

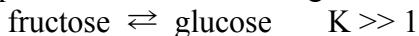
TOPIC G PROBLEMS

For problems 1-5, refer to the video “Introducing Chemical Equilibrium”
(Note: this video is included in the current module.)

- 1) List the defining characteristics of a dynamic equilibrium as described in the video.
- 2) a) The formation and decomposition ammonium chloride is provided as an example of a reversible chemical reaction. Describe the characteristics required of an experimental set-up in order to establish a dynamic chemical equilibrium.
b) Write the equation representing the chemical equilibrium for the system of ammonium chloride, ammonia, and hydrogen chloride.
- 3) a) What is a heterogeneous chemical equilibrium? Search the internet to find an example of a heterogeneous chemical equilibrium system (other than the one in the video.) Write the equilibrium equation for your example.
b) What is a homogenous chemical equilibrium? Search the internet to find an example of a homogeneous equilibrium system. Write the equilibrium equation for your example.
- 4) How can you tell from a graph of **reaction rate vs. time** when a system has established chemical equilibrium? (What is true for the rate of the forward reaction and the rate of the reverse reaction at equilibrium?)
- 5) How can you tell from a graph of **concentrations vs. time** when a system has established chemical equilibrium? (What is true for the concentrations of the products and the concentrations of the reactants at equilibrium?)

For the remaining problems, refer to the textbook, lecture videos, etc.

- 6) For the reaction below, the equilibrium constant K is greater than 1.



If a solution initially contains equal concentrations of fructose and glucose, which of the following statements must be true at that initial moment? Explain your answer.

- a) The forward reaction ($\text{fructose} \rightarrow \text{glucose}$) is faster than the reverse reaction.
- b) The reverse reaction is faster than the forward reaction.
- c) The forward and reverse reactions have equal rates.

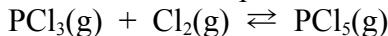
- 7) Write the K_c expressions for each of the following reactions. *Note: the subscript “c” tells you that this is the equilibrium constant in terms of concentrations (mol/L).*

- a) $2 \text{NO(g)} + \text{O}_2\text{(g)} \rightleftharpoons 2 \text{NO}_2\text{(g)}$
- b) $4 \text{Ag(s)} + \text{O}_2\text{(g)} \rightleftharpoons 2 \text{Ag}_2\text{O(s)}$
- c) $\text{CaCO}_3\text{(s)} + \text{CO}_2\text{(aq)} + \text{H}_2\text{O(l)} \rightleftharpoons \text{Ca}^{2+}\text{(aq)} + 2 \text{HCO}_3^-\text{(aq)}$

8) a) Write the K_p expressions for reactions a and b in the previous problem. Note: the subscript "p" tells you that this is the equilibrium constant in terms of partial pressures(atm).

b) If the value of K_c for reaction (a) in the previous is 2.8×10^{11} at 200°C , what is the value of K_p at this temperature?

9) For the reaction below, $K_c = 6.17$ at a certain temperature.



Determine whether each of the following mixtures is at equilibrium. Assume that each mixture is at the same temperature as that for the provided K_c . For each mixture that is not at equilibrium, tell whether the reaction will go forward or backward.

a) A mixture in which the concentration of PCl_3 is 0.0381 M, the concentration of Cl_2 is 0.0593 M, and the concentration of PCl_5 is 0.0139 M.

b) A mixture in which the concentration of PCl_3 is 0.0482 M, the concentration of Cl_2 is 0.289 M, and the concentration of PCl_5 is 0.0455 M.

c) A mixture that contains PCl_3 and PCl_5 , but no Cl_2 .

d) A mixture that contains 0.21 mol of PCl_3 , 0.48 mol of Cl_2 , and 0.39 mol of PCl_5 in an 8.00 L container.

10) If Q , the reaction quotient, is greater than K for a reaction mixture, which of the following will happen?

a) The reaction will go in the direction that increases Q .

b) The reaction will go in the direction that decreases Q .

c) The reaction will go in the direction that increases K .

d) The reaction will go in the direction that decreases K .

