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 = $6.022\times10^{23}\ ^{units}/_{mol}$
$32.00^oF = 0.000^oC = 273.15K$
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, $k_{fp} = -1.86\ ^{oC}/_{m}$; $k_{bp} = 0.52\ ^{oC}/_{m}$
$P_1 = X_1P_1^o$
$\Pi = MRTi$
$C_1V_1 = C_2V_2$
Quadratic formula:
$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

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

$k = Ae^{-Ea/RT}$
$$\ln(k) = \left(\frac{-E_a}{R}\right)\left(\frac{1}{T}\right) + \ln(A)$$
$$\ln\left(\frac{k_1}{k_2}\right) = \frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$
$$pH = pK_a + \log\left(\frac{[\text{conjugate base}]}{[\text{conjugate acid}]}\right)$$

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

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 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 disorder of the system is increasing
    e. The reaction proceeds very quickly

3. If the change in enthalpy for a reaction is positive and the change in entropy is negative:
    a. The system is becoming more disordered
    b. The reaction releases heat
    c. The reaction will be spontaneous at all temperatures
    d. The reaction will be non-spontaneous at all temperatures
    e. The reaction will be spontaneous only at low temperatures

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

5. 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. The value of ΔG is equal to (-logK)
    c. As ΔG gets more positive, K approaches 1
    d. They're not.
    e. As ΔG gets more negative, K gets very large

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

K_2SO_3	CO_2	CH_4
K → +1 S → +4 O → -2	C → +4 O → -2	C → -4 H → +1

Score

7. For each of the following reactions, predict whether the sign if ΔS° will be positive or negative and explain your answer. (12pts)

$$Pb(NO_3)_2(aq) + 2\ NaCl(aq) \leftrightarrows PbCl_2(s) + 2\ NaNO_3(aq)$$

Negative. Aqueous solutions are forming a solid so the disorder of the system is decreasing.

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

Positive. Two gas particles are forming three gas particles so the system is becoming more disordered.

8. For liquid water S° = +69.91 $^{J}/_{mol\cdot K}$ and for gaseous water S° = +188.825 $^{J}/_{mol\cdot K}$. Explain this difference. (10pts)

Gases are more disordered than liquids {for the same substance}. S° is a measure of the disorder of a system or substance, so the value of S° for gaseous water should be higher than the value of S° for liquid water.

9. Methane, $CH_4(g)$, burns in oxygen to form carbon dioxide and water. How much energy is released during the formation of 21.95g of water by this reaction? (20pts)

$$CH_4(g) + 2\ O_2(g) \Leftrightarrow CO_2(g) + 2\ H_2O(g)$$

$$\Delta G^\circ_{rxn} = 1(50.8\,^{kJ}/_{mol}) + 2(0\,^{kJ}/_{mol}) + 1(-394.359\,^{kJ}/_{mol}) + 2(-228.572\,^{kJ}/_{mol}) = -800.7\,^{kJ}/_{mol}$$

$$E = (21.95g\ H_2O(g))\ (1mol\ H_2O / 18.015g\ H_2O)\ (1mol\ rxn / 2mol\ H_2O)\ (800.7kJ / mol\ rxn) = 487.8kJ$$

$$CH_4(g) + 2\ O_2(g) \Leftrightarrow CO_2(g) + 2\ H_2O(l)$$

$$\Delta G^\circ_{rxn} = 1(50.8\,^{kJ}/_{mol}) + 2(0\,^{kJ}/_{mol}) + 1(-394.359\,^{kJ}/_{mol}) + 2(-237.129\,^{kJ}/_{mol}) = -817.8\,^{kJ}/_{mol}$$

$$E = (21.95g\ H_2O(l))\ (1mol\ H_2O / 18.015g\ H_2O)\ (1mol\ rxn / 2mol\ H_2O)\ (817.8kJ / mol\ rxn) = 498.2kJ$$

10. You are studying the reaction of benzoic acid {$C_6H_5CO_2H(s)$} with methanol {$CH_3OH(l)$} to produce methylbenzoate {$C_8H_8O_2(l)$} and water. When you run the reaction at 17.61°C, you find that ΔG for this reaction is -47.92 $^{kJ}/_{mol}$ and ΔS = +34.18 $^{J}/_{mol\cdot K}$ (20pts)
   a. Is the reaction endothermic or exothermic? (*Explain your answer with explicit calculations.*)
   b. Over what temperature range is this reaction spontaneous?

