

Chemical Equilibrium

Section 18.1 Equilibrium: A State of Dynamic Balance

In your textbook, read about chemical equilibrium.

Complete each statement.

- When a reaction results in almost complete conversion of reactants to products, chemists say the reaction goes to completion.
- A reaction that can occur in both the forward and the reverse directions is called a(n) reversible reaction.
- Equilibrium is a state in which the forward and reverse reactions balance each other because they take place at equal rates.
- At equilibrium, the concentrations of reactants and products are constant, but that does not mean that the amounts or concentrations are the same (equal).
- Equilibrium is a state of action, not one of inaction.

In your textbook, read about equilibrium expressions and constants.

For each statement below, write *true* or *false*.

- False 6. The law of chemical equilibrium states that at a given temperature pressure, a chemical system may reach a state in which a particular ratio of reactant to product concentrations has a constant value.
- True 7. The equation $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$ is an example of a homogeneous equilibrium.
- True 8. If an equilibrium constant has a value less than one, the reactants are favored at equilibrium.
- False 9. The value for K_{eq} is constant only at a specific temperature volume.
- False 10. If the equilibrium constant for a reaction at 300 K is 49.7, the concentration of the reactants will be greater than the concentration of the products.
- True 11. A heterogeneous equilibrium means that reactants and products are present in more than one state.
- True 12. The product of the forward chemical reaction is HI, for the equilibrium expression:

$$K_{\text{eq}} = \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]}$$

CHAPTER 18

STUDY GUIDE FOR CONTENT MASTERY

Section 18.1 *continued*

In your textbook, read about determining equilibrium constants.

A chemist did two experiments to determine the equilibrium constant for the reaction of sulfur dioxide with oxygen to form sulfur trioxide. Use the table showing the results of the experiments to answer the following questions.

| $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$ at 873 K | | | |
|--|--------------------------------|---------------------------------|---------------------------------|
| Experiment 1 | | Experiment 2 | |
| Initial concentrations | Equilibrium concentrations | Initial concentrations | Equilibrium concentration |
| $[\text{SO}_2] = 2.00\text{M}$ | $[\text{SO}_2] = 1.50\text{M}$ | $[\text{SO}_2] = 0.500\text{M}$ | $[\text{SO}_2] = 0.590\text{M}$ |
| $[\text{O}_2] = 1.50\text{M}$ | $[\text{O}_2] = 1.26\text{M}$ | $[\text{O}_2] = 0\text{M}$ | $[\text{O}_2] = 0.0450\text{M}$ |
| $[\text{SO}_3] = 3.00\text{M}$ | $[\text{SO}_3] = 3.50\text{M}$ | $[\text{SO}_3] = 0.350\text{M}$ | $[\text{SO}_3] = 0.260\text{M}$ |

13. Write the equation to calculate the equilibrium constant for the reaction.

$$K_{eq} = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]}$$

14. Is this reaction an example of a homogeneous or heterogeneous equilibrium?

Homogeneous equilibrium

15. Calculate the equilibrium constant from the data obtained in experiment 1.

$$K_{eq} = \frac{(3.50)^2}{(1.50)^2 (1.26)} = 4.32$$

16. What is the equilibrium constant for the reaction in experiment 2?

$$K_{eq} = \frac{(0.260)^2}{(0.590)^2 (0.0450)} = 4.32$$

17. Was it necessary to calculate both equilibrium constants? Why or why not?

Yes. It is necessary in order to verify the results and confirm K_{eq} .

18. What does this experiment show about the initial concentrations of products and reactants in a reversible reaction?

The initial concentrations do not affect K_{eq} .

Section 18.2 Factors Affecting Chemical Equilibrium

In your textbook, read about Le Châtelier's Principle.

Answer the following questions.

1. What does Le Châtelier's Principle say?

If a stress is applied to a system @ equilibrium, the system will shift left or right to return to equilibrium.

2. What are three kinds of stresses that can be placed on a system?

Change in concentration, temperature, or pressure.
(volume)

For each reaction below, state the direction, left or right, in which the equilibrium will shift when the indicated substance is added. Identify one other way in which the reaction could be shifted in the same direction you indicated. (Hint: There may be more than one way to do this.)

3. Reaction: $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$; NH_3 added

increase volume /
left; remove N_2 and H_2 ; lower pressure

4. Reaction: $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$; H_2 added

right; add I_2 ; remove HI

5. Reaction: $\text{CO}(\text{g}) + \text{H}_2\text{O} \rightleftharpoons \text{CO}_2(\text{g}) + \text{H}_2(\text{g})$; H_2O added

or NO change $\text{H}_2\text{O}(\text{l})$
right; add CO ; remove CO_2 and H_2

6. Reaction: $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$; SO_3 added

left; remove SO_2 and O_2 ; lower pressure

7. Reaction: $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$; SO_2 added

right: add O_2 ; remove SO_3 ; increase pressure

8. Reaction: $2\text{NCl}_3(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + 3\text{Cl}_2(\text{g})$; NCl_3 added

right: remove N_2 and Cl_2 ; lower pressure

CHAPTER 18

STUDY GUIDE FOR CONTENT MASTERY

Section 18.2 *continued*

In your textbook, read about factors affecting chemical equilibrium.

Use each of the terms below just once to complete the passage.

- | | | | | | |
|------------|--------------|------------|------------|------------|----------|
| • right | • exothermic | • increase | • stress | • catalyst | • energy |
| • smallest | • change | • reverse | • constant | • forward | |

When you decrease the volume of a reaction vessel, you (9) increase the pressure. This causes a reaction at equilibrium to shift to the side with the (10) smallest number of moles. If the reaction has an equal number of moles of reactants and products, changing the volume of the reaction vessel causes no (11) change in the equilibrium.

Changing the temperature of a reaction at equilibrium alters both the equilibrium (12) constant and the equilibrium position. When a reaction is (13) exothermic, which means it releases energy, lowering the temperature shifts the equilibrium to the (14) right because the forward reaction liberates heat and removes the (15) stress.

A (16) catalyst speeds up a reaction by lowering the (17) energy requirements for the reaction, but it does so equally in both the (18) forward and the (19) reverse directions. The reaction will reach equilibrium more quickly, but with no change in the amount of product formed.

For each reaction below, indicate in which direction the equilibrium shifts when the stated stress is applied to the system. Write *R* if the reaction shifts to the right, *L* if it shifts to the left, or *NC* if there is no change.

| Reaction | Stress |
|---|----------------------------|
| <u>L</u> 20. $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g}) + \text{heat}$ | temperature increase |
| <u>R</u> 21. $\text{CO}(\text{g}) + \text{Fe}_3\text{O}_4(\text{s}) \rightleftharpoons \text{CO}_2(\text{g}) + 3\text{FeO}(\text{s})$ | volume increase, <u>P↓</u> |
| <u>R</u> 22. $\text{C}_2\text{H}_2(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CH}_3\text{CHO}(\text{g}) + \text{heat}$ | temperature decrease |
| <u>R</u> 23. $2\text{NO}(\text{g}) + \text{H}_2(\text{g}) \rightleftharpoons \text{N}_2\text{O}(\text{g}) + \text{H}_2\text{O}(\text{g}) + \text{heat}$ | volume decrease, <u>P↑</u> |
| <u>L</u> 24. $\text{Heat} + \text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$ | temperature decrease |
| <u>NC</u> 25. $\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons 2\text{HCl}(\text{g}) + \text{heat}$ | volume decrease, <u>P↑</u> |