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} $^{units}/_{mol}$
$32.00^{o}F = 0.000^{o}C = 273.15K$
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, $k_{fp} = -1.86\,^{oC}/_{m}$; $k_{bp} = 0.52\,^{oC}/_{m}$
$P_1 = X_1P_1^{o}$
$P = cRTi$
$C_1V_1 = C_2V_2$
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	$1/[A]_t = kt + 1/[A]_o$

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

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

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

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

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

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 (7pts each): Circle the letter of the most correct response.

1. A large negative change in free energy means:
   a. The reaction is exothermic
   b. The reaction is spontaneous
   c. The system is becoming less disordered
   d. The reaction is very fast
   e. The reaction is non-spontaneous

2. For a reaction with a large positive ΔS:
   a. Heat is required to make the reaction proceed
   b. The system is becoming much more ordered
   c. The reaction is not spontaneous
   d. The disorder of the system is increasing
   e. The reaction proceeds very slowly

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. 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. The volume of a gas:
   a. Increases as the temperature increases
   b. Remains constant as the amount of gas is increased
   c. Is always a constant
   d. Increases as the pressure increases
   e. Decreases as the kinetic energy increases

6. Ammonia, $NH_3(g)$, burns in oxygen to form nitrogen dioxide and water. How much energy is released during the formation of 34.97g of nitrogen dioxide by this reaction? (20pts)

$$4\,NH_3(g) + 7\,O_2(g) \Leftrightarrow 4\,NO_2(g) + 6\,H_2O(l/g)$$

$$\Delta G° = 4\,(16.4\,^{kJ}/_{mol}) + 7\,(0\,^{kJ}/_{mol}) + 4\,(51.3\,^{kJ}/_{mol}) + 6\,(-237.129\,^{kJ}/_{mol}) = -1151.97\,^{kJ}/_{mol} \quad \{\textit{liquid water}\}$$

$$\Delta G° = 4\,(16.4\,^{kJ}/_{mol}) + 7\,(0\,^{kJ}/_{mol}) + 4\,(51.3\,^{kJ}/_{mol}) + 6\,(-228.572\,^{kJ}/_{mol}) = -1100.63\,^{kJ}/_{mol} \quad \{\textit{gaseous water}\}$$

$$\left(1151.97\,^{kJ}/_{mol\,rxn}\right)\left(\frac{1mol\ rxn}{4mol\ NO_2}\right)\left(\frac{1mol\ NO_2}{46.005g\ NO_2}\right)\left(34.97g\ NO_2\right) = 218.9kJ \quad \{\textit{liquid water}\}$$

$$\left(1100.63\,^{kJ}/_{mol\,rxn}\right)\left(\frac{1mol\ rxn}{4mol\ NO_2}\right)\left(\frac{1mol\ NO_2}{46.005g\ NO_2}\right)\left(34.97g\ NO_2\right) = 209.2kJ \quad \{\textit{gaseous water}\}$$

Score

7. For each of the following reactions, predict whether the sign if ΔSº will be positive or negative and explain your answer. (18pts)

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

ΔS° negative. A solid is forming from aqueous solution and solids are much more organized than aqueous solutions so the disorder in the system should decrease.

$$N_2(g) + 3\,H_2(g) \leftrightarrows 2\,NH_3(g)$$

ΔS° negative. All reactants and products are gases, but there are only 2 product gas particles while there are 4 reactant gas particles, so the reaction is becoming more ordered.

$$C_5H_{12}(l) + 8\,O_2(g) \leftrightarrows 5\,CO_2(g) + 6\,H_2O(g)$$

ΔS° positive. A liquid reagent is forming all gaseous products. Since liquids are more ordered than gases, the disorder of this system should increase. Also, there are 8 gas particles in the reactants and 11 gas particles in the products, this also points toward more disorder in the system.

8. You are studying the reaction of histidine with diethylsulfite. The temperature in your laboratory is 17.71ºC and you find that ΔG for this reaction is -4.661 $^{kJ}/_{mol}$. You have also determined that for this reaction ΔH = +21.61 $^{kJ}/_{mol}$ (20pts)
   a. Is the reaction becoming more or less disordered? (*Explain your answer with explicit calculations.*)
   b. Over what temperature range is this reaction spontaneous?

$$\Delta G = \Delta H - T\Delta S$$
$$-4.661\ ^{kJ}/_{mol} = (+21.61\ ^{kJ}/_{mol}) - (290.86K)(\Delta S)$$
$$\Delta S = 0.09032\ ^{kJ}/_{K.mol}$$

Since ΔS is positive, the reaction is becoming ***more*** disordered.

