Adsorption of Acetic Acid from Solution onto Activated Carbon

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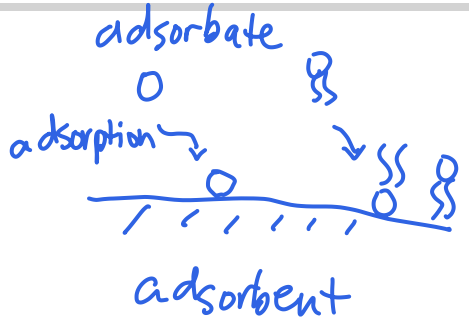
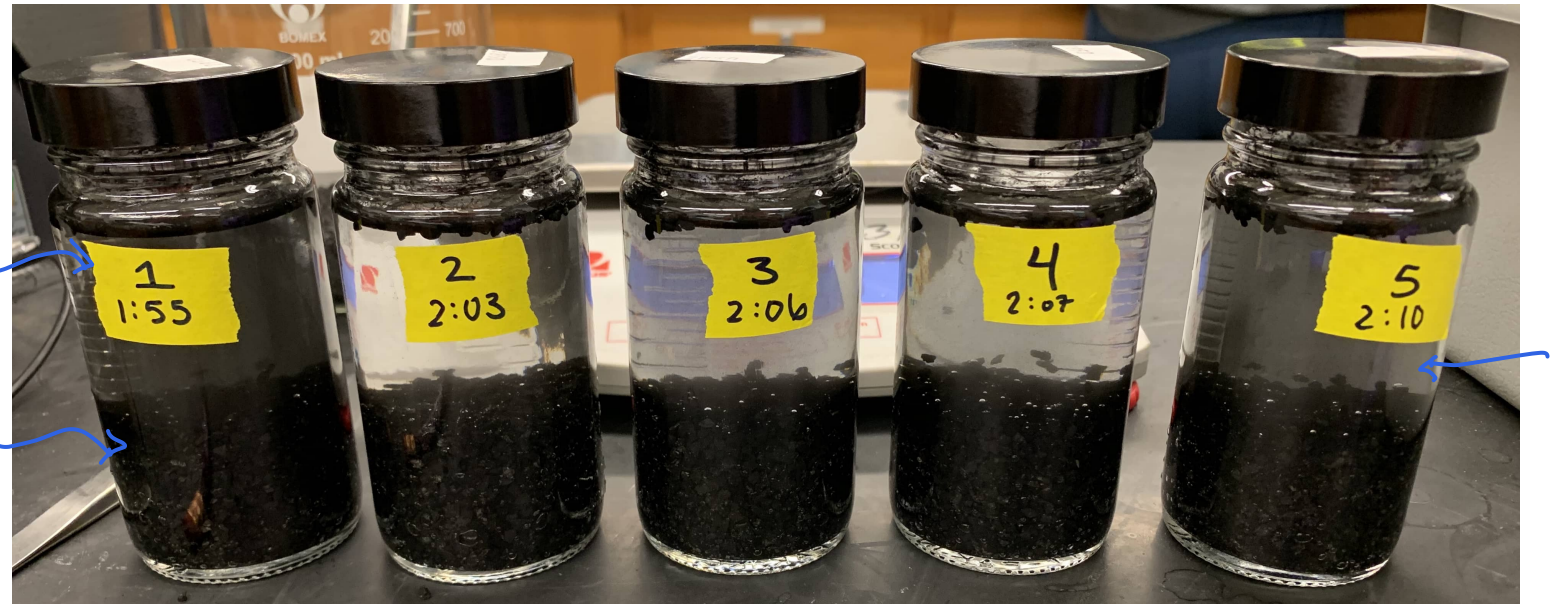
Adsorption of solute to solid surface can be physical or chemical

- **Adsorption** - interaction between solute in dilute solution and solid surface
  - **Adsorbate** - solute
  - **Adsorbent** - solid
- **Chemisorption** - interaction by chemical bonding
- **Physical adsorption** - interaction by intermolecular forces (e.g. van der Waals forces)





acetic acid
↓
adsorption
↓
activated carbon

supernatant
↓
How? C of acid

t_0 t_1 ... ... t_{eq}

kinetics C(t)

