Chemistry 210 Exam 4

Be sure to put your name on each page. This page can be removed from your exam so that you will have a Periodic Table handy throughout the exam, it does not need to be turned in. Show all your work for problems which require any sort of calculation, no credit will be given for answers without work shown. If you have shown a significant amount of work or multiple drawings for a problem, draw a box around what you consider your final answer.

Avogadro's Number = 6.022×10^{23} $^{units}/_{mol}$
$32.00^{o}F = 0.000^{o}C = 273.15K$
Density of Water = $1.000\,^{g}/_{mL}$
$R = 0.08206\ ^{L\bullet atm}/_{mol\bullet K} = 8.314\ ^{J}/_{mol\bullet K}$
$PV=nRT$
$\Delta T_{fp/bp} = k_{fp/bp}\bullet m\bullet i$
For water: $k_{fp} = -1.86\,^{oC}/_{m}$
$k_{bp} = 0.512\,^{oC}/_{m}$
$P_1 = X_1 P_1^{o}$
$\Pi = MRTi$
$C_1V_1 = C_2V_2$
Quadratic formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Integrated Rate Laws:
- 0^{th} order $[A]_t = -kt + [A]_o$
- 1^{st} order $\ln[A]_t = -kt + \ln[A]_o$
- 2^{nd} order $1/[A]_t = kt + 1/[A]_o$

$k = Ae^{-Ea/RT}$

$$\ln(k) = \left(\frac{-E_a}{R}\right)\left(\frac{1}{T}\right) + \ln(A)$$

$$\ln\left(\frac{k_1}{k_2}\right) = \frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$pH = pK_a + \log\left(\frac{[\text{conjugate base}]}{[\text{conjugate acid}]}\right)$$

$E_{cell} = E^{o}_{cell} - \,^{RT}/_{nF}\, ln Q$
$E^{o}_{cell} = \,^{RT}/_{nF}\, ln K^{o}$
$K^{o} = e\wedge(\,^{nF}/_{RT}\, E^{o}_{cell})$
$F = 96485\ ^{J}/_{V\bullet mol\ of\ electrons}$
$\Delta G^{o} = \Delta H^{o}_{system} - T\Delta S^{o}_{system}$
$\Delta G^{o} = -nFE^{o}_{cell} = -RT ln K^{o}$
$\Delta G = \Delta G^{o} + RT ln Q$
$F = 96485\ ^{C}/_{mol\ electrons}$
1A = 1 C / sec

1 **H** 1.0079																	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305											13 **Al** 26.982	14 **Si** 28.086	15 **P** 30.974	16 **S** 32.066	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.88	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.847	27 **Co** 58.933	28 **Ni** 58.69	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.922	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.03	89 **Ac** 227.03	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 (269)	111 (272)	112 (277)		114		116		

58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.94	70 **Yb** 173.04	71 **Lu** 174.97
90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** 237.05	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (258)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Score

Multiple Choice (5pts each): Circle the letter of the most correct response.

1. A reaction will be product-favored/spontaneous if:
   a. $\Delta G^o < 0$
   b. $K_{eq} < 1$
   c. $\Delta H > 0$
   d. $\Delta S^o < 0$
   e. $E°_{cell} < 0$

2. In a spontaneous electrochemical voltaic cell, which of the following is ***true***?
   a. The cell potential is zero
   b. Oxidation occurs at the cathode
   c. Electrons flow from the cathode to the anode
   d. Cations flow through the salt bridge from the cathode to the anode
   e. The metal cathode gains mass as the cell reaction proceeds

3. For a spontaneous redox reaction, which of the following is ***false***?
   a. Oxidation is the process of losing electrons
   b. Gaining electrons is reduction
   c. Electrons appear on the left side of the oxidation half reaction
   d. Water molecules are added to balance any extra oxygen atoms
   e. ΔG is negative.

