APPENDIX D Solutions

Chapter 1

No practice problems

Chapter 2

1. $\text{density} = \frac{\text{mass}}{\text{volume}}$

$\text{volume} = 41\text{ mL} - 20\text{ mL} = 21\text{ mL}$

$\text{density} = \frac{147\text{ g}}{21\text{ mL}} = 7.0\text{ g/mL}$

2. $\text{volume} = \frac{\text{mass}}{\text{density}}$

$\text{volume} = \frac{20\ \cancel{\text{g}}}{4\ \cancel{\text{g}}/\text{mL}} = 5\text{ mL}$

3. $\text{density} = \frac{\text{mass}}{\text{volume}}$

$\text{density} = \frac{20\text{ g}}{5\text{ cm}^3} = 4\text{ g/cm}^3$

The density of pure aluminum is 2.7 g/cm^3, so the cube cannot be made of aluminum.

12. a. 7×10^2 m
b. 3.8×10^4 m
c. 4.5×10^6 m
d. 6.85×10^{11} m
e. 5.4×10^{-3} kg
f. 6.87×10^{-6} kg
g. 7.6×10^{-8} kg
h. 8×10^{-10} kg

13. a. 3.6×10^5 s
b. 5.4×10^{-5} s
c. 5.06×10^3 s
d. 8.9×10^{10} s

14. a. 7×10^{-5} m
b. 3×10^8 m
c. 2×10^2 m
d. 5×10^{-12} m
e. $1.26 \times 10^4\text{ kg} + 0.25 \times 10^4\text{ kg} = 1.51 \times 10^4\text{ kg}$
f. $7.06 \times 10^{-3}\text{ kg} + 0.12 \times 10^{-3}\text{ kg} = 7.18 \times 10^{-3}\text{ kg}$
g. $4.39 \times 10^5\text{ kg} - 0.28 \times 10^5\text{ kg} = 4.11 \times 10^5\text{ kg}$
h. $5.36 \times 10^{-1}\text{ kg} - 0.740 \times 10^{-1}\text{ kg} = 4.62 \times 10^{-1}\text{ kg}$

15. a. 4×10^{10} cm^2
b. 6×10^{-2} cm^2
c. 9×10^{-1} cm^2
d. 5×10^2 cm^2

16. a. 3×10^1 g/cm^3
b. 2×10^3 g/cm^3
c. 3×10^6 g/cm^3
d. 2×10^{-1} g/cm^3

17. a. $360\ \cancel{\text{s}} \times \frac{1000\text{ ms}}{1\ \cancel{\text{s}}} = 360\ 000\text{ ms}$
b. $4800\ \cancel{\text{g}} \times \frac{1\text{ kg}}{1000\ \cancel{\text{g}}} = 4.8\text{ kg}$
c. $5600\ \cancel{\text{dm}} \times \frac{1\text{ m}}{10\ \cancel{\text{dm}}} = 560\text{ m}$
d. $72\ \cancel{\text{g}} \times \frac{1000\text{ mg}}{1\ \cancel{\text{g}}} = 72\ 000\text{ mg}$

18. a. $245\ \cancel{\text{ms}} \times \frac{1\text{ s}}{1000\ \cancel{\text{ms}}} = 0.245\text{ s}$
b. $5\ \cancel{\text{m}} \times \frac{100\text{ cm}}{1\ \cancel{\text{m}}} = 500\text{ cm}$
c. $6800\ \cancel{\text{cm}} \times \frac{1\text{ m}}{100\ \cancel{\text{cm}}} = 68\text{ m}$
d. $25\ \cancel{\text{kg}} \times \frac{1\text{ Mg}}{1000\ \cancel{\text{kg}}} = 0.025\text{ Mg}$

19. $24\ \cancel{\text{h}} \times \frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{h}}} \times \frac{60\text{ s}}{1\ \cancel{\text{min}}} = 86\ 400\text{ s}$

20. $\frac{19.3\ \cancel{\text{g}}}{1\ \cancel{\text{mL}}} \times \frac{10\text{ dg}}{1\ \cancel{\text{g}}} \times \frac{1000\ \cancel{\text{mL}}}{1\text{L}} = 193\ 000\text{ dg/L}$

21. $\frac{90.0\ \cancel{\text{km}}}{1\ \cancel{\text{h}}} \times \frac{0.62\text{ mi}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{60\text{ min}} = 0.930\text{ mi/min}$

29. $\frac{0.19}{1.59} \times 100 = 11.9\%$

$\frac{0.09}{1.59} \times 100 = 5.66\%$

$\frac{0.14}{1.59} \times 100 = 8.80\%$

30. $\frac{0.11}{1.59} \times 100 = 6.92\%$

$\frac{0.10}{1.59} \times 100 = 6.29\%$

$\frac{0.12}{1.59} \times 100 = 7.55\%$

31. a. 4
b. 7
c. 5
d. 3

32. a. 5
b. 3
c. 5
d. 2

33. a. 84 790 kg
b. 38.54 g
c. 256.8 cm
d. 4.936 m

34. a. 5.482×10^{-4} g
b. 1.368×10^{5} kg
c. 3.087×10^{8} mm
d. 2.014 mL

35. a. 142.9 cm
b. 768 kg
c. 0.1119 mg

36. a. 12.12 cm
b. 2.10 cm
c. 2.7×10^{3} cm

37. a. 78 m^2
b. 12 m^2
c. 2.5 m^2
d. 81.1 m^2

38. a. 2.0 m/s
b. 3.00 m/s
c. 2.00 m/s
d. 2.9 m/s

Chapter 3

6. $mass_{reactants} = mass_{products}$

$mass_{reactants} = mass_{water\ electrolyzed}$

$mass_{products} = mass_{hydrogen} + mass_{oxygen}$

$mass_{water\ electrolyzed} = mass_{hydrogen} + mass_{oxygen}$

$mass_{water\ electrolyzed} = 10.0\ g + 79.4\ g = 89.4\ g$

7. $mass_{reactants} = mass_{products}$

$mass_{sodium} + mass_{chlorine} = mass_{sodium\ chloride}$

$mass_{sodium} = 15.6\ g$

$mass_{sodium\ chloride} = 39.7\ g$

Substituting and solving for $mass_{chlorine}$ yields, $15.6\ g + mass_{chlorine} = 39.7\ g$

$mass_{chlorine} = 39.7\ g - 15.6\ g = 24.1\ g$ used in the reaction.

Because the sodium reacts with excess chlorine, all of the sodium is used in the reaction; that is, 15.6 g of sodium are used in the reaction.

8. The reactants are aluminum and bromine. The product is aluminum bromide. The mass of bromine used in the reaction equals the initial mass minus the mass remaining after the reaction is complete. Thus,

$mass_{bromine}$ reacted $= 100.0\ g - 8.5\ g = 91.5\ g$

Because no aluminum remains after the reaction, you know that all of the aluminum is used in the reaction. Thus,
$mass_{aluminum}$ = initial mass of aluminum = 10.3 g

To determine the mass of aluminum bromide formed, use conservation of mass.

$mass_{products} = mass_{reactants}$

$mass_{aluminum\ bromide} = mass_{aluminum} + mass_{bromine}$

$mass_{aluminum\ bromide} = 10.3\ g + 91.5\ g = 101.8\ g$

9. Magnesium and oxygen are the reactants. Magnesium oxide is the product.

$mass_{reactants} = mass_{products}$

$mass_{magnesium} + mass_{oxygen} = mass_{magnesium\ oxide}$

$mass_{magnesium} = 10.0\ g$

$mass_{magnesium\ oxide} = 16.6\ g$

Substituting and solving for $mass_{oxygen}$ yields, $10.0\ g + mass_{oxygen} = 16.6\ g$

$mass_{oxygen} = 16.6\ g - 10.0\ g = 6.6\ g$

20. $\text{percent by mass}_{hydrogen} = \frac{\text{mass}_{hydrogen}}{\text{mass}_{compound}} \times 100$

$\text{percent by mass}_{hydrogen} = \frac{12.4\ \text{g}}{78.0\ \text{g}} \times 100 = 15.9\%$

21. $\text{mass}_{compound} = 1.0\ \text{g} + 19.0\ \text{g} = 20.0\ \text{g}$

$\text{percent by mass}_{hydrogen} = \frac{\text{mass}_{hydrogen}}{\text{mass}_{compound}} \times 100$

$\text{percent by mass}_{hydrogen} = \frac{1.0\ \text{g}}{20.0\ \text{g}} \times 100 = 5.0\%$

22. $\text{mass}_{xy} = 3.50\ \text{g} + 10.5\ \text{g} = 14.0\ \text{g}$

$\text{percent by mass}_{x} = \frac{\text{mass}_{x}}{\text{mass}_{xy}} \times 100$

$\text{percent by mass}_{x} = \frac{3.50\ \text{g}}{14.0\ \text{g}} \times 100 = 25.0\%$

$\text{percent by mass}_{y} = \frac{\text{mass}_{y}}{\text{mass}_{xy}} \times 100$

$\text{percent by mass}_{y} = \frac{10.5\ \text{g}}{14.0\ \text{g}} \times 100 = 75.0\%$

23. Compound I

$\text{mass}_{compound} = 15.0\ \text{g} + 120.0\ \text{g} = 135.0\ \text{g}$

$\text{percent by mass}_{hydrogen} = \frac{\text{mass}_{hydrogen}}{\text{mass}_{compound}} \times 100$

$\text{percent by mass}_{hydrogen} = \frac{15.0\ \text{g}}{135.0\ \text{g}} \times 100 = 11.1\%$

Compound II

$\text{mass}_{compound} = 2.0\ \text{g} + 32.0\ \text{g} = 34.0\ \text{g}$

$\text{percent by mass}_{hydrogen} = \frac{\text{mass}_{hydrogen}}{\text{mass}_{compound}} \times 100$

$\text{percent by mass}_{hydrogen} = \frac{2.0\ \text{g}}{34.0\ \text{g}} \times 100 = 5.8\%$

The composition by percent by mass is not the same for the two compounds. Therefore, they must be different compounds.

24. No, you cannot be sure. The fact that two compounds have the same percent by mass of a single element does not guarantee that the composition of the two compounds is the same.

Chapter 4

11.

Element	Protons	Electrons
a. boron	5	5
b. radon	86	86
c. platinum	78	78
d. magnesium	12	12

12. dysprosium

13. silicon

14.

	Protons and electrons	Neutrons	Isotope	Symbol
b.	20	26	calcium-46	$^{46}_{20}Ca$
c.	8	9	oxygen-17	$^{17}_{8}O$
d.	26	31	iron-57	$^{57}_{26}Fe$
e.	30	34	zinc-64	$^{64}_{30}Zn$
f.	80	124	mercury-204	$^{204}_{80}Hg$

15. For ^{10}B: mass contribution = (10.013 amu)(0.198) = 1.98 amu

For ^{11}B: mass contribution = (11.009 amu)(0.802) = 8.83 amu

Atomic mass of B = 1.98 amu + 8.83 amu = 10.81 amu

16. Helium-4 is more abundant in nature because the atomic mass of naturally occurring helium is closer to the mass of helium-4 (approximately 4 amu) than to the mass of helium-3 (approximately 3 amu).

