CHEM 10123/10125, Exam 1 **Name**_________________________
February 8, 2012 (50 minutes) (please print)

1. SHOW ALL WORK. A saturated, aqueous NaCl solution is 5.40 M NaCl (58.44 g/mol) and is 26.0% NaCl by weight.

a.) (10 points) Calculate the molal concentration of NaCl in this solution.

$$\frac{26.0 \text{ g NaCl}}{(100\text{-}26.0) \text{ g } H_2O} \times \frac{1000 \text{ g } H_2O}{1 \text{ kg } H_2O} \times \frac{1 \text{ mol NaCl}}{58.44 \text{ g NaCl}} = \boxed{\frac{6.01 \text{ mol NaCl}}{\text{kg } H_2O}}$$

b.) (10 points) Calculate the density of this NaCl solution in g/mL.

$$\frac{5.40 \text{ mol NaCl}}{1000 \text{ mL soln}} \times \frac{58.44 \text{ g NaCl}}{1 \text{ mol NaCl}} \times \frac{100 \text{ g soln}}{26.0 \text{ g NaCl}} = \boxed{\frac{1.21 \text{ g soln}}{\text{mL soln}}}$$

2. (11 points) **SHOW ALL WORK**. Suppose that, in an equilibrium mixture of N_2, O_2, and NO at 800 K, the partial pressures of N_2 and O_2 are both 3.90×10^2 torr. Given that $K_p = 3.4 \times 10^{-21}$ for the reaction;

$$N_{2(g)} + O_{2(g)} \rightarrow 2\ NO_{(g)}$$

a) What is the partial pressure of NO?

$K_p = P^2_{NO} / (P_{N2})(P_{O2})$

$P^2_{NO} = (K_p)(P_{N2})(P_{O2}) = (3.4 \times 10^{-21})(3.90 \times 10^2)(3.90 \times 10^2) = 5.17 \times 10^{-16}$

$\mathbf{P_{NO} = 2.3 \times 10^{-8}}$ **torr** $\mathbf{= 3.0 \times 10^{-11}}$ **atm**

b) What is K_c for this reaction?

Since $\Delta n = 2\text{-}2 = 0$, $K_p = K_c(RT)^0$, i.e.
The same as K_p; 3.4×10^{-21}

3. The equilibrium constant, K_c, for the reaction
$SO_{3(g)} + NO_{(g)} \rightleftharpoons NO_{2(g)} + SO_{2(g)}$
was found to be 0.500 at a certain temperature. If 0.240 mol of SO_3 and 0.240 mol of NO are placed in a 2.00 L container and allowed to react, what will be the equilibrium concentration of each gas?

a) (6 points) Write the concentration table, using the variable x.

	$SO_{3(g)}$	$NO_{(g)}$	$NO_{2(g)}$	$SO_{2(g)}$
INIT	0.120 M	0.120 M	0	0
CHANGE	–x	–x	+x	+x
EQUIL	(0.120 – x)	(0.120 – x)	x	x

b) (3 points) Write the equilibrium expression, using the variable x.

$$0.500 = \frac{(x)(x)}{(0.120 - x)(0.120 - x)}$$

c) (6 points) Solve for x.

$0.707 = x / (0.120 – x)$
$0.0849 – 0.707x = x$
$0.0849 = 1.707x$
$x = 0.0497$

d) (2 points) Give the gas concentrations.

$[SO_3]$ = 0.070 M

$[NO_2]$ = 0.0497 M

$[NO]$ = 0.070 M

$[SO_2]$ = 0.0497 M

4. (19 points) A thorough kinetic study has been performed on a certain reaction:

$$2A_{(aq)} \rightarrow B_{(aq)}$$

The room temperature data was plotted as molar concentration versus time (in seconds), and a tangent to the curve at t = 0 had a slope of 5.0×10^{-3}. The log of the concentration was plotted against time to give a straight line with a slope of –0.040. After varying temperatures, a plot of ln k versus 1/T was found to be a straight line with a slope of -3.00×10^{4} and y intercept of 18.2. Answer the following questions about the reaction (***include units with all answers!***).

a) At room temperature, what was the initial instantaneous rate of reaction?

