Membrane Proteins


Review of Membrane Proteins

Target of 40% of drugs!
Another Example: Na-K ATPase

- Chemical potential: $\mu \propto RT \ln[Na^+]$
  - Chemical work (hydrolysis of ATP)
  - Coupled reaction: transport of Na$^+$, K$^+$ ions ($\Delta\mu = \mu_{out} - \mu_{in}$)

- What about charge?
  - Ions will move (current)
  - Different # of ions in and out (voltage)

Review: Charges

• Unit of charge: 1 Coulomb (C)
  – Electron ($e^-$) has charge of 
    $-1.6022 \times 10^{-19}$ C
  – Proton ($H^+$) has charge of 
    $+1.6022 \times 10^{-19}$ C

• **Faraday constant**: Charge of a mole of ions
  $F = 9.64853 \times 10^4$ C mol$^{-1}$
Review: Electricity

- **Current (I):** Flow of electrons through a wire (charge per unit time)
  - Unit is Ampere (C s\(^{-1}\))

- **Voltage (V):** Energy stored in an electric field for a given amount of charge (also called potential)
  - Unit is Volt (J C\(^{-1}\))

- **Power (P):** Energy dissipated per unit time \((P = I \cdot V)\)
  - Unit is Watt (J s\(^{-1}\))
Electrochemistry and Galvanic Cells

• Certain chemical reactions result in transfer of electrons from one compound to another (oxidation-reduction)

• **What if:** What if we could couple electron transfer to current going through a wire?

• **We could measure chemical work** ($\text{dw}^*$ and $\Delta G$) **by measuring the electrical work!**
  – Doesn’t work for all reactions, even all redox reactions
Electrochemistry and Galvanic Cells

• The system:

\[ \text{Zn} \rightarrow 2\text{e}^- + \text{Zn}^{2+} \]

\[ \text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu} \]
Non-PV Work in Galvanic Cells

- For a voltage $\xi$, if $n$ electrons transferred from anode to cathode:
  $$dw^* = -nF\xi$$

- At const $T$ and $P$, remember:
  $$\Delta\overline{G} = dw^*$$

Convention: Galvanic Cells

\[ \text{Zn}(s) \mid \text{ZnSO}_4 (1\text{M}) \parallel \text{CuSO}_4 (1\text{M}) \mid \text{Cu}(s) \]

- **Anode** (where oxidation occurs, net electron loss)
- **Cathode** (where reduction occurs, net electron gain)
- **Phase Boundaries**
- **Salt Bridge**
- **Electrolyte solutions** (with concentrations)
Reaction and Equilibrium

• Overall Reaction is:
  \[ \text{Zn}(s) + \text{Cu}^{2+}(aq) \rightarrow \text{Zn}^{2+}(aq) + \text{Cu}(s) \]

• Equilibrium constant (at equilibrium):
  \[ K_{eq} = \left( \frac{[\text{Zn}^{2+}][\text{Cu}]}{[\text{Zn}][\text{Cu}^{2+}]} \right)_{eq} \]

• Reaction quotient (not at equilibrium):
  \[ Q = \frac{[\text{Zn}^{2+}]}{[\text{Cu}^{2+}]} \]
Relating $\Delta G$ and $\mathcal{E}$

- As before, we know (at const T, P):

$$\Delta \tilde{G} = \Delta \tilde{G}^0 + RT \ln Q$$

- Remember previous result:

$$\Delta \tilde{G} = -nF\mathcal{E}$$
Electrochemistry and Galvanic Cells

• Converting our “Gibbs equation” to volts:

\[ \varepsilon = \varepsilon^0 - \frac{RT}{nF} \ln Q \]

• Special notes:
  – This is called the “Nernst Equation”
  – F is “Faraday’s number,” or 96,485 C mol\(^{-1}\)
  – \(n\) is the total # of moles of electron per mole of reaction (remember \(d\alpha\) reaction variable)
  – Positive voltage is a spontaneous process
Electrochemistry Example

• Copper/Silver Galvanic Cell:
  \[ \text{Ag}^+ + e^- \rightarrow \text{Ag} \quad \varepsilon^0 = 0.799 \text{ V} \]
  \[ \text{Cu}^{2+} + 2e^- \rightarrow \text{Cu} \quad \varepsilon^0 = 0.337 \text{ V} \]

• What is the standard state free energy for a Cu/Ag galvanic cell? Is Ag the cathode or the anode?
Probabilities: Moving toward statistical thermodynamics

• Protein folding:

• What does $\Delta \bar{G}^0$ tell us about this system at equilibrium?
# Folding vs. $\Delta G^0$

<table>
<thead>
<tr>
<th>$\Delta \bar{G}^0$ (kcal mol$^{-1}$)</th>
<th>$\Delta \bar{G}^0$ (kJ mol$^{-1}$)</th>
<th>$K$ (at 298 K)</th>
<th>% Folded</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>63</td>
<td>$1 \times 10^{-11}$</td>
<td>~100</td>
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<tr>
<td>-5</td>
<td>-21</td>
<td>$5 \times 10^3$</td>
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• What does it mean if a protein is 50% folded?