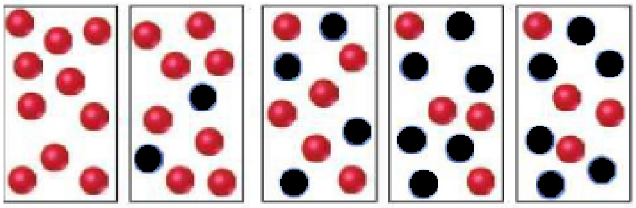
AP Chemistry Unit 8 Equilibrium Problem Sets.

Problem Set 1 – Equilibrium Concepts and Keq

1

15.2 The following diagrams represent a hypothetical reaction A ⟶ B, with A represented by **gray** spheres and B represented by **black** spheres. The sequence from left to right represents the system as time passes. Do the diagrams indicate that the system reaches an equilibrium state? Explain. [Sections 15.1 and 15.2]



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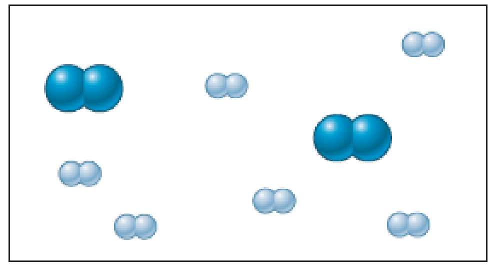
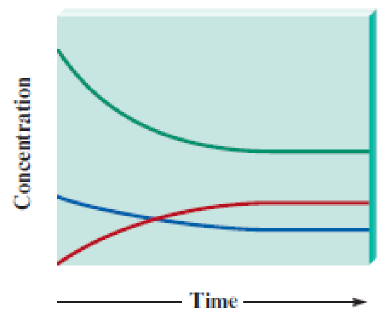
10. Consider an initial mixture of N_2 and H_2 gases that can be represented as follows:



The gases react to form ammonia gas (NH_3) as represented by the following concentration profile:



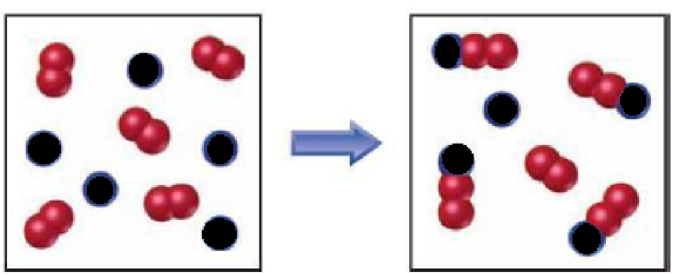
a. Label each plot on the graph as N_2, H_2, or NH_3, and explain your answers.

b. Explain the relative shapes of the plots.

c. When is equilibrium reached? How do you know?

3

15.4 The following diagram represents a reaction shown going to completion. **(a)** Letting A = **gray** spheres and B = **black** spheres, write a balanced equation for the reaction. **(b)** Write the equilibrium-constant expression for the reaction.



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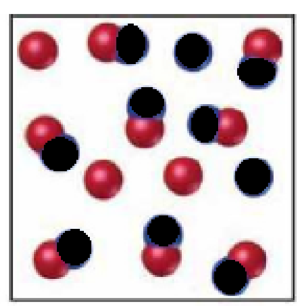
15.3 The following diagram represents an equilibrium mixture produced for a reaction of the type $A + X \rightleftharpoons AX$. If the volume is 1 L, is K greater or smaller than 1?



5

9. The value of the equilibrium constant K depends on which of the following (more than one answer may be correct)?
   a. the initial concentrations of the reactants
   b. the initial concentrations of the products
   c. the temperature of the system
   d. the nature of the reactants and products

   Explain.

6

1. Consider an equilibrium mixture of four chemicals (A, B, C, and D, all gases) reacting in a closed flask according to the equation:

$$A(g) + B(g) \rightleftharpoons C(g) + D(g)$$

   a. You add more A to the flask. How does the concentration of each chemical compare to its original concentration after equilibrium is reestablished? Justify your answer.
   b. You have the original setup at equilibrium, and you add more D to the flask. How does the concentration of each chemical compare to its original concentration after equilibrium is reestablished? Justify your answer.

