

## CHAPTER 13 Chemical Equilibrium

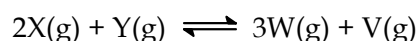
1. Which of the following statements concerning equilibrium is not true?
- A system that is disturbed from an equilibrium condition responds in a manner to restore equilibrium.
  - Equilibrium in molecular systems is dynamic, with two opposing processes balancing one another.
  - The value of the equilibrium constant for a given reaction mixture is the same regardless of the direction from which equilibrium is attained.
  - A system moves spontaneously toward a state of equilibrium.
  - The equilibrium constant is independent of temperature.

**ANS:** e) The equilibrium constant is independent of temperature. **PAGE:** 13.1,2

2. Which of the following statements is true?
- When two opposing processes are proceeding at identical rates, the system is at equilibrium.
  - Catalysts are an effective means of changing the position of an equilibrium.
  - The concentration of the products equals that of reactants and is constant at equilibrium.
  - An endothermic reaction shifts toward reactants when heat is added to the reaction.
  - None of these statements is true.

**ANS:** a) When two opposing processes are proceeding at identical rates, the system is at equilibrium. **PAGE:** 13.1,7

3. Indicate the mass action expression for the following reaction:

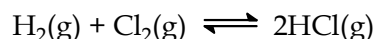


- $[X]^2[Y][W]^3[V]$
- $\frac{[W]^3[V]}{[X]^2[Y]}$
- $\frac{[3W][V]}{[2X][Y]}$
- $\frac{[X]^2[Y]}{[W]^3[V]}$

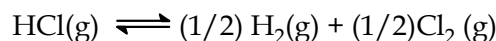
**ANS:** b)  $\frac{[W]^3[V]}{[X]^2[Y]}$  **PAGE:** 13.2

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4. If, at a given temperature, the equilibrium constant for the reaction



is  $K_p$ , then the equilibrium constant for the reaction



can be represented as:

- a)  $\frac{1}{K_p^2}$
- b)  $K_p^2$
- c)  $\frac{1}{\sqrt{K_p}}$
- d)  $\sqrt{K_p}$

ANS: c)  $\frac{1}{\sqrt{K_p}}$

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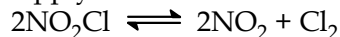
5. The value of the equilibrium constant,  $K$ , is dependent on

- I. The temperature of the system.
  - II. The nature of the reactants and products.
  - III. The concentration of the reactants.
  - IV. The concentration of the products.
- a) I, II
  - b) II, III
  - c) III, IV
  - d) It is dependent on three of these choices.
  - e) It is not dependent on any of these choices.

ANS: a) I, II

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6. Apply the law of mass action to determine the equilibrium expression for



- a)  $2[\text{NO}_2][\text{Cl}_2]/2[\text{NO}_2\text{Cl}]$
- b)  $2[\text{NO}_2\text{Cl}]/2[\text{NO}_2][\text{Cl}_2]$
- c)  $[\text{NO}_2\text{Cl}]^2/[\text{NO}_2]^2[\text{Cl}_2]$
- d)  $[\text{NO}_2]^2[\text{Cl}_2]/[\text{NO}_2\text{Cl}]^2$
- e)  $[\text{NO}_2\text{Cl}]^2[\text{NO}_2]^2[\text{Cl}_2]$

ANS: d)  $[\text{NO}_2]^2[\text{Cl}_2]/[\text{NO}_2\text{Cl}]^2$

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- 7-9. Consider the chemical system  $\text{CO} + \text{Cl}_2 \rightleftharpoons \text{COCl}_2$ ;  $K = 4.6 \times 10^9 \text{ L/mol}$ .

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7. How do the equilibrium concentrations of the reactants compare to the equilibrium concentration of the product?
- They are much smaller.
  - They are much bigger.
  - They are about the same.
  - They have to be exactly equal.
  - You can't tell from the information given.

**Ans:** a) They are much smaller.

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8. If the concentration of the product were to double, what would happen to the equilibrium constant?
- It would double its value.
  - It would become half its current value.
  - It would quadruple its value.
  - It would not change its value.
  - It would depend on the initial conditions of the product.

**Ans:** d) It would not change its value.

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9. Determine the equilibrium constant for the system  $\text{N}_2\text{O}_4 \rightleftharpoons 2\text{NO}_2$  at 25°C. The concentrations are shown here:  $[\text{N}_2\text{O}_4] = 4.27 \times 10^{-2} \text{ M}$ ,  $[\text{NO}_2] = 1.41 \times 10^{-2} \text{ M}$
- 0.33
  - 3.0
  - 0.66
  - 0.05
  - 0.0047

**Ans:** e) 0.0047

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10. At 500.0 K, one mole of gaseous  $\text{ONCl}$  is placed in a one-liter container. At equilibrium it is 9.0% dissociated according to the equation shown here:  $2\text{ONCl} \rightleftharpoons 2\text{NO} + \text{Cl}_2$

Determine the equilibrium constant.