11) For the reaction $\text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g})$, $K_p = 0.0489$ at 256°C . For parts a through d, assume that the reaction is at this temperature.

a) An equilibrium mixture contains 0.100 atm of N_2 and 0.200 atm of H_2 . What is the partial pressure of NH_3 in this mixture?

b) A second equilibrium mixture contains 830 torr of H_2 and 42 torr of NH_3 . What is the partial pressure of N_2 in this mixture?

c) A third equilibrium mixture contains 0.0100 mol/L of N_2 and 0.0300 mol/L of NH_3 .

What is the concentration of H_2 in this mixture?

d) A fourth equilibrium mixture contains equal concentrations of all three chemicals.

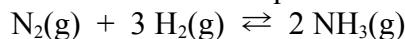
What is the pressure of each substance in this mixture?

12) 1.00 g of N_2O_4 is put into a 5.00 L container and heated to 50°C . At this temperature, the following reaction occurs and reaches equilibrium:



The concentration of NO_2 in the equilibrium mixture is found to be 6.68×10^{-4} M. Calculate K_c and K_p for this reaction at 50°C .

- 13) When 0.100 mol of gaseous N₂ and 0.100 mol of gaseous H₂ are put into a 5.00 L container at 300°C, the following reaction occurs and reaches equilibrium.



The partial pressure of ammonia in the equilibrium mixture is 0.0506 atm. Calculate K_p and K_c for this reaction at 300°C.

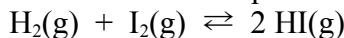
- 14) For the reaction below, K_c = 0.0168 at 250°C:



a) A flask contains 0.100 mol/L of PCl₅. What will be the concentrations of all three gases when the above reaction reaches equilibrium?

b) A different flask contains 0.100 mol/L of PCl₅, 0.200 mol/L of PCl₃, and 0.300 mol/L of Cl₂. What will be the concentrations of all three gases when the above reaction reaches equilibrium?

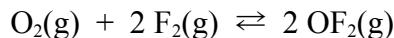
- 15) For the reaction below, K_p = 0.513 at a certain temperature.



a) A flask holds some gaseous HI at this temperature and a pressure of 3.00 atm. What will be the partial pressures of all three gases when the above reaction reaches equilibrium?

b) A second flask contains a mixture of the three gases with the following partial pressures: H₂ = 0.433 atm, I₂ = 0.0471 atm, HI = 0.0310 atm. What will be the partial pressures of all three gases when the above reaction reaches equilibrium?

- 16) Parts a through d of this problem relate to the reaction below:



a) If you add some gaseous F₂ to an equilibrium mixture of these three chemicals, which way will the reaction proceed?

b) If you add some gaseous O₂ to an equilibrium mixture of these three chemicals, what will happen to the partial pressure of F₂ in the mixture (i.e. will it go up, go down, or remain the same)?

c) If you increase the volume of the container, which way will the reaction proceed?

d) If you decrease the volume of the container, what will happen to the mass of OF₂ in the mixture?

e) If you increase the temperature, which way will the reaction proceed? You will need to look up the bond energy values to answer this question.

- 17) Will the value of the equilibrium constant K change in any of the parts of problem 16? If so, which parts?

- 18) Consider an equilibrium mixture of ammonium chloride, ammonia, and hydrogen chloride:

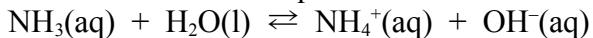


a) If you add a little solid NH₄Cl to the mixture, what will happen to the mass of NH₃?

b) If you add a little gaseous NH₃ to the mixture, what will happen to the mass of HCl?

c) If you add a little gaseous HCl to the mixture, what will happen to the mass of NH₄Cl?

19) The reaction below is allowed to reach equilibrium:

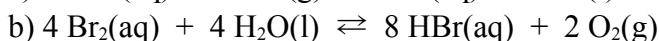
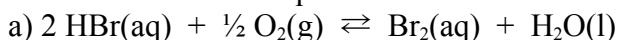


a) If you add a little 1 M HCl to the mixture, which way will the reaction proceed? Or will it be unaffected? Explain your answer.