7

15.12 Consider the reaction $A + B \rightleftharpoons C + D$. Assume that both the forward reaction and the reverse reaction are elementary processes and that the value of the equilibrium constant is very large. **(a)** Which species predominate at equilibrium, reactants or products? **(b)** Which reaction has the larger rate constant, the forward or the reverse? Explain.

8

15.15 When the following reactions come to equilibrium, does the equilibrium mixture contain mostly reactants or mostly products?
(a) $N_2(g) + O_2(g) \rightleftharpoons 2\,NO(g)$; $K_c = 1.5 \times 10^{-10}$
(b) $2\,SO_2(g) + O_2(g) \rightleftharpoons 2\,SO_3(g)$; $K_p = 2.5 \times 10^9$

9

15.13 Write the expression for K_c for the following reactions. In each case indicate whether the reaction is homogeneous or heterogeneous.
(a) $3\,NO(g) \rightleftharpoons N_2O(g) + NO_2(g)$
(b) $CH_4(g) + 2\,H_2S(g) \rightleftharpoons CS_2(g) + 4\,H_2(g)$
(c) $Ni(CO)_4(g) \rightleftharpoons Ni(s) + 4\,CO(g)$
(d) $HF(aq) \rightleftharpoons H^+(aq) + F^-(aq)$
(e) $2\,Ag(s) + Zn^{2+}(aq) \rightleftharpoons 2\,Ag^+(aq) + Zn(s)$

10

15.14 Write the expressions for K_c for the following reactions. In each case indicate whether the reaction is homogeneous or heterogeneous.
(a) $2\,O_3(g) \rightleftharpoons 3\,O_2(g)$
(b) $Ti(s) + 2\,Cl_2(g) \rightleftharpoons TiCl_4(l)$
(c) $2\,C_2H_4(g) + 2\,H_2O(g) \rightleftharpoons 2\,C_2H_6(g) + O_2(g)$
(d) $C(s) + 2\,H_2(g) \rightleftharpoons CH_4(g)$
(e) $4\,HCl(aq) + O_2(g) \rightleftharpoons 2\,H_2O(l) + 2\,Cl_2(g)$

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23. At a given temperature, $K = 1.3 \times 10^{-2}$ for the reaction

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

   Calculate values of K for the following reactions at this temperature.
   a. $\frac{1}{2}N_2(g) + \frac{3}{2}H_2(g) \rightleftharpoons NH_3(g)$
   b. $2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$
   c. $NH_3(g) \rightleftharpoons \frac{1}{2}N_2(g) + \frac{3}{2}H_2(g)$
   d. $2N_2(g) + 6H_2(g) \rightleftharpoons 4NH_3(g)$

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15.24 Consider the equilibrium

$$N_2(g) + O_2(g) + Br_2(g) \rightleftharpoons 2\,NOBr(g)$$

Calculate the equilibrium constant K for this reaction, given the following information (at 298 K):

$$2\,NO(g) + Br_2(g) \rightleftharpoons 2\,NOBr(g) \qquad K = 2.0$$
$$2\,NO(g) \rightleftharpoons N_2(g) + O_2(g) \qquad K = 2.1 \times 10^{30}$$

