

## 16-2 Review and Reinforcement

### *The Law of Chemical Equilibrium*

On the line at the left, write the letter of the description that best matches each term.

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|--------------------------------------|--|
| _____ 1. equilibrium position        | a. equilibrium condition for a chemical reaction involving substances in more than one state                         |
| _____ 2. law of chemical equilibrium | b. used to determine if a reaction has reached equilibrium   |
| _____ 3. reaction quotient           | c. depends on the initial concentrations of the substances in a reaction   |
| _____ 4. homogeneous equilibria      | d. states that every reaction proceeds to an equilibrium state with a specific $K_{eq}$                              |
| _____ 5. law of mass action          | e. expresses the relative concentration of reactants and products at equilibrium in terms of an equilibrium constant |
| _____ 6. heterogeneous equilibria    | f. equilibrium condition for reactions in which products and reactants are in the same state                         |
| _____ 7. equilibrium constant        | g. the ratio of product concentration to reactant concentration at equilibrium                                       |

Answer each of the following questions in the space provided.

8. What is the equilibrium expression for the equation  $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ ?
9. What is the equilibrium expression for the equation  $NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$ ?
10. What is the equilibrium expression for the equation  $As_4O_6(s) + 6C(s) \rightleftharpoons As_4(g) + 6CO(g)$ ?
11. What is the equilibrium expression for the equation  $SnO_2(s) + 2CO(g) \rightleftharpoons Sn(s) + 2CO_2(g)$ ?
12. What is the equilibrium expression for the equation  $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$ ?

**16-2 Review and Reinforcement (continued)**

13. For the reaction  $2\text{CO}(g) \rightleftharpoons \text{C}(s) + \text{CO}_2(g)$ ,  $K_{\text{eq}} = 7.7 \times 10^{-15}$ . At a particular time, the following concentrations are measured:  $[\text{CO}] = 0.034 \text{ M}$ ,  $[\text{CO}_2] = 3.6 \times 10^{-17} \text{ M}$ . Is this reaction at equilibrium? If not, in which direction will the reaction proceed?
14. For the reaction  $\text{N}_2\text{O}_4(g) \rightleftharpoons 2\text{NO}_2(g)$ ,  $K_{\text{eq}} = 0.2$ . At a particular time, the following concentrations are measured:  $[\text{N}_2\text{O}_4] = 2.0 \text{ M}$ ,  $[\text{NO}_2] = 0.2 \text{ M}$ . Is this reaction at equilibrium? If not, in which direction will the reaction proceed?
15. For the reaction  $2\text{ICl}(g) \rightleftharpoons \text{I}_2(g) + \text{Cl}_2(g)$ ,  $K_{\text{eq}} = 0.11$ . At a particular time, the following concentrations are measured:  $[\text{ICl}] = 2.5 \text{ M}$ ,  $[\text{I}_2] = 2.0 \text{ M}$ ,  $[\text{Cl}_2] = 1.2 \text{ M}$ . Is this reaction at equilibrium? If not, in which direction will the reaction proceed?

Match each statement with the appropriate letter. Each letter can be used once, more than once, or not at all.

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|---|--|
| _____ 16. The equilibrium concentration of products is much greater than that of reactants. | a. $K_{\text{eq}}$ is much greater than 1. |
| _____ 17. The equilibrium concentration of products is much less than that of reactants     | b. $K_{\text{eq}}$ is about equal to 1.    |
| _____ 18. There is a considerable amount of both reactants and products at equilibrium.     | c. $K_{\text{eq}}$ is much less than 1.    |

Answer each of the following questions in the space provided.

19. What effect does changing the initial concentration of substances in a reaction have on the equilibrium constant?

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20. What is meant when chemists say that the equilibrium position of a reaction "lies to the left"?

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21. Why are solids and pure liquids left out of equilibrium expressions?

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22. How is the reaction quotient ( $Q$ ) related to the equilibrium constant ( $K_{\text{eq}}$ )?

