Chapter 6 – Old quiz and exam questions – Key

7. Consider the following reactions at equilibrium:

\[ \text{H}_2 (g) + \text{N}_2 (g) \rightleftharpoons \text{NH}_3 (g) \]
\[ \text{NH}_3 (g) + \text{H}_2\text{O} (l) \rightleftharpoons \text{NH}_4^+ (aq) + \text{OH}^- (aq) \]

What will happen if \( \text{HCl} (aq) \) is added to the reaction?

(a) The partial pressure of \( \text{N}_2 (g) \) will decrease
(b) The partial pressure of \( \text{H}_2 (g) \) will increase
(c) The base dissociation constant \( (K_b) \) for \( \text{NH}_3 \) will decrease
(d) The concentration of \( \text{NH}_4^+ (aq) \) will decrease
(e) There will be no change

13. Consider the following reaction at equilibrium:

\[ \text{N}_2 (g) + 3 \text{H}_2 (g) \rightleftharpoons 2 \text{NH}_3 (g) + \text{heat} \]

\[ K_p = 5.3 \times 10^5 \text{ at 298K} \]

Which of the following will cause the reaction to shift to the right?

(a) Decrease the volume of the container at constant temperature
(b) Increase temperature at a constant volume
(c) Increase the partial pressure of \( \text{H}_2 \)
(d) (a) and (c) will cause the reaction to shift to the right
(e) (a), (b), and (c) will cause the reaction to shift to the right

26. Consider the following reactions:

\[ \text{SO}_2 (g) + \frac{1}{2} \text{O}_2 (g) \rightleftharpoons \text{SO}_3 (g) \]
\[ K_p = 3.2 \]
\[ \text{NO} (g) + \frac{1}{2} \text{O}_2 (g) \rightleftharpoons \text{NO}_2 (g) \]
\[ K_p = 0.6 \]

What is the equilibrium constant \( K_p \) for the reaction:

\[ \text{SO}_2 (g) + \text{NO}_2 (g) \rightleftharpoons \text{NO} (g) + \text{SO}_3 (g) \]

(a) 5.3
(b) 3.8
(c) 1.9
(d) 2.6
(e) none of these
31. Consider the following reaction:

\[
\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2 \quad K = 0.16
\]

200. grams of CaCO₃ (molar mass = 100. g/mol) was introduced into an otherwise empty 4.0 L rigid container. At equilibrium, how many grams of CaCO₃ remain?

a) 136 g  
b) 184 g  
c) 114 g  
d) 200. g  
e) none of these

40. Consider the following reaction: \[ \text{N}_2\text{O}_4 (g) \rightleftharpoons 2 \text{NO}_2 (g) \quad K_p = 70.9 \]

A certain pressure of N₂O₄ is initially added to an otherwise empty rigid vessel. At equilibrium, 25.8% of the N₂O₄ remains. What is the partial pressure of NO₂ at equilibrium?

a) 102 atm  
b) 6.2 atm  
c) 51.0 atm  
d) 12.3 atm  
e) 24.7 atm

7. Consider the following reaction: \[ 2\text{NOBr}(g) \rightleftharpoons 2\text{NO}(g) + \text{Br}_2(g) \]

A 1.0-liter vessel was initially filled with pure NOBr, at a pressure of 4.0 atm, at 300 K. After equilibrium was established, the partial pressure of NOBr was 2.5 atm. What is \( K_p \) for the reaction?

a) 0.45  
b) 0.27  
c) 0.18  
d) 0.75  
e) 0.14
8. Nitric oxide, an important pollutant in air, is formed from the elements nitrogen and oxygen at high temperatures, such as those obtained when gasoline burns in an automobile engine.

\[ \text{N}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{NO}(g) \]

For this reaction the equilibrium constant, \( K = 0.01 \) at 2000 °C. Predict the direction in which the system will move to reach equilibrium at 2000 °C if 0.4 moles of \( \text{N}_2 \), 0.1 moles of \( \text{O}_2 \), and 0.08 moles of \( \text{NO} \) are placed in a 1.0-liter container.

a) The system remains unchanged.

b) The concentration of \( \text{NO} \) will decrease; the concentrations of \( \text{N}_2 \) and \( \text{O}_2 \) will increase.

c) The concentration of \( \text{NO} \) will increase; the concentrations of \( \text{N}_2 \) and \( \text{O}_2 \) will decrease.

d) The concentration of \( \text{NO} \) will decrease; the concentrations of \( \text{N}_2 \) and \( \text{O}_2 \) will remain unchanged.

e) More information is necessary.

