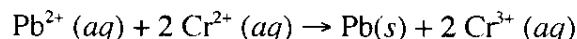
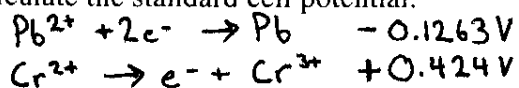


1. (5 points each) A galvanic cell is constructed that carries out the reaction



The initial concentration of  $\text{Pb}^{2+}(\text{aq})$  is 0.15 M, that of  $\text{Cr}^{2+}(\text{aq})$  is 0.20 M, and that of  $\text{Cr}^{3+}(\text{aq})$  is 0.0030 M, and  $T = 25^\circ\text{C}$ .

- (a) Calculate the standard cell potential.



$$\Delta\mathcal{E}^\circ = 0.298\text{V}$$

- (b) Calculate the initial cell voltage.

$$\Delta\mathcal{E} = \Delta\mathcal{E}^\circ - \frac{RT}{nF} \ln Q = \Delta\mathcal{E}^\circ - \frac{0.05916\text{V}}{n} \log Q$$

$$Q = \frac{(0.0030)^2}{(0.15)(0.20)^2} = 0.0015$$

$$\Delta\mathcal{E} = 0.298\text{V} - (-0.0835\text{V}) = 0.382\text{V}$$

- (c) What is the maximum work this cell can do?

$$W_{\text{rev}} = -nF\Delta\mathcal{E} = -2(96485\text{C/mol e}^-)(0.382\text{V}) = -73.6\text{kJ/mol}$$

- (d) Which electrode is the cathode and what is its sign?

Lead (+)

- (e) Calculate the equilibrium constant for the overall cell reaction.

$$\Delta\mathcal{E} = \Delta\mathcal{E}^\circ - \frac{0.05916\text{V}}{n} \log Q$$

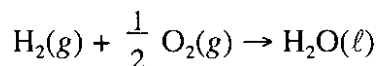
$$0 = \Delta\mathcal{E}^\circ - \frac{0.05916\text{V}}{n} \log K$$

$$K = 10^{\left(\frac{n\Delta\mathcal{E}^\circ}{0.05916\text{V}}\right)}$$

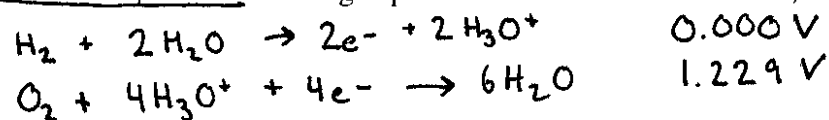
$$K = 10$$

$$K = 1.19 \times 10^{10}$$

2. (15 points) Consider the fuel cell that accomplishes the overall reaction



If the fuel cell operates with 60% efficiency, calculate the amount of electrical work generated per gram of water produced. The gas pressures are constant at 1 atm, and the temperature is 25°C.



$$w = \epsilon \cdot w_{\text{rev}} = \epsilon (-nF\Delta\epsilon)$$

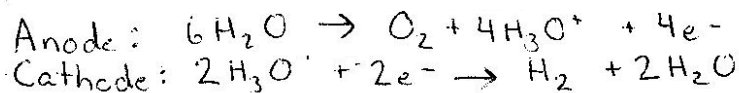
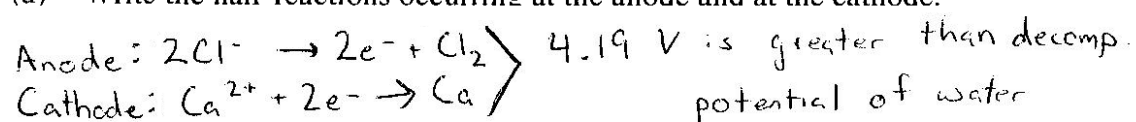
$$w = -(0.6)(2)(96485 \text{ C/mol e}^-)(1.229 \text{ V})$$

$$w = -142 \text{ kJ/mol} \left( \frac{\text{mol}}{18.02 \text{ g}} \right)$$

$$w = -7.88 \text{ kJ/g}$$

3. (15 points) A 0.100 M neutral aqueous  $\text{CaCl}_2$  solution is electrolyzed using platinum electrodes. A current of 1.50 A passes through the solution for 50.0 hours.

- (a) Write the half-reactions occurring at the anode and at the cathode.



- (b) What is the decomposition potential?

$$\Delta\epsilon^0 = 1.229 \text{ V}$$

- (c) Calculate the mass, in grams, of the product formed at the cathode.