Because ΔH and ΔS are both positive, this reaction will be spontaneous at high temperatures and non-spontaneous at low temperatures. The reaction will be neither spontaneous nor non-spontaneous when ΔG = 0 so

$$0 = (+21.61\ ^{kJ}/_{mol}) - (T)(0.09032\ ^{kJ}/_{K.mol})$$
$$T = 239.26K$$

The reaction should be spontaneous at all temperatures above 239.26K.

9. You have a 11.64L of an ideal gas at 1.73atm and 15.15°C. How much volume will the gas occupy at 0.837atm and 34.93°C? (18pts)

Since multiple properties are changing, plug in to the comparative form of the ideal gas law.

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_{21}}{n_2T_2}$$

Since "n" doesn't change, it can be dropped from the equation.

$$(1.73atm)(11.64L) / (288.30K) = (0.837atm)(V_2) / (308.08K)$$
$$V_2 = 25.7L$$

Score

10. You have burned 65.95g of ethene $\{C_2H_4(g)\}$ in oxygen to form carbon dioxide and water. If all of the Gibb's Free Energy liberated by this reaction is used to decompose lead(II) iodide to lead metal and iodine solid, how many grams of iodine solid will be formed? (30pts)

$$C_2H_4(g) + 3\,O_2(g) \Leftrightarrow 2\,CO_2(g) + 2\,H_2O(l/g)$$

$$\Delta G° = (-68.4\,^{kJ}/_{mol}) + 3\,(0\,^{kJ}/_{mol}) + 2\,(-394.359\,^{kJ}/_{mol}) + 2\,(-237.129\,^{kJ}/_{mol}) = -1331.4\,^{kJ}/_{mol}\ \{\textit{liquid water}\}$$

$$\Delta G° = (-68.4\,^{kJ}/_{mol}) + 3\,(0\,^{kJ}/_{mol}) + 2\,(-394.359\,^{kJ}/_{mol}) + 2\,(-228.572\,^{kJ}/_{mol}) = -1314.3\,^{kJ}/_{mol}\ \{\textit{gaseous water}\}$$

$$PbI_2(s) \Leftrightarrow Pb(s) + I_2(s)$$

$$\Delta G° = (173.6\,^{kJ}/_{mol}) + (0\,^{kJ}/_{mol}) + (0\,^{kJ}/_{mol}) = +173.6\,^{kJ}/_{mol}$$

Calculating the amount of energy liberated by burning ethane…

$$(65.95\text{g } C_2H_4)\left(\frac{1\text{mol } C_2H_4}{28.054\text{g } C_2H_4}\right)\left(\frac{1\text{mol rxn1}}{1\text{mol } C_2H_4}\right)\left(\frac{1331.4\text{kJ}}{1\text{mol rxn1}}\right) = 3129.9\text{kJ}\quad\{\textit{liquid water}\}$$

$$(65.95\text{g } C_2H_4)\left(\frac{1\text{mol } C_2H_4}{28.054\text{g } C_2H_4}\right)\left(\frac{1\text{mol rxn1}}{1\text{mol } C_2H_4}\right)\left(\frac{1314.3\text{kJ}}{1\text{mol rxn1}}\right) = 3089.7\text{kJ}\quad\{\textit{gaseous water}\}$$

Using that energy to drive the decomposition of $PbI_2(s)$…

$$(3129.9\text{kJ})\left(\frac{1\text{mol rxn2}}{173.6\text{kJ}}\right)\left(\frac{1\text{mol } I_2}{1\text{mol rxn}}\right)\left(\frac{253.80\text{g } I_2}{1\text{mol } I_2}\right) = 4576\text{g } I_2(s)\text{ formed}\quad\{\textit{liquid water}\}$$

$$(3089.7\text{kJ})\left(\frac{1\text{mol rxn2}}{173.6\text{kJ}}\right)\left(\frac{1\text{mol } I_2}{1\text{mol rxn}}\right)\left(\frac{253.80\text{g } I_2}{1\text{mol } I_2}\right) = 4517\text{g } I_2(s)\text{ formed}\quad\{\textit{gaseous water}\}$$

Thermodynamic Values at 25°C:

Substance	**$\Delta H°_f$ ($^{kJ}/_{mol}$)**	**S° ($^{J}/_{mol\cdot K}$)**	**$\Delta G°_f$ ($^{kJ}/_{mol}$)**
$NH_3(g)$	-45.9	192.8	-16.4
$O_2(g)$	0	205.138	0
$NO_2(g)$	33.2	240.1	51.3
$H_2O(l)$	-285.83	69.91	-237.129
$H_2O(g)$	-241.818	188.825	-228.572
$C_2H_4(g)$	52.4	219.3	68.4
$CO_2(g)$	-393.509	213.74	-394.359
$PbI_2(s)$	-175.5	174.9	-173.6
Pb(s)	0	64.8	0
$I_2(s)$	0	116.14	0

Score