Chemistry 4B SP21 Exam II

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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 ${}^4_2He$ 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 ${}^{22}_{11}Na$

$$ {}^{22}_{11}Na \rightarrow {}^{22}_{10}Ne + {}^{0}_{1}e^{+} + v $$

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

$$ {}^{222}_{88}Ra \rightarrow {}^{218}_{86}Rn + {}^{4}_{2}He $$

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3 (10 pts)

One fission reaction that takes place in nuclear reactors is:

$$^{235}_{92}U + ^{1}_{0}n \rightarrow \; ^{139}_{56}Ba + ^{94}_{36}Kr + 3^{1}_{0}n$$

Calculate the energy released (in joules) when 5.0 g of uranium-235 undergoes this reaction. Use the following masses:
$^{235}_{92}U$: $235.04\ u$, $^{139}_{56}Ba$: $138.91\ u$, $^{94}_{36}Kr$: $93.93\ u$, $^{1}_{0}n$: $1.0087u$

$$\Delta m = m(^{139}_{56}Ba) + m(^{94}_{36}Kr) + 2 * m(^{1}_{0}n) - m(^{235}_{92}U)$$

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

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

$$\Delta E = (-0.1826\ u) * \left(\frac{2.997x10^{8}m}{s}\right)^2 * \left(\frac{1.6605x10^{-27}kg}{u}\right) * 5.0\ g\ ^{235}_{92}U * \left(\frac{1\ mol}{235.05\ g\ ^{235}_{92}U}\right) * \left(6.02310^{23}\frac{atoms}{mol}\right) = -3.49x10^{11}J$$

$$Energy\ released = +3.49x10^{11}J$$

4 (10 pts)

A 250. mg sample of carbon from a piece of cloth excavated from an ancient tomb in Nubia undergoes 1.50 x 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?

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

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

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

$$A = \frac{1.50x10^3 dis.}{10.0\ h} * \frac{1\ h}{3600\ s} * \frac{1}{0.250\ g} = 0.1667\ \frac{Bq}{g}$$

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

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

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5 (10 pts).
Calculate the energy released per gram of starting material in the fusion reaction represented by the following equation:

$$D + D \rightarrow {}^{3}He + n$$

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

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

$$\Delta E = -0.00354\ u * \left(\frac{2.997x10^{8}m}{s}\right)^{2} * \left(\frac{1.6605x10^{-27}kg}{u}\right) * \frac{1\ mol\ D}{2.0141\ g\ D} * \frac{6.022x10^{23}atoms}{mol} * \frac{1}{2\ atoms\ D} = -\frac{7.89x10^{10}J}{g\ D}$$

$$\Delta E = +\frac{7.89x10^{10}J}{g\ D} = +\frac{4.92x10^{23}MeV}{g\ D}$$

6 (10 PTS)
Consider the fuel cell that accomplishes the overall reaction:

$$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$$

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.

$$w_{elec} = -Q\Delta E^o_{cell}$$

$$anode: H_2(g) + 2H_2O(l) \rightarrow 2H_3O^+(aq) + 2e^- : \quad E^o = 0.00\, V$$
$$Cathode: 2H_3O^+(aq) + \frac{1}{2}O_2(g) + 2e^- \rightarrow 3H_2O(l) \; : \; E^o = 1.229\, V$$

$$\Delta E^o_{cell} = 1.229\, V$$
$$Q = nF = 1\ g\ H_2O * \frac{1\ mol\ H_2O}{18.015\ g\ H_2O} * \frac{2\ mol\ e^-}{1\ mol\ H_2O} * \frac{96486\ C}{mol} = 1.0711x10^4 C$$

$$w_{elec} = -(1.0711x10^4 C) * (1.229\ V) * \frac{60}{100} = -7898\, J$$

$$Work\ generated = +7.90x10^3 \frac{J}{g}$$

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

$$Ce^{4+} + 4e^{-} \rightarrow Ce(s)$$

$$(1)\quad Ce^{4+} + e^{-} \rightarrow Ce^{3+} \;:\; E_1^o = 1.61\,V$$

$$(2)\quad Ce^{3+} + 3e^{-} \rightarrow Ce(s) :\; E_2^o = -2.335\,V$$

$$\Delta G = -nFE^o$$

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

$$-nFE_3^o = -nFE_1^o - nFE_2^o$$

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

$$E_3^o = -1.35\,V$$

8 (15 pts).
Determine the potential for the following cell @ 25° C

$$Cr(s)|Cr^{3+}(0.37\ M)||\ Pb^{2+}(9.5x10^{-3}M)|Pb(s)$$

$$Anode: 2x(\ Cr(s) \rightarrow\ Cr^{3+}(aq) + 3e^{-})\ \ :\ E^{o} = -0.74\ V$$

$$Cathode: 3x\big(\ Pb^{2+}(aq) + 2e^{-} \rightarrow\ Pb(s)\big)\ :\ \ E^{o} = -0.1263$$

$$Net: 2Cr(s) + 3Pb^{2+}(aq) \rightarrow 2Cr^{3+}(aq) +\ 3Pb(s)$$

$$\Delta E^{o}_{cell} = E^{o}_{cathode} - E^{o}_{anode} = (-0.1263\ V) + 0.74\ V = 0.6137\ V$$

$$\Delta E_{cell} = \Delta E^{0}_{cell} - \frac{0.0592}{n}\log\left(\frac{[Cr^{3+}]^{2}}{[Pb^{2+}]^{3}}\right) = 0.6137 - \frac{0.0592}{6\ mol\ e^{-}}\,log\,\frac{[0.37]^{2}}{[9.5x10^{-3}]^{3}}$$

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

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9 (10 pts).
The potential for the cell @ 25° C

$$Zn(s)|Zn^{2+}(?)||\ Pb^{2+}(0.10\ M)|Pb(s)$$

is +0.661 V. What is the concentration of Zn^{2+} ions??

$$Anode: (\ Zn(s) \rightarrow\ Zn^{2+}(aq) + 2e^{-})\ \ :\ E^{o} = -0.7628\ V$$

$$Cathode:\ :\ Pb^{2+}(aq) + 2e^{-} \rightarrow\ Pb(s)\ :\ E^{o} = -0.1263$$

$$Net: Zn(s) + Pb^{2+}(aq) \rightarrow Pb(s) + Zn^{2+}(aq)$$

$$\Delta E^{o}_{cell} = E^{o}_{cathode} - E^{o}_{anode} = (-0.1263\ V) + 0.7628\ V = 0.6365\ V$$

$$E_{cell} = \Delta E^{0}_{cell} - \frac{0.0592}{n}\log\left(\frac{[Zn^{2+}]}{[Pb^{2+}]}\right)$$

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

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

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

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