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## 16-2 Practice Problems

- Write the equilibrium expression for the oxidation of hydrogen to form water vapor.  
 $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{H}_2\text{O}(\text{g})$
- Write the equilibrium expression for the formation of nitrosyl bromide.  
 $2\text{NO}(\text{g}) + \text{Br}_2(\text{g}) \rightleftharpoons 2\text{NOBr}(\text{g})$
- Write the equilibrium expression for the following reaction.  
 $\text{NO}(\text{g}) + \text{O}_3(\text{g}) \rightleftharpoons \text{O}_2(\text{g}) + \text{NO}_2(\text{g})$
- Write the equilibrium expression for the following reaction.  
 $\text{CH}_4(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons \text{CH}_3\text{Cl}(\text{g}) + \text{HCl}(\text{g})$
- Write the equilibrium expression for the following reaction.  
 $\text{CH}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + 3\text{H}_2(\text{g})$
- Write the equilibrium expression for the following reaction.  
 $\text{CO}(\text{g}) + 2\text{H}_2(\text{g}) \rightleftharpoons \text{CH}_3\text{OH}(\text{g})$
- Write the equilibrium expression for the combustion of ethane at high temperature.  
 $2\text{C}_2\text{H}_6(\text{g}) + 7\text{O}_2(\text{g}) \rightleftharpoons 4\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{g})$
- Write the equilibrium expression for the decomposition of ethane.  
 $\text{C}_2\text{H}_6(\text{g}) \rightleftharpoons \text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g})$
- Write the equilibrium expression for the following reaction.  
 $\text{Hg}(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons \text{HgI}_2(\text{g})$
- Write the equilibrium expression for the following reaction.  
 $\text{SnO}_2(\text{s}) + 2\text{CO}(\text{g}) \rightleftharpoons \text{Sn}(\text{s}) + 2\text{CO}_2(\text{g})$
- Write the equilibrium expression for the following reaction.  
 $\text{C}(\text{s}) + \text{CO}_2(\text{g}) \rightleftharpoons 2\text{CO}(\text{g})$
- Write the equilibrium expression for the following reaction.  
 $\text{FeO}(\text{s}) + \text{CO}(\text{g}) \rightleftharpoons \text{Fe}(\text{s}) + \text{CO}_2(\text{g})$
- Write the equilibrium expression for the following reaction.  
 $\text{KCl}(\text{l}) + \text{Na}(\text{l}) \rightleftharpoons \text{NaCl}(\text{l}) + \text{K}(\text{g})$
- Write the equilibrium expression for the following reaction.  
 $\text{NaCl}(\text{s}) + \text{H}_2\text{SO}_4(\text{l}) \rightleftharpoons \text{HCl}(\text{g}) + \text{NaHSO}_4(\text{s})$
- Write the equilibrium expression for the following reaction.  
 $\text{P}_4(\text{s}) + 6\text{NO}(\text{g}) \rightleftharpoons \text{P}_4\text{O}_6(\text{s}) + 3\text{N}_2(\text{g})$
- Write the equilibrium expression for the following reaction.  
 $2\text{NO}(\text{g}) + 2\text{H}_2(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$

**16-2 Practice Problems (continued)**

17. Write the equilibrium expression for the following reaction.  
$$\text{H}_2\text{CO}_3(s) \rightleftharpoons \text{H}_2\text{O}(l) + \text{CO}_2(g)$$
18. Write the equilibrium expression for the following reaction.  
$$\text{CO}_2(g) + \text{H}_2(g) \rightleftharpoons \text{CO}(g) + \text{H}_2\text{O}(l)$$
19. At  $740^\circ\text{C}$ ,  $K_{\text{eq}} = 0.0060$  for the decomposition of calcium carbonate ( $\text{CaCO}_3$ ), which is described by the equation  
$$\text{CaCO}_3(s) \rightleftharpoons \text{CaO}(s) + \text{CO}_2(g)$$
  