- $4.4 \times 10^{-4}$
- $2.2 \times 10^2$
- $1.1 \times 10^2$
- $2.2 \times 10^{-4}$
- $9.1 \times 10^{-1}$

**ANS:** a)  $4.4 \times 10^{-4}$

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11. Consider the reaction  $\text{H}_2 + \text{I}_2 \rightleftharpoons 2\text{HI}$  whose  $K = 54.8$  at  $425^\circ\text{C}$ . If an equimolar mixture of reactants gives the concentration of the product to be  $0.50\text{ M}$  at equilibrium, determine the concentration of the hydrogen.

- a)  $4.6 \times 10^{-3}\text{ M}$
- b)  $6.8 \times 10^{-2}\text{ M}$
- c)  $1.2 \times 10^{-3}\text{ M}$
- d)  $9.6 \times 10^{-2}\text{ M}$
- e)  $1.6 \times 10^{-4}\text{ M}$

ANS: b)  $6.8 \times 10^{-2}\text{ M}$

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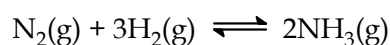
12. Consider the gaseous reaction  $\text{CO}(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons \text{COCl}_2(\text{g})$ . What is the expression for  $K_p$  in terms of  $K$ ?

- a)  $K(RT)$
- b)  $K/(RT)$
- c)  $K(RT)^2$
- d)  $K/(RT)^2$
- e)  $1/K(RT)$

ANS: b)  $K/(RT)$

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13. Find the value of the equilibrium constant ( $K$ ) (at  $500\text{ K}$ ) for



The value for  $K_p$  at  $500\text{ K}$  is  $1.5 \times 10^{-5}/\text{atm}^2$ .

- a)  $7.5 \times 10^{-2}$
- b)  $1.3 \times 10^{-2}$
- c)  $9.6 \times 10^{-2}$
- d)  $2.5 \times 10^{-2}$
- e)  $6.0 \times 10^{-2}$

ANS: e)  $6.0 \times 10^{-2}$

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14. Consider the following reaction:  $\text{CS}_2(\text{g}) + 4\text{H}_2(\text{g}) \rightleftharpoons \text{CH}_4(\text{g}) + 2\text{H}_2\text{S}(\text{g})$   
The equilibrium constant  $K$  is  $0.28$  at  $900^\circ\text{C}$ . What is  $K_p$  at this temperature?

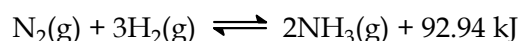
- a)  $5.0 \times 10^{-5}$
- b)  $4.0 \times 10^{-5}$
- c)  $3.0 \times 10^{-5}$
- d)  $2.0 \times 10^{-5}$
- e)  $1.0 \times 10^{-5}$

ANS: c)  $3.0 \times 10^{-5}$

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15. Consider the following system at equilibrium:



Which of the following changes will shift the equilibrium to the right?

- I. increasing the temperature
  - II. decreasing the temperature
  - III. increasing the volume
  - IV. decreasing the volume
  - V. removing some  $\text{NH}_3$
  - VI. adding some  $\text{NH}_3$
  - VII. removing some  $\text{N}_2$
  - VIII. adding some  $\text{N}_2$
- a) I, IV, VI, VII
  - b) II, III, V, VIII
  - c) I, VI, VIII
  - d) I, III, V, VII
  - e) II, IV, V, VIII

ANS: e) II, IV, V, VIII

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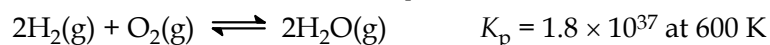
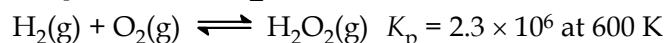
16. If the equilibrium constant for  $\text{A} + \text{B} \rightleftharpoons \text{C}$  is 0.123, then the equilibrium constant for  $2\text{C} \rightleftharpoons 2\text{A} + 2\text{B}$  is \_\_\_\_\_.