9. Consider the following three equilibria occurring simultaneously in solution.

\[ \text{Ca}^{2+} \text{(aq)} + \text{CO}_3^{2-} \text{(aq)} \rightleftharpoons \text{CaCO}_3 \text{(s)} \quad (1) \]
\[ \text{HCO}_3^- \text{(aq)} \rightleftharpoons \text{H}^+ \text{(aq)} + \text{CO}_3^{2-} \text{(aq)} \quad (2) \]
\[ \text{HCO}_3^- \text{(aq)} + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \text{(aq)} + \text{OH}^- \text{(aq)} \quad (3) \]

If \( \text{NaOH} \) is added to the solution, will the amount of \( \text{CaCO}_3 \text{(s)} \) precipitate increase or decrease or stay the same?

a) Increase

b) Decrease

c) Stay the same

4. (5 pts) Determine the relationship between the equilibrium constant with respect to concentrations \((K)\) and the equilibrium constant with respect to pressures \((K_p)\) for the reaction: \( \text{N}_2\text{O}_4 \text{(g)} \rightleftharpoons 2 \text{NO}_2 \text{(g)} \)

a) \( K_p = K \)

b) \( K_p = K(RT)^{-1} \)

c) \( K_p = K(RT)^{1} \)

d) \( K_p = K(RT)^{3} \)

e) none of these

11. (6 pts) Consider the following reaction:

\[ 2 \text{NO}(g) + \text{Br}_2(g) \rightleftharpoons 2 \text{NOBr}(g) \]

At equilibrium, \( P_{\text{NO}} = 7.9 \text{ atm}, P_{\text{Br}_2} = 3.9 \text{ atm}, \) and \( P_{\text{NOBr}} = 9.5 \text{ atm.} \) What is the equilibrium constant \( K_p \) for this reaction?

a) 0.74

b) 0.31

c) 0.37

d) 2.6

e) the initial pressures must be known
14. (6 pts) Consider the following reaction: \[ A (g) + 2 \, B (g) \xleftrightarrow{2 \, C (g) } \] \[ K_p = 314^\circ \]

Initially, \[ P_A = 0.0436 \text{ atm}, \] \[ P_B = 0.956 \text{ atm}, \] and \[ P_C = 2.65 \text{ atm}. \] At equilibrium, which of the following statements is true:

a) \[ P_A > 0.0436 \text{ atm} \]

b) \[ P_C > 2.65 \text{ atm} \]

c) \[ P_B = 0.956 \text{ atm} \]

d) More than one of these statements is true

e) None of these statements are true

17. (6 pts) At \[ 105^\circ \text{C}, \] \[ K_p = 6.4 \times 10^{-3} \] for the reaction:

\[ 2 \, \text{NH}_3 (g) \xleftrightarrow{\text{N}_2 (g) + 3 \, \text{H}_2 (g)} \]

A certain initial pressure of \[ \text{NH}_3 \] is placed into an evacuated rigid container at \[ 105^\circ \text{C}. \] At equilibrium, 65\% of the initial \[ \text{NH}_3 \] remains. What was the initial pressure of \[ \text{NH}_3 \]?