Problem Set 2 – Equilibrium Constant Calculations

1	2
15.27 Gaseous hydrogen iodide is placed in a closed container at 425 °C, where it partially decomposes to hydrogen and iodine: $2\ HI(g) \rightleftharpoons H_2(g) + I_2(g)$. At equilibrium it is found that $[HI] = 3.53 \times 10^{-3}\ M$, $[H_2] = 4.79 \times 10^{-4}\ M$, and $[I_2] = 4.79 \times 10^{-4}\ M$. What is the value of K_c at this temperature?	28. At a particular temperature a 2.00-L flask at equilibrium contains 2.80×10^{-4} mole of N_2, 2.50×10^{-5} mole of O_2, and 2.00×10^{-2} mole of N_2O. Calculate K at this temperature for the reaction $$2N_2(g) + O_2(g) \rightleftharpoons 2N_2O(g)$$ If $[N_2] = 2.00 \times 10^{-4}\ M$, $[N_2O] = 0.200\ M$, and $[O_2] = 0.00245\ M$, does this represent a system at equilibrium?
3	**4**
26. At high temperatures, elemental nitrogen and oxygen react with each other to form nitrogen monoxide: $$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$$ Suppose the system is analyzed at a particular temperature, and the equilibrium concentrations are found to be $[N_2] = 0.041\ M$, $[O_2] = 0.0078\ M$, and $[NO] = 4.7 \times 10^{-4}\ M$. Calculate the value of K for the reaction.	44. The reaction $$2NO(g) + Br_2(g) \rightleftharpoons 2NOBr(g)$$ has $K_p = 109$ at 25°C. If the equilibrium partial pressure of Br_2 is 0.0159 atm and the equilibrium partial pressure of NOBr is 0.0768 atm, calculate the partial pressure of NO at equilibrium.
5	**6**
15.40 At 900 K the following reaction has $K_p = 0.345$: $$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$$ In an equilibrium mixture the partial pressures of SO_2 and O_2 are 0.135 atm and 0.455 atm, respectively. What is the equilibrium partial pressure of SO_3 in the mixture?	15.28 Methanol (CH_3OH) is produced commercially by the catalyzed reaction of carbon monoxide and hydrogen: $CO(g) + 2\ H_2(g) \rightleftharpoons CH_3OH(g)$. An equilibrium mixture in a 2.00-L vessel is found to contain 0.0406 mol CH_3OH, 0.170 mol CO, and 0.302 mol H_2 at 500 K. Calculate K_c at this temperature.
7	**8**
15.29 The equilibrium $2\ NO(g) + Cl_2(g) \rightleftharpoons 2\ NOCl(g)$ is established at 500 K. An equilibrium mixture of the three gases has partial pressures of 0.095 atm, 0.171 atm, and 0.28 atm for NO, Cl_2, and NOCl, respectively. Calculate K_p for this reaction at 500 K.	5. Answer the following question involving masses and equilibrium constants: a. At 1285°C the equilibrium constant for the reaction $Br_{2\,(g)} \longleftrightarrow 2\ Br_{(g)}$ is $K_c = 1.04 \times 10^{-3}$. A 0.200-L vessel containing an equilibrium mixture of gases has 0.245 g $Br_{2\,(g)}$ in it. What is the mass of $Br_{(g)}$ in the vessel? b. For the reaction $H_{2\,(g)} + I_{2\,(g)} \longleftrightarrow 2\ HI_{(g)}$, $K_c = 55.3$ at 700 K. In a 2.00-L flask containing an equilibrium mixture of the three gases, there are 0.056 g H_2 and 4.36 g I_2. What is the mass of HI in the flask?
9	**10**
43. For the reaction $$2H_2O(g) \rightleftharpoons 2H_2(g) + O_2(g)$$ $K = 2.4 \times 10^{-3}$ at a given temperature. At equilibrium in a 2.0-L container it is found that $[H_2O(g)] = 1.1 \times 10^{-1}\ M$ and $[H_2(g)] = 1.9 \times 10^{-2}\ M$. Calculate the moles of $O_2(g)$ present under these conditions.	

Problem Set 3 – Applications of K: Direction (Q) and Extent of Reaction (ICE)

1

15.35 **(a)** How does a reaction quotient differ from an equilibrium constant? **(b)** If $Q_c < K_c$, in which direction will a reaction proceed in order to reach equilibrium? **(c)** What condition must be satisfied so that $Q_c = K_c$?

2

15.37 At 100 °C the equilibrium constant for the reaction $COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$ has the value $K_c = 2.19 \times 10^{-10}$. Are the following mixtures of $COCl_2$, CO, and Cl_2 at 100 °C at equilibrium? If not, indicate the direction that the reaction must proceed to achieve equilibrium. **(a)** $[COCl_2] = 2.00 \times 10^{-3}\,M$, $[CO] = 3.3 \times 10^{-6}\,M$, $[Cl_2] = 6.62 \times 10^{-6}\,M$; **(b)** $[COCl_2] = 4.50 \times 10^{-2}\,M$, $[CO] = 1.1 \times 10^{-7}\,M$, $[Cl_2] = 2.25 \times 10^{-6}\,M$; **(c)** $[COCl_2] = 0.0100\,M$, $[CO] = [Cl_2] = 1.48 \times 10^{-6}\,M$

3

39. The equilibrium constant is 0.0900 at 25°C for the reaction

$$H_2O(g) + Cl_2O(g) \rightleftharpoons 2HOCl(g)$$

For which of the following sets of conditions is the system at equilibrium? For those that are not at equilibrium, in which direction will the system shift?