17. For ^{24}Mg: mass contribution = (23.985 amu)(0.7899) = 18.95 amu

For ^{25}Mg: mass contribution = (24.986 amu)(0.1000) = 2.498 amu

For ^{26}Mg: mass contribution = (25.982 amu)(0.1101) = 2.861 amu

Atomic mass of Mg = 18.95 amu + 2.498 amu + 2.861 amu = 24.31 amu

Chapter 5

1. $c = \lambda\nu$

$3.00 \times 10^8 \text{ m/s} = (4.90 \times 10^{-7} \text{ m})\nu$

$$\nu = \frac{3.00 \times 10^8 \cancel{\text{m}}/\text{s}}{4.90 \times 10^{-7} \cancel{\text{m}}} = 6.12 \times 10^{14} \text{ s}^{-1}$$

2. $c = \lambda\nu$

$3.00 \times 10^8 \text{ m/s} = (1.15 \times 10^{-10} \text{ m})\nu$

$$\nu = \frac{3.00 \times 10^8 \cancel{\text{m}}/\text{s}}{1.15 \times 10^{-10} \cancel{\text{m}}} = 2.61 \times 10^{18} \text{ s}^{-1}$$

3. The speed of all electromagnetic waves is 3.00×10^8 m/s.

4. $c = \lambda\nu$

$94.7 \text{ MHz} = 9.47 \times 10^7 \text{ Hz}$

$3.00 \times 10^8 \text{ m/s} = \lambda(9.47 \times 10^7 \text{ Hz})$

$$\lambda = \frac{3.00 \times 10^8 \text{ m}/\cancel{\text{s}}}{9.47 \times 10^7 \cancel{\text{s}^{-1}}} = 3.17 \text{ m}$$

5. a. $E_{photon} = h\nu =$
$(6.626 \times 10^{-34} \text{ J}\cdot\cancel{\text{s}})(6.32 \times 10^{20} \cancel{\text{s}^{-1}})$
$E_{photon} = 4.19 \times 10^{-13}$ J

b. $E_{photon} = h\nu =$
$(6.626 \times 10^{-34} \text{ J}\cdot\cancel{\text{s}})(9.50 \times 10^{13} \cancel{\text{s}^{-1}})$
$E_{photon} = 6.29 \times 10^{-20}$ J

c. $E_{photon} = h\nu =$
$(6.626 \times 10^{-34} \text{ J}\cdot\cancel{\text{s}})(1.05 \times 10^{16} \cancel{\text{s}^{-1}})$
$E_{photon} = 6.96 \times 10^{-18}$ J

6. a. gamma ray or X ray
b. infrared
c. ultraviolet

18. a. bromine (35 electrons): $[Ar]4s^23d^{10}4p^5$
b. strontium (38 electrons): $[Kr]5s^2$
c. antimony (51 electrons): $[Kr]5s^24d^{10}5p^3$
d. rhenium (75 electrons): $[Xe]6s^24f^{14}5d^5$
e. terbium (65 electrons): $[Xe]6s^24f^9$
f. titanium (22 electrons): $[Ar]4s^23d^2$

19. Sulfur (16 electrons) has the electron configuration $[Ne]3s^23p^4$. Therefore, 6 electrons are in orbitals related to the third energy level of the sulfur atom.

20. Chlorine (17 electrons) has the electron configuration $[Ne]3s^23p^5$, or $1s^22s^22p^63s^23p^5$. Therefore, 11 electrons occupy p orbitals in a chlorine atom.

21. indium (In)

22. barium (Ba)

23. a. ·Mg·
b. :S: (with dots above and below)
c. ·Br: (with dots above and below)
d. Rb·
e. ·Tl· (with dot above)
f. :Xe: (with dots above and below)

Chapter 6

7.

Electron configuration	Group	Period	Block
a. $[Ne]3s^2$	2A	3	s-block
b. $[He]2s^2$	2A	2	s-block
c. $[Kr]5s^24d^{10}5p^5$	7A	5	p-block

8. a. $[Ar]4s^2$
b. [Xe]
c. $[Ar]\ 4s^23d^{10}$
d. $[He]2s^22p^4$

9. a. Sc, Y, La, Ac
b. N, P, As, Sb, Bi
c. Ne, Ar, Kr, Xe, Rn

16. Largest: Na
Smallest: S

17. Largest: Xe
Smallest: He

18. No. If all you know is that the atomic number of one element is 20 greater than that of the other, then you will be unable to determine the specific groups and periods that the elements are in. Without this information, you cannot apply the periodic trends in atomic size to determine which element has the larger radius.

Chapter 7

No Practice Problems

Solutions

Chapter 8

7. $3\ \cancel{\text{Na ions}}\left(\frac{1+}{\cancel{\text{Na ion}}}\right) + 1\ \cancel{\text{N ion}}\left(\frac{3-}{\cancel{\text{N ion}}}\right) =$

$3(1+) + 1(3-) = 0$

The overall charge on one formula unit of Na_3N is zero.

8. $2\ \cancel{\text{Li ions}}\left(\frac{1+}{\cancel{\text{Li ion}}}\right) + 1\ \cancel{\text{O ion}}\left(\frac{2-}{\cancel{\text{O ion}}}\right) =$

$2(1+) + 1(2-) = 0$

The overall charge on one formula unit of Li_2O is zero.

9. $1\ \cancel{\text{Sr ion}}\left(\frac{2+}{\cancel{\text{Sr ion}}}\right) + 2\ \cancel{\text{F ions}}\left(\frac{1-}{\cancel{\text{F ion}}}\right) =$

$1(2+) + 2(1-) = 0$

The overall charge on one formula unit of SrF_2 is zero.

10. $2\ \cancel{\text{Al ions}}\left(\frac{3+}{\cancel{\text{Al ion}}}\right) + 3\ \cancel{\text{S ions}}\left(\frac{2-}{\cancel{\text{S ion}}}\right) =$

$2(3+) + 3(2-) = 0$

The overall charge on one formula unit of Al_2S_3 is zero.

11. $3\ \cancel{\text{Cs ions}}\left(\frac{1+}{\cancel{\text{Cs ion}}}\right) + 1\ \cancel{\text{P ion}}\left(\frac{3-}{\cancel{\text{P ion}}}\right) =$

$3(1+) + 1(3-) = 0$

The overall charge on one formula unit of Cs_3P is zero.

19. KI

20. $MgCl_2$

21. $AlBr_3$

22. Cs_3N

23. BaS

24. $NaNO_3$

25. $Ca(ClO_3)_2$

26. $Al_2(CO_3)_3$

27. K_2CrO_4

28. $MgCO_3$

29. sodium bromide

30. calcium chloride

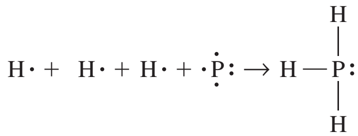
31. potassium hydroxide

32. copper(II) nitrate

33. silver chromate

Chapter 9

1.



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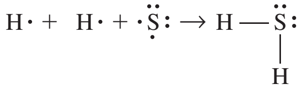

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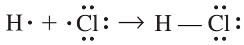

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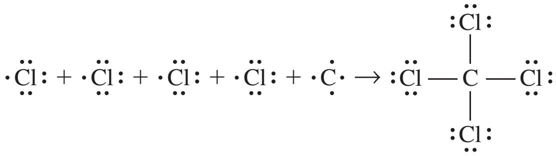

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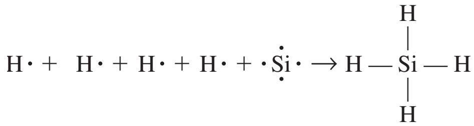


13. carbon tetrachloride

14. diarsenic trioxide

15. carbon monoxide

16. sulfur dioxide

17. nitrogen trifluoride

18. hydroiodic acid

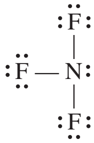
19. chloric acid

20. chlorous acid

21. sulfuric acid

22. hydrosulfuric acid

30.



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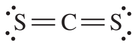

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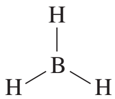

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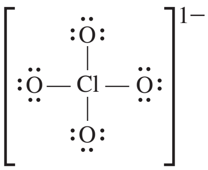

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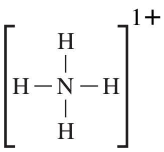

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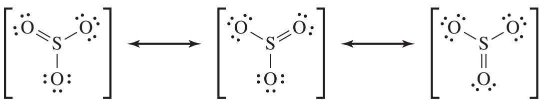

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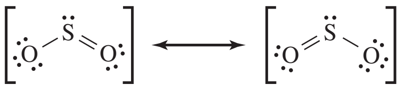

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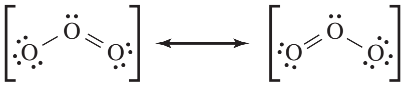
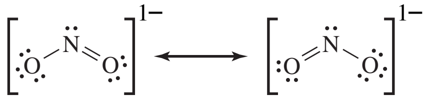
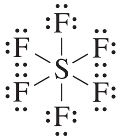
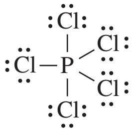
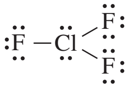


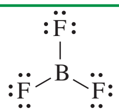
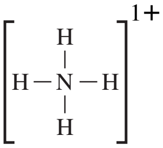
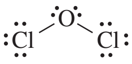
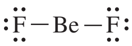
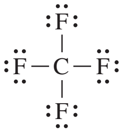
Solutions

38. 

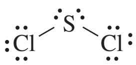
39. 

40. 

41. 

