

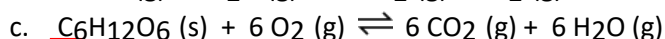
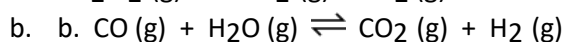
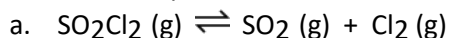
## Unit 7 Review for Midterms

### Equilibrium

You should be able to:

- Explain equilibrium in terms of rates of forward and reverse reactions
- Explain equilibrium in terms of observations of a reversible chemical reaction
- Interpret graphs of concentration, partial pressure, or reaction rates vs time and equilibrium
- Explain the relationship between direction of a reaction and relative rates of forward and reverse reactions
- Write equilibrium expressions for reversible reactions ( $K_c$  and  $K_p$ )
- Know when to use brackets in an equilibrium expression
- Know when to use an equilibrium expression ( $K$ ) or reaction quotient ( $Q$ ) calculation
- Explain which direction a reaction will proceed based on a comparison of  $Q$  and  $K$
- Calculate  $K_c$  or  $K_p$  based on equilibrium concentrations or pressures
- Explain the relationship between very large or very small values of  $K$  and the relative concentrations of reactants and/or products at equilibrium
- Manipulate reversible equations and their respective  $K$  values to achieve an overall equilibrium expression
- Use an ICE chart to determine equilibrium concentrations or pressures given initial concentrations/pressures and  $K$
- Draw a particulate model representing reversible reactions
- Identify the response of a system at equilibrium to a stress using Le Chatelier's principle
- Relate Le Chatelier's principle to  $Q$  and  $K$
- Write solubility-product expressions for salt dissolutions
- Calculate the solubility of a salt based on  $K_{sp}$
- Perform solubility calculations in the presence of a common ion
- Understand how the presence of a common ion affects solubility of a salt
- Identify the effect of pH on the solubility of a salt

1. For each of the equations below, write the expression for  $K_p$ :



2. Put the following  $K$  values in order of increasing product-favored ability.

a.  $K = 4 \times 10^{-5}$

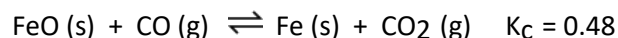
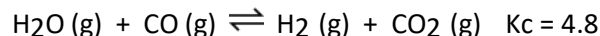
b.  $K = 2 \times 10^{-9}$

c.  $K = 7 \times 10^{-5}$

d.  $K = 3 \times 10^{-3}$

3. For the reaction:  $2 \text{NO}_2 (\text{g}) \rightleftharpoons \text{N}_2\text{O}_4 (\text{g})$  At equilibrium  $[\text{N}_2\text{O}_4] = 0.25 \text{ M}$  &  $[\text{NO}_2] = 0.175 \text{ M}$ . Calculate  $K_c$
4. For the reaction:  $2 \text{NH}_3 (\text{g}) \rightleftharpoons \text{N}_2 (\text{g}) + 3 \text{H}_2 (\text{g})$   $K_p = 32$  . At equilibrium  $P_{\text{NH}_3} = 0.64 \text{ atm}$  &  $P_{\text{N}_2} = 1.18 \text{ atm}$ . Calculate  $P_{\text{H}_2}$

5. Given the following equations:



Calculate the  $K_c$  value for:



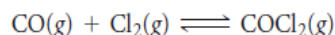
6. For the reaction:  $2 \text{NOCl} (\text{g}) \rightleftharpoons 2 \text{NO} (\text{g}) + \text{Cl}_2 (\text{g})$

$$K_c = 1.2 \times 10^{-3}$$

If the initial  $[\text{NOCl}] = 0.15 \text{ M}$ ,  $[\text{NO}] = 0.75 \text{ M}$ , and  $[\text{Cl}_2] = 0.05 \text{ M}$ , is the system at equilibrium? If not, which way will the reaction shift, left or right?

7. For the equation:  $2 \text{KClO}_3 (\text{s}) \rightleftharpoons 2 \text{KCl} (\text{s}) + 3 \text{O}_2 (\text{g})$ , you start with some  $\text{KClO}_3$  that decomposes into the products. At equilibrium, there is some solid remaining and the total pressure in the flask is  $0.29 \text{ atm}$ . Calculate the value of  $K_p$ .

8. Write the equilibrium-constant expression  $K_c$ .

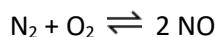


- a. What does the value of  $K_c$  indicate for this reaction?

$$K_c = 4.56 \times 10^9$$

- b. If the initial concentration of  $\text{CO}$  is  $0.55 \text{ M}$  and the initial concentration of  $\text{Cl}_2$  is  $0.38 \text{ M}$ , what are the equilibrium concentrations of all reactants and products?

