

1 (10 pts; 5 each) Briefly rationalize the following observations regarding the cosmic abundance of the elements:

- a) Even Z nuclei are more abundant than odd Z nuclei

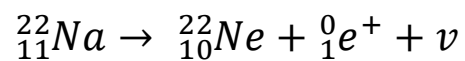
An even number of protons allows for spin pairing, which increases stability.

- b) In the lighter elements, those with mass number divisible by 4 are more abundant

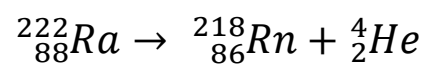
The helium nucleus ${}^4_2\text{He}$ is one of the main building blocks in nucleosynthesis. It is produced from hydrogen burning, and subsequent helium burning produces elements with mass number divisible by 4.

2. (10 pts; 5 each) Write balanced equations that represent the following nuclear reactions:

a) Positron emission by ${}_{11}^{22}\text{Na}$

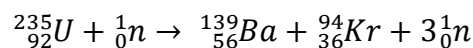


b) Alpha emission by ${}_{88}^{222}\text{Ra}$



3 (10 pts)

One fission reaction that takes place in nuclear reactors is:



Calculate the energy released (in joules) when 5.0 g of uranium-235 undergoes this reaction. Use the following masses:

$${}^{235}_{92}\text{U}: 235.04 \text{ u}, {}^{139}_{56}\text{Ba}: 138.91 \text{ u}, {}^{94}_{36}\text{Kr}: 93.93 \text{ u}, {}^1_0\text{n}: 1.0087 \text{ u}$$

$$\Delta m = m({}^{139}_{56}\text{Ba}) + m({}^{94}_{36}\text{Kr}) + 2 * m({}^1_0\text{n}) - m({}^{235}_{92}\text{U})$$

$$\Delta m = (138.91) + (93.93) + 2(1.0087) - (235.04) = -0.1826 \text{ u}$$

$$\Delta E = \Delta mc^2$$

$$\Delta E = (-0.1826 \text{ u}) * \left(\frac{2.997 \times 10^8 \text{ m}}{\text{s}}\right)^2 * \left(\frac{1.6605 \times 10^{-27} \text{ kg}}{\text{u}}\right) * 5.0 \text{ g } {}^{235}_{92}\text{U} * \left(\frac{1 \text{ mol}}{235.05 \text{ g } {}^{235}_{92}\text{U}}\right) * \left(6.02310^{23} \frac{\text{atoms}}{\text{mol}}\right) = -3.49 \times 10^{11} \text{ J}$$

$$\text{Energy released} = +3.49 \times 10^{11} \text{ J}$$

4 (10 pts)

A 250. mg sample of carbon from a piece of cloth excavated from an ancient tomb in Nubia undergoes 1.50×10^3 disintegrations in 10.0 h. If a current 1.00 g sample of carbon shows 921 disintegrations per hour, how old is the cloth?

$$A = A_0 e^{-kt}$$

$$\ln\left(\frac{A}{A_0}\right) = -kt$$

$$t = \frac{\ln\left(\frac{A_0}{A}\right)}{k} = \frac{t_{1/2} * \ln\left(\frac{A_0}{A}\right)}{\ln(2)}$$

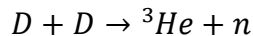
$$A = \frac{1.50 \times 10^3 \text{ dis.}}{10.0 \text{ h}} * \frac{1 \text{ h}}{3600 \text{ s}} * \frac{1}{0.250 \text{ g}} = 0.1667 \frac{\text{Bq}}{\text{g}}$$

$$A_0 = \frac{921 \text{ dis.}}{\text{h}} * \frac{1 \text{ h}}{3600 \text{ s}} * \frac{1}{1.00 \text{ g}} = 0.2558 \frac{\text{Bq}}{\text{g}}$$

$$t = \frac{5730 \text{ yrs} * \ln\left(\frac{0.2558 \frac{\text{Bq}}{\text{g}}}{0.1667 \frac{\text{Bq}}{\text{g}}}\right)}{\ln(2)} = 3540 \text{ yrs}$$

5 (10 pts).

Calculate the energy released per gram of starting material in the fusion reaction represented by the following equation:



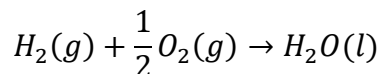
Use the following masses: D : 2.0141 u , ${}^3\text{He}$: 3.0160 u

$$\Delta m = m({}^3\text{He}) + m(n) - 2m(D) = (3.0160 \text{ } u) + (1.00866) - 2(2.0141) = -0.00354 \text{ } u$$

$$\begin{aligned} \Delta E &= -0.00354 \text{ } u * \left(\frac{2.997 \times 10^8 \text{ } m}{s} \right)^2 * \left(\frac{1.6605 \times 10^{-27} \text{ } kg}{u} \right) * \frac{1 \text{ } mol \text{ } D}{2.0141 \text{ } g \text{ } D} \\ &* \frac{6.022 \times 10^{23} \text{ } atoms}{mol} * \frac{1}{2 \text{ } atoms \text{ } D} = - \frac{7.89 \times 10^{10} \text{ } J}{g \text{ } D} \\ \Delta E &= + \frac{7.89 \times 10^{10} \text{ } J}{g \text{ } D} = + \frac{4.92 \times 10^{23} \text{ } MeV}{g \text{ } D} \end{aligned}$$