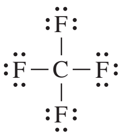
	Molecule	Geometry		Bond angle	Hybridization
49.	BF_3		Trigonal planar	120°	sp^2
50.	NH_4^+		Tetrahedral	109°	sp^3
51.	OCl_2		Bent	104.5°	sp^3
52.	BeF_2		Linear	180°	sp
53.	CF_4		Tetrahedral	109°	sp^3

60. SCl_2 is polar because the molecule is asymmetric (bent).

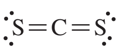


61. H_2S is polar because the molecule is asymmetric (bent).

62. CF_4 is nonpolar because the molecule is symmetric (tetrahedral).



63. CS_2 is nonpolar because the molecule is symmetric (linear).



Chapter 10

1. $H_2(g) + Br_2(g) \rightarrow HBr(g)$

2. $CO(g) + O_2(g) \rightarrow CO_2(g)$

3. $KClO_3(s) \rightarrow KCl(s) + O_2(g)$

4. $FeCl_3(aq) + 3NaOH(aq) \rightarrow Fe(OH)_3(s) + 3NaCl(aq)$

5. $CS_2(l) + 3O_2(g) \rightarrow CO_2(g) + 2SO_2(g)$

6. $Zn(s) + H_2SO_4(aq) \rightarrow H_2(g) + ZnSO_4(aq)$

14. $2Al(s) + 3S(s) \rightarrow Al_2S_3(s)$ synthesis

15. $H_2O(l) + N_2O_5(g) \rightarrow 2HNO_3(aq)$ synthesis

16. $4NO_2(g) + O_2(g) \rightarrow 2N_2O_5(g)$ synthesis and combustion

17. $2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$ combustion

18. $2Al_2O_3(s) \rightarrow 4Al(s) + 3O_2(g)$

19. $Ni(OH)_2(s) \rightarrow NiO(s) + H_2O(l)$

20. $2NaHCO_3(s) \rightarrow Na_2CO_3(aq) + CO_2(g) + H_2O(l)$

21. Yes. K is above Zn in the metal activity series.
$2K(s) + ZnCl_2(aq) \rightarrow Zn(s) + 2KCl(aq)$

22. No. Cl is below F in the halogen activity series.

23. No. Fe is below Na in the metal activity series.

24. $LiI(aq) + AgNO_3(aq) \rightarrow AgI(s) + LiNO_3(aq)$

25. $BaCl_2(aq) + K_2CO_3(aq) \rightarrow BaCO_3(s) + 2KCl(aq)$

26. $Na_2C_2O_4(aq) + Pb(NO_3)_2(aq) \rightarrow PbC_2O_4(s) + 2NaNO_3(aq)$

33. chemical equation:
$KI(aq) + AgNO_3(aq) \rightarrow KNO_3(aq) + AgI(s)$

complete ionic equation:
$\cancel{K^+}(aq) + I^-(aq) + Ag^+(aq) + \cancel{NO_3^-}(aq) \rightarrow \cancel{K^+}(aq) + \cancel{NO_3^-}(aq) + AgI(s)$

net ionic equation: $I^-(aq) + Ag^+(aq) \rightarrow AgI(s)$

34. chemical equation: $2(NH_4)_3PO_4(aq) + 3Na_2SO_4(aq) \rightarrow 3(NH_4)_2SO_4(aq) + 2Na_3PO_4(aq)$

complete ionic equation: $\cancel{6NH_4^+}(aq) + \cancel{2PO_4^{3-}}(aq) + \cancel{6Na^+}(aq) + \cancel{3SO_4^{2-}}(aq) \rightarrow \cancel{6NH_4^+}(aq) + \cancel{3SO_4^{2-}}(aq) + \cancel{6Na^+}(aq) + \cancel{2PO_4^{3-}}(aq)$

No reaction occurs; therefore, there is no net ionic equation.

35. chemical equation:
$AlCl_3(aq) + 3NaOH(aq) \rightarrow Al(OH)_3(s) + 3NaCl(aq)$

complete ionic equation:
$Al^{3+}(aq) + \cancel{3Cl^-}(aq) + \cancel{3Na^+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s) + \cancel{3Na^+}(aq) + \cancel{3Cl^-}(aq)$

net ionic equation:
$Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$

36. chemical equation:
$Li_2SO_4(aq) + Ca(NO_3)_2(aq) \rightarrow 2LiNO_3(aq) + CaSO_4(s)$

complete ionic equation:
$2Li^+(aq) + SO_4^{2-}(aq) + Ca^{2+}(aq) + 2NO_3^-(aq) \rightarrow$
$2Li^+(aq) + 2NO_3^-(aq) + CaSO_4(s)$

net ionic equation:
$SO_4^{2-}(aq) + Ca^{2+}(aq) \rightarrow CaSO_4(s)$

37. chemical equation: $5Na_2CO_3(aq) + 2MnCl_5(aq) \rightarrow$
$10NaCl(aq) + Mn_2(CO_3)_5(s)$

complete ionic equation:
$10Na^+(aq) + 5CO_3^{2-}(aq) + 2Mn^{5+}(aq) + 10Cl^-(aq)$
$\rightarrow 10Na^+(aq) + 10Cl^-(aq) + Mn_2(CO_3)_5(s)$

net ionic equation:
$5CO_3^{2-}(aq) + 2Mn^{5+}(aq) \rightarrow Mn_2(CO_3)_5(s)$

38. chemical equation:
$H_2SO_4(aq) + 2KOH(aq) \rightarrow 2H_2O(l) + K_2SO_4(aq)$

complete ionic equation:
$2H^+(aq) + SO_4^{2-}(aq) + 2K^+(aq) + 2OH^-(aq) \rightarrow$
$2H_2O(l) + 2K^+(aq) + SO_4^{2-}(aq)$

net ionic equation:
$2H^+(aq) + 2OH^-(aq) \rightarrow 2H_2O(l)$
or $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

39. chemical equation:
$2HCl(aq) + Ca(OH)_2(aq) \rightarrow 2H_2O(l) + CaCl_2(aq)$

complete ionic equation:
$2H^+(aq) + 2Cl^-(aq) + Ca^{2+}(aq) + 2OH^-(aq) \rightarrow$
$2H_2O(l) + Ca^{2+}(aq) + 2Cl^-(aq)$

net ionic equation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

40. chemical equation:
$HNO_3(aq) + NH_4OH(aq) \rightarrow H_2O(l) + NH_4NO_3(aq)$

complete ionic equation:
$H^+(aq) + NO_3^-(aq) + NH_4^+(aq) + OH^-(aq) \rightarrow$
$H_2O(l) + NH_4^+(aq) + NO_3^-(aq)$

net ionic equation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

41. chemical equation:
$H_2S(aq) + Ca(OH)_2(aq) \rightarrow 2H_2O(l) + CaS(aq)$

complete ionic equation:
$2H^+(aq) + S^{2-}(aq) + Ca^{2+}(aq) + 2OH^-(aq) \rightarrow$
$2H_2O(l) + Ca^{2+}(aq) + S^{2-}(aq)$

net ionic equation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

42. chemical equation: $H_3PO_4(aq) + 3NaOH(aq) \rightarrow$
$3H_2O(l) + Na_3PO_4(aq)$

complete ionic equation:
$3H^+(aq) + PO_4^{3-}(aq) + 3Na^+(aq) + 3OH^-(aq) \rightarrow$
$3H_2O(l) + 3Na^+(aq) + PO_4^{3-}(aq)$

net ionic equation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

43. chemical equation: $2HClO_4(aq) + K_2CO_3(aq) \rightarrow$
$H_2O(l) + CO_2(g) + 2KClO_4(aq)$

complete ionic equation:
$2H^+(aq) + 2ClO_4^-(aq) + 2K^+(aq) + CO_3^{2-}(aq) \rightarrow$
$H_2O(l) + CO_2(g) + 2K^+(aq) + 2ClO_4^-(aq)$

net ionic equation:
$2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$

44. chemical equation:
$H_2SO_4(aq) + 2NaCN(aq) \rightarrow 2HCN(g) + Na_2SO_4(aq)$

complete ionic equation:
$2H^+(aq) + SO_4^{2-}(aq) + 2Na^+(aq) + 2CN^-(aq) \rightarrow$
$2HCN(g) + 2Na^+(aq) + SO_4^{2-}(aq)$

net ionic equation:
$2H^+(aq) + 2CN^-(aq) \rightarrow 2HCN(g)$
or $H^+(aq) + CN^-(aq) \rightarrow HCN(g)$

45. chemical equation: $2HBr(aq) + (NH_4)_2CO_3(aq) \rightarrow$
$H_2O(l) + CO_2(g) + 2NH_4Br(aq)$

complete ionic equation:
$2H^+(aq) + 2Br^-(aq) + 2NH_4^+(aq) + CO_3^{2-}(aq) \rightarrow$
$H_2O(l) + CO_2(g) + 2NH_4^+(aq) + 2Br^-(aq)$

net ionic equation:
$2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$

46. chemical equation:
$2HNO_3(aq) + KRbS(aq) \rightarrow H_2S(g) + KRb(NO_3)_2(aq)$

complete ionic equation: $2H^+(aq) + 2NO_3^-(aq) +$
$K^+(aq) + Rb^+(aq) + S^{2-}(aq) \rightarrow H_2S(g) + K^+(aq) +$
$Rb^+(aq) + 2NO_3^-(aq)$

net ionic equation: $2H^+(aq) + S^{2-}(aq) \rightarrow H_2S(g)$

Chapter 11

1. $2.50 \text{ mol Zn} \times \dfrac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol}}$

$= 1.51 \times 10^{24}$ atoms of Zn

2. $3.25 \text{ mol } AgNO_3 \times \dfrac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mol}}$

$= 1.96 \times 10^{24}$ formula units of $AgNO_3$

3. $11.5 \text{ mol } H_2O \times \dfrac{6.02 \times 10^{23} \text{ molecules}}{1 \text{ mol}}$

$= 6.92 \times 10^{24}$ molecules of H_2O

4. a. $5.75 \times 10^{24} \text{ atoms Al} \times \dfrac{1 \text{ mol}}{6.02 \times 10^{23} \text{ atoms}}$

$= 9.55$ mol Al

b. $3.75 \times 10^{24} \text{ molecules } CO_2 \times \dfrac{1 \text{ mol}}{6.02 \times 10^{23} \text{ molecules}} = 6.23 \text{ mol } CO_2$

c. $3.58 \times 10^{23} \text{ formula units } ZnCl_2 \times \dfrac{1 \text{ mol}}{6.02 \times 10^{23} \text{ formula units}} = 0.595 \text{ mol } ZnCl_2$

d. $2.50 \times 10^{20} \text{ atoms Fe} \times \dfrac{1 \text{ mol}}{6.02 \times 10^{23} \text{ atoms}}$

$= 4.15 \times 10^{-4}$ mol Fe

11. a. $3.57 \text{ mol Al} \times \dfrac{26.98 \text{ g Al}}{1 \text{ mol Al}} = 96.3 \text{ g Al}$

b. $42.6 \text{ mol Si} \times \dfrac{28.09 \text{ g Si}}{1 \text{ mol Si}} = 1.20 \times 10^3 \text{ g Si}$

c. $3.45 \text{ mol Co} \times \dfrac{58.93 \text{ g Co}}{1 \text{ mol Co}} = 203 \text{ g Co}$

d. $2.45 \text{ mol Zn} \times \dfrac{65.38 \text{ g Zn}}{1 \text{ mol Zn}} = 1.60 \times 10^2 \text{ g Zn}$

12. a. $25.5 \text{ g Ag} \times \dfrac{1 \text{ mol Ag}}{107.9 \text{ g Ag}} = 0.236 \text{ mol Ag}$

b. $300.0 \text{ g S} \times \dfrac{1 \text{ mol S}}{32.07 \text{ g S}} = 9.355 \text{ mol S}$

c. $125 \text{ g Zn} \times \dfrac{1 \text{ mol Zn}}{65.38 \text{ g Zn}} = 1.91 \text{ mol Zn}$

d. $1.00 \text{ kg Fe} \times \dfrac{1000 \text{ g Fe}}{1 \text{ kg Fe}} \times \dfrac{1 \text{ mol Fe}}{55.85 \text{ g Fe}}$

$= 17.9$ mol Fe

13. a. $55.2 \text{ g Li} \times \dfrac{1 \text{ mol Li}}{6.941 \text{ g Li}} \times \dfrac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol}}$

$= 4.79 \times 10^{24}$ atoms Li

b. $0.230 \text{ g Pb} \times \dfrac{1 \text{ mol Pb}}{207.2 \text{ g Pb}} \times \dfrac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol}}$

