(2) Yes, the evidence from many systems shows that the rate at which reactant particles are colliding to form products is equal to the rate at which products are colliding to form reactants.
(3) When a system reaches equilibrium, the reactant amounts will have decreased to some specific extent. If the remaining reactants are present to much less than 1%, the reaction is considered quantitative. In reactions where significant (detectable) amounts of reactants remain, equilibrium theory must be taken into account.
(4) Yes, if the equilibrium constant is known, the chemical amount of product that should form can be accurately predicted.

Chapter 15 REVIEW

Part 1

(Pages 705–706)

1. B
2. C
3. 70.3
4. D
5. A
6. B
7. C
8. B
9. A
10. 0.400

Solutions

3. $$p = \frac{4.22 \text{ mol}}{6.00 \text{ mol}} \times 100\% = 70.3\%$$

6. $$K_{\text{reverse}} = \frac{1}{K_{\text{forward}}} = \frac{1}{2.4 \times 10^3} = 4.2 \times 10^{-4}$$

10. $$\Delta[CH_4(g)] = 0.110 \text{ mol/L} - 0.010 \text{ mol/L} = 0.100 \text{ mol/L}$$

$$\Delta[H_2(g)] = 0.100 \text{ mol/L} \times \frac{4}{1} = 0.400 \text{ mol/L}$$

$$[H_2(g)]_{eq} = 0 + 0.400 \text{ mol/L} = 0.400 \text{ mol/L}$$

Part 2

(Pages 706–709)

11. Chemical equilibrium is a state of a closed system in which all macroscopic properties are constant.
12. Chemical equilibrium is explained as a balance between forward and reverse processes occurring simultaneously, at the same rate.
13. "Reactants favoured" refers to an equilibrium where the reactant to product ratio is quite high. If the ratio is greater than 99%, the reaction may be considered "nonspontaneous" or the reaction extent described as "negligible."
14. (a) When a soft drink bottle has just been opened, it is in a non-equilibrium state. Carbon dioxide gas escapes from the solution as the rate of decomposition of carbonic acid into carbon dioxide exceeds the rate for formation of carbonic acid from carbon dioxide gas and water.

(b) When the bottle is sealed and at a constant temperature, it is in an equilibrium state. Carbon dioxide gas and water are in equilibrium with carbonic acid.

15. A catalyst does not affect the state of equilibrium. It affects both forward and reverse reactions, and decreases the time required to reach equilibrium.

16. (a) $N_2(g) + 3\ H_2(g) \xrightleftharpoons{<10\%} 2\ NH_3(g)$ $\quad K_c = \frac{[NH_3(g)]^2}{[N_2(g)]\ [H_2(g)]^3}$

(b) $2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(g)$ $\quad K_c = \frac{[H_2O(g)]^2}{[H_2(g)]^2\ [O_2(g)]}$

(c) $CO(g) + H_2O(g) \xrightleftharpoons{675} CO_2(g) + H_2(g)$ $\quad K_c = \frac{[CO_2(g)]\ [H_2(g)]}{[CO(g)]\ [H_2O(g)]}$

17. At equilibrium the concentration of the product is *very* much greater than the concentration of the reactants. The extremely large equilibrium constant shows that the reaction is quantitative.

18. $O_2(g) \leftrightarrows O_2(aq)$

$$K_c = \frac{[O_2(aq)]}{[O_2(g)]}$$

19. $\left[O_2(aq)\right] = \frac{0.042\ \cancel{g}}{1\ L} \times \frac{1\ mol}{32.00\ \cancel{g}} = 0.0013\ mol/L$

20. $\left[O_2(g)\right] = \frac{1\ mol}{24.8\ L} = 0.0403\ mol/L$

21. $K_c = \frac{[O_2(aq)]}{[O_2(g)]} = \frac{0.0013\ \cancel{mol/L}}{0.0403\ \cancel{mol/L}} = 0.032$

22. No. The value of the equilibrium constant will not change. The only factor that affects the value of the equilibrium constant is temperature.

23. When the gas above the water is pure $O_2(g)$, the concentration of reactant (oxygen gas) in the equilibrium is much higher than it is when the gas above the water is air. This shifts the equilibrium towards the product side, resulting in more O_2 dissolving into the water.

24. If climate change leads to an increase in the average temperature of water, the solubility of $O_2(g)$ in such areas will, according to the solubility rules for gases, decrease. Aquatic organisms that require oxygen will therefore have less dissolved oxygen available to them and will have lower survival rates.

25. Both increasing the concentration of the reactant (by adding more) and decreasing the concentration of the product (by removing some) will increase the yield of the product. Ideally, both these changes can be done continuously, in which case the reaction will be constantly shifting toward products and never reaching equilibrium—thus producing the most product in the least time.

26. (a)

Concentration	$C_2H_2(g)$ (mol/L)	$H_2(g)$ (mol/L)	$C_2H_4(g)$ (mol/L)
Initial	1.00	1.00	0
Change	-0.060	-0.060	+0.060
Equilibrium	0.94	0.94	0.060

$$K_c = \frac{[C_2H_4(g)]}{[C_2H_2(g)]\ [H_2(g)]} = \frac{0.060}{(0.94)^2} = 0.068$$