4. How are the change in Gibb's Free Energy and the equilibrium constant for a reaction related?
   a. As K approaches zero, ΔG approaches zero
   b. They're not.
   c. The value of ΔG is equal to (-logK)
   d. As ΔG gets more positive, K approaches 1
   e. As ΔG gets more negative, K gets very large

5. Which of the following types of nuclear radiation consists of the *heaviest* particles?
   a. α-radiation ("alpha" radiation)
   b. β-radiation ("beta" radiation)
   c. γ-radiation("gamma" radiation)
   d. None of these, all nuclear radiation has the same mass

Problems:

6. Give the oxidation number for each atom in the following formulas. (8pts each formula)

Na_3PO_3

Oxidation Numbers:
Na = +1
P = +3
O = -2

$HOCH_2CH_2OH$

Oxidation Numbers:
H = +1
O = -2
C = -1

Score

7. The halogens (F_2, Cl_2, Br_2, I_2) all appear in your Standard Reduction Potential tables in half-cells of the type:

$$X_2 + 2\,e^- \rightarrow 2\,X^{-1}$$

Explain the trend in $E°_{red}$ for these halogens. (10 pts)

As we move *down* the Periodic Table, $E°_{red}$ for the half-cell gets *less positive* which is less spontaneous.
As we move *down* the Periodic Table, the halogens get *bigger*.
Reduction is gaining electrons, so any species that is undergoing reduction must be able to attract additional electrons. As the halogens get larger, the attraction for additional electrons decreases (Coulomb's Law, effective nuclear charge, shielding effects), so the reduction becomes less spontaneous, so the $E°_{red}$ should get less positive.

8. For each of the following pairs of half-reactions/half-cells, determine the voltage of the spontaneous reaction/cell and write a balanced equation for the spontaneous reaction, identifying the oxidation and reduction half-reactions. (12pts each)

$Cr^{3+}(aq)|Cr(s)$ and $Sn^{4+}(aq)|\ Sn^{2+}(aq)$

Oxidation:	$2\ (\ Cr(s) \Leftrightarrow Cr^{+3}(aq) + 3e^-\ )$	$E°_{ox} =$ +0.74V
Reduction:	$3\ (\ 2e^- + Sn^{+4}(aq) \Leftrightarrow Sn^{+2}(aq)\ )$	$E°_{red} =$ +0.13V
Net Reaction:	$2\ Cr(s) + 3\ Sn^{+4}(aq) \Leftrightarrow 3\ Sn^{+2}(aq) + 2\ Cr^{+3}(aq)$	$E°_{cell} =$ +0.87V

$Al^{3+}(aq)|Al(s)$ and $O_2(g)|H_2O(l)$

Oxidation:	$4\ (\ Al(s) \Leftrightarrow Al^{+3}(aq) + 3e^-\ )$	$E°_{ox} =$ +1.66V
Reduction:	$3\ (\ 4H^+(aq) + 4e^- + O_2(g) \Leftrightarrow 2\ H_2O(l)\ )$	$E°_{red} =$ +1.23V
Net Reaction:	$12\ H^+(aq) + 4\ Al(s) + 3\ O_2(g) \Leftrightarrow 6\ H_2O(l) + 4\ Al^{+3}(aq)$	$E°_{cell} =$ +2.89V

$PbO_2(s)|Pb(s)$ and $MnO_4^{-1}(aq)|Mn^{+2}(aq)$

Oxidation:	$4\ (\ 4\ H_2O(l) + Mn^{+2}(aq) \Leftrightarrow MnO_4^{-1}(aq) + 5e^- + 8\ H^+(aq)\ )$	$E°_{ox} =$ -1.51V
Reduction:	$5\ (\ 4\ H^+(aq) + 4e^- + PbO_2(s) \Leftrightarrow Pb(s) + 2\ H_2O(l)\ )$	$E°_{red} =$ +1.93V
Rxn:	$20\ H^+(aq) + 16\ H_2O(l) + 4\ Mn^{+2}(aq) + 5\ PbO_2(s) \Leftrightarrow 5\ Pb(s) + 4\ MnO_4^{-1}(aq) + 32\ H^+(aq) + 10\ H_2O(l)$	$E°_{cell} =$ +0.42V
Net Rxn:	$6\ H_2O(l) + 4\ Mn^{+2}(aq) + 5\ PbO_2(s) \Leftrightarrow 5\ Pb(s) + 4\ MnO_4^{-1}(aq) + 12\ H^+(aq)$	$E°_{cell} =$ +0.42V