$= 6.68 \times 10^{20}$ atoms Pb

c. $11.5 \text{ g Hg} \times \dfrac{1 \text{ mol Hg}}{200.6 \text{ g Hg}} \times \dfrac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol}}$

$= 3.45 \times 10^{22}$ atoms Hg

d. $45.6 \text{ g Si} \times \dfrac{1 \text{ mol Si}}{28.09 \text{ g Si}} \times \dfrac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol}}$

$= 9.77 \times 10^{23}$ atoms Si

e. $0.120 \text{ kg Ti} \times \dfrac{1000 \text{ g Ti}}{1 \text{ kg Ti}} \times \dfrac{1 \text{ mol Ti}}{47.88 \text{ g Ti}} \times \dfrac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 1.51 \times 10^{24} \text{ atoms Ti}$

14. a. $6.02 \times 10^{24} \text{ atoms Bi} \times \dfrac{1 \text{ mol}}{6.02 \times 10^{23} \text{ atoms}} \times \dfrac{209.0 \text{ g Bi}}{1 \text{ mol Bi}} = 2.09 \times 10^3 \text{ g Bi}$

b. $1.00 \times 10^{24} \text{ atoms Mn} \times \dfrac{1 \text{ mol}}{6.02 \times 10^{23} \text{ atoms}} \times \dfrac{54.94 \text{ g Mn}}{1 \text{ mol Mn}} = 91.3 \text{ g Mn}$

c. $3.40 \times 10^{22} \text{ atoms He} \times \dfrac{1 \text{ mol}}{6.02 \times 10^{23} \text{ atoms}} \times \dfrac{4.003 \text{ g He}}{1 \text{ mol He}} = 0.226 \text{ g He}$

d. $1.50 \times 10^{15} \text{ atoms N} \times \dfrac{1 \text{ mol}}{6.02 \times 10^{23} \text{ atoms}} \times \dfrac{14.01 \text{ g N}}{1 \text{ mol N}} = 3.49 \times 10^{-8} \text{ g N}$

e. $1.50 \times 10^{15} \text{ atoms U} \times \dfrac{1 \text{ mol}}{6.02 \times 10^{23} \text{ atoms}} \times \dfrac{238.0 \text{ g U}}{1 \text{ mol U}} = 5.93 \times 10^{-7} \text{ g U}$

20. $2.50 \text{ mol } ZnCl_2 \times \dfrac{2 \text{ mol } Cl^-}{1 \text{ mol } ZnCl_2} = 5.00 \text{ mol } Cl^-$

21. $1.25 \text{ mol } C_6H_{12}O_6 \times \dfrac{6 \text{ mol C}}{1 \text{ mol } C_6H_{12}O_6} = 7.50 \text{ mol C}$

$1.25 \text{ mol } C_6H_{12}O_6 \times \dfrac{12 \text{ mol H}}{1 \text{ mol } C_6H_{12}O_6} = 15.0 \text{ mol H}$

$1.25 \text{ mol } C_6H_{12}O_6 \times \dfrac{6 \text{ mol O}}{1 \text{ mol } C_6H_{12}O_6} = 7.50 \text{ mol O}$

22. $3.00 \text{ mol } Fe_2(SO_4)_3 \times \dfrac{3 \text{ mol } SO_4^{2-}}{1 \text{ mol } Fe_2(SO_4)_3}$

$= 9.00 \text{ mol } SO_4^{2-}$

23. $5.00 \text{ mol } P_2O_5 \times \dfrac{5 \text{ mol O}}{1 \text{ mol } P_2O_5} = 25.0 \text{ mol O}$

24. $11.5 \text{ mol } H_2O \times \dfrac{2 \text{ mol H}}{1 \text{ mol } H_2O} = 23.0 \text{ mol H}$

Solutions

25. NaOH

$1 \text{ mol Na} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}} = 22.99 \text{ g}$

$1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 16.00 \text{ g}$

$1 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = \underline{1.008 \text{ g}}$

molar mass NaOH = 40.00 g/mol

$CaCl_2$

$1 \text{ mol Ca} \times \frac{40.08 \text{ g Ca}}{1 \text{ mol Ca}} = 40.08 \text{ g}$

$2 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} = \underline{70.90 \text{ g}}$

molar mass $CaCl_2$ = 110.98 g/mol

$KC_2H_3O_2$

$1 \text{ mol K} \times \frac{39.10 \text{ g K}}{1 \text{ mol K}} = 39.10 \text{ g}$

$2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} = 24.02 \text{ g}$

$3 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 3.024 \text{ g}$

$2 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{32.00 \text{ g}}$

molar mass $KC_2H_3O_2$ = 98.14 g/mol

$Sr(NO_3)_2$

$1 \text{ mol Sr} \times \frac{87.62 \text{ g Sr}}{1 \text{ mol Sr}} = 87.62 \text{ g}$

$2 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} = 28.02 \text{ g}$

$6 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{96.00 \text{ g}}$

molar mass $Sr(NO_3)_2$ = 211.64 g/mol

$(NH_4)_3PO_4$

$3 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} = 42.03 \text{ g}$

$12 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 12.096 \text{ g}$

$1 \text{ mol P} \times \frac{30.97 \text{ g P}}{1 \text{ mol P}} = 30.97 \text{ g}$

$4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{64.00 \text{ g}}$

molar mass $(NH_4)_3PO_4$ = 149.10 g/mol

26. C_2H_5OH

$2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} = 24.02 \text{ g}$

$6 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 6.048 \text{ g}$

$1 \text{ mol O} \times \frac{16.00 \text{ g O}}{\text{mol O}} = \underline{16.00 \text{ g}}$

molar mass C_2H_5OH = 46.07 g/mol

$C_{12}H_{22}O_{11}$

$12 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} = 144.12 \text{ g}$

$22 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 22.176 \text{ g}$

$11 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{176.00 \text{ g}}$

molar mass $C_{12}H_{22}O_{11}$ = 342.30 g/mol

HCN

$1 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 1.008 \text{ g}$

$1 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} = 12.01 \text{ g}$

$1 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} = \underline{14.01 \text{ g}}$

molar mass HCN = 27.03 g/mol

CCl_4

$1 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} = 12.01 \text{ g}$

$4 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} = \underline{141.80 \text{ g}}$

molar mass CCl_4 = 153.81 g/mol

H_2O

$2 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 2.016 \text{ g}$

$1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{16.00 \text{ g}}$

molar mass H_2O = 18.02 g/mol

27. Step 1: Find the molar mass of H_2SO_4.

$2 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 2.016 \text{ g}$

$1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} = 32.07 \text{ g}$

$4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{64.00 \text{ g}}$

molar mass H_2SO_4 = 98.09 g/mol

Step 2: Make mole → mass conversion.

$3.25 \text{ mol } H_2SO_4 \times \frac{98.09 \text{ g } H_2SO_4}{1 \text{ mol } H_2SO_4} = 319 \text{ g } H_2SO_4$

Solutions

28. Step 1: Find the molar mass of $ZnCl_2$.

$$1 \text{ mol Zn} \times \frac{65.38 \text{ g Zn}}{1 \text{ mol Zn}} = 65.38 \text{ g}$$

$$2 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} = \underline{70.90 \text{ g}}$$

molar mass $ZnCl_2$ = 136.28 g/mol

Step 2: Make mole → mass conversion.

$$4.35 \times 10^{-2} \text{ mol } ZnCl_2 \times \frac{136.28 \text{ g } ZnCl_2}{1 \text{ mol } ZnCl_2}$$

$= 5.93$ g $ZnCl_2$

29. Step 1: Find the molar mass of $KMnO_4$.

$$1 \text{ mol K} \times \frac{39.10 \text{ g K}}{1 \text{ mol K}} = 39.10 \text{ g}$$

$$1 \text{ mol Mn} \times \frac{54.94 \text{ g Mn}}{1 \text{ mol Mn}} = 54.94 \text{ g}$$

$$4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{64.00 \text{ g}}$$

molar mass $KMnO_4$ = 158.04 g/mol

Step 2: Make mole → mass conversion.

$$2.55 \text{ mol } KMnO_4 \times \frac{158.04 \text{ g } KMnO_4}{1 \text{ mol } KMnO_4}$$

$= 403$ g $KMnO_4$

30. a. Step 1: Find the molar mass of $AgNO_3$.

$$1 \text{ mol Ag} \times \frac{107.9 \text{ g Ag}}{1 \text{ mol Ag}} = 107.9 \text{ g}$$

$$1 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} = 14.01 \text{ g}$$

$$3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{48.00 \text{ g}}$$

molar mass $AgNO_3$ = 169.9 g/mol

Step 2: Make mass → mole conversion.

$$22.6 \text{ g } AgNO_3 \times \frac{1 \text{ mol } AgNO_3}{169.9 \text{ g } AgNO_3}$$

$= 0.133$ mol $AgNO_3$

b. Step 1: Find molar mass of $ZnSO_4$.

$$1 \text{ mol Zn} \times \frac{65.39 \text{ g Zn}}{1 \text{ mol Zn}} = 65.39 \text{ g}$$

$$1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} = 32.07 \text{ g}$$

$$4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{64.00 \text{ g}}$$

molar mass $ZnSO_4$ = 161.46 g/mol

Step 2: Make mass → mole conversion.

$$6.50 \text{ g } ZnSO_4 \times \frac{1 \text{ mol } ZnSO_4}{161.46 \text{ g } ZnSO_4}$$

$= 0.0403$ mol $ZnSO_4$

c. Step 1: Find the molar mass of HCl.

$$1 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 1.008 \text{ g}$$

$$1 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} = \underline{35.45 \text{ g}}$$

molar mass HCl = 36.46 g/mol

Step 2: Make mass → mole conversion.

$$35.0 \text{ g HCl} \times \frac{1 \text{ mol HCl}}{36.46 \text{ g HCl}} = 0.960 \text{ mol HCl}$$

d. Step 1: Find the molar mass of Fe_2O_3.

$$2 \text{ mol Fe} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}} = 111.70 \text{ g}$$

$$3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{48.00 \text{ g}}$$

molar mass Fe_2O_3 = 159.70 g/mol

Step 2: Make mass → mole conversion.

$$25.0 \text{ g } Fe_2O_3 \times \frac{1 \text{ mol } Fe_2O_3}{159.70 \text{ g } Fe_2O_3}$$

$= 0.157$ mol Fe_2O_3

e. Step 1: Find the molar mass of $PbCl_4$.

$$1 \text{ mol Pb} \times \frac{207.2 \text{ g Pb}}{1 \text{ mol Pb}} = 207.2 \text{ g}$$

$$4 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} = \underline{141.80 \text{ g}}$$

molar mass $PbCl_4$ = 349.0 g/mol

Step 2: Make mass → mole conversion.

$$254 \text{ g } PbCl_4 \times \frac{1 \text{ mol } PbCl_4}{349.0 \text{ g } PbCl_4} = 0.728 \text{ mol } PbCl_4$$

31. Step 1: Find the molar mass of Ag_2CrO_4.

$$2 \text{ mol Ag} \times \frac{107.9 \text{ g Ag}}{1 \text{ mol Ag}} = 215.8 \text{ g}$$

$$1 \text{ mol Cr} \times \frac{52.00 \text{ g Cr}}{1 \text{ mol Cr}} = 52.00 \text{ g}$$

$$4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{64.00 \text{ g}}$$

molar mass Ag_2CrO_4 = 331.8 g/mol

Step 2: Make mass → mole conversion.