- a)  $1.00 - 2(0.123)$
- b) 8.13
- c) 0.123
- d) 66.1
- e) 16.3

ANS: d) 66.1

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17. Calculate  $K_p$  for  $\text{H}_2\text{O}(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) \rightleftharpoons \text{H}_2\text{O}_2(\text{g})$  at 600 K, using the following data:



- a)  $4.4 \times 10^{43}$
- b)  $9.8 \times 10^{24}$
- c)  $1.2 \times 10^{-4}$
- d)  $5.4 \times 10^{-13}$
- e)  $2.6 \times 10^{-31}$

ANS: d)  $5.4 \times 10^{-13}$

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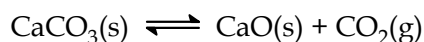
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18. Given the equation:  $2\text{NOCl}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g}) + \text{Cl}_2(\text{g})$ . The equilibrium constant is 0.0150 at 115°C. Calculate  $K_p$ .
- a) 0.0150
  - b) 0.478
  - c) 0.142
  - d)  $1.41 \times 10^{-4}$
  - e) none of these

ANS: b) 0.478

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19. For the reaction below,  $K_p = 1.16$  at 800°C.



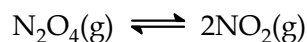
If a 20.0-gram sample of  $\text{CaCO}_3$  is put into a 10.0-liter container and heated to 800°C, what percent of the  $\text{CaCO}_3$  will react to reach equilibrium?

- a) 14.6%
- b) 65.9%
- c) 34.1%
- d) 100.0%
- e) none of these

ANS: b) 65.9%

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20. At -80°C,  $K$  for the reaction



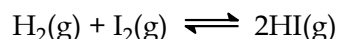
is  $4.66 \times 10^{-8}$ . We introduce 0.050 mole of  $\text{N}_2\text{O}_4$  into a 1.0-L vessel at -80°C and let equilibrium be established. The total pressure in the system at equilibrium will be:

- a) 0.23 atm
- b) 0.79 atm
- c) 1.3 atm
- d) 2.3 atm
- e) none of these

ANS: b) 0.79 atm

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21. The reaction



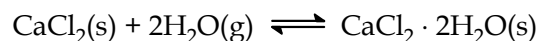
has  $K_p = 45.9$  at 763 K. A particular equilibrium mixture at that temperature contains gaseous HI at a partial pressure of 4.00 atm and hydrogen gas at a partial pressure of 0.200 atm. What is the partial pressure of  $\text{I}_2$ ?

- a) 0.200 atm
- b) 0.436 atm
- c) 1.74 atm
- d) 0.574 atm
- e) 14.3 atm

ANS: c) 1.74 atm

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22. Consider the reaction:



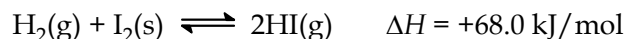
The equilibrium constant for the reaction as written is

- a)  $K = \frac{[\text{CaCl}_2 \cdot 2\text{H}_2\text{O}]}{[\text{CaCl}_2][\text{H}_2\text{O}]^2}$
- b)  $K = \frac{1}{[\text{H}_2\text{O}]^2}$
- c)  $K = \frac{1}{2[\text{H}_2\text{O}]}$
- d)  $K = [\text{H}_2\text{O}]^2$
- e)  $K = \frac{[\text{CaCl}_2 \cdot 2\text{H}_2\text{O}]}{[\text{H}_2\text{O}]^2}$

ANS: b)  $K = \frac{1}{[\text{H}_2\text{O}]^2}$

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23–24. Consider the following equilibrium:



23. The proper  $K_{\text{eq}}$  expression is:

- a)  $\frac{[\text{H}_2][\text{I}_2]}{[\text{HI}]}$
- b)  $\frac{\sqrt{([\text{H}_2][\text{I}_2])}}{[\text{HI}]^2}$

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c)  $\frac{[\text{HI}]}{\sqrt{[\text{H}_2]}}$

d)  $\frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]}$

e)  $\frac{[\text{HI}]^2}{[\text{H}_2]}$

ANS: e)  $\frac{[\text{HI}]^2}{[\text{H}_2]}$

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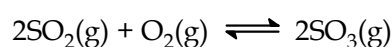
24. Which of the following statements about the equilibrium is false?

- a) If the system is heated, the right side is favored.
- b) This is a heterogeneous equilibrium.
- c) If the pressure on the system is increased by changing the volume, the left side is favored.
- d) Adding more  $\text{H}_2(\text{g})$  increases the equilibrium constant.
- e) Removing HI as it forms forces the equilibrium to the right.

ANS: d) Adding more  $\text{H}_2(\text{g})$  increases the equilibrium constant.

