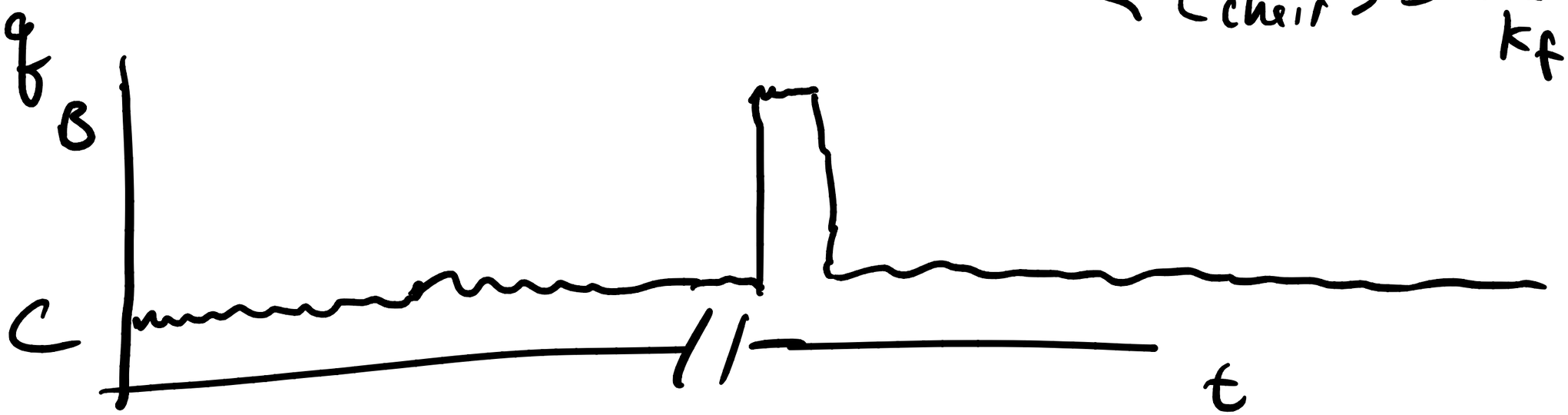
more stable

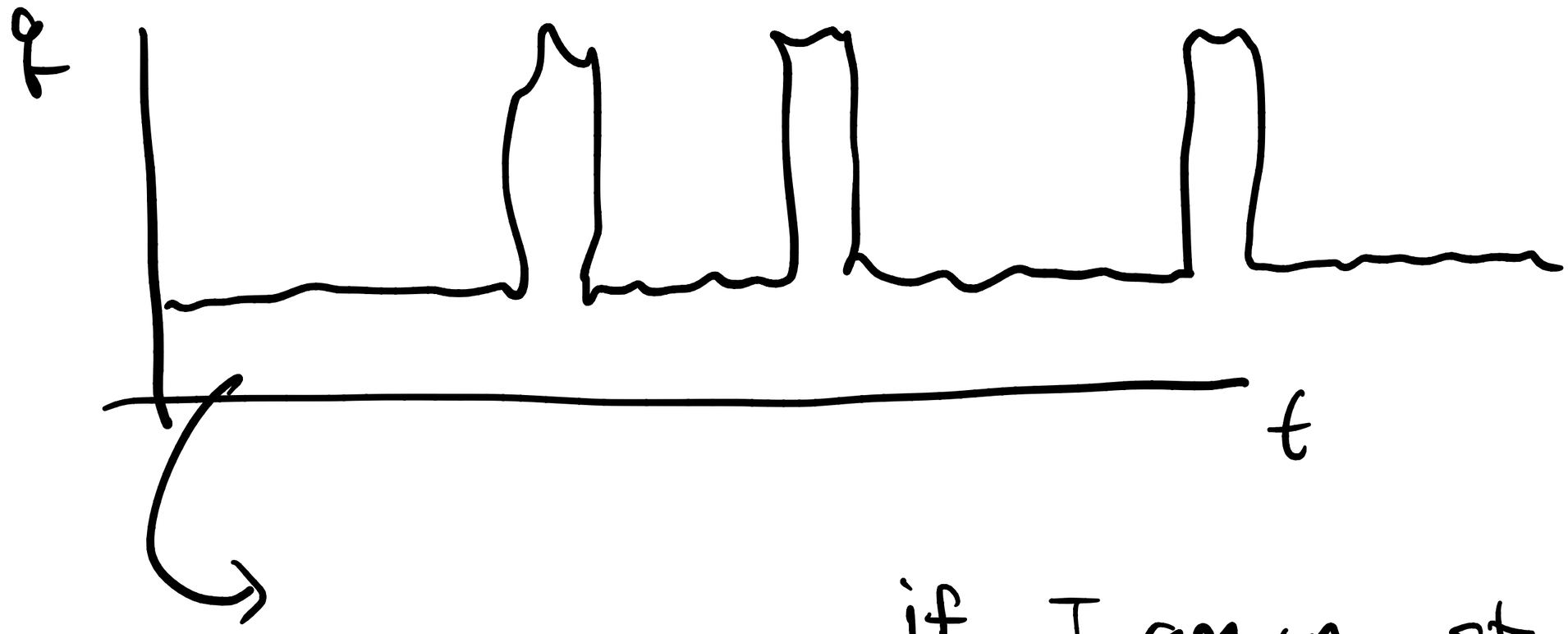
$$K_{eq} = \frac{[boat]}{[chair]}$$

$$K_{eq} = \frac{k_f}{k_b}$$

$$\langle \tau_{boat} \rangle = \frac{1}{k_b}$$

$$\langle \tau_{chair} \rangle = \frac{1}{k_f}$$





Time correlation function

if I am in state A at time t, how likely am I to be in state A at time $t + \Delta t$