$$25.8 \text{ g } Ag_2CrO_4 \times \frac{1 \text{ mol } Ag_2CrO_4}{331.8 \text{ g } Ag_2CrO_4}$$

$= 0.0778$ mol Ag_2CrO_4

Step 3: Make mole → formula unit conversion.

$$0.0778 \text{ mol } Ag_2CrO_4 \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mol}}$$

$= 4.68 \times 10^{22}$ formula units Ag_2CrO_4

a. $$4.68 \times 10^{22} \text{ formula units } Ag_2CrO_4 \times \frac{2 \text{ } Ag^+ \text{ ions}}{1 \text{ formula unit } Ag_2CrO_4} = 9.36 \times 10^{22} \text{ } Ag^+ \text{ ions}$$

b. $$4.68 \times 10^{22} \text{ formula units } Ag_2CrO_4 \times \frac{1 \text{ } CrO_4^{2-} \text{ ion}}{1 \text{ formula unit } Ag_2CrO_4}$$

$= 4.68 \times 10^{22}$ CrO_4^{2-} ions

c. $$\frac{331.8 \text{ g } Ag_2CrO_4}{1 \text{ mol } Ag_2CrO_4} \times \frac{1 \text{ mol}}{6.02 \times 10^{23} \text{ formula units}}$$

$= 5.51 \times 10^{-22}$ g Ag_2CrO_4/formula unit

Solutions

32. Step 1: Find the number of moles of NaCl.

$$4.59 \times 10^{24} \text{ formula units NaCl} \times \frac{1 \text{ mol}}{6.02 \times 10^{23} \text{ formula units}} = 7.62 \text{ mol NaCl}$$

Step 2: Find the molar mass of NaCl.

$$1 \text{ mol Na} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}} = 22.99 \text{ g}$$

$$1 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} = \underline{35.45 \text{ g}}$$

molar mass NaCl = 58.44 g/mol

Step 3: Make mole → mass conversion.

$$7.62 \text{ mol NaCl} \times \frac{58.44 \text{ g NaCl}}{1 \text{ mol NaCl}} = 445 \text{ g NaCl}$$

33. Step 1: Find molar mass of C_2H_5OH.

$$2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} = 24.02 \text{ g}$$

$$6 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 6.048 \text{ g}$$

$$1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{16.00 \text{ g}}$$

molar mass C_2H_5OH = 46.07 g/mol

Step 2: Make mass → mole conversion.

$$45.6 \text{ g } C_2H_5OH \times \frac{1 \text{ mol } C_2H_5OH}{46.07 \text{ g } C_2H_5OH}$$

$= 0.990 \text{ mol } C_2H_5OH$

Step 3: Make mole → molecule conversion.

$$0.990 \text{ mol } C_2H_5OH \times \frac{6.02 \times 10^{23} \text{ molecules}}{1 \text{ mol}}$$

$= 5.96 \times 10^{23}$ molecules C_2H_5OH

a. $5.96 \times 10^{23} \text{ molecules } C_2H_5OH \times \frac{2 \text{ C atoms}}{1 \text{ molecule } C_2H_5OH} = 1.19 \times 10^{24} \text{ C atoms}$

b. $5.96 \times 10^{23} \text{ molecules } C_2H_5OH \times \frac{6 \text{ H atoms}}{1 \text{ molecule } C_2H_5OH} = 3.58 \times 10^{24} \text{ H atoms}$

c. $5.96 \times 10^{23} \text{ molecules } C_2H_5OH \times \frac{1 \text{ O atom}}{1 \text{ molecule } C_2H_5OH} = 5.96 \times 10^{23} \text{ O atoms}$

34. Step 1: Find the molar mass of Na_2SO_3.

$$2 \text{ mol Na} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}} = 45.98 \text{ g}$$

$$1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} = 32.07 \text{ g}$$

$$3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{48.00 \text{ g}}$$

molar mass Na_2SO_3 = 126.04 g/mol

Step 2: Make mass → mole conversion.

$$2.25 \text{ g } Na_2SO_3 \times \frac{1 \text{ mol } Na_2SO_3}{126.04 \text{ g } Na_2SO_3}$$

$= 0.0179 \text{ mol } Na_2SO_3$

Step 3: Make mole → formula unit conversion.

$$0.0179 \text{ mol } Na_2SO_3 \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mol}}$$

$= 1.08 \times 10^{22}$ formula units Na_2SO_3

a. $1.08 \times 10^{22} \text{ formula units } Na_2SO_3 \times \frac{2 \text{ Na}^+ \text{ ions}}{1 \text{ formula unit } Na_2SO_3} = 2.16 \times 10^{22} \text{ Na}^+ \text{ ions}$

b. $1.08 \times 10^{22} \text{ formula units } Na_2SO_3 \times \frac{1 \text{ SO}_3^{2-} \text{ ions}}{1 \text{ formula unit } Na_2SO_3} = 1.08 \times 10^{22} \text{ SO}_3^{2-} \text{ ions}$

c. $\frac{126.08 \text{ g } Na_2SO_3}{1 \text{ mol } Na_2SO_3} \times \frac{1 \text{ mol}}{6.02 \times 10^{23} \text{ formula units}}$

$= 2.09 \times 10^{-22}$ g Na_2SO_3 /formula unit

35. Step 1: Find the molar mass of CO_2.

$$1 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} = 12.01 \text{ g}$$

$$2 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{32.00 \text{ g}}$$

molar mass CO_2 = 44.01 g/mol

Step 2: Make mass → mole conversion.

$$52.0 \text{ g } CO_2 \times \frac{1 \text{ mol } CO_2}{44.01 \text{ g } CO_2} = 1.18 \text{ mol } CO_2$$

Step 3: Make mole → molecule conversion.

$$1.18 \text{ mol } CO_2 \times \frac{6.02 \times 10^{23} \text{ molecules}}{1 \text{ mol}}$$

$= 7.11 \times 10^{23}$ molecules CO_2

a. $7.11 \times 10^{23} \text{ molecules } CO_2 \times \frac{1 \text{ C atom}}{1 \text{ molecule } CO_2}$

$= 7.11 \times 10^{23}$ C atoms

b. $7.11 \times 10^{23} \text{ molecules } CO_2 \times \frac{2 \text{ O atoms}}{1 \text{ molecule } CO_2}$

$= 1.42 \times 10^{24}$ O atoms

c. $\frac{44.01 \text{ g } CO_2}{1 \text{ mol } CO_2} \times \frac{1 \text{ mol}}{6.02 \times 10^{23} \text{ molecules}}$

$= 7.31 \times 10^{-23}$ g CO_2/molecule

42. Steps 1 and 2: Assume 1 mole; calculate molar mass of $CaCl_2$.

$$1 \text{ mol Ca} \times \frac{40.08 \text{ g Ca}}{1 \text{ mol Ca}} = 40.08 \text{ g}$$

$$2 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} = \underline{70.90 \text{ g}}$$

molar mass $CaCl_2$ = 110.98 g/mol

Solutions

Step 3: Determine percent by mass of each element.

$$\text{percent Ca} = \frac{40.08 \text{ g Ca}}{110.98 \text{ g CaCl}_2} \times 100 = 36.11\% \text{ Ca}$$

$$\text{percent Cl} = \frac{70.90 \text{ g Cl}}{110.98 \text{ g CaCl}_2} \times 100 = 63.89\% \text{ Cl}$$

43. Steps 1 and 2: Assume 1 mole; calculate molar mass of Na_2SO_4.

$$2 \text{ mol Na} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}} = 45.98 \text{ g}$$

$$1 \text{ mol S} \times \frac{32.06 \text{ g S}}{1 \text{ mol S}} = 32.07 \text{ g}$$

$$4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{64.00 \text{ g}}$$

$$\text{molar mass Na}_2\text{SO}_4 = 142.05 \text{ g/mol}$$

Step 3: Determine percent by mass of each element.

$$\text{percent Na} = \frac{45.98 \text{ g Na}}{142.05 \text{ g Na}_2\text{SO}_4} \times 100 = 32.37\% \text{ Na}$$

$$\text{percent S} = \frac{32.07 \text{ g S}}{142.05 \text{ g Na}_2\text{SO}_4} \times 100 = 22.58\% \text{ S}$$

$$\text{percent O} = \frac{64.00 \text{ g O}}{142.05 \text{ g Na}_2\text{SO}_4} \times 100 = 45.05\% \text{ O}$$

44. Steps 1 and 2: Assume 1 mole; calculate molar mass of H_2SO_3.

$$2 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 2.016 \text{ g}$$

$$1 \text{ mol S} \times \frac{32.06 \text{ g S}}{1 \text{ mol S}} = 32.06 \text{ g}$$

$$3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{48.00 \text{ g}}$$

$$\text{molar mass H}_2\text{SO}_3 = 82.08 \text{ g/mol}$$

Step 3: Determine percent by mass of S.

$$\text{percent S} = \frac{32.06 \text{ g S}}{82.08 \text{ g H}_2\text{SO}_3} \times 100 = 39.06\% \text{ S}$$

Repeat steps 1 and 2 for $H_2S_2O_8$. Assume 1 mole; calculate molar mass of $H_2S_2O_8$.

$$2 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 2.016 \text{ g}$$

$$2 \text{ mol S} \times \frac{32.06 \text{ g S}}{1 \text{ mol S}} = 64.12 \text{ g}$$

$$8 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{128.00 \text{ g}}$$

$$\text{molar mass H}_2\text{S}_2\text{O}_8 = 194.14 \text{ g/mol}$$

Step 3: Determine percent by mass of S.

$$\text{percent S} = \frac{64.12 \text{ g S}}{194.14 \text{ g H}_2\text{S}_2\text{O}_8} \times 100 = 33.03\% \text{ S}$$

H_2SO_3 has a larger percent by mass of S.

45. Steps 1 and 2: Assume 1 mole; calculate molar mass of H_3PO_4.

$$3 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 3.024 \text{ g}$$

$$1 \text{ mol P} \times \frac{30.97 \text{ g P}}{1 \text{ mol P}} = 30.97 \text{ g}$$

$$4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 64.00 \text{ g}$$

$$\text{molar mass H}_3\text{PO}_4 = 97.99 \text{ g/mol}$$

Step 3: Determine percent by mass of each element.

$$\text{percent H} = \frac{3.024 \text{ g H}}{97.99 \text{ g H}_3\text{PO}_4} \times 100 = 3.08\% \text{ H}$$

$$\text{percent P} = \frac{30.97 \text{ g P}}{97.99 \text{ g H}_3\text{PO}_4} \times 100 = 31.61\% \text{ P}$$

$$\text{percent O} = \frac{64.00 \text{ g O}}{97.99 \text{ g H}_3\text{PO}_4} \times 100 = 65.31\% \text{ O}$$

46. Step 1: Assume 100 g sample; calculate moles of each element.

$$36.84 \text{ g N} \times \frac{1 \text{ mol N}}{14.01 \text{ g N}} = 2.630 \text{ mol N}$$

$$63.16 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 3.948 \text{ mol O}$$

Step 2: Calculate mole ratios.

$$\frac{2.630 \text{ mol N}}{2.630 \text{ mol N}} = \frac{1.000 \text{ mol N}}{1.000 \text{ mol N}} = \frac{1 \text{ mol N}}{1 \text{ mol N}}$$

$$\frac{3.948 \text{ mol O}}{2.630 \text{ mol N}} = \frac{1.500 \text{ mol O}}{1.000 \text{ mol N}} = \frac{1.5 \text{ mol O}}{1 \text{ mol N}}$$

The simplest ratio is 1 mol N: 1.5 mol O.

