
Graded problems:

1. **Voltages and work obtained from batteries.** A galvanic cell is created with electrodes of Mn and MnO dipping into an aqueous solution. The overall cell reaction is:

$$Mn_{(s)} + H_2O_{(g)} = MnO_{(s)} + H_{2(g)}$$

Thermodynamic data for the free energy change in forming water and MnO are given below.

a. Calculate the standard EMF of this galvanic cell at 500K.

b. Determine the maximum work that can be obtained from the cell at 500K if the partial pressure of H_2 is 0.045 atm and the partial pressure of H_2O is 0.5 atm.

c. Calculate the EMF when the ratio of the pressures P_{H2}/P_{H2O} is maintained at 1000/1 at T=500K.

Thermodynamic data:

$$H_{2(g)} + \frac{1}{2}O_{2(g)} = H_2O_{(g)} \qquad \Delta\overline{G}_{rxn,o} = -246{,}000 + 54.8T\frac{J}{mole}$$

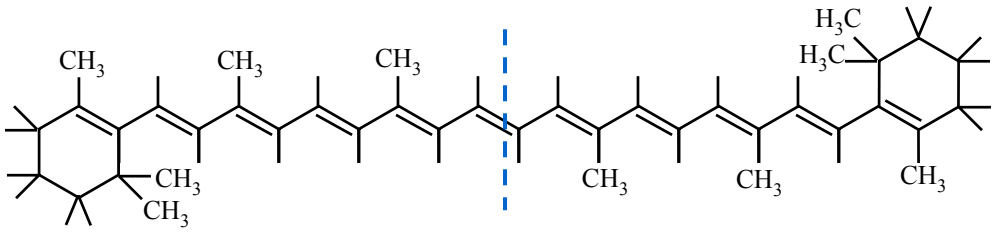
$$Mn_{(s)} + \frac{1}{2}O_{2(g)} = MnO_{(s)} \qquad \Delta\overline{G}_{rxn,o} = -384{,}700 + 72.8T\frac{J}{mole}$$

2. **Batteries can be used to directly measure free energies of reactions**. Calculate the change in standard state free energy at 298K for the reaction:

$$Sn_{(s)} + Pb^{++}_{(aq)} = Sn^{++}_{(aq)} + Pb_{(s)}$$

…if the potential difference measured using a voltmeter between tin and lead electrodes in a Daniell cell (having $SnSO_4$ and $PbSO_4$ solutions as the electrolyte media) is 0.014 V.

3. **The power of carrots:** All-trans beta-carotene (shown below) is the most common form of this molecule in vegetables (e.g. carrots).



What would be the size of the confining region for the electron responsible for the orange color of carrots ? (Hint: in order for a carrot to be orange, it needs to absorb photons of appropriate wavelength. Assume the electronic transition is from the ground state to the first excited state).

4. Determine which of the following operators are linear, and which are Hermitian:
   - x
   - $[x,p_x]$
   - $\frac{d^2}{dx^2}$
   - $i\frac{d^2}{dx^2}$
   - exp(…)
   - $[yp_z-zp_y,zp_x-xp_z]$

5. Sketch the graph of the two lowest energy eigenfunctions of the 1-dimensional harmonic oscillator. Show graphically and analytically that they are orthogonal.

Optional problems:

6. Mortimer 14.66