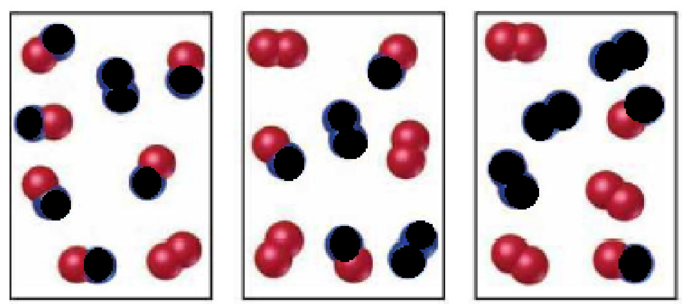
a. A 1.0-L flask contains 1.0 mole of HOCl, 0.10 mole of Cl_2O, and 0.10 mole of H_2O.

b. A 2.0-L flask contains 0.084 mole of HOCl, 0.080 mole of Cl_2O, and 0.98 mole of H_2O.

c. A 3.0-L flask contains 0.25 mole of HOCl, 0.0010 mole of Cl_2O, and 0.56 mole of H_2O.

4

15.6 The reaction $A_2 + B_2 \rightleftharpoons 2\,AB$ has an equilibrium constant $K_c = 1.5$. The following diagrams represent reaction mixtures containing A_2 molecules **gray**, B_2 molecules **black**, and AB molecules. **(a)** Which reaction mixture is at equilibrium? **(b)** For those mixtures that are not at equilibrium, how will the reaction proceed to reach equilibrium?



(i) (ii) (iii)

5

At a particular temperature, a 2.00-L flask at equilibrium contains 2.80×10^{-4} moles of N_2, 2.50×10^{-5} moles of O_2, and 2.00×10^{-2} moles of N_2O based on:

$\mathbf{N_{2\,(g)} + O_{2\,(g)} \longleftrightarrow 2\,NO_{(g)}}$. In a different trial of the same reaction, $[N_2] = 2.00 \times 10^{-4}$ M, $[N_2O] = 0.200$ M, and $[O_2] = 0.00245$ M, does this represent a system at equilibrium? If not, what directional shift must take place to establish equilibrium?

6

15.42 **(a)** At 800 K the equilibrium constant for $I_2(g) \rightleftharpoons 2\,I(g)$ is $K_c = 3.1 \times 10^{-5}$. If an equilibrium mixture in a 10.0-L vessel contains 2.67×10^{-2} g of I(g), how many grams of I_2 are in the mixture? **(b)** For $2\,SO_2(g) + O_2(g) \rightleftharpoons 2\,SO_3(g)$, $K_p = 3.0 \times 10^4$ at 700 K. In a 2.00-L vessel the equilibrium mixture contains 1.17 g of SO_3 and 0.105 g of O_2. How many grams of SO_2 are in the vessel?

7

15.31 A mixture of 0.10 mol of NO, 0.050 mol of H_2, and 0.10 mol of H_2O is placed in a 1.0-L vessel at 300 K. The following equilibrium is established:

$$2\,NO(g) + 2\,H_2(g) \rightleftharpoons N_2(g) + 2\,H_2O(g)$$

At equilibrium $[NO] = 0.062\,M$. **(a)** Calculate the equilibrium concentrations of H_2, N_2, and H_2O. **(b)** Calculate K_c.

8

15.32 A mixture of 1.374 g of H_2 and 70.31 g of Br_2 is heated in a 2.00-L vessel at 700 K. These substances react as follows:

$$H_2(g) + Br_2(g) \rightleftharpoons 2\,HBr(g)$$

At equilibrium the vessel is found to contain 0.566 g of H_2. **(a)** Calculate the equilibrium concentrations of H_2, Br_2, and HBr. **(b)** Calculate K_c.