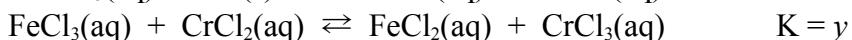
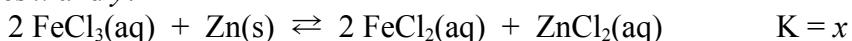
b) If you add a little 1 M MgCl₂ to the mixture, which way will the reaction proceed? Or will it be unaffected? Explain your answer.

c) If you add a little 1 M NH₄NO₃ to the mixture, which way will the reaction proceed? Or will it be unaffected? Explain your answer.

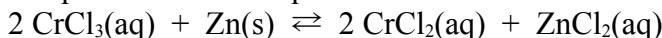
20) For the reaction $4 \text{HBr}(\text{aq}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{Br}_2(\text{aq}) + 2 \text{H}_2\text{O}(\text{l})$, $K_c = 6.7 \times 10^{10}$. Use this information to calculate the equilibrium constant for each of the following reactions.



21) Consider the following reactions, where the equilibrium constants are represented by the variables x and y :



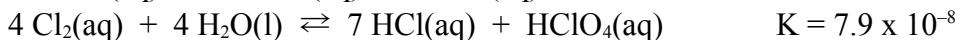
Write an expression for the equilibrium constant for the reaction below, in terms of x and y .



22) Calculate the equilibrium constant for the following reaction:



Use the following equilibrium constants.



23) The concentration of H⁺ ions in a solution is 0.315 M.

a) Calculate the concentration of OH⁻ ions in this solution.

b) Where did these OH⁻ ions come from?

c) What is the pH of this solution?

24) The pH of an HCl solution is 2.88.

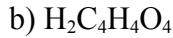
a) What is the concentration of H⁺ ions in this solution?

b) What is the concentration of OH⁻ ions in this solution?

c) What is the concentration of Cl⁻ ions in this solution?

25) Calculate the pH of a 7.4×10^{-4} M solution of Ba(OH)₂.

26) Write the K_a expression and the corresponding chemical equation for each of the following weak acids.



27) The pH of a 0.464 M solution of phosphorous acid (H_3PO_3) is 1.11. Using this information, calculate the K_a of phosphorous acid. (You may assume that only one hydrogen ion dissociates from phosphorous acid.)

28) Calculate the pH of a 0.27 M solution of HCO_2H (formic acid, $K_a = 1.8 \times 10^{-4}$)

29) Determine which solution from each of the following pairs has the higher pH. You may need to refer to the K_a values in Table 12.4.2 of your textbook.

- a) 0.1 M HCl or 0.1 M HNO_2
- b) 0.1 M HF or 0.1 M HClO
- c) 0.1 M HCN or 0.1 M NaCN

30) Each of the following species can function as an acid. Write the formula of its conjugate base.

- a) $\text{HC}_3\text{H}_5\text{O}_3$
- b) N_2H_5^+
- c) H_2O
- d) HCO_3^-
- e) H_2SO_4

31) Each of the following species can function as a base. Write the formula of its conjugate acid.

- a) NH_3
- b) HSO_3^-
- c) H_2O
- d) PO_4^{3-}

32) Identify the acid and the base in each of the following reactions.

- a) $\text{HNO}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_3\text{O}^+(\text{aq}) + \text{NO}_2^-(\text{aq})$
- b) $\text{H}_2\text{PO}_4^-(\text{aq}) + \text{HSO}_4^-(\text{aq}) \rightarrow \text{H}_3\text{PO}_4(\text{aq}) + \text{SO}_4^{2-}(\text{aq})$

33) For each of the following reactions, tell whether the equilibrium will favor the reactants or the products. Use the K_a values in Table 12.4.2 of your textbook.

- a) $\text{HC}_3\text{H}_5\text{O}_3(\text{aq}) + \text{CN}^-(\text{aq}) \rightleftharpoons \text{C}_3\text{H}_5\text{O}_3^-(\text{aq}) + \text{HCN}(\text{aq})$
- b) $\text{HOCl}(\text{aq}) + \text{OH}^-(\text{aq}) \rightleftharpoons \text{OCl}^-(\text{aq}) + \text{H}_2\text{O}(\text{l})$