Rate = Δconc. / Δtime = slope = 5.0×10^{-3} mol L^{-1} s^{-1}

b) Ten minutes after the reaction has started, is the rate faster, slower, the same, or you cannot tell from the data given?

Slower

Concentration decreases with time therefore the rate will decrease as well.

c) What is the value of the room temperature rate constant?

k = - slope = 0.040 s^{-1}

d) What units should the rate constant have?

s^{-1}

e) Write the rate equation for the reaction.

Rate = k [A] = (0.040)[A]

f) Calculate the $t_{1/2}$ for this reaction.

$t_{1/2}$ = ln 2 / k = ln 2 / 0.040 = 17 sec.

g) **SHOW ALL WORK**. Calculate the energy of activation of this reaction in kJ/mol, and the frequency factor.

Arrhenius plot slope = $-3.00 \times 10^{4} = -E_a/R$

$\mathbf{E_a}$ = (3.00×10^{4} K)(8.314×10^{-3} kJ/mol.K) = **249 kJ/mol**

Arrhenius plot intercept = 18.2 = ln A

A = $e^{18.2}$ = **8.02×10^{7} s^{-1}**

5. (4 points) Fill in the blanks. A **surfactant** is a molecule with a hydrophobic "tail" and a hydrophilic "head" that forms **micelles** when dissolved in water.

6. (6 points) Name three factors that affect reaction rates.

Nature of the Reactants
Ability of reactants to come in contact
Concentrations of the reactants
Temperature of the system
Presence of a *catalyst*

7. (4 points) Choose one of the factors you listed in question #6 and explain its effect using collision theory.

The ability of reactant to come in contact: if the molecules are not lined up correctly then no reaction occurs. Therefore the ability of reactants to come in contact with each other to make an effective collision is key in collision theory.

8. Using the data,

(1) $SnO_{2(s)} + 2\ H_{2(g)} \rightleftharpoons Sn_{(s)} + 2\ H_2O_{(g)}$ $K_{p1} = 8.12$
(2) $H_{2(g)} + CO_{2(g)} \rightleftharpoons H_2O_{(g)} + CO_{(g)}$ $K_{p2} = 0.771$

Calculate the value of K_p for the following reaction.

$$SnO_{2(s)} + 2\ CO_{(g)} \rightleftharpoons Sn_{(s)} + 2\ CO_{2(g)}$$

a) (5 points) Describe how the equations must be manipulated in order to obtain the final equation. [e.g. "reverse eqn (1)", "multiply eqn (2) by 2", etc…]

Reverse equation (2), multiply equation (2) by 2, then add eq. (1)

b) (5 points) Show how the equilibrium constants must be manipulated in order to obtain the final equilibrium constant. [e.g. "$K_p = K_{p1}/2$", etc]

$$K_p = (K_{p1})\ (1 / K_{p2}^{\ 2}) = K_{p1} / (K_{p2})^2$$

c) (5 points) Give the numerical value of K_p for the final reaction.

$K_p = (8.12) / (0.771)^2 = 13.7$

9. (12 points) ***Briefly*** define the following terms:

reaction order—is the value of the exponent(s) on the concentrations of reactants in the rate equation. Overall order is the sum of all exponents.

enzyme—a biological catalyst that increases the rate of biochemical reactions

colligative property—a characteristic of a solution that depends on the number particles dissolved in it but not their identity

10. (18 points) **SHOW ALL WORK** A sample of a drug ($C_{21}H_{23}O_5N$, MW = 369 g/mol) mixed with lactose (a sugar, $C_{12}H_{22}O_{11}$, MW = 342 g/mol) was analyzed by osmotic pressure to determine the amount sugar present. If 100 mL of solution containing 1.00 g of the drug-sugar mixture has an osmotic pressure of 519 torr at 25 °C, what is the percent sugar present in the drug/sugar mixture?