a) \[ 5.1 \times 10^{-3} \text{ atm} \]

b) \[ 3.3 \times 10^{-2} \text{ atm} \]

c) \[ 5.7 \times 10^{-3} \text{ atm} \]

d) \[ 1.7 \times 10^{-3} \text{ atm} \]

e) more information is needed

1. (5 pts) What is the equilibrium constant expression \( (K_p) \) for the following reaction:

\[ \text{NH}_2\text{NO}_3 (s) \xleftrightarrow{\text{N}_2\text{O} (g) + 2 \, \text{H}_2\text{O} (g)} \]

\[ a) \quad K_p = \frac{(P_{\text{N}_2\text{O}})(P_{\text{H}_2\text{O}})^2}{(P_{\text{NH}_2\text{NO}_3})} \]

\[ b) \quad K_p = \frac{(P_{\text{N}_2\text{O}})}{(P_{\text{NH}_2\text{NO}_3})} \]

\[ c) \quad K_p = (P_{\text{N}_2\text{O}}) \]

\[ d) \quad K_p = (P_{\text{N}_2\text{O}})(P_{\text{H}_2\text{O}})^2 \]

\[ e) \quad \text{none of these} \]

3. (5 pts) When a reaction reaches equilibrium, the concentrations of the products equal the concentrations of the reactants.

a) True

b) False

4. (5 pts) The value of the equilibrium constant \( K \) depends on the initial concentrations of the reactants.

a) True

b) False

5. (5 pts) Determine the relationship between the equilibrium constant with respect to concentrations \( (K) \) and the equilibrium constant with respect to pressures \( (K_p) \).

\[ 2 \, \text{C}_2\text{H}_6 (s) + 7 \, \text{O}_2 (g) \xleftrightarrow{6 \, \text{H}_2\text{O} (l) + 4 \, \text{CO}_2 (g)} \]

\[ a) \quad K_p = K \]

\[ b) \quad K_p = K(RT)^3 \]

\[ c) \quad K_p = K(RT)^1 \]

\[ d) \quad K_p = K(RT)^{-3} \]

\[ e) \quad \text{none of these} \]
7. (5 pts) For a particular reaction, the equilibrium constant $K_p$ is equal to $4.3 \times 10^{-5}$ at 341 K. For the same reaction, $K_p$ is equal to $3.7 \times 10^{-2}$ at 632 K. On which side of the reaction is heat?

a) Right side  

b) Left side  

c) heat does not affect the reaction

8. (5 pts) Consider the following reaction at equilibrium: $\text{PCl}_3 \ (g) + \text{Cl}_2 \ (g) \rightleftharpoons \text{PCl}_5 \ (g)$

Determine the direction this reaction will shift when the volume of the container is increased at a constant temperature:

a) Shift to the left ($\leftarrow$), $K$ stays the same  

b) Shift to the right ($\rightarrow$), $K$ stays the same  

c) Shift to the left ($\leftarrow$), $K$ decreases  

d) Shift to the right ($\rightarrow$), $K$ increases  

e) No shift, $K$ stays the same

9. (6 pts) Consider the following reactions in the same solution, both at equilibrium:

\[ \text{BaSO}_4 \ (s) \rightleftharpoons \text{Ba}^{2+} \ (aq) + \text{SO}_4^{2-} \ (aq) \]

\[ \text{SO}_4^{2-} \ (aq) + \text{H}_2\text{O} \ (l) \rightleftharpoons \text{HSO}_4^- \ (aq) + \text{OH}^- \ (aq) \]

If nitric acid (HNO$_3$) is added to this solution at a constant temperature, what will happen to the concentration of Ba$^{2+}$ ions in solution?

a) Increase  

b) Decrease  

c) Stay the same

15. (6 pts) Consider the following reaction that takes place at a constant temperature:

\[ 2 \text{SO}_3 \ (g) \rightleftharpoons 2 \text{SO}_2 \ (g) + \text{O}_2 \ (g) \]

Initially, 23.9 moles of SO$_3$ is placed into a 95 L rigid container. At equilibrium, 2.6 moles of SO$_2$ are present. Calculate $K$ for this reaction.

