Name: _____

Chemistry 210 Exam 2

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} $^{\text{units}}/_{\text{mol}}$
$32.00^{o}F = 0.000^{o}C = 273.15K$
Density of Water = $1.000\ ^{g}/_{mL}$
$R = 0.08206\ ^{L \cdot atm}/_{mol \cdot K} = 8.314\ ^{J}/_{mol \cdot K}$
1atm = 760torr = 760mmHg = 101.325kPa
$PV=nRT$
$\Delta T_{fp/bp} = k_{fp/bp} \cdot m \cdot i$
For water: $k_{fp} = -1.86\ ^{^{o}C}/_{m}$
$k_{bp} = 0.512\ ^{^{o}C}/_{m}$
$P_1 = X_1 P_1^{o}$
$\Pi = MRTi$
$C_1V_1 = C_2V_2$

Integrated Rate Laws:

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

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

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

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

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

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

Quadratic formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

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	71 **Lu** 174.97	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	103 **Lr** (260)	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		

57 **La** 138.91	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
89 **Ac** 227.03	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)

Score

Multiple Choice (5pts each): Circle the letter of the most correct response.

1. For a reaction at equilibrium:
   a. The reactants and products must be in the gas phase.
   b. The reaction has stopped.
   c. The mass of reactants is equal to the mass of products.
   d. The concentration of reactants is equal to the concentration of products.
   e. The rate of the forward reaction is equal to the rate of the reverse reaction.

2. Which of the following is ***false*** regarding equilibrium?
   a. The rates of the forward and reverse reactions are equal
   b. Equilibrium concentrations do not depend upon whether you approach equilibrium from the left or the right
   c. The concentrations of products and reactants does not change once the reaction has reached equilibrium
   d. Equilibrium can often be shifted by changing pressure or temperature
   e. The forward and reverse reactions stop when a system reaches equilibrium

3. Which of the following is ***true*** regarding equilibrium reactions?
   a. If K = 1, the reaction has stopped.
   b. If K < 0, the reaction reaches equilibrium very quickly.
   c. If K is very large, the limiting reactant is very nearly used up.
   d. If K > 1, the reaction is reactant-favored.
   e. If K < 1, the reaction is product-favored.

4. Which of the following equilibrium constant expressions is correct for the given reaction:

$$2\,HNO_3(g) + NO(g) \leftrightarrow 2\,NO_2(g) + H_2O(g)$$

   a. $K_c = \dfrac{2[NO_2]_{eq}[H_2O]_{eq}}{2[HNO_3]_{eq}[NO]_{eq}}$

   b. $K_c = \dfrac{[NO_2]^2_{eq} + [H_2O]_{eq}}{[HNO_3]^2_{eq} + [NO]_{eq}}$

   c. $K_c = \dfrac{[NO_2]^2_{eq}[H_2O]_{eq}}{[HNO_3]^2_{eq}[NO]_{eq}}$

   d. $K_c = \dfrac{[HNO_3]^2_{eq}[NO]_{eq}}{[NO_2]^2_{eq}[H_2O]_{eq}}$

   e. $K_c = \dfrac{[NO_2]^2_{eq}}{[HNO_3]^2_{eq}[NO]_{eq}}$

5. Considering the reaction given, all of the following stresses will shift the equilibrium to the right except:

$$CO(g) + H_2O(g) \leftrightarrow CO_2(g) + H_2(g) \qquad \Delta H_{rxn} = 131\ {}^{kJ}/_{mol}$$

   a. Adding carbon monoxide to the system
   b. Increasing the pressure on the system
   c. Removing hydrogen from the system
   d. Removing carbon dioxide from the system
   e. Increasing the temperature of the system

6. All of the following can be explained by LeChatelier's Principle except:
   a. Removing a gaseous reactant will shift the equilibrium left.
   b. Increasing the temperature of an endothermic reaction will shift the equilibrium right.
   c. Increasing the pressure will shift an equilibrium toward the side that has more gas particles.
   d. Removing a gaseous product will shift the equilibrium right.
   e. Adding more of an aqueous reactant will shift the equilibrium right.