9. If  $1.40 \text{ mole}$  of  $\text{N}_2$  and  $2.86 \text{ mole}$  of  $\text{O}_2$  are mixed in a  $3.00 \text{ L}$  container at  $1100^\circ \text{C}$ , what are the concentrations of  $\text{NO}$ ,  $\text{N}_2$ , and  $\text{O}_2$  at equilibrium?  $K_c = 2.60 \times 10^{-7}$



10. For the following reaction:  $2 \text{SO}_2 (\text{g}) + \text{O}_2 (\text{g}) \rightleftharpoons 2 \text{SO}_3 (\text{g})$   $\Delta H = -50 \text{ kJ/mol}$

What will be the effect of doing each of the following actions on the above equilibrium?

- |  |      |       |           |
|--|------|-------|-----------|
| a) Decreasing temperature              | Left | Right | No Change |
| b) Increasing $\text{O}_2 (\text{g})$  | Left | Right | No Change |
| c) Decreasing $\text{SO}_2 (\text{g})$ | Left | Right | No Change |
| d) Increasing volume                   | Left | Right | No Change |
| e) Increasing $\text{SO}_3 (\text{g})$ | Left | Right | No Change |
| f) Adding $\text{N}_2 (\text{g})$      | Left | Right | No Change |

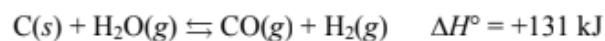
11. Solid calcium phosphate is dissolved in water.

- Write the equation for this dissolution.
- Write the solubility-product expression.
- If  $K_{sp} = 2.0 \times 10^{-29}$ , calculate the molar solubility of calcium phosphate.
- Calculate the molar solubility of calcium phosphate in  $0.0010 \text{ M}$  calcium nitrate.

12. Calcium fluoride has a solubility of 0.016 g/L.
- Calculate the molar solubility of calcium fluoride.
  - Write the equation for this dissolution.
  - Write the solubility-product expression.
  - Calculate the  $K_{sp}$  value.
  - Using your  $K_{sp}$  value from part d, calculate the molar solubility of calcium fluoride in 0.10 M sodium fluoride solution.
13. Does a precipitate form when 0.10 L of  $8.0 \times 10^{-3}$  M  $\text{Pb}(\text{NO}_3)_2$  is added to 0.40 L of  $5.0 \times 10^{-3}$  M  $\text{Na}_2\text{SO}_4$ ? Explain. The  $K_{sp}$  value of lead (II) sulfate is  $6.3 \times 10^{-7}$ .

### AP Questions

1. Several reactions are carried out using  $\text{AgBr}$ , a cream-colored silver salt for which the value of the solubility-product constant,  $K_{sp}$ , is  $5.0 \times 10^{-13}$  at 298 K.
- Write the expression for the solubility-product constant,  $K_{sp}$ , of  $\text{AgBr}$ .
  - Calculate the value of  $[\text{Ag}^+]$  in 50.0 mL of a saturated solution of  $\text{AgBr}$  at 298 K.
  - A 50.0 mL sample of distilled water is added to the solution described in part (b), which is in a beaker with some solid  $\text{AgBr}$  at the bottom. The solution is stirred and equilibrium is reestablished. Some solid  $\text{AgBr}$  remains in the beaker. Is the value of  $[\text{Ag}^+]$  greater than, less than, or equal to the value you calculated in part (b)? Justify your answer.
  - Calculate the minimum volume of distilled water, in liters, necessary to completely dissolve a 5.0 g sample of  $\text{AgBr}(s)$  at 298 K. (The molar mass of  $\text{AgBr}$  is  $188 \text{ g mol}^{-1}$ .)
  - A student mixes 10.0 mL of  $1.5 \times 10^{-4}$  M  $\text{AgNO}_3$  with 2.0 mL of  $5.0 \times 10^{-4}$  M  $\text{NaBr}$  and stirs the resulting mixture. What will the student observe? Justify your answer with calculations.
  - The color of another salt of silver,  $\text{AgI}(s)$ , is yellow. A student adds a solution of  $\text{NaI}$  to a test tube containing a small amount of solid, cream-colored  $\text{AgBr}$ . After stirring the contents of the test tube, the student observes that the solid in the test tube changes color from cream to yellow.
    - Write the chemical equation for the reaction that occurred in the test tube.
    - Which salt has the greater value of  $K_{sp}$ :  $\text{AgBr}$  or  $\text{AgI}$ ? Justify your answer.



A rigid container holds a mixture of graphite pellets ( $\text{C}(s)$ ),  $\text{H}_2\text{O}(g)$ ,  $\text{CO}(g)$ , and  $\text{H}_2(g)$  at equilibrium. State whether the number of moles of  $\text{CO}(g)$  in the container will increase, decrease, or remain the same after each of the following disturbances is applied to the original mixture. For each case, assume that all other variables remain constant except for the given disturbance. Explain each answer with a short statement.

- (a) Additional  $\text{H}_2(g)$  is added to the equilibrium mixture at constant volume.
- (b) The temperature of the equilibrium mixture is increased at constant volume.
- (c) The volume of the container is decreased at constant temperature.
- (d) The graphite pellets are pulverized.