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 = $1.000\,^{g}/_{mL}$
$R = 0.08206\ ^{L\bullet atm}/_{mol\bullet K} = 8.314\ ^{J}/_{mol\bullet K}$
$PV=nRT$
$\Delta T_{fp/bp} = k_{fp/bp}\bullet m\bullet i$
For water, $k_{fp} = -1.86\,^{^\circ C}/_{m}$; $k_{bp} = 0.52\,^{^\circ C}/_{m}$
$P_1 = X_1P_1^{o}$
$\Pi = MRTi$
$C_1V_1 = C_2V_2$
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 $1/[A]_t = kt + 1/[A]_o$
$k = Ae^{-Ea/RT}$

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

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

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

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

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

2. 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 > 1, the reaction is reactant-favored.
   d. If K < 1, the reaction is product-favored.
   e. If K is very large, the limiting reactant is very nearly used up.

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

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. $K_c = \frac{2[NO_2]_{eq}[H_2O]_{eq}}{2[HNO_3]_{eq}[NO]_{eq}}$
   b. $K_c = \frac{[NO_2]^2_{eq} + [H_2O]_{eq}}{[HNO_3]^2_{eq} + [NO]_{eq}}$
   c. $K_c = \frac{[NO_2]^2_{eq}[H_2O]_{eq}}{[HNO_3]^2_{eq}[NO]_{eq}}$
   d. $K_c = \frac{[HNO_3]^2_{eq}[NO]_{eq}}{[NO_2]^2_{eq}[H_2O]_{eq}}$
   e. $K_c = \frac{[NO_2]^2_{eq}}{[HNO_3]^2_{eq}[NO]_{eq}}$

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

Score

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

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

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

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

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

9. Which of the following is ***true*** regarding catalysts and catalyzed reactions?
   a. Catalysts always have to be solids
   b. The presence of a catalyst changes the activation energy for a reaction
   c. The presence of a catalyst does not change the mechanism of a reaction
   d. The concentration of a catalyst cannot appear in the rate law for a reaction
   e. The presence of a catalyst changes the energy of the products and reactants in a reaction

10. Which of the following is ***false*** regarding reaction mechanisms?
   a. The observed rate law must agree with the rate law of the slowest step
   b. The steps of the mechanism can contain chemical species that do not appear in the overall correctly balanced chemical equation
   c. The observed rate law is equal to the sum of the rate laws from all steps
   d. Catalysts can appear in the steps of a mechanism
   e. A mechanism must be composed of elementary reactions

True/False: For each of the following statements, circle T for true and F for false. For all false statements, give a brief explanation of *why* the statement is false. (3pts each row)

		Statement	If false, explain why (briefly)
11.	T **F**	The observed rate law is equal to the sum of the rate laws from all steps	**$Rate_{obs}$ is consistent with the rate of the slowest step**
12.	**T** F	Catalysts can appear in the steps of a mechanism	
13.	T **F**	The presence of a catalyst changes the equilibrium constant for a reaction	**Equilibrium is a thermodynamic phenomenon, catalysts only change the kinetics of a rxn**
14.	**T** F	Equilibrium can often be shifted by changing pressure or temperature	

Score

15.	T **F**	At equilibrium, the concentration of reactants and products are equal	**@ Equilibrium, the concentrations do not *change*, but they are rarely equal**
16.	T **F**	If K > 1, the reaction is reactant-favored.	**If K>1, the rxn is *product*-favored**
17.	**T** F	The reaction quotient indicates the direction that the reaction must shift to reach equilibrium	
18.	**T** F	If $Q<K_c$, the system needs to shift toward the products to reach equilibrium	

Problems:

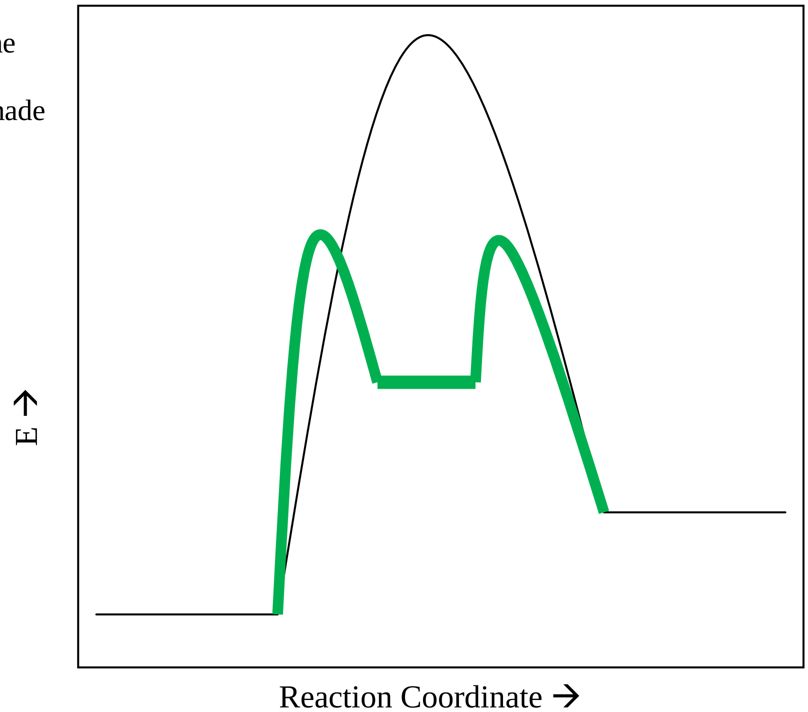
19. You have been studying the reaction of $N_2O(g)$ with $O_2(g)$ to form $NO_2(g)$. After your system has reached equilibrium, you find that the concentrations of all species are: $[N_2O]_{eq}$ = 0.193M, $[O_2]_{eq}$ = 0.275M, $[NO_2]_{eq}$ = 0.846M. What is the value of the equilibrium constant for this reaction? (10pts)