Score

7. The reaction quotient for a reaction:
   a. Is usually a negative number
   b. Is a constant
   c. Is the concentration of reactants divided by the concentration of products
   d. Tells you how fast the reaction happens
   e. Tells you what direction the reaction must shift to reach equilibrium

8. Which of the following statements is ***false*** regarding the reaction quotient, *Q*?
   a. It tells the direction that the reaction must shift to reach equilibrium
   b. If $Q<K_c$, the system needs to shift toward the products to reach equilibrium
   c. If $Q=K_c$, the system is at equilibrium
   d. If $Q>K_c$, the system needs to shift toward the products to reach equilibrium
   e. It has the same mathematical form as the equilibrium constant

Problems: Show your work and write your final answer(s) in the answer box.

9. For the reaction:

$$3\ CH_3OH(g) + N_2(g) \leftrightarrows 3\ CH_2O(g) + 2\ NH_3(g) \qquad \Delta H = +683.2\ {}^{kJ}/_{mol}$$

The equilibrium concentrations are observed: $[CH_3OH]_{eq} = 0.349M$, $[N_2]_{eq} = 0.226M$, $[CH_2O]_{eq} = 0.106\ M$, $[NH_3]_{eq} = 0.261\ M$. What is the equilibrium constant for this reaction? (12pts)

$$K = \{[CH_2O]_{eq}^3\ [NH_3]_{eq}^2\} / \{[CH_3OH]_{eq}^3\ [N_2]_{eq}\}$$
$$K = \{(0.106)^3\ (0.261)^2\} / \{(0.349)^3\ (0.226)\} = 8.45\times10^{-3}$$

Reactant-favored (the question doesn't ask this…)

10. You have been studying the reaction of $N_2O(g)$ with $O_2(g)$ to form $NO_2(g)$. After your system has reached equilibrium, you find that the concentrations of all species are: $[N_2O]_{eq} = 0.237M$, $[O_2]_{eq} = 0.581M$, $[NO_2]_{eq} = 0.976M$. What is the value of the equilibrium constant for this reaction? (16pts)

$$2\ N_2O(g) + 3\ O_2(g) \leftrightarrows 4\ NO_2(g)$$
$$K = \{[NO_2]_{eq}^4\} / \{[N_2O]_{eq}^2\ [O_2]_{eq}^3\}$$
$$K = \{(0.976)^4\} / \{(0.237)^2\ (0.581)^3\} = 82.4$$

Product-favored (the question doesn't ask this…)

11. A saturated potassium bromide solution is prepared by dissolving KBr in pure water and has a potassium ion concentration of 5.118M at some temperature. What is the K_{sp} of potassium bromide at this temperature? (16pts)

$$KBr(s) \leftrightarrows K^{+1}(aq) + Br^{-1}(aq)$$
$$K_{sp} = [K^{+1}]_{eq}\ [Br^{-1}]_{eq}$$

Since we're preparing this solution "by dissolving KBr in pure water", the equilibrium concentration of $K^{+1}(aq)$ must be equal to the equilibrium concentration of $Br^{-1}(aq)$, so…

$$K = (5.118)\ (5.118) = 26.19$$

Product-favored = "soluble" (the question doesn't ask this…)
Set up a table for this one if you're having a hard time following it…

Score

12. What are the concentrations of strontium ions (Atomic # = 38) and hydroxide ions in a saturated solution of strontium hydroxide prepared from strontium hydroxide solid in water ($K_{sp} = 3.84x10^{-3}$)? (16pts)

$K_{sp} = [Sr^{+2}]_{eq} [OH^{-1}]_{eq}^2$

	$Sr(OH)_2(s)$ ⇆	$Sr^{+2}(aq)$ +	$2\ OH^{-1}(aq)$
$[\ ]_{initial}$	XXXXXX	0 M	0 M
$\Delta [\ ]$	XXXXXX	+ x M	+ 2x M
$[\ ]_{equilibrium}$	XXXXXX	x M	2x M