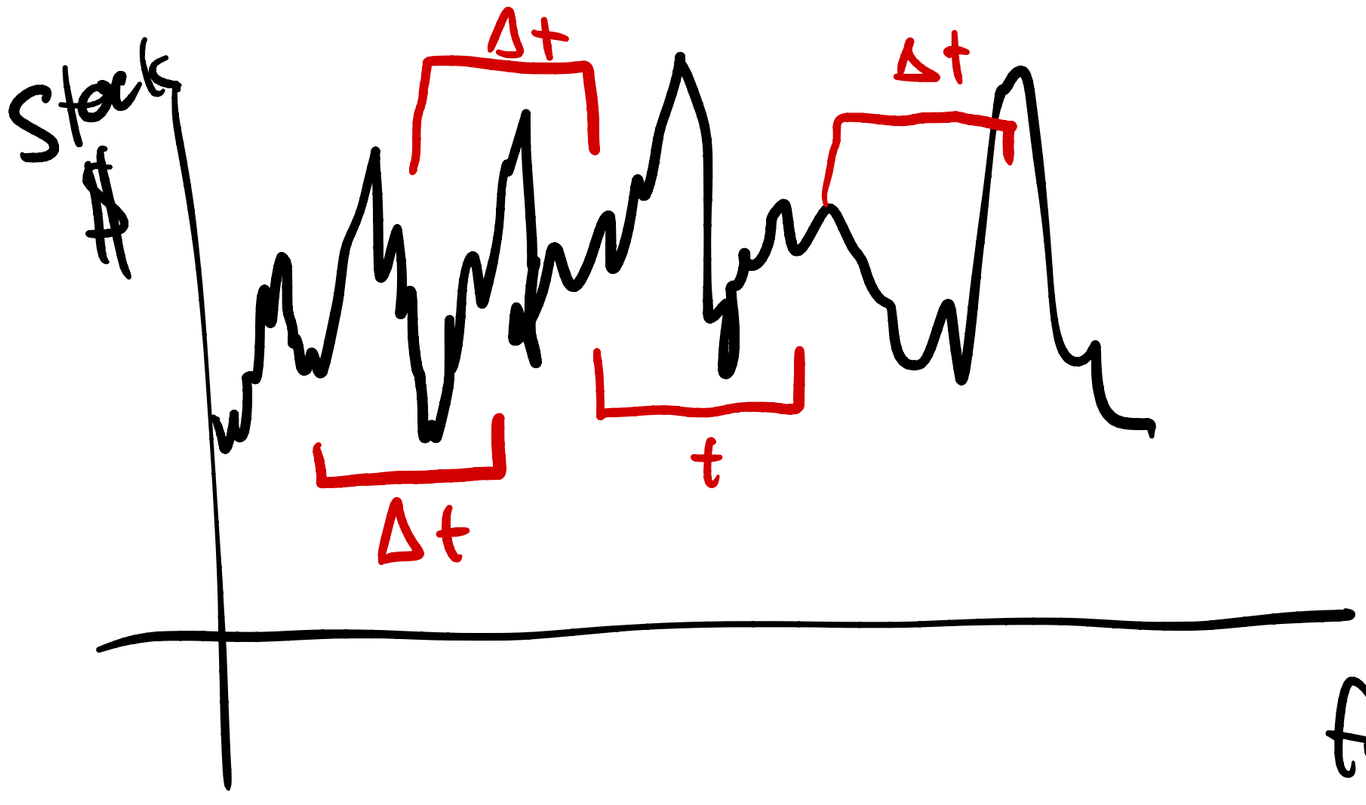
Measure of correlation

$$\delta q(t) = q(t) - \langle q \rangle$$

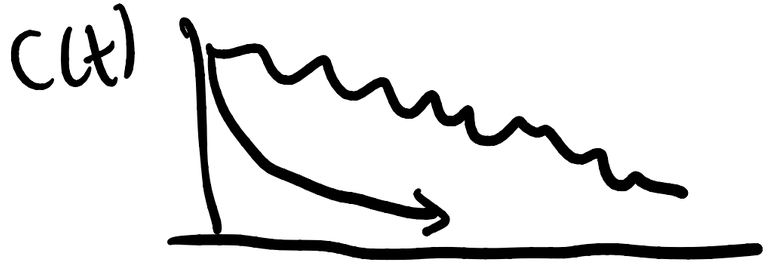
$$C(\Delta t) \approx \frac{\langle \delta q(t+\Delta t)\, \delta q(t) \rangle}{\langle \delta q(t)\, \delta q(t) \rangle} \qquad \langle \delta q \rangle = 0?$$

$C(0) = 1$

$C(t \to \infty) =$



$$\tau_{rxn} = \int_0^\infty C(\Delta t)\, e^{-kt}\, d\Delta t$$



for 1st order $\tau_{rxn} = \frac{1}{k}$

Key ideas: average over an "ensemble" many molecules, is the same as a long time average