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25. Consider the reaction:



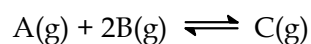
at constant temperature. Initially a container is filled with pure  $\text{SO}_3(\text{g})$  at a pressure of 2 atm, after which equilibrium is reached. If  $y$  is the partial pressure of  $\text{O}_2$  at equilibrium, the value of  $K_p$  is:

- a)  $\frac{(2 - 2y)^2}{(y^2)(2y)}$
- b)  $\frac{(2 - y)^2}{(y^2)(y/2)}$
- c)  $\frac{(2 - y)^2}{(2y)^2(y)}$
- d)  $\frac{(2 - 2y)^2}{(2y)^2(y)}$
- e) none of these

ANS: d)  $\frac{(2 - 2y)^2}{(2y)^2(y)}$

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26–27. For the reaction given below, 2.00 moles of A and 3.00 moles of B are placed in a 6.00-L container.



26. At equilibrium, the concentration of A is 0.300 mol/L. What is the concentration of B at equilibrium?

- a) 0.300 mol/L
- b) 0.433 mol/L
- c) 0.500 mol/L
- d) 0.600 mol/L
- e) none of these

ANS: b) 0.433 mol/L

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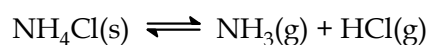
27. At equilibrium, the concentration of A is 0.300 mol/L. What is the value of  $K$ ?

- a) 0.146
- b) 0.253
- c) 0.300
- d) 0.589
- e) 1.043

ANS: d) 0.589

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28. A 10.0-g sample of solid  $\text{NH}_4\text{Cl}$  is heated in a 5.00-L container to  $900^\circ\text{C}$ . At equilibrium the pressure of  $\text{NH}_3(\text{g})$  is 1.20 atm.



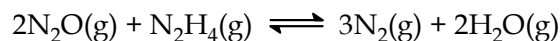
The equilibrium constant,  $K_p$ , for the reaction is:

- a) 1.20
- b) 1.44
- c) 2.40
- d) 31.0
- e) none of these

ANS: b) 1.44

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29. The following reaction is investigated (assume an ideal gas mixture):



Initially there are 0.10 moles of  $\text{N}_2\text{O}$  and 0.25 moles of  $\text{N}_2\text{H}_4$  in a 10.0-L container. If there are 0.06 moles of  $\text{N}_2\text{O}$  at equilibrium, how many moles of  $\text{N}_2$  are present at equilibrium?

- a) 0.9
- b) 0.04
- c) 0.06
- d) 0.02
- e) none of these

ANS: c) 0.06

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30. At a certain temperature  $K$  for the reaction



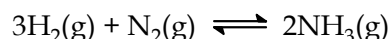
is 7.5 liters/mole. If 2.0 moles of  $\text{NO}_2$  are placed in a 2.0-liter container and permitted to react at this temperature, calculate the concentration of  $\text{N}_2\text{O}_4$  at equilibrium.

- a) 0.39 moles/liter
- b) 0.65 moles/liter
- c) 0.82 moles/liter
- d) 7.5 moles/liter
- e) none of these

**ANS:** a) 0.39 moles/liter

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31. Initially 2.0 moles of  $\text{N}_2(\text{g})$  and 4.0 moles of  $\text{H}_2(\text{g})$  were added to a 1.0-liter container and the following reaction then occurred:



The equilibrium concentration of  $\text{NH}_3(\text{g}) = 0.68$  moles/liter at  $700^\circ\text{C}$ . The value for  $K$  at  $700^\circ\text{C}$  for the formation of ammonia is:

- a)  $3.6 \times 10^{-3}$
- b)  $1.4 \times 10^{-1}$
- c)  $1.1 \times 10^{-2}$
- d)  $5.0 \times 10^{-2}$
- e) none of these

**ANS:** c)  $1.1 \times 10^{-2}$

**PAGE:** 13.5

32. Consider the reaction  $\text{C}(\text{s}) + \text{CO}_2(\text{g}) \rightleftharpoons 2\text{CO}(\text{g})$ . At 1273 K the  $K_p$  value is 167.5. What is the  $P_{\text{CO}}$  at equilibrium if the  $P_{\text{CO}_2}$  is 0.10 atm at this temperature?

- a) 16.7 atm
- b) 2.0 atm
- c) 1.4 atm
- d) 4.1 atm
- e) 250 atm

**ANS:** c) 4.1 atm

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33. Which of the following is true for a system whose equilibrium constant is relatively small?

- a) It will take a short time to reach equilibrium.
- b) It will take a long time to reach equilibrium.
- c) The equilibrium lies to the left.
- d) The equilibrium lies to the right.
- e) Two of these.