Find  $Q$  and predict how the reaction will proceed if  $[\text{CO}_2] = 0.0004 \text{ M}$ .
20. For the reaction  
$$\text{CO}(g) + \text{H}_2\text{O}(g) \rightleftharpoons \text{H}_2(g) + \text{CO}_2(g)$$
  
 $K_{\text{eq}} = 5.10$  at  $527^\circ\text{C}$ . If  $[\text{CO}] = 0.15 \text{ M}$ ,  $[\text{H}_2\text{O}] = 0.25 \text{ M}$ ,  $[\text{H}_2] = 0.42 \text{ M}$ , and  $[\text{CO}_2] = 0.37 \text{ M}$ , calculate  $Q$  and determine how the reaction will proceed.
21. At  $340^\circ\text{C}$ ,  $K_{\text{eq}} = 0.064$  for the reaction  
$$\text{Fe}_2\text{O}_3(s) + 3\text{H}_2(g) \rightleftharpoons 2\text{Fe}(s) + 3\text{H}_2\text{O}(g)$$
  
Given that  $[\text{H}_2] = 0.45 \text{ M}$  and  $[\text{H}_2\text{O}] = 0.37 \text{ M}$ , find  $Q$  and predict how the reaction will proceed.
22. At  $2130^\circ\text{C}$ ,  $K_{\text{eq}} = 0.0025$  for the reaction  
$$\text{N}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{NO}(g)$$
  
If  $[\text{N}_2] = 0.81 \text{ M}$ ,  $[\text{O}_2] = 0.75 \text{ M}$ , and  $[\text{NO}] = 0.030 \text{ M}$ , find  $Q$  and determine the direction in which the reaction will proceed.
23. Ammonia is synthesized from nitrogen and hydrogen in the reaction  
$$\text{N}_2(g) + 3\text{H}_2(g) \rightleftharpoons 2\text{NH}_3(g)$$
  
At  $500^\circ\text{C}$ , the equilibrium constant for this reaction is 0.080. Given that  $[\text{NH}_3] = 0.0596 \text{ M}$ ,  $[\text{N}_2] = 0.600 \text{ M}$ , and  $[\text{H}_2] = 0.420 \text{ M}$ , find  $Q$  and predict how the reaction will proceed.
24. The decomposition of antimony pentachloride ( $\text{SbCl}_5$ ) is described by the equation  
$$\text{SbCl}_5(g) \rightleftharpoons \text{SbCl}_3(g) + \text{Cl}_2(g)$$
  
At  $448^\circ\text{C}$ , the equilibrium constant for this reaction is 0.0251. What is the value of  $Q$  if  $[\text{SbCl}_5] = 0.095 \text{ M}$ ,  $[\text{SbCl}_3] = 0.020 \text{ M}$ , and  $[\text{Cl}_2] = 0.050 \text{ M}$ ? How will this reaction proceed?
25. At  $1000^\circ\text{C}$ ,  $K_{\text{eq}} = 1.0 \times 10^{-13}$  for the decomposition of hydrofluoric acid ( $\text{HF}$ ), as described in the reaction  
$$2\text{HF}(g) \rightleftharpoons \text{H}_2(g) + \text{F}_2(g)$$
  
If  $[\text{HF}] = 23.0 \text{ M}$ ,  $[\text{H}_2] = 0.540 \text{ M}$ , and  $[\text{F}_2] = 0.380 \text{ M}$ , determine the value of  $Q$  and predict how the reaction will proceed.
26. At  $1227^\circ\text{C}$ ,  $K_{\text{eq}}$  for the following reaction is 0.15.  
$$2\text{SO}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{SO}_3(g)$$
  
If  $[\text{SO}_2] = 0.344 \text{ M}$ ,  $[\text{O}_2] = 0.172 \text{ M}$ , and  $[\text{SO}_3] = 0.056 \text{ M}$ , find  $Q$  and determine how the reaction will proceed.