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 = $6.022\text{x}10^{23}\ ^{\text{units}}/_{\text{mol}}$
$32.00^{o}\text{F} = 0.000^{o}\text{C} = 273.15\text{K}$
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: $k_{fp} = -1.86\ ^{^oC}/_{m}$
$k_{bp} = 0.512\ ^{^oC}/_{m}$
$P_1 = X_1P_1^{o}$
$\Pi = MRTi$
$C_1V_1 = C_2V_2$
Quadratic formula:

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

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

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

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

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

$E_{cell} = E^{o}_{cell} - {}^{RT}/_{nF}\ lnQ$
$E^{o}_{cell} = {}^{RT}/_{nF}\ lnK^{o}$
$K^{o} = e\wedge({}^{nF}/_{RT}\ E^{o}_{cell})$
$F = 96485\ ^{J}/_{V\bullet \text{mol of electrons}}$
$\Delta G^{o} = \Delta H^{o}_{system} - T\Delta S^{o}_{system}$
$\Delta G^{o} = -nFE^{o}_{cell} = -RTlnK^{o}$
$\Delta G = \Delta G^{o} + RTlnQ$
$F = 96485\ ^{C}/_{\text{mol electrons}}$
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 (4pts each): Circle the letter of the most correct response.

1. A large negative change in free energy means:
   a. The reaction is very slow
   b. The reaction is exothermic
   c. The reaction is not spontaneous
   d. The system is becoming more disordered
   e. The reaction is spontaneous

2. For a reaction with a small negative ΔS:
   a. Heat is liberated by the reaction
   b. The system is becoming more ordered
   c. The reaction is not spontaneous
   d. The temperature of the system is increasing
   e. The reaction proceeds very quicky

3. 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. $E°_{cell} < 0$

4. A reaction will be spontaneous at relatively high temperature and non-spontaneous at relatively low temperature if:
   a. $\Delta H^o_{system} > 0$ and $\Delta S^o_{system} > 0$
   b. $\Delta H^o_{system} < 0$ and $\Delta S^o_{system} > 0$
   c. $\Delta H^o_{system} > 0$ and $\Delta S^o_{system} = 0$
   d. $\Delta H^o_{system} > 0$ and $\Delta S^o_{system} < 0$
   e. $\Delta H^o_{system} < 0$ and $\Delta S^o_{system} < 0$

5. 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

6. 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.

7. 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

Score

Problems:

8. For each of the following reactions, predict the sign of $\Delta S°$ and explain your answer (5pts each):

$$H_2SO_4(aq) + Mg(OH)_2(aq) \Leftrightarrow MgSO_4(s) + 2\ H_2O(l)$$

$$2\ NO_2(g) \Leftrightarrow 2\ NO(g) + O_2(g)$$

9. Give the oxidation number for each atom in the following formulas. (5pts each formula)

K_2SO_3 CH_3OH

10. You are studying the reaction of acetic acid $\{CH_3CO_2H(l)\}$ with iso-propanol $\{C_3H_8O(l)\}$ to produce isopropylacetate $\{C_5H_{10}O_2(l)\}$ and water. When you run the reaction at 22.67ºC, you find that ΔG for this reaction is $-35.19\ ^{kJ}/_{mol}$ and $\Delta S = +79.18\ ^{J}/_{mol\bullet K}$ (10pts)
    a. Is the reaction endothermic or exothermic? (*Explain your answer with explicit calculations.*)
    b. Over what temperature range is this reaction spontaneous?

11. The alkaline earth metals (Be, Mg, Ca, Sr, Ba) all appear in your Standard Reduction Potential tables in half-cells of the type:

$$M^{+2}(aq) + 2\ e^- \rightarrow M(s)$$

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

Score

12. You are studying a process for which $\Delta H° = +30.71\,{}^{kJ}/_{mol}$ and $\Delta S° = +192.44\,{}^{J}/_{mol \bullet K}$. What is $\Delta G°$ for this process at 25.00°C? Will the reaction be more or less spontaneous at 20.00°C? (8pts)

13. Ammonia {$NH_3(g)$} can burn in oxygen to form nitrogen dioxide and water. How much {Gibb's Free} energy can be liberated by burning 15.772g of ammonia in an unlimited supply of oxygen? (10pts)

14. 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. (10pts each)

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

    $Al^{3+}(aq)|Al(s)$ and $F_2(g)|F^{-1}(aq)$

    $PbO_2(s)|Pb(s)$ and $Cr_2O_7^{-2}(aq)|Cr^{3+}(aq)$

Score

15. 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 0.80 V. You have found the following materials: a box of iron (Fe) nails, a silver (Ag) necklace, $Fe(NO_3)_3$, $FeSO_4$, and $AgNO_3$. What cell(s) can you construct to power your flashlight? Explain your choices. (12 pts)

16. How many grams of ethane $\{C_2H_6(g)\}$ would you have to burn to liberate enough Gibb's Free Energy to break 14.227g of CaO(s) into Ca(s) and $O_2(g)$? (Assume 100% efficiency.) (12 pts)

17. When nitrogen gas and oxygen gas are sealed in a vessel, reactions occur that generate $N_2O_4(g)$ and $N_2O_5(g)$. If these are the only products, and ΔG^o is the only factor that affects the composition of this mixture, which of these products would you expect to be present in higher quantity at the end of the reaction? (Explain your answer with explicit calculations/numbers.) (10 pts)

Score

Thermodynamic Values at 25°C:

Substance	ΔH^o_f ($^{kJ}/_{mol}$)	S^o ($^{J}/_{mol\bullet K}$)	ΔG^o_f ($^{kJ}/_{mol}$)
$NH_3(g)$	-46.11	+192.45	-16.45
$O_2(g)$	0	+205.138	0
$NO_2(g)$	+33.18	+240.06	+51.31
$H_2O(g)$	-241.8	+188.8	-228.6
$H_2O(l)$	-285.8	+69.91	-237.2
$C_2H_6(g)$	-84.68	+229.2	-32.0
$CO_2(g)$	-393.5	+213.6	-394.4
$CaO(s)$	-635.1	+39.75	-604.0
$Ca(s)$	0	+41.4	0
$N_2O_4(g)$	+9.16	+304.2	-81.7
$N_2O_5(g)$	+11.3	+355.6	-94.4

Standard Reduction Potentials at 25°C:

Half cell	E^o_{red} (volts)		Half cell	E^o_{red} (volts)
$Au^{3+}(aq)\|Au(s)$	-1.50		$Be^{+2}(aq)\|Be(s)$	-1.97
$Sn^{4+}(aq)\| Sn^{2+}(aq)$	+0.15		$Mg^{+2}(aq)\|Mg(s)$	-2.36
$Al^{3+}(aq)\|Al(s)$	-1.676		$Ca^{+2}(aq)\|Ca(s)$	-2.84
$F_2(g)\|F^{-1}(aq)$	+2.87		$Sr^{+2}(aq)\|Sr(s)$	-2.89
$PbO_2(s)\|Pb(s)$	+1.93		$Ba^{+2}(aq)\|Ba(s)$	-2.92
$Cr_2O_7^{-2}(aq)\|Cr^{3+}(aq)$	+1.33		$Fe^{2+}(aq)\|Fe(s)$	-0.44
$Fe^{3+}(aq)\|Fe(s)$	-0.04		$Ag^{+}(aq)\|Ag(s)$	+0.799

Score