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**ANS:** c) The equilibrium lies to the left. **PAGE:** 13.5

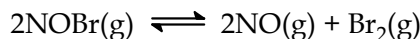
34. The reaction quotient for a system is  $7.2 \times 10^2$ . If the equilibrium constant for the system is 36, what will happen as equilibrium is approached?
- There will be a net gain in product.
  - There will be a net gain in reactant.
  - There will be a net gain in both product and reactant.
  - There will be no net gain in either product or reactant.
  - The equilibrium constant will decrease until it equals the reaction quotient.

**ANS:** b) There will be a net gain in reactant. **PAGE:** 13.5

35. Consider the following equilibrated system:  $2\text{NO}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g}) + \text{O}_2(\text{g})$ . If the  $K_p$  value is 0.860, find the equilibrium pressure of the  $\text{O}_2$  gas if the  $\text{NO}_2$  gas pressure is 0.520 atm and the  $P_{\text{NO}}$  is 0.300 atm at equilibrium.
- 1.49 atm
  - 0.78 atm
  - 0.40 atm
  - 0.99 atm
  - 2.58 atm

**ANS:** e) 2.58 atm **PAGE:** 13.5

- 36–37. Consider the following reaction (assume an ideal gas mixture):



A 1.0-liter vessel was initially filled with pure NOBr, at a pressure of 4.0 atm, at 300 K.

36. After equilibrium was established, the partial pressure of NOBr was 2.5 atm. What is  $K_p$  for the reaction?
- 0.45
  - 0.27
  - 0.18
  - 0.75
  - none of these

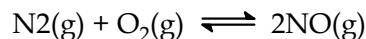
**ANS:** b) 0.27 **PAGE:** 13.5,6

37. After equilibrium was reached, the volume was increased to 2.0 liters, while the temperature was kept at 300 K. This will result in:
- an increase in  $K_p$ .
  - a decrease in  $K_p$ .
  - a shift in the equilibrium position to the right.
  - a shift in the equilibrium position to the left.
  - none of these

**ANS:** c) a shift in the equilibrium position to the right. **PAGE:** 13.7

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38–39. 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. At 2000°C,  $K$  for the reaction



is 0.01.

38. 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.

- The system remains unchanged.
- The concentration of  $\text{NO}$  will decrease; the concentrations of  $\text{N}_2$  and  $\text{O}_2$  will increase.
- The concentration of  $\text{NO}$  will increase; the concentrations of  $\text{N}_2$  and  $\text{O}_2$  will decrease.
- The concentration of  $\text{NO}$  will decrease; the concentrations of  $\text{N}_2$  and  $\text{O}_2$  will remain unchanged.
- More information is necessary.

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

**PAGE:** 13.5

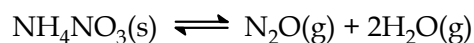
39. A 1-L container originally holds 0.4 mol of  $\text{N}_2$ , 0.1 mol of  $\text{O}_2$ , and 0.08 mole of  $\text{NO}$ . If the volume of the container holding the equilibrium mixture of  $\text{N}_2$ ,  $\text{O}_2$ , and  $\text{NO}$  is decreased to 0.5 L without changing the quantities of the gases present, how will their concentrations change?

- The concentration of  $\text{NO}$  will increase; the concentrations of  $\text{N}_2$  and  $\text{O}_2$  will decrease.
- The concentrations of  $\text{N}_2$  and  $\text{O}_2$  will increase; and the concentration of  $\text{NO}$  will decrease.
- The concentrations of  $\text{N}_2$ ,  $\text{O}_2$ , and  $\text{NO}$  will increase.
- The concentrations of  $\text{N}_2$ ,  $\text{O}_2$ , and  $\text{NO}$  will decrease.
- There will be no change in the concentrations of  $\text{N}_2$ ,  $\text{O}_2$ , and  $\text{NO}$ .

**ANS:** c) The concentrations of  $\text{N}_2$ ,  $\text{O}_2$ , and  $\text{NO}$  will increase.

**PAGE:** 13.5,7

40. A sample of solid  $\text{NH}_4\text{NO}_3$  was placed in an evacuated container and then heated so that it decomposed explosively according to the following equation:



At equilibrium the total pressure in the container was found to be 3.20 atm at a temperature of 500°C. Calculate  $K_p$ .

- 4.10
- 1.23
- 2.56
- 4.85
- 1.14

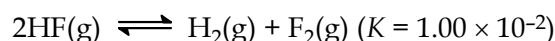
CHAPTER 13 Chemical Equilibrium

ANS: d) 4.85

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CHAPTER 13 Chemical Equilibrium

41. Consider the following reaction:



Given 1.00 mole of HF(g), 0.500 mole of H<sub>2</sub>(g), and 0.750 mole of F<sub>2</sub>(g) are mixed in a 5.00-L flask, determine the reaction quotient, *Q*, and the net direction to achieve equilibrium.