Answer: $\Pi V = nRT$
(519/760)(0.100) = n(0.0821)(298)
n = 0.0027<u>9</u>122 mol drug/sugar mix
1.00 g / 0.0027<u>9</u>122 mol = 35<u>8</u>.266 g/mol average
(x)(369) + (1-x)(342) = 35<u>8</u>.266 g/mol
27x + 342 = 35<u>8</u>.266
x = 0.602, so 60 mol % drug, **40 mol % sugar**
(**38% by mass**)

11. (12 points) **SHOW ALL WORK**. At a certain temperature, the following reaction has $K_c = 45$. The reaction was started with 3.0 M Br_2 and 1.5 M Cl_2. After the reaction proceeded for several minutes, the concentration of BrCl was found to be 2.60 M. Determine whether or not the system has reached equilibrium by calculating the appropriate quantity. (Hint; the quadratic formula is not required!)

$$Br_{2(g)} + Cl_{2(g)} \rightleftharpoons 2\ BrCl_{(g)}$$

$K_c = 45 = [BrCl]_2/[Br_2][Cl_2]$

	$[Br_2]$	$[Cl_2]$	[BrCl]
Init	3.0 M	1.5 M	0
Change	-x	-x	+2x
Equil	1.7 M	0.2 M	2.60 M

x = 1.30 M

Solve for Q.

$Q = (2.60)^2/(1.7)(0.2) = 20$

$Q < K_c$, so it has not reached equilibrium.

12. (12 points) **SHOW ALL WORK**. For the reaction below, it is found that a plot of 1/[NO2] versus time gives a straight line with a slope of 0.255 $M^{-1}\ s^{-1}$. How long will it take for the concentration of NO_2 to decrease from 1.00 M to 0.25 M?

$$NO_{2(g)} \rightleftharpoons NO_{(g)}) + O_{(g)}$$

2^{nd} order reaction, so

$1/[A]_t = kt + 1/[A]_0$

$1/0.25 = kt + 1/1 = 4 = kt + 1$

$kt = 3$

$k = 0.255$, so

t = 12 s

CHEM 10123/10125, Exam 1 **Name**________________________
February 8, 2012 (50 minutes) (please print)

1. SHOW ALL WORK. A saturated, aqueous NaCl solution is 4.40 M NaCl (58.44 g/mol) and is 18.0% NaCl by weight.
a) (10 points) Calculate the molal concentration of NaCl in this solution.

$$\frac{18.0 \text{ g NaCl}}{(100\text{-}18.0) \text{ g } H_2O} \times \frac{1000 \text{ g } H_2O}{1 \text{ kg } H_2O} \times \frac{1 \text{ mol NaCl}}{58.44 \text{ g NaCl}} = \boxed{\frac{3.76 \text{ mol NaCl}}{\text{kg } H_2O}}$$

b) (10 points) Calculate the density of this NaCl solution in g/mL.

$$\frac{4.40 \text{ mol NaCl}}{1000 \text{ mL soln}} \times \frac{58.44 \text{ g NaCl}}{1 \text{ mol NaCl}} \times \frac{100 \text{ g soln}}{18.0 \text{ g NaCl}} = \boxed{\frac{1.43 \text{ g soln}}{\text{mL soln}}}$$

2. (11 points) **SHOW ALL WORK**. Suppose that, in an equilibrium mixture of HCl, Cl_2, and H_2 at 500 K, the partial pressure of H_2 is 3.15 x 10^{-5} torr and that of Cl_2 is 6.23 x 10^{-5} torr. Given that K_p = 4.0 x 10^{18} for the reaction;

$$H_{2(g)} + Cl_{2(g)} \rightarrow 2\ HCl_{(g)}$$

a) What is the partial pressure of HCl?

$K_p = P^2_{HCl} / (P_{Cl2})(P_{H2})$

$P^2_{HCl} = (Kp)\ (P_{Cl2})(P_{H2}) = (4.0 \times 10^{18})\ (6.23 \times 10^{-5})\ (3.15 \times 10^{-5}) = 7.8 \times 10^9$

P_{HCl} = **8.9 x 10^4 torr**, or **1.2 x 10^2 atm**

b) What is K_c for this reaction?