Equilibrium C_{eq}

Titration determines the concentration of the acetic acid in the supernatant

- Acetic acid equivalence point has pH = 8.7 (Why?)
- Phenolphthalein turns from colorless to pink at pH = 8.2 ~ 10.0
- Calculating acid concentration at equivalence point

$$\text{mol acid} = \text{mol base}$$

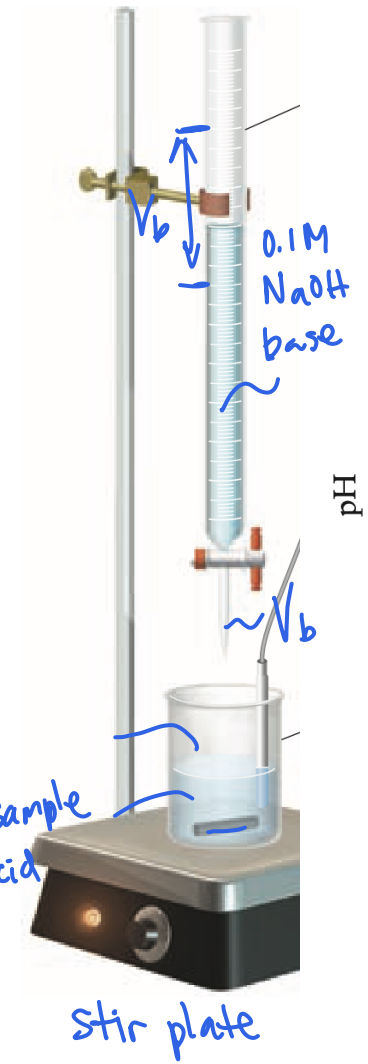
$$C_a V_a = C_b V_b$$

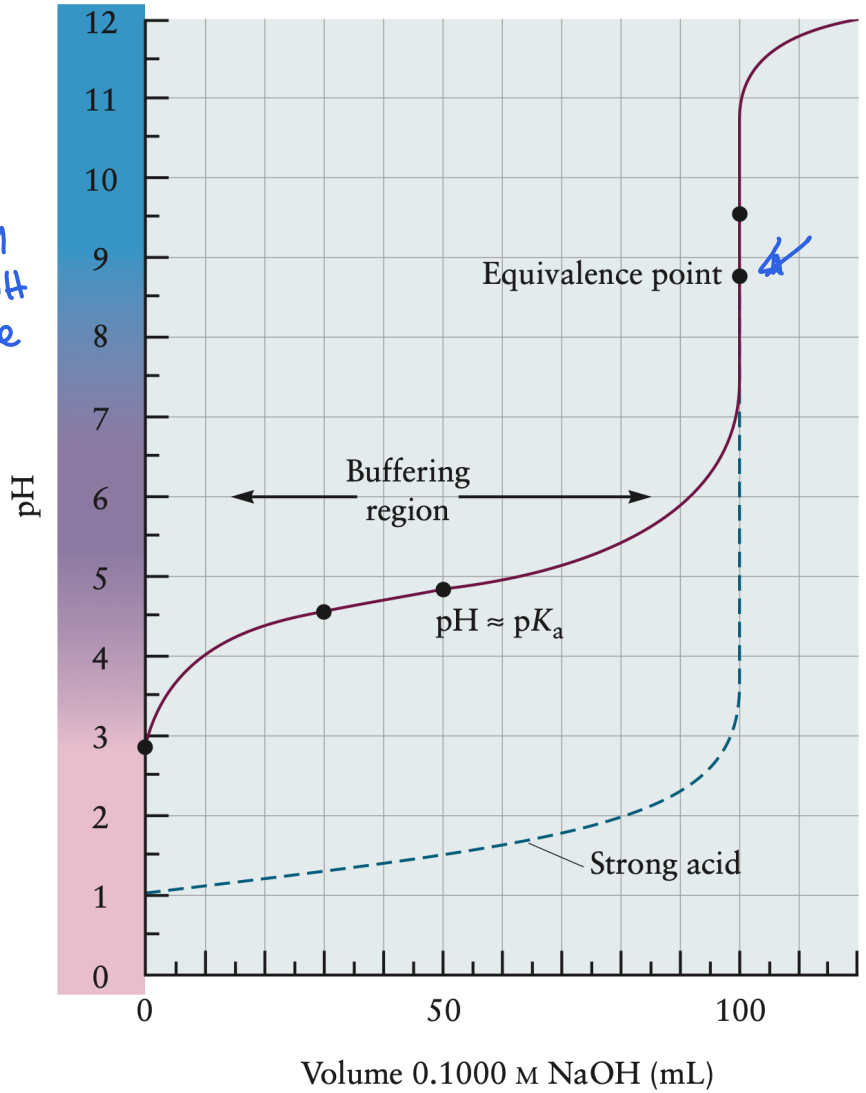
$$C_a = \frac{C_b V_b}{V_a} = \frac{(0.1\text{M})\, V_b}{(10\text{mL})} = 0.01 \left(\frac{\text{M}}{\text{mL}}\right) V_b$$

- Estimate maximum volume of base needed to reach equivalence point

$$V_b = \frac{C_a V_a}{C_b}$$

Max at initial time pt





Oxtoby et al. *Principles of Modern Chemistry* 7th edition (2011).