Plugging in to the K_{sp} expression… $3.84x10^{-3} = (x)(2x)^2 = 4x^3$

$x = 9.8648x10^{-2}$ → $[Sr^{+2}]_{eq} = 9.86x10^{-2}$M, $[OH^{-1}]_{eq} = 0.197$M

13. When 0.267mols of sulfur dioxide {$SO_2(g)$} and 0.338mols of fluorine gas {$F_2(g)$} are sealed together in a 1.500L vessel, they reach equilibrium with thionyl fluoride {$SOF_2(g)$} and oxygen {$O_2(g)$}. The equilibrium concentration of $F_2(g)$ is found to be 0.207 M. (25pts)
    a. What are the equilibrium concentrations of all products and reactants?
    b. What is the value of K_c?
    c. Is the reaction product-favored or reactant-favored?

	$2\ SO_2(g)$ +	$2\ F_2(g)$ ⇆	$2\ SOF_2(g)$ +	$O_2(g)$
$[\ ]_{initial}$	0.267mol/1.500L = 0.178 M	0.338mol/1.500L = 0.2253 M	0 M	0 M
$\Delta [\ ]$	– 2x M	– 2x M	+ 2x M	+ x M
$[\ ]_{equilibrium}$	(0.178 – 2x) M	(0.2253 – 2x) M	2x M	x M

$K = \{ [SOF_2]_{eq}^2 [O_2]_{eq} \} / \{ [SO_2]_{eq}^2 [F_2]_{eq}^2 \} = (2x)^2(x) / (0.178 – 2x)^2(0.2253 – 2x)^2$

From the problem, $[F_2]_{eq} = 0.207$M. Plugging in and solving for x…

$0.2253 – 2x = 0.207$ → $x = 9.167x10^{-3}$

$[SOF_2]_{eq} = 0.0183$M; $[O_2]_{eq} = 0.00917$M; $[SO_2]_{eq} = 0.1597$M; $[F_2]_{eq} = 0.207$M

$K = (0.0183)^2 (0.00917) / (0.1597)^2 (0.207)^2 = 2.81x10^{-3}$ → reactant-favored

14. $NH_3(g)$ reacts with ClO(g) to form $NO_3(g)$ and HCl(g) with an equilibrium constant of $3.62x10^{-8}$. In a 2.00L reaction vessel, you have combined 0.293mols of NH_3 with 0.379mols of ClO. What are the concentrations of all reactants and products when this reaction reaches equilibrium? (25pts)

	$NH_3(g)$ +	$3\ ClO(g)$ ⇆	$NO_3(g)$ +	$3\ HCl(g)$
$[\ ]_{initial}$	0.293mol/2.00L = 0.1465M	0.379mol/2.00L = 0.1895 M	0 M	0 M
$\Delta [\ ]$	– x M	– 3x M	+ x M	+ 3x M
$[\ ]_{equilibrium}$	(0.1465 – x) M	(0.1895 – 3x) M	x M	3x M

$K = \{ [NO_3]_{eq} [HCl]_{eq}^3 \} / \{ [NH_3]_{eq} [ClO]_{eq}^3 \} = (x)(3x)^3 / (0.1465 – x)(0.1895 – 3x)^3 = 3.62x10^{-8}$

This wouldn't be *impossible* to solve for x, but it'd be challenging. Assumptions to the rescue!

Assume $3x << 0.1895$ (if this is true then $x << 0.1465$…), simplifies to…

$(x)(3x)^3 / (0.1465)(0.1895)^3 = 3.62x10^{-8}$

$27x^4 = (3.62x10^{-8})(0.1465)(0.1895)^3$

$x = 1.075x10^{-3}$

CHECK YOUR ASSUMPTION! $3(1.075x10^{-3})$ is ~1.7% of 0.1895, so this assumption is OK.

$[NO_3]_{eq} = 1.08x10^{-3}$ M; $[HCl]_{eq} = 3.23x10^{-3}$ M; $[NH_3]_{eq} = 0.145$ M ; $[ClO]_{eq} = 0.186$ M

Score