$$2\,N_2O(g) + 3\,O_2(g) \Leftrightarrow 4\,NO_2(g)$$

$$K = \{[NO_2]_{eq}^4\} \,/\, \{[N_2O]_{eq}^2\,[O_2]_{eq}^3\} = (0.846)^4 \,/\, \{(0.193)^2(0.275)^3\} = 661$$

20. The reaction coordinate diagram at the right represents an uncatalyzed reaction. Modify the diagram to represent the same reaction in the presence of a catalyst and describe why you made any changes. (10pts)

Use of a catalyst lowers the activation energy of a reaction by changing the mechanism



Score

21. $NH_3(g)$ reacts with $ClO(g)$ to form $NO_3(g)$ and $HCl(g)$ with an equilibrium constant of $5.72x10^{-8}$. In a 2.00L reaction vessel, you have combined 0.293mols of NH_3 with 0.481mols of ClO. What are the concentrations of all reactants and products when this reaction reaches equilibrium? (20pts)

Setting everything up in a table:

	$NH_3(g)$ +	3 ClO(g) ⇔	$NO_3(g)$ +	3 HCl(g)
Initial	(0.293mol NH_3) / (2.00L) = 0.1465M	(0.481mol ClO) / (2.00L) = 0.2405M	0M	0M
Δ	-x	-3x	+x	+3x
@Equil	(0.1465-x)M	(0.2405-3x)M	xM	3xM

Plugging in to the equilibrium constant expression:

$$K_c = \frac{[NO_3]_{eq}[HCl]^3_{eq}}{[NH_3]_{eq}[ClO]^3_{eq}} = \frac{(x)(3x)^3}{(0.1465-x)(0.2405-3x)^3} = 5.72x10^{-8}$$

This would be an ugly polynomial expression, BUT since the equilibrium constant is rather reactant-favored we can try an assumption. The amount of reactant that is lost during this reaction should be quite small, so let's assume 3x << 0.2405 {and x << 0.1465}. The equilibrium constant expression then simplifies to:

$$\frac{(27x^4)}{(0.1465)(0.2405)^3} = 5.72x10^{-8}$$

Solving, x = $1.44x10^{-3}$

CHECK YOUR ASSUMPTION!! 3x is less than 1% of 0.2405, so our assumption is valid. Hooray!!

Plugging in to get all of the reactant and product concentrations:

$[NH_3]_{eq}$ = 0.145M; $[ClO]_{eq}$ = 0.236M; $[NH_3]_{eq}$ = $1.44x10^{-3}$M; $[NH_3]_{eq}$ = $4.32x10^{-3}$M

22. When 0.295mols of sulfur dioxide {$SO_2(g)$} and 0.379mols 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 0.191 M. (20pts)
    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?

Setting everything up in a table:

	2 $SO_2(g)$ +	2 $F_2(g)$ ⇔	2 $SOF_2(g)$ +	$O_2(g)$
Initial	(0.295mol SO_2)/(1.500L) = 0.1966M	(0.379mol F_2)/(1.500L) = 0.2527M	0M	0M
Δ	-2x	-2x	+2x	+x
@Equil	(0.1966-2x)M	(0.2527-2x)M	2xM	xM

The problems gives $[F_2]_{eq}$ = 0.191M, so

0.2527 – 2x = 0.191M

x = 0.03085

Plugging in to get all of the concentrations,

$[SO_2]_{eq}$ = 0.1349M; $[F_2]_{eq}$ = 0.191M; $[SOF_2]_{eq}$ = 0.0617M; $[O_2]_{eq}$ = 0.03085M

Plugging in to the equilibrium constant expression:

$$K_c = \frac{[SOF_2]^2_{eq}[O2]_{eq}}{[SO_2]^2_{eq}[F_2]^2_{eq}} = \frac{(0.0617)^2(0.03085)}{(0.1349)^2(0.191)^2} = 0.177$$

Since K<1, the equilibrium is reactant-favored, though not by much.

Score