9

48. At a particular temperature, 8.0 moles of NO_2 is placed into a 1.0-L container and the NO_2 dissociates by the reaction

$$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$$

At equilibrium the concentration of $NO(g)$ is 2.0 M. Calculate K for this reaction.

10

15.43 At 2000 °C the equilibrium constant for the reaction

$$2\,NO(g) \rightleftharpoons N_2(g) + O_2(g)$$

is $K_c = 2.4 \times 10^3$. If the initial concentration of NO is 0.200 M, what are the equilibrium concentrations of NO, N_2, and O_2?

11

15.44 For the equilibrium

$$Br_2(g) + Cl_2(g) \rightleftharpoons 2\,BrCl(g)$$

at 400 K, $K_c = 7.0$. If 0.25 mol of Br_2 and 0.25 mol of Cl_2 are introduced into a 1.0-L container at 400 K, what will be the equilibrium concentrations of Br_2, Cl_2, and BrCl?

12

15.45 At 373 K, $K_p = 0.416$ for the equilibrium

$$2\,NOBr(g) \rightleftharpoons 2\,NO(g) + Br_2(g)$$

If the pressures of $NOBr(g)$ and $NO(g)$ are equal, what is the equilibrium pressure of $Br_2(g)$?

13

56. At a particular temperature, $K_p = 0.25$ for the reaction

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

a. A flask containing only N_2O_4 at an initial pressure of 4.5 atm is allowed to reach equilibrium. Calculate the equilibrium partial pressures of the gases.

b. A flask containing only NO_2 at an initial pressure of 9.0 atm is allowed to reach equilibrium. Calculate the equilibrium partial pressures of the gases.

c. From your answers to parts a and b, does it matter from which direction an equilibrium position is reached?

14

15.48 At 80 °C, $K_c = 1.87 \times 10^{-3}$ for the reaction

$$PH_3BCl_3(s) \rightleftharpoons PH_3(g) + BCl_3(g)$$

(a) Calculate the equilibrium concentrations of PH_3 and BCl_3 if a solid sample of PH_3BCl_3 is placed in a closed vessel and decomposes until equilibrium is reached. **(b)** If the flask has a volume of 0.500 L, what is the minimum mass of $PH_3BCl_3(s)$ that must be added to the flask to achieve equilibrium?

15

15.50 At 25 °C the reaction

$$CaCrO_4(\mathbf{s}) \rightleftharpoons Ca^{2+}(aq) + CrO_4^{2-}(aq)$$

has an equilibrium constant $K_c = 7.1 \times 10^{-4}$. What are the equilibrium concentrations of Ca^{2+} and CrO_4^{2-} in a saturated solution of $CaCrO_4$?

16

Problem Set 4 More ICE and Le Chatelier's Principle

1	2
57. At 35°C, $K = 1.6 \times 10^{-5}$ for the reaction $2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$ Calculate the concentrations of all species at equilibrium for each of the following original mixtures. **a.** 2.0 moles of pure NOCl in a 2.0-L flask **b.** 1.0 mole of NOCl and 1.0 mole of NO in a 1.0-L flask **c.** 2.0 moles of NOCl and 1.0 mole of Cl_2 in a 1.0-L flask	**54.** At 25°C, $K = 0.090$ for the reaction $H_2O(g) + Cl_2O(g) \rightleftharpoons 2HOCl(g)$ Calculate the concentrations of all species at equilibrium for each of the following cases. **a.** 1.0 g H_2O and 2.0 g Cl_2O are mixed in a 1.0-L flask. **b.** 1.0 mole of pure HOCl is placed in a 2.0-L flask.
3	**4**
62. A sample of solid ammonium chloride was placed in an evacuated container and then heated so that it decomposed to ammonia gas and hydrogen chloride gas. After heating, the total pressure in the container was found to be 4.4 atm. Calculate K_p at this temperature for the decomposition reaction $NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$	**78.** For the reaction $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ at 600. K, the equilibrium constant, K_p, is 11.5. Suppose that 2.450 g PCl_5 is placed in an evacuated 500.-mL bulb, which is then heated to 600. K. **a.** What would be the pressure of PCl_5 if it did not dissociate? **b.** What is the partial pressure of PCl_5 at equilibrium? **c.** What is the total pressure in the bulb at equilibrium? **d.** What is the percent dissociation of PCl_5 at equilibrium?
5	**6**
80. For the following reaction at a certain temperature $H_2(g) + F_2(g) \rightleftharpoons 2HF(g)$ it is found that the equilibrium concentrations in a 5.00-L rigid container are $[H_2] = 0.0500\ M$, $[F_2] = 0.0100\ M$, and $[HF] = 0.400\ M$. If 0.200 mole of F_2 is added to this equilibrium mixture, calculate the concentrations of all gases once equilibrium is reestablished.	**61.** At 25°C, $K_p = 2.9 \times 10^{-3}$ for the reaction $NH_4OCONH_2(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$ In an experiment carried out at 25°C, a certain amount of NH_4OCONH_2 is placed in an evacuated rigid container and allowed to come to equilibrium. Calculate the total pressure in the container at equilibrium.
7	**8**
Phosgene, $COCl_2$, is prepared from CO and Cl_2 according to the following equation: CO + Cl_2---> $COCl_2$. Kc at 395 °C is 1.23×10^3. If 2.00 mol of CO and 3.50 mol of Cl_2 are added to a 5.00 liter reaction vessel at 395 °C, what would the equilibrium concentrations be for all species?	**86.** For the reaction below, $K_p = 1.16$ at 800.°C. $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$ If a 20.0-g sample of $CaCO_3$ is put into a 10.0-L container and heated to 800.°C, what percentage by mass of the $CaCO_3$ will react to reach equilibrium?