Step 3: Convert decimal fraction to whole number.

In this case, multiply by 2, because $1.5 \times 2 = 3$. Therefore, the empirical formula is N_2O_3.

Solutions

47. Step 1: Assume 100 g sample; calculate moles of each element

$$35.98 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} = 1.334 \text{ mol Al}$$

$$64.02 \text{ g S} \times \frac{1 \text{ mol S}}{32.06 \text{ g S}} = 1.996 \text{ mol S}$$

Step 2: Calculate mole ratios.

$$\frac{1.334 \text{ mol Al}}{1.334 \text{ mol Al}} = \frac{1.000 \text{ mol Al}}{1.000 \text{ mol Al}} = \frac{1 \text{ mol Al}}{1 \text{ mol Al}}$$

$$\frac{1.996 \text{ mol S}}{1.334 \text{ mol Al}} = \frac{1.500 \text{ mol S}}{1.000 \text{ mol Al}} = \frac{1.5 \text{ mol S}}{1 \text{ mol Al}}$$

The simplest ratio is 1 mol Al: 1.5 mol S.

Step 3: Convert decimal fraction to whole number.

In this case, multiply by 2, because $1.5 \times 2 = 3$. Therefore, the empirical formula is Al_2S_3.

48. Step 1: Assume 100 g sample; calculate moles of each element.

$$81.82 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 6.813 \text{ mol C}$$

$$18.18 \text{ g H} \times \frac{1 \text{ mol H}}{1.008 \text{ g H}} = 18.04 \text{ mol H}$$

Step 2: Calculate mole ratios.

$$\frac{6.813 \text{ mol C}}{6.813 \text{ mol C}} = \frac{1.000 \text{ mol C}}{1.000 \text{ mol C}} = \frac{1 \text{ mol C}}{1 \text{ mol C}}$$

$$\frac{18.04 \text{ mol H}}{6.813 \text{ mol C}} = \frac{2.649 \text{ mol H}}{1.000 \text{ mol C}} = \frac{2.65 \text{ mol H}}{1 \text{ mol C}}$$

The simplest ratio is 1 mol: 2.65 mol H.

Step 3: Convert decimal fraction to whole number.

In this case, multiply by 3, because $2.65 \times 3 = 7.95 \approx 8$. Therefore, the empirical formula is C_3H_8.

49. Step 1: Assume 100 g sample; calculate moles of each element.

$$60.00 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 5.00 \text{ mol C}$$

$$4.44 \text{ g H} \times \frac{1 \text{ mol H}}{1.008 \text{ g H}} = 4.40 \text{ mol H}$$

$$35.56 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 2.22 \text{ mol O}$$

Step 2: Calculate mole ratios.

$$\frac{5.00 \text{ mol C}}{2.22 \text{ mol O}} = \frac{2.25 \text{ mol C}}{1.00 \text{ mol O}} = \frac{2.25 \text{ mol C}}{1 \text{ mol O}}$$

$$\frac{4.40 \text{ mol H}}{2.22 \text{ mol O}} = \frac{1.98 \text{ mol H}}{1.00 \text{ mol O}} = \frac{2 \text{ mol H}}{1 \text{ mol O}}$$

$$\frac{2.22 \text{ mol O}}{2.22 \text{ mol O}} = \frac{1.00 \text{ mol O}}{1.00 \text{ mol O}} = \frac{1 \text{ mol O}}{1 \text{ mol O}}$$

The simplest ratio is 2.25 mol C: 2 mol H: 1 mol O.

Step 3: Convert decimal fraction to whole number.

In this case, multiply by 4, because $2.25 \times 4 = 9$. Therefore, the empirical formula is $C_9H_8O_4$.

50. Step 1: Assume 100 g sample; calculate moles of each element.

$$10.89 \text{ g Mg} \times \frac{1 \text{ mol Mg}}{24.31 \text{ g Mg}} = 0.4480 \text{ mol Mg}$$

$$31.77 \text{ g Cl} \times \frac{1 \text{ mol Cl}}{35.45 \text{ g Cl}} = 0.8962 \text{ mol Cl}$$

$$57.34 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 3.584 \text{ mol O}$$

Step 2: Calculate mole ratios.

$$\frac{0.4480 \text{ mol Mg}}{0.4480 \text{ mol Mg}} = \frac{1.000 \text{ mol Mg}}{1.000 \text{ mol Mg}} = \frac{1 \text{ mol Mg}}{1 \text{ mol Mg}}$$

$$\frac{0.8962 \text{ mol Cl}}{0.4480 \text{ mol Mg}} = \frac{2.000 \text{ mol Cl}}{1.000 \text{ mol Mg}} = \frac{2 \text{ mol Cl}}{1 \text{ mol Mg}}$$

$$\frac{3.584 \text{ mol O}}{0.4480 \text{ mol Mg}} = \frac{7.999 \text{ mol O}}{1.000 \text{ mol Mg}} = \frac{8 \text{ mol O}}{1 \text{ mol Mg}}$$

The empirical formula is $MgCl_2O_8$.

The simplest ratio is 1 mol Mg: 2 mol Cl: 8 mol O.

51. Step 1: Assume 100 g sample; calculate moles of each element

$$65.45 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 5.450 \text{ mol C}$$

$$5.45 \text{ g H} \times \frac{1 \text{ mol H}}{1.008 \text{ g H}} = 5.41 \text{ mol H}$$

$$29.09 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 1.818 \text{ mol O}$$

Step 2: Calculate mole ratios

$$\frac{5.450 \text{ mol C}}{1.818 \text{ mol O}} = \frac{3.000 \text{ mol C}}{1.000 \text{ mol O}} = \frac{3 \text{ mol C}}{1 \text{ mol O}}$$

$$\frac{5.41 \text{ mol H}}{1.818 \text{ mol O}} = \frac{2.97 \text{ mol H}}{1.00 \text{ mol O}} = \frac{3 \text{ mol H}}{1 \text{ mol O}}$$

$$\frac{1.818 \text{ mol O}}{1.818 \text{ mol O}} = \frac{1.000 \text{ mol O}}{1.000 \text{ mol O}} = \frac{1 \text{ mol O}}{1 \text{ mol O}}$$

The simplest ratio is 1 mol:2.65 mol H.

Therefore, the empirical formula is C_3H_3O.

Step 3: Calculate the molar mass of the empirical formula.

$$3 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} = 36.03 \text{ g}$$

$$3 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 3.024 \text{ g}$$

$$1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = \underline{16.00 \text{ g}}$$

molar mass C_3H_3O = 55.05 g/mol

Step 4: Determine whole number multiplier.

$$\frac{110.0 \text{ g/mol}}{55.05 \text{ g/mol}} = 1.998, \text{ or } 2$$

The molecular formula is $C_6H_6O_2$.

Solutions

52. Step 1: Assume 100 g sample; calculate moles of each element.

$$49.98\ \cancel{g\ C} \times \frac{1\ mol\ C}{12.01\ \cancel{g\ C}} = 4.162\ mol\ C$$

$$10.47\ \cancel{g\ H} \times \frac{1\ mol\ H}{1.008\ \cancel{g\ H}} = 10.39\ mol\ H$$

Step 2: Calculate mole ratios.

$$\frac{4.162\ mol\ C}{4.162\ mol\ C} = \frac{1.000\ mol\ C}{1.000\ mol\ C} = \frac{1\ mol\ C}{1\ mol\ C}$$

$$\frac{10.39\ mol\ H}{4.162\ mol\ C} = \frac{2.50\ mol\ H}{1.000\ mol\ C} = \frac{2.5\ mol\ H}{1\ mol\ C}$$

The simplest ratio is 1 mol C: 2.5 mol H.

Because $2.5 \times 2 = 5$, the empirical formula is C_2H_5.

Step 3: Calculate the molar mass of the empirical formula.

$$2\ \cancel{mol\ C} \times \frac{12.01\ g\ C}{1\ \cancel{mol\ C}} = 24.02\ g$$

$$5\ \cancel{mol\ H} \times \frac{1.008\ g\ H}{1\ \cancel{mol\ H}} = \underline{5.040\ g}$$

molar mass C_2H_5 = 29.06 g/mol

Step 4: Determine whole number multiplier.

$$\frac{58.12\ \cancel{g/mol}}{29.06\ \cancel{g/mol}} = 2.000$$

The molecular formula is C_4H_{10}.

53. Step 1: Assume 100 g sample; calculate moles of each element.

$$46.68\ \cancel{g\ N} \times \frac{1\ mol\ N}{14.01\ \cancel{g\ N}} = 3.332\ mol\ N$$

$$53.32\ \cancel{g\ O} \times \frac{1\ mol\ O}{16.00\ \cancel{g\ O}} = 3.333\ mol\ O$$

Step 2: Calculate mole ratios.

$$\frac{3.332\ mol\ N}{3.332\ mol\ N} = \frac{1.000\ mol\ N}{1.000\ mol\ N} = \frac{1\ mol\ N}{1\ mol\ N}$$

$$\frac{3.333\ mol\ O}{3.332\ mol\ N} = \frac{1.000\ mol\ O}{1.000\ mol\ N} = \frac{1\ mol\ O}{1\ mol\ N}$$

The simplest ratio is 1 mol N: 1 mol O.

The empirical formula is NO.

Step 3: Calculate the molar mass of the empirical formula.

$$1\ \cancel{mol\ N} \times \frac{14.01\ g\ N}{1\ \cancel{mol\ N}} = 14.01\ g$$

$$1\ \cancel{mol\ O} \times \frac{16.00\ g\ O}{1\ \cancel{mol\ O}} = \underline{16.00}\ g$$

molar mass NO = 30.01 g /mol

Step 4: Determine whole number multiplier.

$$\frac{60.01\ \cancel{g/mol}}{30.01\ \cancel{g/mol}} = 2.000$$

The molecular formula is N_2O_2.

54. Step 1: Calculate moles of each element.

$$19.55\ \cancel{g\ K} \times \frac{1\ mol\ K}{39.10\ \cancel{g\ K}} = 0.5000\ mol\ K$$

$$4.00\ \cancel{g\ O} \times \frac{1\ mol\ O}{16.00\ \cancel{g\ O}} = 0.250\ mol\ O$$

Step 2: Calculate mole ratios.

$$\frac{0.5000\ mol\ K}{0.250\ mol\ O} = \frac{2.00\ mol\ K}{1.00\ mol\ O} = \frac{2\ mol\ K}{1\ mol\ O}$$

$$\frac{0.250\ mol\ O}{0.250\ mol\ O} = \frac{1.00\ mol\ O}{1.00\ mol\ O} = \frac{1\ mol\ O}{1\ mol\ O}$$

The simplest ratio is 2 mol K: 1 mol O.

