Name: _____

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} $^{\text{units}}/_{\text{mol}}$
$32.00^{\circ}F = 0.000^{\circ}C = 273.15K$
Density of Water = $1.000\ ^{g}/_{mL}$
$R = 0.08206\ ^{L \cdot atm}/_{mol \cdot K} = 8.314\ ^{J}/_{mol \cdot K}$
$PV=nRT$
$\Delta T_{fp/bp} = k_{fp/bp} \cdot m \cdot i$
For water: $k_{fp} = -1.86\ ^{^{\circ}C}/_{m}$
$k_{bp} = 0.512\ ^{^{\circ}C}/_{m}$
$P_1 = X_1 P_1^{\circ}$
$\Pi = MRTi$
$C_1V_1 = C_2V_2$
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 $1/[A]_t = kt + 1/[A]_o$

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

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

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

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

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

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)

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 order 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 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.

Score

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

Problems:

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

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

Negative. Aqueous solutions are significantly more disordered than solids and more disordered than pure solvent.

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

Positive. Two gas particles are reacting to form three gas particles, so this system is probably getting more disordered.

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

Na_3PO_4

Na → +1
P → +5
O → -2

CH_3OH

C → -2
H → +1
O → -2

10. Ammonia {$NH_3(g)$} can burn in oxygen to form nitrogen dioxide and water. How much energy can be liberated by burning 21.964g of ammonia in an unlimited supply of oxygen? (20pts)

$$4\,NH_3(g) + 7\,O_2(g) \rightarrow 4\,NO_2(g) + 6\,H_2O(g)$$
$$4(16.45^{kJ}/_{mol}) + 7(0^{kJ}/_{mol}) + 4(51.31^{kJ}/_{mol}) + 6(-228.6^{kJ}/_{mol}) = -1100.56^{kJ}/_{mol})$$
$$(21.964g\,NH_3)\left(\frac{1mol\,NH_3}{17.031g\,NH_3}\right)\left(\frac{1mol\,rxn}{4mols\,NH_3}\right)\left(\frac{1100.56kJ}{1mol\,rxn}\right) = 354.84kJ\,liberated$$

11. You would like to plate 4.38g of chromium (atomic # = 24) using an electrolytic cell containing a solution of chromium(III) nitrate and operating at 2.37A. How long will you have to run the cell? (20pts)

$$Cr^{3+}(aq) + 3\,e^- \rightarrow Cr(s)$$
$$(4.38g\,Cr)\left(\frac{1mol\,Cr}{51.996g\,Cr}\right)\left(\frac{3\,mol\,e^-}{1\,mol\,Cr}\right)\left(\frac{96485C}{1mol\,e^-}\right)\left(\frac{1\,sec}{2.37C}\right) = 10300\,sec = 171\,minutes = 2.86\,hours$$

Score

12. 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 $-27.39^{kJ}/_{mol}$ and ΔS = $+34.18\ ^{J}/_{mol\cdot K}$ (20pts)
    a. Is the reaction endothermic or exothermic? (*Explain your answer with explicit calculations.*)

$$\Delta G = \Delta H - T\Delta S$$
$$-27.39^{kJ}/_{mol} = \Delta H - (22.67+273.15K)(0.03418^{kJ}/_{mol\cdot K})$$
$$\Delta H = -17.28^{kJ}/_{mol}$$

Since ΔH is negative, the reaction is exothermic

    b. Over what temperature range is this reaction spontaneous?

Since ΔH is negative and ΔS is positive, this reaction will be spontaneous at all temperatures.

13. 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 reaction that occurs, identifying the oxidation and reduction half-reactions. (18pts each)

$Au^{3+}(aq)|Au(s)$ and $Br_2(l)|Br^{-1}(aq)$

From the standard reduction potentials, bromide ion will be oxidized in the spontaneous cell.

$$2\ (\ 3\ e^- + Au^{+3}(aq) \rightarrow Au(s)\ ) \qquad E°_{red} = +1.50V$$
$$3\ (\ 2\ Br^{-1}(aq) \rightarrow Br_2(l) + 2\ e^-\ ) \qquad E°_{ox} = -1.09V$$
$$2\ Au^{+3}(aq) + 6\ Br^{-1}(aq) \rightarrow 3\ Br_2(l) + 2\ Au(s) \qquad E°_{cell} = +0.41V$$

$MnO_2(s)|Mn^{2+}(aq)$ and $Cr_2O_7^{-2}(aq)|Cr^{3+}(aq)$

From the standard reduction potentials, manganese(II) ion will be oxidized in the spontaneous cell.

$$14\ H^+(aq) + 6\ e^- + Cr_2O_7^{-2}(aq) \rightarrow 2\ Cr^{+3}(aq) + 7\ H_2O(l)\ ) \qquad E°_{red} = +1.33V$$
$$3\ (\ 2\ H_2O(l) + Mn^{+2}(aq) \rightarrow MnO_2(s) + 2\ e^- + 4\ H^+(aq)\ ) \quad E°_{ox} = -1.21V$$
$$2\ H^+(aq) + 3\ Mn^{+2}(aq) + Cr_2O_7^{-2}(aq) \rightarrow 3\ MnO_2(s) + 2\ Cr^{+3}(aq) + H_2O(l) \qquad E°_{cell} = +0.12V$$

Thermodynamic Values at 25ºC:

Substance	$\Delta H°_f$ ($^{kJ}/_{mol}$)	$S°$ ($^{J}/_{mol\cdot K}$)	$\Delta G°_f$ ($^{kJ}/_{mol}$)
$NH_3(g)$	-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

Standard Reduction Potentials at 25ºC:

Half cell	$E°_{red}$ (volts)	Half cell	$E°_{red}$ (volts)
$Cr^{3+}(aq)|Cr(s)$	-0.74	$MnO_2(s)|Mn^{2+}(aq)$	+1.21
$Au^{3+}(aq)|Au(s)$	+1.50	$Cr_2O_7^{-2}(aq)|Cr^{3+}(aq)$	+1.33
$Br_2(l)|Br^{-1}(aq)$	+1.09		

Score