a) $2.0 \times 10^{-4}$  

b) $1.9 \times 10^{-2}$  

c) $1.7 \times 10^{-3}$  

d) $2.1 \times 10^{-3}$  

e) $2.7 \times 10^{-3}$
3. (5 pts) Consider the following reaction in a closed container: \[ \text{heat} + \text{CCl}_4 (g) \rightleftharpoons \text{C} (s) + 2 \text{Cl}_2 (g) \]

Predict the direction the reaction will shift if C (s) is added to the container at constant V and T.

a) Reaction shifts left (\(<\)---)

b) Reaction shifts right (---\(\rightarrow\))

c) No shift occurs

4. (5 pts) Consider the following reaction in a closed container: \[ \text{heat} + \text{CCl}_4 (g) \rightleftharpoons \text{C} (s) + 2 \text{Cl}_2 (g) \]

Predict the direction the reaction will shift if temperature is increased at constant V.

a) Reaction shifts left (\(<\)---)

b) Reaction shifts right (---\(\rightarrow\))

c) No shift occurs

5. (5 pts) Consider the reaction \[ \text{N}_2 (g) + 3 \text{H}_2 (g) \rightleftharpoons 2 \text{NH}_3 (g) \quad K_p = 2.9 \text{ at } 100^\circ \text{C} \]

A container is initially filled with 1.4 atm of \text{N}_2, 0.25 atm of \text{H}_2, and 0.34 atm of \text{NH}_3 at 100°C. Which of the following statements is true?

a) The reaction is at equilibrium

b) The reaction proceeds to the right (---\(\rightarrow\)) until it reaches equilibrium

c) The reaction proceeds to the left (\(<\)---) until it reaches equilibrium

7. (6 pts) Using the following information, calculate \( K \) for the reaction \[ \text{CH}_4 (g) + 2 \text{H}_2 \text{O} (g) \rightleftharpoons \text{CO}_2 (g) + 4 \text{H}_2 (g) \]

\[ \text{CO} (g) + \text{H}_2 \text{O} (g) \rightleftharpoons \text{CO}_2 (g) + \text{H}_2 (g) \quad K = 108 \]

\[ \text{CO} (g) + 3 \text{H}_2 (g) \rightleftharpoons \text{H}_2 \text{O} (g) + \text{CH}_4 (g) \quad K = 32.0 \]

a) \(365\)

b) \(76.0\)

c) \(3450\)

d) \(3.38\)

e) \(0.296\)

15. (6 pts) Consider the following reaction: \[ 2 \text{NOBr} (g) \rightleftharpoons 2 \text{NO} (g) + \text{Br}_2 (g) \]

Initially, 1.9 atm of \text{NOBr} is placed into an otherwise empty flask. At equilibrium, the total pressure in the flask is 2.7 atm. What is the equilibrium constant \( K_p \) for this reaction?

a) \(3.4\)

b) \(11\)

c) \(2.7\)

d) \(8.2\)

e) \(23\)
16. (6 pts) A sample of solid NH₄NO₃ was placed into an evacuated container and heated to 750°C so that it decomposed according to the following reaction: \[ \text{NH}_4\text{NO}_3 (s) \rightleftharpoons \text{N}_2\text{O} (g) + 2 \text{H}_2\text{O} (g) \]

If \( K_p \) for this reaction is 5800 at 750°C, what is the partial pressure of \( \text{N}_2\text{O} \) in this container at equilibrium?

a) 5800 atm  
b) 14 atm  
(c) 11 atm  
d) 18 atm  
e) 76 atm

3. (5 pts) Consider the following reaction: \[ \text{Cu}^{2+} (aq) + 2 \text{Ag} (s) \rightleftharpoons 2 \text{Ag}^+ (aq) + \text{Cu} (s) \]

Predict the direction the reaction will shift if NaCl is added to the reaction mixture at constant T. Assume the addition of NaCl does not change the volume of the solution. Hint: Consider whether the addition of NaCl will result in the formation of a precipitate.

a) Reaction shifts left (\( \leftarrow \rightarrow \))  
b) Reaction shifts right (\( \rightarrow \rightarrow \))  
c) No shift occurs