The empirical formula is K_2O.

55. Step 1: Calculate moles of each element

$$174.86\ \cancel{g\ Fe} \times \frac{1\ mol\ Fe}{55.85\ \cancel{g\ Fe}} = 3.131\ mol\ Fe$$

$$75.14\ \cancel{g\ O} \times \frac{1\ mol\ O}{16.00\ \cancel{g\ O}} = 4.696\ mol\ O$$

Step 2: Calculate mole ratios.

$$\frac{3.131\ mol\ Fe}{3.131\ mol\ Fe} = \frac{1.000\ mol\ Fe}{1.000\ mol\ Fe} = \frac{1\ mol\ Fe}{1\ mol\ Fe}$$

$$\frac{4.696\ mol\ O}{3.131\ mol\ Fe} = \frac{1.500\ mol\ O}{1.000\ mol\ Fe} = \frac{1.5\ mol\ O}{1\ mol\ Fe}$$

The simplest ratio is 1 mol Fe: 1.5 mol O.

Because $1.5 \times 2 = 3$, the empirical formula is Fe_2O_3.

56. Step 1: Calculate moles of each element.

$$17.900\ \cancel{g\ C} \times \frac{1\ mol\ C}{12.01\ \cancel{g\ C}} = 1.490\ mol\ C$$

$$1.680\ \cancel{g\ H} \times \frac{1\ mol\ H}{1.008\ \cancel{g\ H}} = 1.667\ mol\ H$$

$$4.225\ \cancel{g\ O} \times \frac{1\ mol\ O}{16.00\ \cancel{g\ O}} = 0.2641\ mol\ O$$

$$1.228\ \cancel{g\ N} \times \frac{1\ mol\ N}{14.01\ \cancel{g\ N}} = 0.08765\ mol\ N$$

Step 2: Calculate mole ratios.

$$\frac{0.08765\ mol\ N}{0.08765\ mol\ N} = \frac{1.000\ mol\ N}{1.000\ mol\ N} = \frac{1\ mol\ N}{1\ mol\ N}$$

$$\frac{1.490\ mol\ C}{0.08765\ mol\ N} = \frac{17.00\ mol\ C}{1.000\ mol\ N} = \frac{17\ mol\ C}{1\ mol\ N}$$

$$\frac{1.667\ mol\ H}{0.08765\ mol\ N} = \frac{19.02\ mol\ H}{1.000\ mol\ N} = \frac{19\ mol\ H}{1\ mol\ N}$$

$$\frac{0.2641\ mol\ O}{0.08765\ mol\ N} = \frac{3.013\ mol\ O}{1.000\ mol\ N} = \frac{3\ mol\ O}{1\ mol\ N}$$

The simplest ratio is 17 mol C: 19 mol H: 3 mol O: 1 mol N.

The empirical formula is $C_{17}H_{19}O_3N$.

57. Step 1: Calculate moles of each element.

$$0.545 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} = 0.0202 \text{ mol Al}$$

$$0.485 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 0.0303 \text{ mol O}$$

Step 2: Calculate mole ratios.

$$\frac{0.0202 \text{ mol Al}}{0.0202 \text{ mol Al}} = \frac{1.00 \text{ mol Al}}{1.00 \text{ mol Al}} = \frac{1 \text{ mol Al}}{1 \text{ mol Al}}$$

$$\frac{0.0303 \text{ mol O}}{0.0202 \text{ mol Al}} = \frac{1.50 \text{ mol O}}{1.00 \text{ mol Al}} = \frac{1.5 \text{ mol O}}{1 \text{ mol Al}}$$

The simplest ratio is 1 mol Al: 1.5 mol O.

Because $1.5 \times 2 = 3$, the empirical formula is Al_2O_3.

63. Step 1: Assume 100 g sample; calculate moles of each component.

$$48.8 \text{ g } MgSO_4 \times \frac{1 \text{ mol } MgSO_4}{120.38 \text{ g } MgSO_4}$$

$$= 0.405 \text{ mol } MgSO_4$$

$$51.2 \text{ g } H_2O \times \frac{1 \text{ mol } H_2O}{18.02 \text{ g } H_2O} = 2.84 \text{ mol } H_2O$$

Step 2: Calculate mole ratios.

$$\frac{0.405 \text{ mol } MgSO_4}{0.405 \text{ mol } MgSO_4} = \frac{1.00 \text{ mol } MgSO_4}{1.00 \text{ mol } MgSO_4}$$

$$= \frac{1 \text{ mol } MgSO_4}{1 \text{ mol } MgSO_4}$$

$$\frac{2.84 \text{ mol } H_2O}{0.405 \text{ mol } MgSO_4} = \frac{7.01 \text{ mol } H_2O}{1.00 \text{ mol } MgSO_4}$$

$$= \frac{7 \text{ mol } H_2O}{1 \text{ mol } MgSO_4}$$

The formula of the hydrate is $MgSO_4{\cdot}7H_2O$. Its name is magnesium sulfate heptahydrate.

64. Step 1: Calculate the mass of water driven off.

mass of hydrated compound − mass of anhydrous compound remaining

$= 11.75 \text{ g } CoCl_2{\cdot}xH_2O - 9.25 \text{ g } CoCl_2$

$= 2.50 \text{ g } H_2O$

Step 2: Calculate moles of each component.

$$9.25 \text{ g } CoCl_2 \times \frac{1 \text{ mol } CoCl_2}{129.83 \text{ g } CoCl_2} = 0.0712 \text{ mol } CoCl_2$$

$$2.50 \text{ g } H_2O \times \frac{1 \text{ mol } H_2O}{18.02 \text{ g } H_2O} = 0.139 \text{ mol } H_2O$$

Step 2: Calculate mole ratios.

$$\frac{0.0712 \text{ mol } CoCl_2}{0.0712 \text{ mol } CoCl_2} = \frac{1.00 \text{ mol } CoCl_2}{1.00 \text{ mol } CoCl_2} = \frac{1 \text{ mol } CoCl_2}{1 \text{ mol } CoCl_2}$$

$$\frac{0.139 \text{ mol } H_2O}{0.0712 \text{ mol } CoCl_2} = \frac{1.95 \text{ mol } H_2O}{1.00 \text{ mol } CoCl_2} = \frac{2 \text{ mol } H_2O}{1 \text{ mol } CoCl_2}$$

The formula of the hydrate is $CoCl_2{\cdot}2H_2O$. Its name is cobalt(II) chloride dihydrate.

Chapter 12

1. a. 1 molecule N_2 + 3 molecules $H_2 \rightarrow$ 2 molecules NH_3

1 mole N_2 + 3 moles $H_2 \rightarrow$ 2 moles NH_3

28.02 g N_2 + 6.06 g $H_2 \rightarrow$ 34.08 g NH_3

b. 1 molecule HCl + 1 formula unit KOH $\rightarrow$ 1 formula unit KCl + 1 molecule H_2O

1 mole HCl + 1 mole KOH $\rightarrow$ 1 mole KCl + 1 mole H_2O

36.46 g HCl + 56.11 g KOH $\rightarrow$ 74.55 g KCl + 18.02 g H_2O

c. 4 atoms Zn + 10 molecules $HNO_3 \rightarrow$ 4 formula units $Zn(NO_3)_2$ + 1 molecule N_2O + 5 molecules H_2O

4 moles Zn + 10 moles $HNO_3 \rightarrow$ 4 moles $Zn(NO_3)_2$ + 1 mole N_2O + 5 moles H_2O

261.56 g Zn + 630.2 g $HNO_3 \rightarrow$ 757.56 g $Zn(NO_3)_2$ + 44.02 g N_2O + 90.10 g H_2O

d. 2 atoms Mg + 1 molecule $O_2 \rightarrow$ 2 formula units MgO

2 moles Mg + 1 mole $O_2 \rightarrow$ 2 moles MgO

48.62 g Mg + 32.00 g $O_2 \rightarrow$ 80.62 g MgO

e. 2 atoms Na + 2 molecules $H_2O \rightarrow$ 2 formula units NaOH + 1 molecule H_2

2 moles Na + 2 moles $H_2O \rightarrow$ 2 moles NaOH + 1 mole H_2

45.98 g Na + 36.04 g $H_2O \rightarrow$ 80.00 g NaOH + 2.02 g H_2

2. a. $\frac{4 \text{ mol Al}}{3 \text{ mol } O_2}$ $\frac{3 \text{ mol } O_2}{2 \text{ mol } Al_2O_3}$ $\frac{2 \text{ mol } Al_2O_3}{4 \text{ mol Al}}$

$\frac{3 \text{ mol } O_2}{4 \text{ mol Al}}$ $\frac{2 \text{ mol } Al_2O_3}{3 \text{ mol } O_2}$ $\frac{4 \text{ mol Al}}{2 \text{ mol } Al_2O_3}$

b. $\frac{3 \text{ mol Fe}}{4 \text{ mol } H_2O}$ $\frac{3 \text{ mol Fe}}{4 \text{ mol } H_2}$ $\frac{3 \text{ mol Fe}}{1 \text{ mol } Fe_3O_4}$

$\frac{4 \text{ mol } H_2O}{3 \text{ mol Fe}}$ $\frac{4 \text{ mol } H_2}{3 \text{ mol Fe}}$ $\frac{1 \text{ mol } Fe_3O_4}{3 \text{ mol Fe}}$

$\frac{1 \text{ mol } Fe_3O_4}{4 \text{ mol } H_2}$ $\frac{1 \text{ mol } Fe_3O_4}{4 \text{ mol } H_2O}$ $\frac{4 \text{ mol } H_2O}{4 \text{ mol } H_2}$

$\frac{4 \text{ mol } H_2}{1 \text{ mol } Fe_3O_4}$ $\frac{4 \text{ mol } H_2O}{1 \text{ mol } Fe_3O_4}$ $\frac{4 \text{ mol } H_2}{4 \text{ mol } H_2O}$

c. $\frac{2 \text{ mol HgO}}{2 \text{ mol Hg}}$ $\frac{1 \text{ mol } O_2}{2 \text{ mol Hg}}$ $\frac{1 \text{ mol } O_2}{2 \text{ mol HgO}}$

$\frac{2 \text{ mol Hg}}{2 \text{ mol HgO}}$ $\frac{2 \text{ mol Hg}}{1 \text{ mol } O_2}$ $\frac{2 \text{ mol HgO}}{1 \text{ mol } O_2}$