Score

9. After a strong storm, you are without electricity and would like to construct a flashlight from some materials you have found in your garage. You have a lightbulb that will produce light if you apply a voltage greater than 1.6 V. You have found the following materials: a gold (Au) necklace, a nickel (Ni) coin, a lead (Pb) pipe, an aluminum (Al) can , gold(III) nitrate, nickel(II) chloride, lead(II) nitrate, and aluminum(III) chloride What cell(s) can you construct to power your flashlight? Explain your choice(s). (15 pts)

Possible half-cells: $Au^{+3}|Au$ ($E°_{red}$ = +1.50V); $Ni^{+2}|Ni$ ($E°_{red}$ = -0.28V); $Pb^{+2}|Pb$ ($E°_{red}$ = -0.126V); $Al^{+3}|Al$ ($E°_{red}$ = -1.66V)
The sign has to change on the potential of the oxidation half-cell, so the $Au^{+3}|Au$ half-cell will always be the reduction half in this system (the cathode). Coupling the gold cathode with any of the other half-cells as anode will give >+1.6V assuming standard conditions.

$Al|Al^{+3}||Au^{+3}|Au$ $E°_{cell}$ = +1.66V + 1.50V = +3.16V
$Ni|Ni^{+2}||Au^{+3}|Au$ $E°_{cell}$ = +0.28V + 1.50V = +1.78V
$Pb|Pb^{+2}||Au^{+3}|Au$ $E°_{cell}$ = +0.126V + 1.50V = +1.63V

10. You would like to plate some platinum onto a small piece of jewelry. If you submerge the jewelry in 0.761M $Pt(NO_3)_2$(aq) and pass 1.382amperes through the solution for 1.85 minutes, how many grams of Pt will have plated onto the piece of jewelry? (12 pts)

$2e^- + Pt^{+2}(aq) \Leftrightarrow Pt(s)$
(1.382C/sec)(1.85min)(60sec/min)(1mol e^-/96485C)(1mol Pt/2mol e^-)(195.08g Pt/mol Pt) = 0.155g Pt(s)

11. Americium is a non-naturally occurring element with an atomic number of 95. The rate law constant for the nuclear decay of Americium is $1.91x10^{-7}$ sec^{-1}. What is the half-life of this process (12 pts)

Plugging in to the 1st order integrated rate law expression…
$\ln (x/2) = -kt + \ln x$
$\ln (1/2) = -(1.91x10^{-7}\ sec^{-1})t_{1/2}$
$t_{1/2}$ = 3630000 seconds = 60500 minutes = 1010 hours = 42.0 days

Score

12. The half-life of ^{14}C is 5730 years. If a 13.63kg sample of ^{14}C is allowed to naturally decay for 18295 years, how much ^{14}C will remain in the sample? (12 pts)

18295 / 5730 = 3.1928 half-lives will pass, so

$(13.63kg)(1/2)^{3.1928}$ = 1.491kg ^{14}C will remain

13. If mendelevium, ^{258}Md, undergoes alpha decay *twice*, what is the product of the reaction. (12 pts)

During alpha decay, the equivalent of a helium nucleus is ejected from the nucleus.
The first alpha decay will be:

$${}^{258}_{101}Md \rightarrow {}^{4}_{2}He + {}^{254}_{99}Es$$

The second alpha decay will be:

$${}^{254}_{99}Es \rightarrow {}^{4}_{2}He + {}^{250}_{97}Bk$$

Standard Reduction Potentials at 25°C:

Half cell	E^o_{red} (volts)
$F_2\|F^{-1}$	+2.87
$Cl_2\|Cl^{-1}$	+1.359
$Br_2\|Br^{-1}$	+1.065
$I_2\|I^{-1}$	+0.536
$Cr^{3+}\|Cr$	-0.74
$Sn^{4+}\|Sn^{2+}$	+0.13
$Al^{3+}\|Al$	-1.66
$O_2\|H_2O$	+1.23

Half cell	E^o_{red} (volts)
$PbO_2\|Pb$	+1.93
$MnO_4^{-1}\|Mn^{+2}$	+1.51
$Au^{+3}\|Au$	+1.50
$Ni^{2+}\|Ni$	-0.28
$Pb^{+2}\|Pb$	-0.126
$Pt^{+2}\|Pt$	+1.188

Score