Review: Gas Phase Equilibrium

This material will not be directly on the exams but you will need to know it to be successful in Chem 112.

You can use these problems as a review.

Answers to these problems are at the end of this packet.

1. For a chemical reaction at equilibrium, the relationship between the rate constants for the forward and reverse reactions (k_f and k_r) and the equilibrium constant for the process (K_eq) is

   \[ k_f \quad \frac{A}{k_r} \quad B \]

   A. \( K_{eq} = k_f k_r \)
   B. \( K_{eq} = k_f - k_r \)
   C. \( K_{eq} = k_f + k_r \)
   D. \( K_{eq} = k_f / k_r \)
   E. \( K_{eq} = k_r / k_f \)

2. Which of the following will change the value of an equilibrium constant?
   1. changing temperature
   2. adding a catalyst
   3. varying the initial concentration of reactants

   A. 1 only
   B. 2 only
   C. 1 and 2
   D. 1 and 3
   E. all three

3. What is \( K_c \) for the following reaction?

   \[ \text{HCl}(g) + \text{NH}_3(g) \rightleftharpoons \text{NH}_4\text{Cl}(s) \]

   A. \( \left[ \text{NH}_4\text{Cl} \right] \)
   B. \( \left[ \text{HCl} \right] \left[ \text{NH}_3 \right] \)
   C. \( \left[ \text{HCl} \right] \left[ \text{NH}_3 \right] \)
   D. \( \left[ \text{HCl} \right] \left[ \text{NH}_3 \right] \)
   E. \( \left[ \text{HCl} \right] \left[ \text{NH}_3 \right] \)

4. Consider the following three reactions:
   1. \( \text{H}_2(g) + \text{Cl}_2(g) \rightleftharpoons 2 \text{HCl}(g) \)
   2. \( \text{C}(s) + \text{H}_2\text{O}(g) \rightleftharpoons \text{CO}(g) + \text{H}_2(g) \)
   3. \( \text{Fe}_3\text{O}_4(s) + 4\text{H}_2(g) \rightleftharpoons 3 \text{Fe}(s) + 4\text{H}_2\text{O}(g) \)

   For which of these would \( K_p = K_c \)?

   A. 1 only
   B. 1 and 2 only
   C. 1 and 3 only
   D. 3 only
   E. 2 and 3 only

5. At 50°C, \( K_c = 2.2 \times 10^3 \) for the reaction

   \[ 3 \text{Fe}(s) + 4 \text{H}_2\text{O}(g) \rightleftharpoons \text{Fe}_3\text{O}_4(s) + 4 \text{H}_2(g) \]

   What is the value of \( K_p \) at 200°C for this reaction?

   A. \( 8.8 \times 10^3 \)
   B. \( 2.2 \times 10^3 \)
   C. \( 5.5 \times 10^2 \)
   D. \( 3.5 \times 10^4 \)
   E. This question cannot be answered with the information provided.

6. For the following reaction, \( K_p = 1.96 \) at 700 K.

   \[ \text{NOCl}(g) \rightleftharpoons \text{NO}(g) + \frac{1}{2} \text{Cl}_2(g) \]

   What is \( K_p \) for the reaction below at this same temperature?

   \[ \text{Cl}_2(g) + 2 \text{NO}(g) \rightleftharpoons 2 \text{NOCl} \quad (g) \]

   A. \( 1.96 \)
   B. \( 3.85 \)
   C. \( 0.260 \)
   D. \( 0.509 \)
   E. None of the above is within 5% of the correct answer.
7. When solid NH$_4$HS is placed in a closed, evacuated flask at 28°C, the solid dissociates according to the equation:

\[
\text{NH}_4\text{HS(s)} \rightleftharpoons \text{NH}_3(g) + \text{H}_2\text{S(g)}.
\]

The total pressure of the equilibrium mixture is 0.766 atm. Determine $K_p$ at this temperature.

A. 0.147  
B. 0.383  
C. 0.587  
D. 0.766  
E. 6.80

8. $K_c$ for the reaction below equals 125 at a particular temperature.

\[
\text{F}_2(g) + \text{Cl}_2(g) \rightleftharpoons 2 \text{FCl(g)}
\]

Suppose a system involving this reaction is already at equilibrium and the concentrations of F$_2$ and Cl$_2$ are found to be [F$_2$] = 0.115 M and [Cl$_2$] = 0.221 M. What is the concentration of FCl in the system?

A. [FCl] = 2.54 \times 10^{-2} M  
B. [FCl] = 3.17 M  
C. [FCl] = 1.78 M  
D. [FCl] = 1.43 \times 10^{-2} M  
E. None of the above is within 5% of the correct answer

9. At a certain temperature, 0.300 moles of NO, 0.200 moles of Cl$_2$, and 0.500 moles of ClNO were placed in a 25.0 L vessel and allowed to reach equilibrium:

\[
2 \text{NO(g) + Cl}_2(g) \rightleftharpoons 2 \text{ClNO(g)}.
\]

At equilibrium, 0.600 moles of ClNO were present. The number of moles of Cl$_2$ present at equilibrium is

A. 0.100  
B. 0.150  
C. 0.200  
D. 0.250  
E. 0.300

10. Consider the reaction 2 NH$_3(g) \rightleftharpoons N_2(g) + 3 \text{H}_2(g)$. Suppose 6 moles of pure NH$_3$ are placed in a 1.0–liter flask and allowed to reach equilibrium. If $X$ represents the concentration in moles per liter of N$_2$ present in the system once equilibrium is reached, which one of the following will represent the concentration of NH$_3$ at equilibrium in moles per liter?