9

15.52 Consider $4\,NH_3(g) + 5\,O_2(g) \rightleftharpoons 4\,NO(g) + 6\,H_2O(g)$, $\Delta H = -904.4$ kJ. How does each of the following changes affect the yield of NO at equilibrium? Answer increase, decrease, or no change: **(a)** increase $[NH_3]$; **(b)** increase $[H_2O]$; **(c)** decrease $[O_2]$; **(d)** decrease the volume of the container in which the reaction occurs; **(e)** add a catalyst; **(f)** increase temperature.

10

15.51 Consider the following equilibrium, for which $\Delta H < 0$

$$2\,SO_2(g) + O_2(g) \rightleftharpoons 2\,SO_3(g)$$

How will each of the following changes affect an equilibrium mixture of the three gases? **(a)** $O_2(g)$ is added to the system; **(b)** the reaction mixture is heated; **(c)** the volume of the reaction vessel is doubled; **(d)** a catalyst is added to the mixture; **(e)** the total pressure of the system is increased by adding a noble gas; **(f)** $SO_3(g)$ is removed from the system.

11

65. An important reaction in the commercial production of hydrogen is

$$CO(g) + H_2O(g) \rightleftharpoons H_2(g) + CO_2(g)$$

How will this system at equilibrium shift in each of the five following cases?

a. Gaseous carbon dioxide is removed.

b. Water vapor is added.

c. In a rigid reaction container, the pressure is increased by adding helium gas.

d. The temperature is increased (the reaction is exothermic).

e. The pressure is increased by decreasing the volume of the reaction container.

12

64. Predict the shift in the equilibrium position that will occur for each of the following reactions when the volume of the reaction container is increased.

a. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

b. $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

c. $H_2(g) + F_2(g) \rightleftharpoons 2HF(g)$

d. $COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$

e. $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

13

Methanol (CH_3OH) can be made by the reaction of CO with H_2: $\mathbf{CO_{(g)} + 2\,H_{2\,(g)} \Leftrightarrow CH_3OH_{(g)}}$

a)Use the following thermochemical data to calculate ΔH° for this reaction:

$CO_{(g)}$	-110.5 kJ/mol
$CH_3OH_{(g)}$	-201.0 kJ/mol

b)To maximize the equilibrium yield of methanol, would you use a high or low temperature? Explain.

c)To maximize the equilibrium yield of methanol, would you use a high or low pressure? Explain.

14

82. Consider the reaction

$$Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons FeSCN^{2+}(aq)$$

How will the equilibrium position shift if

a. water is added, doubling the volume?

b. $AgNO_3(aq)$ is added? (AgSCN is insoluble.)

c. $NaOH(aq)$ is added? [$Fe(OH)_3$ is insoluble.]

d. $Fe(NO_3)_3(aq)$ is added?