Since Δn = 2-2 =0, $K_p = K_c(RT)^0$, i.e.
The same as K_p, 4.0 x 10^{18}

3. At 25 °C, K_c = 0.145 for the following reaction in the solvent CCl_4:

$$2\ BrCl_{(g)} \rightleftharpoons Br_{2(g)} + Cl_{2(g)}$$

If the initial concentrations ***of each substance*** in a solution are 0.0400 M, what will their equilibrium concentrations be?

a) (6 points) Write the concentration table, using the variable x.

	$BrCl_{(g)}$	$Br_{2(g)}$	$Cl_{2(g)}$
INIT	0.0400 M	0.0400 M	0.0400 M
CHANGE	+2x	–x	–x
EQUIL	0.0400 + 2x	0.0400 – x	0.0400 – x

b) (3 points) Write the equilibrium expression, using the variable x.

$$0.145 = \frac{(0.0400 - x)(0.0400 - x)}{(0.0400 + 2x)^2}$$

c) (6 points) Solve for x.

$0.381(0.0400 + 2x) = (0.0400 - x)$
$0.0152 + 1.762x = 0.0400$
$1.762x = 0.0248$
$x = 0.0141$

d) (2 points) Give the gas concentrations.

[BrCl] = 0.0682 M

[Cl_2] = 0.0259 M

[Br_2] = 0.0259 M

4. (19 points) A thorough kinetic study has been performed on a certain reaction:

$$2A_{(aq)} \rightarrow B_{(aq)}$$

The room temperature data was plotted as molar concentration versus time (in seconds), and a tangent to the curve at t = 0 had a slope of 8.2×10^{-3}. The log of the concentration was plotted against time to give a straight line with a slope of –0.068. After varying temperatures, a plot of ln k versus 1/T was found to be a straight line with a slope of -6.00×10^{5} and y intercept of 26.8. Answer the following questions about the reaction (***include units with all answers!***).

a) What is the value of the room temperature rate constant?

k = -slope = 0.068

b) What units should the rate constant have?

s^{-1}

c) At room temperature, what was the initial instantaneous rate of reaction?

Rate = Δcon. / Δtime = slope = 8.2×10^{-3} mol L^{-1} s^{-1}

d) Ten minutes after the reaction has started, is the rate faster, slower, the same, or you cannot tell from the data given?

Slower

Concentration decreases with time therefore the rate will decrease as well.

e) Write the rate equation for the reaction.

Rate = k [A] = (0.068) ([A])

f) Calculate the $t_{½}$ for this reaction.

$t_{½}$ = ln 2 / k = ln 2 / 0.068 = 10 sec.

g) **SHOW ALL WORK**. Calculate the energy of activation of this reaction in kJ/mol, and the frequency factor.

Arrhenius plot slope = $-6.00 \times 10^{5} = -E_a/R$

$\mathbf{E_a}$ = $(6.00 \times 10^{5}$ K$)(8.314 \times 10^{-3}$ kJ/mol.K) = **4.99×10^{3} kJ/mol**

Arrhenius plot intercept = 26.8 = ln A

A = $e^{26.8}$ = **4.36×10^{11} s^{-1}**

5. (4 points) Fill in the blanks. Milk is an example of an **emulsion**, which is a liquid dispersed in another liquid to make a **colloidal** dispersion.

6. (6 points) Name three factors that affect reaction rates.

Nature of the Reactants
Ability of reactants to come in contact
Concentrations of the reactants
Temperature of the system
Presence of a *catalyst*

7. (4 points) Choose one of the factors you listed in question #6 and explain its effect using collision theory.

The ability of reactant to come in contact is great for collision theory. If the molecules are not lined up correctly then no reaction occurs. Therefore the ability of reactants to come in contact with each other to make an effective collision is the purpose behind collision theory.

