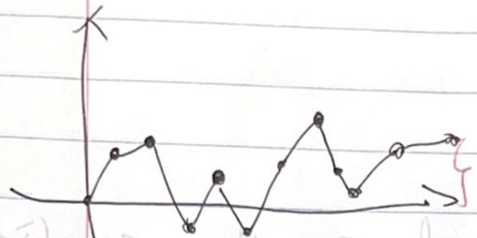
Last Time Diffusion or $ma = F_{random}$



$\delta x(t) = \Delta x_1 + \Delta x_2 + \ldots = \sum_{i=1}^{k} \Delta x_j$ — gaussian random variable (CLT)

$t = k \cdot \Delta t$

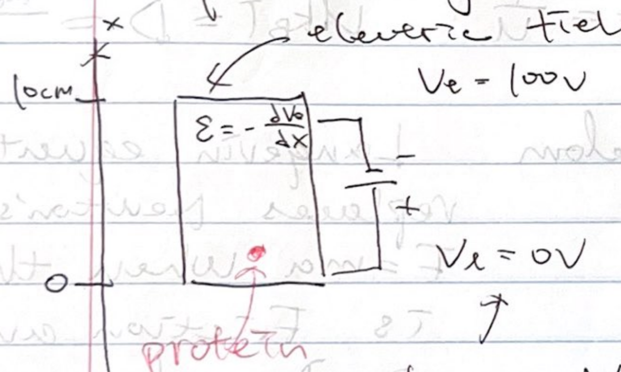
$\Rightarrow \langle \delta x^2 \rangle = k \cdot \langle \Delta x^2 \rangle = \frac{\langle \Delta x^2 \rangle}{\Delta t} \cdot t$ or

Average square displacement $\langle \delta x^2 \rangle = 2Dt$

if we derive $2D = \frac{\langle \delta x^2 \rangle}{\Delta t}$

Today: Drift velocity and flux:

ex: protein gel electrophoresis



voltage $V_e = -\mathcal{E}x$

From stat mech/thermo

$E = TS - PV + un + \ldots + V_e Q$

charge of protein spot

$= TS - PV + un - \mathcal{E}xQ$

$\frac{\partial E}{\partial n} = u \Rightarrow \frac{\partial^2 E}{\partial n \partial x} = \frac{\partial u}{\partial x}$

$\frac{\partial E}{\partial x} = -F_{applied} = -\mathcal{E}Q \quad Q = n \cdot z$

unit charge

$$\frac{\partial^2 G}{\partial u \, dn} = -\varepsilon \frac{\partial Q}{\partial n} = -\varepsilon \cdot Z$$

But $\frac{\partial^2 f}{\partial x \partial y} = \frac{\partial^2 f}{\partial y \partial x}$

$-\frac{\partial u}{\partial x} = \varepsilon Z = F_{applied}$, in the applied force per mole of protein.

So it ~~tu~~ turns out that our protein spot sees 3 forces: friction ∝ collision ~ velocity

$$ma = F = F_{applied} + F_{random} + F_{friction}.$$

friction coefficient

$\Rightarrow -\frac{\partial u}{\partial x} + F_{random} - \gamma \cdot v \cancel{=0}$ (3 forces >> ma) see p 31 $\gamma = \frac{P}{k_B T}$

u = mobility $\gamma = \frac{1}{u}$ $u k_B T = D = \frac{k_B T}{\gamma}$

$-\frac{\partial u}{\partial x} = \gamma v - F_{random}$ Langevin equation replaces Newton's law $F = ma$ when there is friction and random force.

ex: Let's neglect for a moment F_{random}

$$-\frac{\partial u}{\partial x} = \varepsilon \cdot Z = \gamma \cdot v \Rightarrow v_{drift} = \frac{\varepsilon \cdot Z}{\gamma}$$

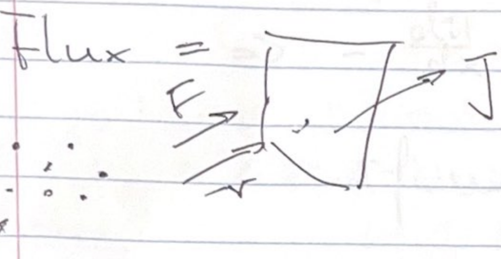
protein radius

$\gamma = 6\pi\eta r$

solution viscosity

Aristotle vs Newton: Aristotle was right in most cases!

Flux =



concentration C

$$J\left(\frac{\text{moles}}{m^2 \cdot s}\right) = \underset{m/s}{v} \cdot \underset{\text{moles}/cm^3}{c}$$

But we also know

$$-\frac{\partial \mu}{\partial x} = \gamma \cdot v = \frac{1}{U} v$$

$$\frac{J}{c} = v$$

$$-U \frac{\partial \mu}{\partial x} = v$$

$$\Rightarrow \boxed{J = -U \cdot c \frac{d\mu}{dx}}$$