15

84. The synthesis of ammonia gas from nitrogen gas and hydrogen gas represents a classic case in which a knowledge of kinetics and equilibrium was used to make a desired chemical reaction economically feasible. Explain how each of the following conditions helps to maximize the yield of ammonia.

a. running the reaction at an elevated temperature

b. removing the ammonia from the reaction mixture as it forms

c. using a catalyst

d. running the reaction at high pressure

16

83. Chromium(VI) forms two different oxyanions, the orange dichromate ion, $Cr_2O_7^{2-}$, and the yellow chromate ion, CrO_4^{2-}. (See the following photos.) The equilibrium reaction between the two ions is

$$Cr_2O_7^{2-}(aq) + H_2O(l) \rightleftharpoons 2CrO_4^{2-}(aq) + 2H^+(aq)$$

Explain why orange dichromate solutions turn yellow when sodium hydroxide is added.

Problem Set 5 Solution Equilibria and Ksp

1	2
Write balanced equations for the dissolution (dissociation) reactions and the corresponding solubility product expressions for each of the following solids: a)$AgC_2H_3O_2$ b)$Al(OH)_3$ c)$Ca_3(PO_4)_2$	The molar solubility of Ag_2SO_4 is 1.44×10^{-2} mol/L. Calculate the K_{sp} of this compound.
3	**4**
The solubility of $CaSO_4$ (MM = 136.04 g/mol) is 0.955 g/L. Calculate the K_{sp} of $CaSO_4$.	Calculate the molar solubility of $Co(OH)_3$ ($K_{sp} = 2.51 \times 10^{-43}$) in moles per liter
5	**6**
Barium sulfate is a contrast agent for X-ray scans that are most often associated with the gastrointestinal tract. Calculate the mass of $BaSO_4$ that can dissolve in 100.0 mL of solution. The K_{sp} value for $BaSO_4$ is 1.5×10^{-9}.	A saturated solution of AgCl ($K_{sp} = 1.77 \times 10^{-10}$) contains a white precipitate of solid AgCl. When a solution of I^- ions is added, the white precipitate disappears and is replaced by a yellow precipitate of AgI, ($K_{sp} = 8.52 \times 10^{-17}$). How can this observation be explained?
7	**8**
Which is more soluble, AgCl, $K_{sp} = 2x\ 10^{-10}$ or Ag_2CO_3, $K_{sp} = 8 \times 10^{-12}$? Show calculations to support your answer.	Consider the solubility equilibrium: $AgI \Leftrightarrow Ag^+(aq) + I^-(aq)$ ($K_{sp} = 8.52 \times 10^{-17}$). Calculate the solubility of AgI in pure water. Then calculate the new solubility of AgI in a solution containing 1.00×10^{-3} M NaI.
9	**10**
Determine the solubility of lead(II) fluoride, $K_{sp} = 4.0 \times 10^{-8}$ in: a) 0.10 M $Pb(NO_3)_2$ b) 0.010 M NaF	A 200.0 mL solution of 4.00×10^{-3} M $BaCl_2$ is added to a 600.0 mL solution of 8.00×10^{-3} M K_2SO_4. Assuming that the volumes are additive, will $BaSO_4$ ($K_{sp} = 1.08 \times 10^{-10}$) precipitate from this solution?
11	**12**
Will a precipitate of $Ca(OH)_2$ ($K_{sp} = 5.02 \times 10^{-6}$) form if 2.00 mL of 0.200 M NaOH is added to 1.00×10^3 mL of 0.100 M $CaCl_2$?	Lead(II) chromate has a K_{sp} of 2.0×10^{-16}. Exactly 4.0 mL of 0.0040 M lead(II) nitrate is mixed with 2.0 mL of 0.00020 M sodium chromate. a) Write the precipitation reaction (net ionic). b) Show the K_{sp} expression for this solid precipitate dissociating. c) Will a precipitate form? Show calculations to support your answer. d) What would be the effect on the solubility equilibrium system if concentrated potassium chromate solution is added?
13	**14**
A solution is prepared by adding 50.0 mL of 0.10 M $Pb(NO_3)_2$ with 50.0 mL of 1.0 M KCl. Calculate the concentrations of Pb^{2+} and Cl^- at equilibrium (K_{sp} for $PbCl_{2\,(s)} = 1.6 \times 10^{-5}$).	

