CHEM 130 Name ____
Quiz 8 – November 3, 2016

Complete the following problems. Write your final answers in the blanks provided.

1. From the information in the table below, determine the ΔG^o for the following reaction. (8 pts)

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

Reaction	ΔG^o
$N_2(g) + O_2(g) \rightarrow 2NO(g)$	+173.1 kJ
$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$	-1010.5 kJ
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$	-33.0kJ
$2N_2(g) + O_2(g) \rightarrow 2N_2O(g)$	+208.4 kJ

$2[2NO(g) \rightarrow N_2(g) + O_2(g)]$	-2(+173.1 kJ)
$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$	-1010.5 kJ
$2[N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)]$	2(-33.0kJ)
$\cancel{4NO} + \cancel{4NH_3} + 5O_2 + \cancel{2N_2} + 6H_2 \rightarrow \cancel{2N_2} + \cancel{2}\ O_2 + \cancel{4NO} + 6H_2O + \cancel{4NH_3}$	(-346.2 kJ) +(-1010.5 kJ) +(-66.0 kJ)
$1/3(3O_2 + 6H_2 \rightarrow 6H_2O)$	1/3(-1422.7 kJ)
$O_2 + 2H_2 \rightarrow 2H_2O$	**-474.3 kJ**

Answer______**-474.3 kJ** ______

2. For each of the reactions below, select which of the following describes the reaction and justify your assertion in a sentence or two. (a) spontaneous at all temperatures, (b) nonspontaneous at all temperatures, (c) spontaneous at high temperatures, (d) spontaneous at low temperatures, (e) unable to tell. (8 pts)

   a. $PCl_3(g) + Cl_2(g) \rightarrow PCl_5(g)$ $\Delta H^o = -87.9$ kJ

   $\Delta H^o < 0$ and $\Delta S^o < 0$ (since there are fewer moles of gas on the products side compared to the reactants side) for this reaction. Thus, this reaction is spontaneous at low temperatures and non-spontaneous at high temperatures.

   b. $NH_4CO_2NH_2(s) \rightarrow 2NH_3(g) + CO_2(g)$ $\Delta H^o = +159.2$ kJ

   $\Delta H^o > 0$ and $\Delta S^o > 0$ (since there are more moles of gas on the products side compared to the reactants side) for this reaction. This reaction is non-spontaneous at low temperatures, but spontaneous at high temperatures.

3. A possible reaction for converting methanol to ethanol is

$$CO(g) + 2H_2(g) + CH_3OH(g) \rightarrow C_2H_5OH(g) + H_2O(g)$$

Use the information below to calculate ΔG^o and determine whether the reaction is spontaneous under standard conditions at 25°C. Is there a temperature where the sign of ΔG^o changes? (9 pts)

Compound	**$\Delta H^o{}_f$, kJ mol^{-1}**	**$\Delta G^o{}_f$, kJ mol^{-1}**	**$S^o{}_f$, J mol^{-1} K^{-1}**
$CO(g)$	-110.5	-137.2	+197.7
$H_2(g)$	0	0	+130.7
$CH_3OH(g)$	-200.7	-162.0	+239.8
$C_2H_5OH(g)$	-235.1	-168.5	+282.7
$H_2O(g)$	-241.8	-228.6	+188.8

$$\Delta H^o = [\Delta H^o{}_f(C_2H_5OH(g)) + \Delta H^o{}_f(H_2O(g))] – [\Delta H^o{}_f(CO(g)) +2\Delta H^o{}_f(H_2(g)) +\Delta H^o{}_f(CH_3OH(g))]$$

$$\Delta H^o = [-235.1 \text{ kJ} +(-241.8 \text{ kJ})] – [(-110.5 \text{ kJ}) +2(0 \text{ kJ}) +(-200.7 \text{ kJ})]$$

$$\Delta H^o = -165.7 \text{ kJ}$$

$$\Delta S^o = [S^o{}_f(C_2H_5OH(g)) + S^o{}_f(H_2O(g))] – [S^o{}_f(CO(g)) +2S^o{}_f(H_2(g)) +S^o{}_f(CH_3OH(g))]$$

$$\Delta S^o = [282.7 \text{ J/K} +(188.8 \text{ J/K})] – [(197.7 \text{ J/K}) +2(130.7 \text{ J/K}) +(239.8 \text{ J/K})]$$

$$\Delta S^o = -227.4 \text{ J/K}$$

$$\mathbf{\Delta G^o = \Delta H^o - T\Delta S^o = -165.7 \text{ kJ} –(298 \text{ K})(-0.2274 \text{ kJ/K}) = -97.9 \text{ kJ}}$$