A. $6 - (X/2)$  
B. $6 - X$  
C. $6 - 2X$  
D. $3 - 2X$  
E. None of the above is correct

11. For the following reaction $K_c = 4.0$ at a particular temperature.

\[
\text{N}_2(g) + \text{O}_2(g) \rightleftharpoons 2 \text{NO(g)}
\]
Suppose we begin an experiment by mixing 1.0 mol of N\textsubscript{2} and 1.0 mol of O\textsubscript{2} in a 1.0 liter container. What will the concentration of NO be once equilibrium is reached at the given temperature?

A. [NO] = 0.25 M  
B. [NO] = 0.50 M  
C. [NO] = 0.67 M  
D. [NO] = 1.0 M  
E. None of the above is within 5% of the correct answer

12. At 750°C, \( K_p = 0.770 \) for the reaction

\[
\text{H}_2(\text{g}) + \text{CO}_2(\text{g}) \rightleftharpoons \text{H}_2\text{O}(\text{g}) + \text{CO}(\text{g})
\]

If 0.200 atm of \( \text{H}_2 \) and 0.200 atm of \( \text{CO}_2 \) are admitted into a rigid container and allowed to reach equilibrium, what will the equilibrium partial pressure of CO be?

A. 0.0935 atm  
B. 0.109 atm  
C. 1.43 atm  
D. 0.100 atm  
E. 0.770 atm

13. At high temperatures one mole of hydrogen gas reacts with one mole of bromine gas to form hydrogen bromide. At a given temperature the equilibrium constant is 57.6. If at the same temperature, a mixture of \( 4.67 \times 10^{-3} \) M bromine gas, \( 2.14 \times 10^{-3} \) hydrogen gas, and \( 2.40 \times 10^{-2} \) M hydrogen bromide gas is made, then

A. the system is at equilibrium.  
B. the system is far from equilibrium and will shift to form more hydrogen gas.  
C. the system is far from equilibrium and will shift to form more hydrogen bromide gas.  
D. nothing can be deduced since we do not know whether the reaction is endothermic or exothermic.  
E. nothing can be deduced since we do not know whether the equilibrium constant is \( K_c \) or \( K_p \).

14. Which one of the following equilibriums is least affected by a change in the volume of the system?

A. \( 2 \text{C(s)} + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{CO(g)} \)  
B. \( 2 \text{NO}_2(\text{g}) \rightleftharpoons \text{N}_2\text{O}_4(\text{g}) \)  
C. \( \text{H}_2(\text{g}) + \text{S(ℓ)} \rightleftharpoons \text{H}_2\text{S(g)} \)  
D. \( \text{H}_2\text{O(ℓ)} \rightleftharpoons \text{H}_2\text{O(g)} \)  
E. \( 2 \text{NO(g)} + \text{Cl}_2(\text{g}) \rightleftharpoons 2 \text{NOCl(g)} \)
15. Nickel (II) oxide can be reduced to nickel metal by treatment with carbon monoxide as indicated in the reaction

\[ \text{CO}(g) + \text{NiO}(s) \rightleftharpoons \text{CO}_2(g) + \text{Ni}(s) \quad K_p = 20 \text{ at } 500^\circ C \]

If the reaction chamber contains some solid Ni and NiO, 400 mm Hg of CO\(_2\) and 20 mm Hg of CO, all at equilibrium, which one of the following changes will lead to the reduction of more nickel oxide at 500\(^\circ\)C?

A. Doubling the amount of NiO(s) present.
B. Adding CO\(_2\) to raise its pressure to 700 mm Hg.
C. Adding CO to raise its pressure to 40 mm Hg.
D. Removal of half of the NiO(s) present.
E. Doubling the volume of the reaction chamber at 500\(^\circ\)C.

16. For the reaction FeO(s) + CO(g) \rightleftharpoons Fe(s) + CO\(_2\)(g),

A. the usual expression for the equilibrium constant is 
   \[ K_c = \frac{[\text{Fe}][\text{CO}_2]}{[\text{FeO}][\text{CO}]} \]
B. addition of CO\(_2\)(g) will increase \( K_c \).
C. increasing the volume of an equilibrium mixture at constant temperature will cause the number of moles of CO\(_2\) to increase as the mixture re–equilibrates.
D. adding more FeO to an equilibrium mixture will cause the number of moles of CO\(_2\) to increase as the system re–equilibrates.
E. None of the above statements is true

**Review Equilibrium**

1. D
2. A
3. C
4. C
5. E
6. C
7. A
8. C
9. B
10. C
11. D
12. A
13. A
14. C
15. C
16. E