W could write a balanced equation for this problem, but we don't need one. We can just plug into

$$\Delta G = \Delta H - T\Delta S$$

$$(-47.92\,^{kJ}/_{mol}) = \Delta H - (17.61+273.15K)(0.03418\,^{kJ}/_{mol\cdot K})$$

$$\Delta H = -37.98\,^{kJ}/_{mol} \rightarrow \text{exothermic}$$

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

Score

11. You have burned 65.95g of ethane {$C_2H_6(g)$} in oxygen to form carbon dioxide and water. If all of the Gibb's Free Energy liberated by this reaction is used to decompose iron(III) chloride to iron metal and chlorine gas, how many grams of iron metal will be formed? (25pts)

$$2\,C_2H_6(g) + 7\,O_2(g) \Leftrightarrow 4\,CO_2(g) + 6\,H_2O(g)$$

$$\Delta G^\circ_{rxn} = 2(32.89\,^{kJ}/_{mol}) + 7(0\,^{kJ}/_{mol}) + 4(-394.359\,^{kJ}/_{mol}) + 6(-228.572\,^{kJ}/_{mol}) = -2883.09\,^{kJ}/_{mol}$$

$$E = (65.95g\ C_2H_6(g))\ (1mol\ C_2H_6 / 30.069g\ C_2H_6)\ (1mol\ rxn / 2mol\ C_2H_6)\ (2883.09kJ / mol\ rxn) = 3161.7kJ$$

$$2\,C_2H_6(g) + 7\,O_2(g) \Leftrightarrow 4\,CO_2(g) + 6\,H_2O(l)$$

$$\Delta G^\circ_{rxn} = 2(32.89\,^{kJ}/_{mol}) + 7(0\,^{kJ}/_{mol}) + 4(-394.359\,^{kJ}/_{mol}) + 6(-237.129\,^{kJ}/_{mol}) = -2934.43\,^{kJ}/_{mol}$$

$$E = (65.95g\ C_2H_6(g))\ (1mol\ C_2H_6 / 30.069g\ C_2H_6)\ (1mol\ rxn / 2mol\ C_2H_6)\ (2934.43kJ / mol\ rxn) = 3218.0kJ$$

$$2\,FeCl_3(s) \Leftrightarrow 2\,Fe(s) + 3\,Cl_2(g)$$

$$\Delta G^\circ_{rxn} = 2(334.18\,^{kJ}/_{mol}) + 2(0\,^{kJ}/_{mol}) + 3(0\,^{kJ}/_{mol}) = 668.36\,^{kJ}/_{mol}$$

$$g\ Fe(s) = (3161.8kJ)\ (1mol\ rxn / 668.36kJ)\ (2mol\ Fe(s) / 1mol\ rxn)\ (55.847g\ Fe / 1mol\ Fe) = 528.4g\ Fe(s)$$

$$g\ Fe(s) = (3218.0kJ)\ (1mol\ rxn / 668.36kJ)\ (2mol\ Fe(s) / 1mol\ rxn)\ (55.847g\ Fe / 1mol\ Fe) = 537.8g\ Fe(s)$$

12. For each of the following ***unbalanced*** chemical reactions, identify and write the oxidation and reduction half-reactions, and write the balanced redox reaction. (25pts)

$$Ce^{4+}(aq) + Al(s) \Leftrightarrow Ce^{3+}(aq) + Al^{3+}(aq)$$

Oxidation: $Al(s) \Leftrightarrow Al^{3+}(aq) + 3e^-$

Reduction: $3\,(\ 1e^- + Ce^{4+}(aq) \Leftrightarrow Ce^{3+}(aq)\ )$

Full redox rxn: $Al(s) + 3\,Ce^{4+}(aq) \Leftrightarrow 3\,Ce^{3+}(aq) + Al^{3+}(aq)$

$$Cr^{3+}(aq) + Ni^{2+}(aq) \Leftrightarrow Cr_2O_7^{2-}(aq) + Ni(s)$$

Oxidation: $7\,H_2O(l) + 2\,Cr^{3+}(aq) \Leftrightarrow Cr_2O_7^{2-}(aq) + 6e^- + 14\,H^+(aq)$

Reduction: $3\,(\ 2e^- + Ni^{2+}(aq) \Leftrightarrow Ni(s)\ )$

Full redox rxn: $7\,H_2O(l) + 2\,Cr^{3+}(aq) + 3\,Ni^{2+}(aq) \Leftrightarrow 3\,Ni(s) + Cr_2O_7^{2-}(aq) + 14\,H^+(aq)$

Thermodynamic Values at 25°C:

Substance	**ΔH^o_f ($^{kJ}/_{mol}$)**	**S^o ($^{J}/_{mol\cdot K}$)**	**ΔG^o_f ($^{kJ}/_{mol}$)**
$CH_4(g)$	-74.8	186.3	-50.8
$O_2(g)$	0	205.138	0
$CO_2(g)$	-393.509	213.74	-394.359
$H_2O(l)$	-285.83	69.91	-237.129
$H_2O(g)$	-241.818	188.825	-228.572
$C_2H_6(g)$	-84.68	229.5	-32.89
$FeCl_3(s)$	-400.39	142.3	-334.18
$Fe(s)$	0	27.15	0
$Cl_2(g)$	0	222.96	0

Score