- a) *Q* = 0.150; the equilibrium shifts to the right.
- b) *Q* = 0.375; the equilibrium shifts to the left.
- c) *Q* = 0.150; the equilibrium shifts to the left.
- d) *Q* = 0.375; the equilibrium shifts to the right.
- e) *Q* = 0.150; the system is at equilibrium.

**ANS:** b) *Q* = 0.375; the equilibrium shifts to the left.

**PAGE:** 13.5

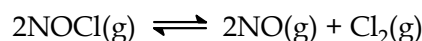
42. Equilibrium is reached in chemical reactions when:

- a) the rates of the forward and reverse reactions become equal.
- b) the concentrations of reactants and products become equal.
- c) the temperature shows a sharp rise.
- d) all chemical reactions stop.
- e) the forward reaction stops.

**ANS:** a) the rates of the forward and reverse reactions become equal.

**PAGE:** 13.1

43–46. Consider the following equilibrium:



with *K* = 1.6 × 10<sup>-5</sup>. 1.00 mole of pure NOCl and 1.00 mole of pure Cl<sub>2</sub> are placed in a 1.00-L container.

43. If *x* moles of NOCl react, what is the equilibrium concentration of NO?

- a) +*x*
- b) +2*x*
- c) -*x*
- d) -2*x*
- e) *x*<sup>2</sup>

**ANS:** a) +*x*

**PAGE:** 13.6

CHAPTER 13 Chemical Equilibrium

44. If  $x$  moles of  $\text{NOCl}$  react, what is the equilibrium concentration of  $\text{Cl}_2$ ?

- a)  $+x$
- b)  $+\frac{x}{2}$
- c)  $1 + x$
- d)  $1 + \frac{x}{2}$
- e)  $1 + 2x$

ANS: d)  $1 + \frac{x}{2}$

PAGE: 13.6

45. Calculate the equilibrium concentration of  $\text{NO}(\text{g})$ .

- a) 1.0 M
- b)  $1.6 \times 10^{-5}$  M
- c) 0.50 M
- d)  $6.2 \times 10^{-4}$  M
- e)  $4.0 \times 10^{-3}$  M

ANS: e)  $4.0 \times 10^{-3}$  M

PAGE: 13.6

46. Calculate the equilibrium concentration of  $\text{Cl}_2(\text{g})$ .

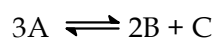
- a)  $1.6 \times 10^{-5}$  M
- b) 1.0 M
- c) 0.50 M
- d)  $6.2 \times 10^{-4}$  M
- e)  $4.0 \times 10^{-3}$  M

ANS: b) 1.0 M

PAGE: 13.6

47-49. The questions below refer to the following system:

A 3.00-liter flask initially contains 1.50 mol of gas A and 0.450 mol of gas B. Gas A decomposes according to the following reaction:



The equilibrium concentration of gas C is 0.100 mol/L.

47. Determine the equilibrium concentration of gas A.

- a) 0.100 M
- b) 0.200 M
- c) 0.300 M
- d) 0.500 M
- e) none of these

ANS: b) 0.200 M

PAGE: 13.5



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48. Determine the equilibrium concentration of gas B.

- a) 0.150 M
- b) 0.200 M
- c) 0.350 M
- d) 0.450 M
- e) none of these

**ANS:** c) 0.350 M

**PAGE:** 13.5

49. Determine the value of the equilibrium constant,  $K$ .

- a) 0.117
- b) 0.175
- c) 0.227
- d) 1.53
- e) none of these

**ANS:** d) 1.53

**PAGE:** 13.5

50. Nitrogen gas ( $N_2$ ) reacts with hydrogen gas ( $H_2$ ) to form ammonia ( $NH_3$ ). At  $200^\circ C$  in a closed container, 1.0 atm of nitrogen gas is mixed with 2.0 atm of hydrogen gas. At equilibrium, the total pressure is 2.0 atm. Calculate the partial pressure of hydrogen gas at equilibrium.

- a) 2.0 atm
- b) 0.50 atm
- c) 1.5 atm
- d) 0.0 atm
- e) none of these

**ANS:** b) 0.50 atm

**PAGE:** 13.6

51. Given the equation  $A(aq) + 2B(aq) \rightleftharpoons 3C(aq) + 2D(aq)$ . 45.0 mL of 0.050 M A is mixed with 25.0 mL 0.100 M B. At equilibrium the concentration of C is 0.0410 M. Calculate  $K$ .