Langmuir adsorption isotherm $\Gamma(C)$ describes monolayer with homogeneous energy

mol adsorbed / g solid — concentration @ eqm

- Assumptions
  - Adsorption is restricted to a monolayer
    - Solid-solute interactions decays rapidly with distance
  - All adsorption sites are equivalent
    - Surface energy homogeneity - Energy of adsorption does not depend on extent of surface coverage
- Fraction of surface covered by adsorbed solute

fitting — eqm conc.

$$\Theta = \frac{kC}{1+kC} = \frac{\Gamma}{\Gamma_m} = \frac{\text{mol adsorbed solute / mass solid}}{\text{mol adsorbed solute if close-packed monolayer / mass solid}}$$

Γ_∞

- Langmuir isotherm

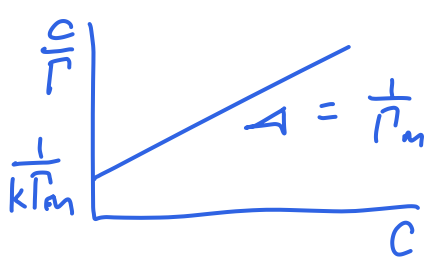
$$\boxed{\Gamma = \Gamma_m \frac{kC}{1+kC}}$$

$\Gamma(C)$

- Linear form of Langmuir isotherm

$$\frac{C}{\Gamma} = \frac{C}{\Gamma_m} + \frac{1}{k\Gamma_m}$$

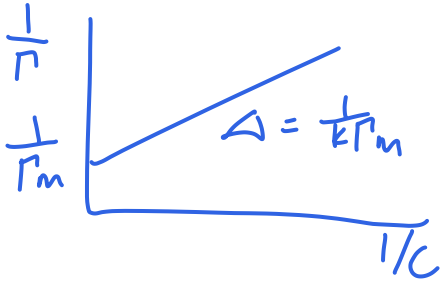
slope — intercept

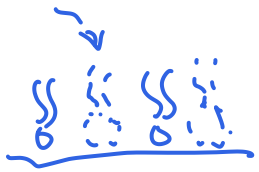


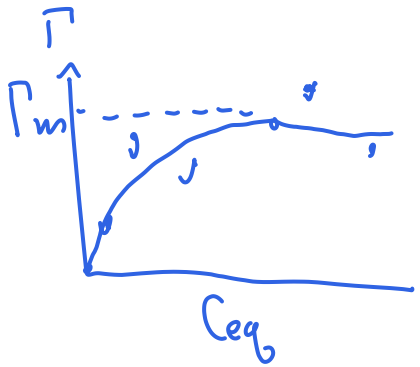
- Lineweaver-Burk plot

$$\frac{1}{\Gamma} = \frac{1}{k\Gamma_m}\frac{1}{C} + \frac{1}{\Gamma_m}$$

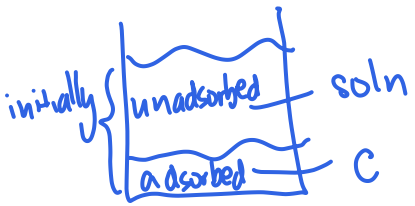
slope — intercept







mol adsorbed = mol initial − mol in supernatant (left unadsorbed)



Specific area of solid surface can be calculated from Langmuir isotherm

- Specific area of solid surface = area / mass solid

  ↳ $\Sigma(\mathrm{m}^2/\mathrm{g}) = \Gamma_m(\mathrm{mol/g}) N_A A_0(\mathrm{Å}^2/\mathrm{molecule}) \times 10^{-20}$

  Γ_m: mol adsorbed / mass solid; N_A: Avg #; A_0: cross-sectional area of molecule

- BET measurement for SA using N_2 adsorption

Freundlich isotherm $\Gamma(C)$ describes energy heterogeneity

- Assumptions
  - Surface energy heterogeneity - Energy of adsorption varies exponentially with extent of surface coverage
    - Low energy sites filled first
  - No limiting value of surface area - adsorption sites become less and less favorable
- Freundlich isotherm

$\alpha, \beta \rightarrow$ consts

mol ads / mass solid

$$\boxed{\Gamma = \alpha C^{\beta}}$$

eqm conc.

- Linear form of Freundlich isotherm

$$\log \Gamma = \log \alpha + \beta \log C$$

intercept