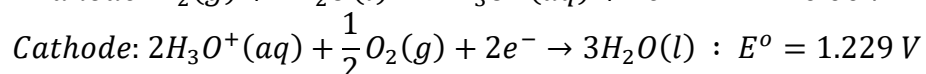
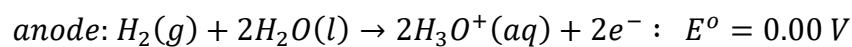
6 (10 PTS)

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.

$$w_{elec} = -Q\Delta E_{cell}^o$$

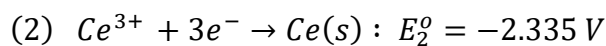
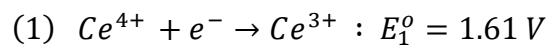
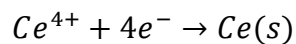


$$Q = nF = 1 g H_2O * \frac{\Delta E_{cell}^o = 1.229 V}{18.015 g H_2O} * \frac{2 mol e^-}{1 mol H_2O} * \frac{96486 C}{mol} = 1.0711 \times 10^4 C$$

$$w_{elec} = -(1.0711 \times 10^4 C) * (1.229 V) * \frac{60}{100} = -7898 J$$

$$\text{Work generated} = +7.90 \times 10^3 \frac{J}{g}$$

7 (15 PTS). Using the given standard reduction potentials, determine the standard potential for the reaction:



$$\Delta G = -nFE^{\circ}$$

$$\Delta G_3 = \Delta G_1 + \Delta G_2$$

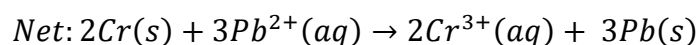
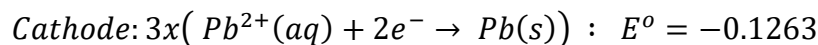
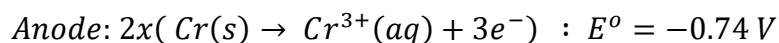
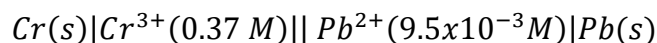
$$-nFE_3^{\circ} = -nFE_1^{\circ} - nFE_2^{\circ}$$

$$E_3^{\circ} = \frac{-nE_1^{\circ} - nE_2^{\circ}}{n} = \frac{(1 \text{ mol } e^{-})(1.61 \text{ V}) + (3 \text{ mol } e^{-})(-2.335 \text{ V})}{4 \text{ mol } e^{-}} = -1.35 \text{ V}$$

$$E_3^{\circ} = -1.35 \text{ V}$$

8 (15 pts).

Determine the potential for the following cell @ 25° C



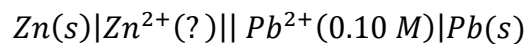
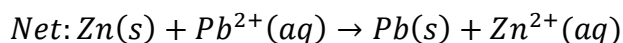
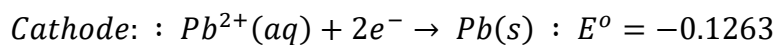
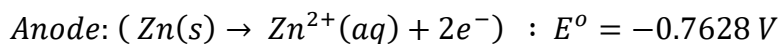
$$\Delta E_{\text{cell}}^{\circ} = E_{\text{cathode}}^{\circ} - E_{\text{anode}}^{\circ} = (-0.1263\text{ V}) + 0.74\text{ V} = 0.6137\text{ V}$$

$$\Delta E_{\text{cell}} = \Delta E_{\text{cell}}^{\circ} - \frac{0.0592}{n} \log \left(\frac{[\text{Cr}^{3+}]^2}{[\text{Pb}^{2+}]^3} \right) = 0.6137 - \frac{0.0592}{6\text{ mol } e^{-}} \log \frac{[0.37]^2}{[9.5\times 10^{-3}]^3}$$

$$\Delta E_{\text{cell}} = 0.562\text{ V}$$

9 (10 pts).

The potential for the cell @ 25° C

is +0.661 V. What is the concentration of Zn²⁺ ions??

$$\Delta E_{\text{cell}}^{\circ} = E_{\text{cathode}}^{\circ} - E_{\text{anode}}^{\circ} = (-0.1263\text{ V}) + 0.7628\text{ V} = 0.6365\text{ V}$$

$$E_{\text{cell}} = \Delta E_{\text{cell}}^{\circ} - \frac{0.0592}{n} \log \left(\frac{[\text{Zn}^{2+}]}{[\text{Pb}^{2+}]} \right)$$

$$0.661\text{ V} = 0.6365\text{ V} - \frac{0.0592}{n} \log \left(\frac{[\text{Zn}^{2+}]}{[0.10]} \right)$$

$$-\frac{2\text{ mol } e^{-} * (0.661 - 0.6365)\text{V}}{0.0591} = \log \left(\frac{[\text{Zn}^{2+}]}{[0.10]} \right)$$

$$0.10\text{ M} * 10^{-\frac{2\text{ mol } e^{-} * (0.661 - 0.6365)\text{V}}{0.0591}} = [\text{Zn}^{2+}]$$

$$[\text{Zn}^{2+}] = 0.0149\text{ M}$$