Since ΔS^o and ΔH^o have the same sign, there must be a temperature that causes the sign of ΔG^o to change. You can calculate that temperature as shown below but you did not have to.

$$0 = \Delta H^o - T\Delta S^o$$

$$T = \Delta H^o/\Delta S^o = -165.7 \text{ kJ}/(0.2274 \text{ kJ/K}) = 729 \text{ K}$$

You could also have calculated ΔG^o from the $\Delta G^o{}_f$ values as shown below:

$$\Delta G^o = [\Delta G^o{}_f(C_2H_5OH(g)) + \Delta G^o{}_f(H_2O(g))] – [\Delta G^o{}_f(CO(g)) +2\Delta G^o{}_f(H_2(g)) +\Delta G^o{}_f(CH_3OH(g))]$$

$$\Delta G^o = [-168.5 \text{ kJ} +(-228.6 \text{ kJ})] – [(-137.2 \text{ kJ}) +2(0 \text{ kJ}) +(-162.0 \text{ kJ})]$$

$$\mathbf{\Delta G^o = -97.9 \text{ kJ}}$$

NOTE: You could make the judgment on whether ΔG^o changes sign without actually calculating ΔH^o and ΔS^o. Looking at the reaction, there are 5 moles of gas on the reactant side and two moles of gas on the product side, indicating the ΔS^o will be negative. Since $\Delta G^o = \Delta H^o - T\Delta S^o$, if ΔS^o is negative, the only way ΔG^o could be negative as well is if ΔH^o is also negative. If ΔS^o and ΔH^o both have the same sign, there must be a temperature where the sign of ΔG^o changes.

Answer____________________

Possibly Useful Information

$K = {}^{o}C + 273.15$	$q=mc\Delta T$	$q=n_{LR}\Delta H_{rxn}$	$q=m\Delta H$
$\Delta S_{universe} = \Delta S_{system} - \Delta S_{surr}$		$\Delta G = \Delta H - T\Delta S$	$\Delta S_{surr} = -\Delta H_{sys}/T$

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 H 1.00794																	2 He 4.00260
3 Li 6.941	4 Be 9.01218											5 B 10.811	6 C 12.011	7 N 14.0067	8 O 15.9994	9 F 18.9984	10 Ne 20.1797
11 Na 22.9898	12 Mg 24.3050											13 Al 26.9815	14 Si 28.0855	15 P 30.9738	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.9559	22 Ti 47.88	23 V 50.9415	24 Cr 51.9961	25 Mn 54.9381	26 Fe 55.847	27 Co 58.9332	28 Ni 58.693	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.9216	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.9059	40 Zr 91.224	41 Nb 92.9064	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.906	46 Pd 106.42	47 Ag 107.868	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.757	52 Te 127.60	53 I 126.904	54 Xe 131.29
55 Cs 132.905	56 Ba 137.327	57 *La 138.906	72 Hf 178.49	73 Ta 180.948	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.967	80 Hg 200.59	81 Tl 204.383	82 Pb 207.2	83 Bi 208.980	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.025	89 †Ac 227.028	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Ds (271)	111 Rg (272)							

*Lanthanide series	58 Ce 140.115	59 Pr 140.908	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.965	64 Gd 157.25	65 Tb 158.925	66 Dy 162.50	67 Ho 164.930	68 Er 167.26	69 Tm 168.934	70 Yb 173.04	71 Lu 174.967
†Actinide series	90 Th 232.038	91 Pa 231.036	92 U 238.029	93 Np 237.048	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)