- a) 7.3
- b) 0.34
- c) 0.040
- d) 0.14
- e) none of these

**ANS:** c) 0.040

**PAGE:** 13.5

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52. Given the reaction  $A(g) + B(g) \rightleftharpoons C(g) + D(g)$ . You have the gases A, B, C, and D at equilibrium. Upon adding gas A, the value of  $K$ :
- increases because by adding A, more products are made, increasing the product to reactant ratio.
  - decreases because A is a reactant of the product to reactant ratio decreases.
  - does not change because A does not figure into the product to reactant ratio.
  - does not change as long as the temperature is constant.
  - depends on whether the reaction is endothermic or exothermic.

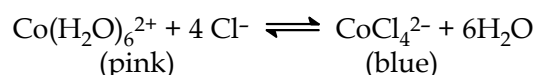
**ANS:** d) does not change as long as the temperature is constant. **PAGE:** 13.2, 7

53. The equilibrium system  $2A \rightleftharpoons 2B + C$  has a very small equilibrium constant:  $K = 2.6 \times 10^{-6}$ . Initially 3 moles of A are placed in a 1.5-L flask. Determine the concentration of C at equilibrium.
- 0.011 M
  - 0.022 M
  - 0.033 M
  - 0.044 M
  - 2.0 M

**ANS:** a) 0.011 M **PAGE:** 13.6

54–57. The questions below refer to the following system:

Cobalt chloride is added to pure water. The  $\text{Co}^{2+}$  ions hydrate. The hydrated form then reacts with the  $\text{Cl}^-$  ions to set up the equilibrium shown here:



54. Which statement below describes the change that the system will undergo if hydrochloric acid is added?
- It should become more blue.
  - It should become more pink.
  - The equilibrium will shift to the right.
  - The equilibrium will shift to the left.
  - Two of these.

**ANS:** e) Two of these. **PAGE:** 13.7

55. Which statement below describes the change that the system will undergo if water is added?
- More chlorine ions will be produced.
  - More water will be produced.
  - The equilibrium will shift to the right.
  - The color will become more blue.
  - There will be less of the hydrated cobalt ion at the new equilibrium position.

**ANS:** a) More chlorine ions will be produced. **PAGE:** 13.7

## CHAPTER 13 Chemical Equilibrium

56. Which statement below describes the change that the system will undergo if silver nitrate is added?
- It should become more blue.
  - It should become more pink.
  - Water will be produced.
  - The silver ion will react with the  $\text{CoCl}_4^{2-}$ .
  - Nothing will change.

**ANS:** b) It should become more pink.

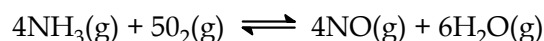
**PAGE:** 13.7

57. Which statement below describes the change that the system will undergo if acetone (whose density is lower than water and is insoluble in water) is added?
- The system will become pink on the top and blue on the bottom.
  - The system will become blue on the top and pink on the bottom.
  - The system will become intensely pink in the middle.
  - The system will become intensely blue on the top and clear on the bottom.
  - The system will become intensely pink on the top and clear on the bottom.

**ANS:** b) The system will become blue on the top and pink on the bottom.

**PAGE:** 13.7

58–60. The following questions refer to the equilibrium shown here:



58. What would happen to the system if oxygen were added?
- More ammonia would be produced.
  - More oxygen would be produced.
  - The equilibrium would shift to the right.
  - The equilibrium would shift to the left.
  - Nothing would happen.

**ANS:** c) The equilibrium would shift to the right.

**PAGE:** 13.7

59. What would happen to the system if the pressure were decreased?
- Nothing would happen.
  - More oxygen would be produced.
  - The water vapor would become liquid water.
  - The ammonia concentration would increase.
  - The NO concentration would increase.

**ANS:** e) The NO concentration would increase.

**PAGE:** 13.7

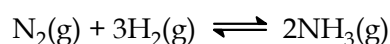
CHAPTER 13 Chemical Equilibrium

60. For a certain reaction at 25.0°C, the value of  $K$  is  $1.2 \times 10^{-3}$ . At 50.0°C the value of  $K$  is  $3.4 \times 10^{-1}$ . This means that the reaction is
- exothermic.
  - endothermic.
  - never favorable.
  - More information is needed.
  - None of these (a-d)

ANS: a) Endothermic

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61. Ammonia is prepared industrially by the reaction:



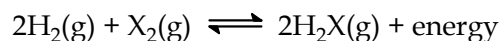
For the reaction,  $\Delta H^\circ = -92.2 \text{ kJ}$  and  $K$  (at 25°C) =  $4.0 \times 10^8$ . When the temperature of the reaction is increased to 500°C, which of the following is true?