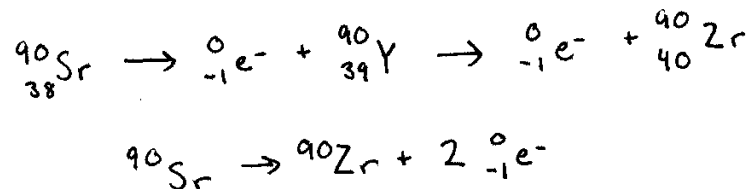
$$Q = nF$$

$$n = \frac{It}{F} = \frac{(1.50 \text{ A})(50.0 \text{ hr})(3600 \text{ s/hr})}{96485 \text{ C/mol e}^-} = 2.80 \text{ mol e}^-$$

$$m = 2.80 \text{ mol e}^- \left( \frac{1 \text{ mol H}_2}{2 \text{ mol e}^-} \right) \left( \frac{2.016 \text{ g H}_2}{\text{mol}} \right) = 2.82 \text{ g H}_2$$

4. (5 points each) Strontium-90 is one of the most hazardous products of atomic weapons testing because of its long half-life ( $t_{1/2} = 28.1$  years) and its tendency to accumulate in bone.

(a) Write nuclear equations for the decay of  $^{90}\text{Sr}$  via the successive emission of two beta particles.



(b) The atomic mass of  $^{90}\text{Sr}$  is 89.9073 u and that of  $^{90}\text{Zr}$  is 89.9043 u. Calculate the energy released per  $^{90}\text{Sr}$  atom, in MeV, in decaying to  $^{90}\text{Zr}$ .

$$\Delta m = {}_{40}^{90}\text{Zr} - {}_{38}^{90}\text{Sr} = -0.00300\text{u}$$

$$\Delta E = (-0.00300\text{u}) \left( \frac{931.49\text{ MeV}}{\text{u}} \right) \quad \left| \quad \begin{array}{l} \Delta m = -4.98 \times 10^{-30}\text{ kg} \\ \Delta E = \Delta mc^2 = -4.48 \times 10^{-13}\text{ J} \\ = -2.79\text{ MeV} \end{array} \right.$$

(c) What will be the initial activity of 1.0 g of  $^{90}\text{Sr}$  released into the environment, in disintegrations per second?

$$A = kN \quad k = \frac{\ln 2}{t_{1/2}} \quad N = \frac{m}{M} \cdot N_A$$

$$A = \frac{\ln 2}{28.1\text{ yr}} \left( \frac{1.0\text{ g}}{90\text{ g/mol}} \right) 6.022 \times 10^{23}\text{ mol}^{-1} = 1.65 \times 10^{20}\text{ yr}^{-1}$$

$$= 5.23 \times 10^{12}\text{ s}^{-1}$$

(d) What activity will the material from part (c) show after 100 years?

$$A_2 = A_1 e^{-kt} = (5.23 \times 10^{12}\text{ s}^{-1}) \exp\left(-100\text{ yr} \left(\frac{\ln 2}{28.1\text{ yr}}\right)\right)$$

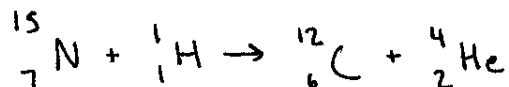
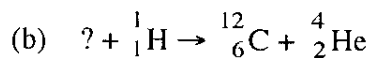
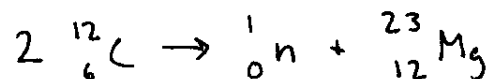
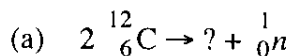
$$= 4.44 \times 10^{11}\text{ s}^{-1}$$

5. (5 points) The solar system abundances of the elements Li, Be, and B are four to seven orders of magnitude lower than those of the elements that immediately follow them: C, N, and O. Explain.

There is no synthetic route to Li, Be, and B in main sequence stars.

Most Li, Be, and B was created in trace amounts during the Big Bang.

6. (5 points each) Complete and balance the following equations for nuclear reactions that are thought to take place in stars:



## 7. (5 points each)

- (a) Explain why elements heavier than
- $^{56}\text{Fe}$
- are not synthesized in normal stars.

$^{56}\text{Fe}$  has the most stable nucleus (highest binding energy per nucleon). Producing heavier elements by fusion is endothermic.

- (b) Write the
- net
- equation for the fusion reaction that powers our sun.