8. Using the data,

(1) $Ag(NH_3)_2^+{}_{(aq)} \rightleftharpoons Ag^+{}_{(aq)} + 2\ NH_{3(aq)}$ $K_{c1} = 6.3 \times 10^{-8}$
(2) $Ag_3PO_{4(s)} \rightleftharpoons 3\ Ag^+{}_{(aq)} + PO_4^{3-}{}_{(aq)}$ $K_{c2} = 2.8 \times 10^{-18}$

Calculate the value of K_c for the following reaction.

$$Ag_3PO_{4(s)} + 6\ NH_{3(aq)} \rightleftharpoons 3\ Ag(NH_3)_2^+{}_{(aq)} + PO_4^{3-}{}_{(aq)}$$

a) (5 points) Describe how the equations must be manipulated in order to obtain the final equation. [e.g. “reverse eqn (1)”, “multiply eqn (2) by 2”, etc…]

Multiply eqn (1) by 3 and reverse it, then add that to eqn (2).

b) (5 points) Show how the equilibrium constants must be manipulated in order to obtain the final equilibrium constant. [e.g. “$K_c = K_{c1}/2$”, etc]

$K_c = (K_{c1}^{-3})(K_{c2})$

c) (5 points) Give the numerical value of K_c for the final reaction.

$K_c = (1/2.50 \times 10^{-22})(2.8 \times 10^{-18}) = (3.999 \times 10^{12})(2.8 \times 10^{-18}) = 1.1 \times 10^{4}$

9. (12 points) ***Briefly*** define the following terms:

Tyndall effect—scattering of light by a colloidal dispersion

osmosis—the flow of solvent from a solution of lower solute concentration to one of higher solute concentration

catalyst—a substance that increases the rate of a chemical reaction but is not consumed by the reaction

10. (18 points) **SHOW ALL WORK**. A sample of a drug ($C_{22}H_{23}O_6N_2$, MW = 411 g/mol) mixed with lactose (a sugar, $C_{13}H_{22}O_{11}$, MW = 354 g/mol) was analyzed by osmotic pressure to determine the amount sugar present. If 100 mL of solution containing 1.15 g of the drug-sugar mixture has an osmotic pressure of 548 torr at 25 °C, what is the percent sugar present in the drug/sugar mixture?

Answer: $\Pi V = nRT$

(548/760)(0.100) = n(0.0821)(298)

n = 2.9<u>4</u>718 x 10^{-3} mol drug/sugar mix

1.15 g / 2.9<u>4</u>718 x 10^{-3} mol = 39<u>0</u>.202 g/mol average

(x)(354) + (1-x)(411) = 39<u>0</u>.202 g/mol

2<u>0</u>.798 = 57x

x = 0.36487, so **36 mol % sugar (33 mass %)**

11. (12 points) **SHOW ALL WORK**. At a certain temperature, the following reaction has K_c = 32. The reaction was started with 1.5 M Br_2 and 2.0 M Cl_2. After the reaction proceeded for several minutes, the concentration of BrCl was found to be 1.50 M. Determine whether or not the system has reached equilibrium by calculating the appropriate quantity. (Hint; the quadratic formula is not required!)

$$Br_{2(g)} + Cl_{2(g)} \rightleftharpoons 2\ BrCl_{(g)}$$

$K_c = 32 = [BrCl]_2/[Br_2][Cl_2]$

	$[Br_2]$	$[Cl_2]$	[BrCl]
Init	1.5 M	2.0 M	0
Change	-x	-x	+2x
Equil	0.75 M	1.25 M	1.50 M

x = 0.75 M

Solve for Q.

$Q = (1.50)^2/(0.75)(1.25) = 2.4$

$Q < K_c$, so it has not reached equilibrium.

12. (12 points) **SHOW ALL WORK**. For the reaction below, it is found that a plot of $1/[NO_2]$ versus time gives a straight line with a slope of 0.310 $M^{-1}\ s^{-1}$. How long will it take for the concentration of NO_2 to decrease from 2.00 M to 0.50 M?

$$NO_{2(g)} \rightleftharpoons NO_{(g)} + O_{(g)}$$

2^{nd} order reaction, so

$1/[A]_t = kt + 1/[A]_0$

$1/0.50 = kt + 1/2.00 = 2 = kt + 0.5$

$kt = 1.5$

$k = 0.310$, so

t = 4.8 s