- $K$  for the reaction will be larger at 500°C than at 25°C.
- At equilibrium, more  $\text{NH}_3$  is present at 500°C than at 25°C.
- Product formation (at equilibrium) is not favored as the temperature is raised.
- The reaction of  $\text{N}_2$  with  $\text{H}_2$  to form ammonia is endothermic.
- None of these is true.

ANS: c) Product formation (at equilibrium) is not favored as the temperature is raised.

PAGE: 13.7

- 62–65. Consider the following equilibrium:



62. Addition of  $\text{X}_2$  to a system described by the above equilibrium

- will cause  $[\text{H}_2]$  to decrease.
- will cause  $[\text{X}_2]$  to decrease.
- will cause  $[\text{H}_2\text{X}]$  to decrease.
- will have no effect.
- cannot possibly be carried out.

ANS: a) will cause  $[\text{H}_2]$  to decrease.

PAGE: 13.7

63. Addition of argon to the above equilibrium

- will cause  $[\text{H}_2]$  to decrease.
- will cause  $[\text{X}_2]$  to increase.
- will cause  $[\text{H}_2\text{X}]$  to increase.
- will have no effect.
- cannot possibly be carried out.

ANS: d) will have no effect.

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CHAPTER 13 Chemical Equilibrium

64. Increasing the pressure by decreasing the volume will cause
- the reaction to occur to produce  $H_2X$ .
  - the reaction to occur to produce  $H_2$  and  $X_2$ .
  - the reaction to occur to produce  $H_2$  but no more  $X_2$ .
  - no reaction to occur.
  - $X_2$  to dissociate.

**ANS:** a) the reaction to occur to produce  $H_2X$ .

**PAGE:** 13.7

65. Increasing the temperature will cause
- the reaction to occur to produce  $H_2X$ .
  - the reaction to occur to produce  $H_2$  and  $X_2$ .
  - the reaction to occur to produce  $H_2$  but no more  $X_2$ .
  - no reaction to occur.
  - an explosion.

**ANS:** b) the reaction to occur to produce  $H_2$  and  $X_2$ .

**PAGE:** 13.7

66. The value of equilibrium constant  $K$  is dependent on
- the initial concentrations of the reactants.
  - the initial concentrations of the products.
  - the temperature of the system.
  - the nature of the reactants and products.
- I, II
  - II, III
  - III, IV
  - It is dependent on three of these choices.
  - It is not dependent on any of these choices.

**ANS:** c) III, IV

**PAGE:** 13.2

67-72. Given the equation  $2A(g) \rightleftharpoons 2B(g) + C(g)$ . At a particular temperature,  $K = 1.6 \times 10^4$ .

67. If you start with 2.0 M of chemical A, calculate the equilibrium concentration of chemical C.
- $8.3 \times 10^{-3}$  M
  - $6.25 \times 10^{-5}$  M
  - 2.0 M
  - 0.99 M
  - none of these

**ANS:** d) 0.99 M

**PAGE:** 13.6

CHAPTER 13 Chemical Equilibrium

68. If you mixed 5.0 mol B, 0.10 mol C, and 0.0010 mol A in a one-liter container, which direction would the reaction initially proceed?
- a) To the left.
  - b) To the right.
  - c) The above mixture is the equilibrium mixture.
  - d) Cannot tell from the information given.
  - e) None of these (a-d)

**ANS:** a) To the left.

**PAGE:** 13.5

69. At a higher temperature,  $K = 1.8 \times 10^{-5}$ . If you start with 2.0 M of chemical A, calculate the equilibrium concentration of chemical C.
- a)  $6.0 \times 10^{-3}$  M
  - b)  $2.6 \times 10^{-2}$  M
  - c) 1.0 M
  - d)  $2.1 \times 10^{-2}$  M
  - e) none of these

**ANS:** b)  $2.6 \times 10^{-2}$  M

**PAGE:** 13.6

70. Addition of chemical B to an equilibrium mixture of the above will
- a) cause [A] to increase.
  - b) cause [C] to increase.
  - c) have no effect.
  - d) cannot be determined.
  - e) none of these.

**ANS:** a) cause [A] to increase.

**PAGE:** 13.7

71. Placing the equilibrium mixture in an ice bath (thus lowering the temperature) will
- a) cause [A] to increase.
  - b) cause [B] to increase.
  - c) have no effect.
  - d) cannot be determined.
  - e) none of these.

**ANS:** b) cause [B] to increase.

**PAGE:** 13.7

72. Raising the pressure by lowering the volume of the container will
- a) cause [A] to increase.
  - b) cause [B] to increase.
  - c) have no effect.
  - d) cannot be determined.
  - e) none of these.

**ANS:** a) cause [A] to increase.

**PAGE:** 13.7