7. (6 pts) Consider the following reaction: \( \frac{1}{3} \text{N}_2 (g) + \frac{1}{2} \text{Br}_2 (g) + \frac{1}{2} \text{O}_2 (g) \rightleftharpoons \text{NOBr} (g) \quad K = 4.4 \times 10^{-14} \)

Calculate \( K \) for the for the reaction: \[ 2 \text{NOBr} (g) \rightleftharpoons \text{N}_2 (g) + \text{Br}_2 (g) + \text{O}_2 (g) \]

a) 5.2 \times 10^{26}  
b) 4.5 \times 10^{13}  
c) 1.9 \times 10^{-27}  
d) 4.4 \times 10^{-14}  
e) 2.3 \times 10^{13}

8. (6 pts) Consider the following reaction: \[ \text{CaCO}_3 (s) \rightleftharpoons \text{CaO} (s) + \text{CO}_2 (g) \]

At 273K, the equilibrium constant with respect to concentrations (K) equals 55.6. Calculate the equilibrium constant with respect to pressures (\( K_p \)) at 273K.

a) 1250  
b) 55.6  
c) 2.48  
d) 27600  
e) 8600

15. (6 pts) Consider the reaction \[ 2 \text{NH}_3 (g) \rightleftharpoons \text{N}_2 (g) + 3 \text{H}_2 (g) \quad K_p = 2.3 \times 10^{-4} \]

Initially, 3.2 atm of NH₃ is placed into an otherwise empty container. At equilibrium, what will be the partial pressure of \( \text{H}_2 \)?

a) 0.054 atm  
b) 6.9 \times 10^{-5} atm  
c) 0.015 atm  
d) 0.28 atm  
e) 0.16 atm
9. (5 pts) Consider the following reactions at equilibrium in aqueous solution:

\[
\text{FeS (s)} \rightleftharpoons \text{Fe}^{2+} + \text{S}^{2-} \\
\text{S}^{2-} + \text{H}_2\text{O (l)} \rightleftharpoons \text{HS}^- + \text{OH}^- \\
\text{HS}^- + \text{H}_2\text{O (l)} \rightleftharpoons \text{H}_2\text{S} + \text{OH}^- 
\]

When HCl is added to this system at constant temperature, what will happen to the concentration of Fe\(^{2+}\)?

a) increase  
b) decrease  
c) remain the same

10. (5 pts) Consider the following reaction:  
\[2 \text{HBr (g)} \rightleftharpoons \text{Br}_2 (g) + \text{H}_2 (g) \quad K_p = 21\]

Initially, the pressure of HBr = 2.50 atm. The initial pressures of H\(_2\) and Br\(_2\) are zero. Determine the partial pressure of Br\(_2\) when the system comes to equilibrium.

a) 0.24 atm  
b) 11.5 atm  
c) 1.25 atm  
c) 2.50 atm  
e) 1.13 atm

13. (6 pts) Consider the following reaction:  
\[2 \text{SO}_2 (g) + \text{O}_2 (g) \rightleftharpoons 2 \text{SO}_3 (g)\]

This reaction is performed in a 4.0 L container. At equilibrium, there are 1.3 moles of SO\(_3\), 0.63 moles of O\(_2\), and 2.3 moles of SO\(_2\). Calculate the equilibrium constant \(K\) for this reaction.

a) 5.0  
b) 1.2  
c) 20  
d) 2.8  
e) 11

18. (6 pts) Consider the following reaction:  
\[\text{CaCO}_3 (s) \rightleftharpoons \text{CaO (s)} + \text{CO}_2 (g) \quad K_p = 1.16 \text{ at } 780^\circ\text{C}\]

If a 23.0 gram sample of CaCO\(_3\) (100 g/mol) is put into an evacuated 10.0 L container and heated to 780\(^\circ\)C, what percentage of the CaCO\(_3\) will remain at equilibrium?

a) 41.6%  
b) 86.6%  
c) 100%  
d) 74.3%  
e) 49.5%