CHEM 121 **Name**____

Quiz 7 **March 20, 2009**

1. For the equilibrium below, $K_c = 2.0\text{x}10^{-6}$. What is the equilibrium concentration of oxygen (in moles/L) if 0.20 mol CO_2 and 0.10 mol CO were initially placed into an evacuated 0.50 L vessel and the system is allowed to come to equilibrium? (9 points)

$$2CO_2\ (g) \rightleftarrows 2CO\ (g) + O_2\ (g)$$

Since we have zero O_2 intitially, we know we cannot be at equilibrium so we must use an ICE table or some other approach to find equilibrium concentrations.

	$2CO_2$	$\rightleftarrows$	2CO	+	O_2
I	0.40 M		0.20 M		0
C	-2x		+2x		+x
E	0.40-2x		0.20+2x		x

$$K_c = \frac{[CO]^2[O_2]}{[CO_2]^2} = \frac{(0.20+2x)^2x}{(0.40-2x)^2}$$

Without some simplification, we will need to solve a third order polynomial. Can we simplify? Since K is small, we would not expect the reaction to proceed very far to the right. Also, the presence of CO intitially will further impede the reaction. So, we expect x to be small. Lets assume x<<0.20. If this is so, the K_c expression changes.

$$K_c = \frac{(0.20+\cancel{2x})^2x}{(0.40-\cancel{2x})^2} = \frac{(0.20)^2x}{(0.40)^2}$$

After rearranging we find that $x = K_c(0.40)^2/(0.20)^2 = 8.0 \times 10^{-6}$. So, **$[O_2] = 8.0 \times 10^{-6}$M.** Was our assumption OK? 0.20 – 0.0000080 = 0.1999920, which to the correct number of sig figs is indistinguishable from 0.20, so our assumption is fine. We could have used a calculator or computer to solve the third order polynomial. Doing so on my calculator gave a value for x of $7.998\text{x}10^{-6}$.

2. Solid ammonium nitrate can decompose to dintrogen oxide gas and liquid water by the reaction below. What is the ΔG^o at 298K? At what temperature, if any, does spontaneity of the reaction change? (9 points)

$$NH_4NO_3\ (s) \rightarrow 2\ N_2O\ (g) + H_2O\ (\ell)$$

Species	ΔH^o_f (kJ/mol)	S^o_f (J/mol)
NH_4NO_3 (s)	-365.6	151.1
N_2O (g)	+82.05	219.9
H_2O (ℓ)	-285.8	69.91

For my incorrectly balanced reaction above:

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

$$\Delta H^o = 2\Delta H^o_f(N_2O) + \Delta H^o_f(H_2O)] – [\Delta H^o_f(NH_4NO_3)]$$
$$\Delta H^o = [2(+82.05) + (-285.8)] – [(-365.6)]\text{kJ}$$
$$\Delta H^o = +243.9\ \text{kJ}$$

$$\Delta S^o = 2\Delta S^o_f(N_2O) + \Delta S^o_f(H_2O)] – [\Delta S^o_f(NH_4NO_3)]$$
$$\Delta S^o = [2(219.9) + (69.91)] – [(151.1)]\text{J/K}$$
$$\Delta S^o = +358.6\ \text{J/K}$$

$$\Delta G^o = 243.9\ \text{kJ/mol} - 298\ \text{K}(0.3586\ \text{kJ/mol K}) = \mathbf{+137.0\ kJ}$$

To find the temperature where spontaneity changes, set ΔG^o =0 and solve for T:
$T = \Delta H^o/\Delta S^o = 243.9/0.3586 =$ **680 K.**

For the correctly balanced reaction:

$$NH_4NO_3\ (s) \rightarrow N_2O\ (g) + 2\ H_2O\ (\ell)$$

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

$$\Delta H^o = \Delta H^o_f(N_2O) + 2\Delta H^o_f(H_2O)] - [\Delta H^o_f(NH_4NO_3)]$$
$$\Delta H^o = [(+82.05) + 2(-285.8)] - [(-365.6)]kJ$$
$$\Delta H^o = -123.95\ kJ$$

$$\Delta S^o = \Delta S^o_f(N_2O) + 2\Delta S^o_f(H_2O)] - [\Delta S^o_f(NH_4NO_3)]$$
$$\Delta S^o = [(219.9) + 2(69.91)] - [(151.1)]J/K$$
$$\Delta S^o = +208.6\ J/K$$

$$\Delta G^o = -123.95\ kJ/mol - 298\ K(0.2086\ kJ/mol\ K) = \mathbf{-186.1\ kJ}$$

Since ΔH^o is negative and ΔS^o is positive and since $\Delta G^o = \Delta H^o - T\Delta S^o$, there is no temperature where the reaction is nonspontaneous. Since T is always positive, $\Delta G^o = \Delta H^o - T\Delta S^o$ will be negative at all temperatures when ΔH^o is negative and ΔS^o is positive.

3. 25.4 mL of 0.116 M H_2SO_4 is mixed with 22.4 mL of 0.282 M NaOH. What is the pH of the resulting solution? (7 points)
This is a strong acid/strong base reaction. The pH will be determined by what's left after the acid and base react.

$$H_2SO_4 + 2NaOH \rightarrow 2NaCl + 2\ H_2O$$

$$25.4\ mL \times \frac{0.116\ mol\ H_2SO_4}{L} \times \frac{2\ mol\ NaOH}{1\ mol\ H_2SO_4} = 5.89_3\ mmol\ NaOH\ needed\ to\ consume\ all\ H_2SO_4$$

$$22.4\ mL \times \frac{0.282\ mol\ H_2SO_4}{L} = 6.31_7\ mmol\ NaOH\ present$$

So,H_2SO_4 is the limting reagent, some NaOH will be left over, how much?

$$(6.31_9 - 5.89_3) = 0.424\ mmol$$

This will dissociate completely to give 0.426 mmol of OH^- or an [OH] of:

$$\frac{0.424\ mmol\ OH^-}{(25.4+22.4)mL} = 8.87_0 \times 10^{-3}M$$

$$pOH = -\log(8.87_0 \times 10^{-3}) = 2.05_2$$
$$\mathbf{pH = 14 - pOH = 11.95}$$

Possibly Useful Information

$\Delta G = \Delta H - T\Delta S$	$^{o}C = K - 273.15$	$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
$pH + pOH = 14$	$K_aK_b = K_w$	$K_p = K_c(RT)^{\Delta n}$

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	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)