Problem Set 6 Solution Equilibria and Ksp Set 2

1	2
9. $Ag_2S(s)$ has a larger molar solubility than CuS even though Ag_2S has the smaller K_{sp} value. Explain how this is possible.	**25.** The concentration of Pb^{2+} in a solution saturated with $PbBr_2(s)$ is 2.14×10^{-2} *M*. Calculate K_{sp} for $PbBr_2$.
3	**4**
35. For each of the following pairs of solids, determine which solid has the smallest molar solubility. **a.** $CaF_2(s)$, $K_{sp} = 4.0 \times 10^{-11}$, or $BaF_2(s)$, $K_{sp} = 2.4 \times 10^{-5}$ **b.** $Ca_3(PO_4)_2(s)$, $K_{sp} = 1.3 \times 10^{-32}$, or $FePO_4(s)$, $K_{sp} = 1.0 \times 10^{-22}$	**39.** The K_{sp} for silver sulfate (Ag_2SO_4) is 1.2×10^{-5}. Calculate the solubility of silver sulfate in each of the following. **a.** water **b.** 0.10 *M* $AgNO_3$ **c.** 0.20 *M* K_2SO_4
5	**6**
23. Approximately 0.14 g nickel(II) hydroxide, $Ni(OH)_2(s)$, dissolves per liter of water at 20°C. Calculate K_{sp} for $Ni(OH)_2(s)$ at this temperature.	**28.** Calculate the solubility of each of the following compounds in moles per liter. **a.** PbI_2, $K_{sp} = 1.4 \times 10^{-8}$ **b.** $CdCO_3$, $K_{sp} = 5.2 \times 10^{-12}$ **c.** $Sr_3(PO_4)_2$, $K_{sp} = 1 \times 10^{-31}$
7	**8**
41. Calculate the solubility of solid $Ca_3(PO_4)_2$ ($K_{sp} = 1.3 \times 10^{-32}$) in a 0.20-*M* Na_3PO_4 solution.	**44.** The solubility of $Pb(IO_3)_2(s)$ in a 0.10-*M* KIO_3 solution is 2.6×10^{-11} mol/L. Calculate K_{sp} for $Pb(IO_3)_2(s)$.
9	**10**
50. A solution contains 1.0×10^{-5} *M* Ag^+ and 2.0×10^{-6} *M* CN^-. Will AgCN(*s*) precipitate? (K_{sp} for AgCN(*s*) is 2.2×10^{-12}.)	**52.** A solution contains 2.0×10^{-3} *M* Ce^{3+} and 1.0×10^{-2} *M* IO_3^{3-}. Will $Ce(IO_3)_3(s)$ precipitate? [K_{sp} for $Ce(IO_3)_3$ is 3.2×10^{-10}.]
11	**12**
53. Calculate the final concentrations of $K^+(aq)$, $C_2O_4^{2-}(aq)$, $Ba^{2+}(aq)$, and $Br^-(aq)$ in a solution prepared by adding 0.100 L of 0.200 *M* $K_2C_2O_4$ to 0.150 L of 0.250 *M* $BaBr_2$. (For BaC_2O_4, $K_{sp} = 2.3 \times 10^{-8}$.)	**57.** A solution contains 1.0×10^{-5} *M* Na_3PO_4. What is the minimum concentration of $AgNO_3$ that would cause precipitation of solid Ag_3PO_4 ($K_{sp} = 1.8 \times 10^{-18}$)?
13	**14**
82. Calculate the mass of manganese hydroxide present in 1300 mL of a saturated manganese hydroxide solution. For $Mn(OH)_2$, $K_{sp} = 2.0 \times 10^{-13}$.	**59.** A solution is 1×10^{-4} *M* in NaF, Na_2S, and Na_3PO_4. What would be the order of precipitation as a source of Pb^{2+} is added gradually to the solution? The relevant K_{sp} values are $K_{sp}(PbF_2) = 4 \times 10^{-8}$, $K_{sp}(PbS) = 7 \times 10^{-29}$, and $K_{sp}[Pb_3(PO_4)_2] = 1 \times 10^{-54}$.