Solutions

3. a. $ZnO(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2O(l)$

$$\frac{1 \text{ mol } ZnO}{2 \text{ mol } HCl} \quad \frac{1 \text{ mol } ZnO}{1 \text{ mol } ZnCl_2} \quad \frac{1 \text{ mol } ZnO}{1 \text{ mol } H_2O}$$

$$\frac{2 \text{ mol } HCl}{1 \text{ mol } ZnO} \quad \frac{2 \text{ mol } HCl}{1 \text{ mol } ZnCl_2} \quad \frac{2 \text{ mol } HCl}{1 \text{ mol } H_2O}$$

$$\frac{1 \text{ mol } ZnCl_2}{1 \text{ mol } ZnO} \quad \frac{1 \text{ mol } ZnCl_2}{2 \text{ mol } HCl} \quad \frac{1 \text{ mol } ZnCl_2}{1 \text{ mol } H_2O}$$

$$\frac{1 \text{ mol } H_2O}{1 \text{ mol } ZnO} \quad \frac{1 \text{ mol } H_2O}{2 \text{ mol } HCl} \quad \frac{1 \text{ mol } H_2O}{1 \text{ mol } ZnCl_2}$$

b. $2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$

$$\frac{2 \text{ mol } C_4H_{10}}{13 \text{ mol } O_2} \quad \frac{2 \text{ mol } C_4H_{10}}{8 \text{ mol } CO_2} \quad \frac{2 \text{ mol } C_4H_{10}}{10 \text{ mol } H_2O}$$

$$\frac{13 \text{ mol } O_2}{2 \text{ mol } C_4H_{10}} \quad \frac{8 \text{ mol } CO_2}{2 \text{ mol } C_4H_{10}} \quad \frac{10 \text{ mol } H_2O}{2 \text{ mol } C_4H_{10}}$$

$$\frac{10 \text{ mol } H_2O}{13 \text{ mol } O_2} \quad \frac{10 \text{ mol } H_2O}{8 \text{ mol } CO_2} \quad \frac{8 \text{ mol } CO_2}{13 \text{ mol } O_2}$$

$$\frac{13 \text{ mol } O_2}{10 \text{ mol } H_2O} \quad \frac{8 \text{ mol } CO_2}{10 \text{ mol } H_2O} \quad \frac{13 \text{ mol } O_2}{8 \text{ mol } CO_2}$$

9. $2SO_2(g) + O_2(g) + 2H_2O(l) \rightarrow 2H_2SO_4(aq)$

$$12.5 \cancel{\text{ mol } SO_2} \times \frac{2 \text{ mol } H_2SO_4}{2 \cancel{\text{ mol } SO_2}}$$

$= 12.5$ mol H_2SO_4 produced

$$12.5 \cancel{\text{ mol } SO_2} \times \frac{1 \text{ mol } O_2}{2 \cancel{\text{ mol } SO_2}} = 6.25 \text{ mol } O_2 \text{ needed}$$

10. a. $2CH_4(g) + S_8(s) \rightarrow 2CS_2(l) + 4H_2S(g)$

b. $$1.50 \cancel{\text{ mol } S_8} \times \frac{2 \text{ mol } CS_2}{1 \cancel{\text{ mol } S_8}} = 3.00 \text{ mol } CS_2$$

c. $$1.50 \cancel{\text{ mol } S_8} \times \frac{4 \text{ mol } H_2S}{1 \cancel{\text{ mol } S_8}} = 6.00 \text{ mol } H_2S$$

11. $TiO_2(s) + C(s) + 2Cl_2(g) \rightarrow TiCl_4(s) + CO_2(g)$

Step 1: Make mole → mole conversion.

$$1.25 \cancel{\text{ mol } TiO_2} \times \frac{2 \text{ mol } Cl_2}{1 \cancel{\text{ mol } TiO_2}} = 2.50 \text{ mol } Cl_2$$

Step 2: Make mole → mass conversion.

$$2.50 \cancel{\text{ mol } Cl_2} \times \frac{70.9 \text{ g } Cl_2}{1 \cancel{\text{ mol } Cl_2}} = 177 \text{ g } Cl_2$$

12. Step 1: Balance the chemical equation.

$2NaCl(s) \rightarrow 2Na(s) + Cl_2(g)$

Step 2: Make mole → mole conversion.

$$2.50 \cancel{\text{ mol } NaCl} \times \frac{1 \text{ mol } Cl_2}{2 \cancel{\text{ mol } NaCl}} = 1.25 \text{ mol } Cl_2$$

Step 3: Make mole → mass conversion.

$$1.25 \cancel{\text{ mol } Cl_2} \times \frac{70.9 \text{ g } Cl_2}{1 \cancel{\text{ mol } Cl_2}} = 88.6 \text{ g } Cl_2$$

13. $2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$

Step 1: Make mass → mole conversion.

$$100.0 \cancel{\text{ g } NaN_3} \times \frac{1 \text{ mol } NaN_3}{65.02 \cancel{\text{ g } NaN_3}} = 1.538 \text{ mol } NaN_3$$

Step 2: Make mole → mole conversion.

$$1.538 \cancel{\text{ mol } NaN_3} \times \frac{3 \text{ mol } N_2}{2 \cancel{\text{ mol } NaN_3}} = 2.307 \text{ mol } N_2$$

Step 3: Make mole → mass conversion.

$$2.307 \cancel{\text{ mol } N_2} \times \frac{28.02 \text{ g } N_2}{1 \cancel{\text{ mol } N_2}} = 64.64 \text{ g } N_2$$

14. Step 1: Balance the chemical equation.

$2SO_2(g) + O_2(g) + 2H_2O(l) \rightarrow 2H_2SO_4(aq)$

Step 2: Make mass → mole conversion.

$$2.50 \cancel{\text{ g } SO_2} \times \frac{1 \text{ mol } SO_2}{64.07 \cancel{\text{ g } SO_2}} = 0.0390 \text{ mol } SO_2$$

Step 3: Make mole → mole conversion.

$$0.0390 \cancel{\text{ mol } SO_2} \times \frac{2 \text{ mol } H_2SO_4}{2 \cancel{\text{ mol } SO_2}} =$$

0.0390 mol H_2SO_4

Step 4: Make mole → mass conversion.

$$0.0390 \cancel{\text{ mol } H_2SO_4} \times \frac{98.09 \text{ g } H_2SO_4}{1 \cancel{\text{ mol } H_2SO_4}}$$

$= 3.83$ g H_2SO_4

20. $6Na(s) + Fe_2O_3(s) \rightarrow 3Na_2O(s) + 2Fe(s)$

Step 1: Make mass → mole conversion.

$$100.0 \cancel{\text{ g Na}} \times \frac{1 \text{ mol Na}}{22.99 \cancel{\text{ g Na}}} = 4.350 \text{ mol Na}$$

$$100.0 \cancel{\text{ g } Fe_2O_3} \times \frac{1 \text{ mol } Fe_2O_3}{159.7 \cancel{\text{ g } Fe_2O_3}}$$

$= 0.6261$ mol Fe_2O_3

Step 2: Make mole ratio comparison.

$$\frac{0.6261 \text{ mol } Fe_2O_3}{4.350 \text{ mol Na}} \quad \text{compared to} \quad \frac{1 \text{ mol } Fe_2O_3}{6 \text{ mol Na}}$$

0.1439 compared to 0.1667

a. The actual ratio is less than the needed ratio, so iron(III) oxide is the limiting reactant.

b. Sodium is the excess reactant.

c. Step 1: Make mole → mole conversion.

$$0.6261 \cancel{\text{ mol } Fe_2O_3} \times \frac{2 \text{ mol Fe}}{1 \cancel{\text{ mol } Fe_2O_3}} = 1.252 \text{ mol Fe}$$

Step 2: Make mole → mass conversion.

$$1.252 \cancel{\text{ mol Fe}} \times \frac{55.85 \text{ g Fe}}{1 \cancel{\text{ mol Fe}}} = 69.92 \text{ g Fe}$$

d. Step 1: Make mole → mole conversion.

$$0.6261 \cancel{\text{ mol } Fe_2O_3} \times \frac{6 \text{ mol Na}}{1 \cancel{\text{ mol } Fe_2O_3}}$$

$= 3.757$ mol Na needed

Solutions

Step 2: Make mole $\rightarrow$ mass conversion.

$$3.757 \text{ mol Na} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}} = 86.36 \text{ g Na needed}$$

100.0 g Na given − 86.36 g Na needed
= 13.63 g Na in excess

21. Step 1: Write the balanced chemical equation.

$$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$$

Step 2: Make mass $\rightarrow$ mole conversion.

$$88.0 \text{ g } CO_2 \times \frac{1 \text{ mol CO2}}{44.01 \text{ g } CO_2} = 2.00 \text{ mol } CO_2$$

$$64.0 \text{ g } H_2O \times \frac{1 \text{ mol } H_2O}{18.02 \text{ g } H_2O} = 3.55 \text{ mol } H_2O$$

Step 3: Make mole ratio comparison.

$$\frac{2.00 \text{ mol } CO_2}{3.55 \text{ mol } H_2O} \quad \text{compared to} \quad \frac{6 \text{ mol } CO_2}{6 \text{ mol } H_2O}$$

0.563 compared to 1.00

a. The actual ratio is less than the needed ratio, so carbon dioxide is the limiting reactant.

b. Water is the excess reactant.

Step 1: Make mole $\rightarrow$ mole conversion.

$$2.00 \text{ mol } CO_2 \times \frac{6 \text{ mol } H_2O}{6 \text{ mol } CO_2} = 2.00 \text{ mol } H_2O$$

Step 2: Make mole $\rightarrow$ mass conversion.

$$2.00 \text{ mol } H_2O \times \frac{18.02 \text{ g } H_2O}{1 \text{ mol } H_2O}$$
$$= 36.0 \text{ g } H_2O \text{ needed}$$

64.0 g H_2O given − 36.0 g H_2O needed
= 28.0 g H_2O in excess

c. Step 1: Make mole $\rightarrow$ mole conversion.

$$2.00 \text{ mol } CO_2 \times \frac{1 \text{ mol } C_6H_{12}O_6}{6 \text{ mol } CO_2}$$
$$= 0.333 \text{ mol } C_6H_{12}O_6$$

Step 2: Make mole $\rightarrow$ mass conversion.

$$0.333 \text{ mol } C_6H_{12}O_6 \times \frac{180.2 \text{ g } C_6H_{12}O_6}{1 \text{ mol } C_6H_{12}O_6}$$
$$= 60.0 \text{ g } C_6H_{12}O_6$$

27. $Al(OH)_3(s) + 3HCl(aq) \rightarrow AlCl_3(aq) + 3H_2O(l)$

Step 1: Make mass $\rightarrow$ mole conversion.

$$14.0 \text{ g } Al(OH)_3 \times \frac{1 \text{ mol } Al(OH)_3}{78.0 \text{ g } Al(OH)_3}$$
$$= 0.179 \text{ mol } Al(OH)_3$$

Step 2: Make mole $\rightarrow$ mole conversion.

$$0.179 \text{ mol } Al(OH)_3 \times \frac{1 \text{ mol } AlCl_3}{1 \text{ mol } Al(OH)_3}$$
$$= 0.179 \text{ mol } AlCl_3$$

Step 3: Make mole $\rightarrow$ mass conversion.

$$0.179 \text{ mol } AlCl_3 \times \frac{133.3 \text{ g } AlCl_3}{1 \text{ mol } AlCl_3} = 23.9 \text{ g } AlCl_3$$

23.9 g of $AlCl_3$ is the theoretical yield.

$$\% \text{ yield} = \frac{22.0 \text{ g } AlCl_3}{23.9 \text{ g } AlCl_3} \times 100 = 92.1\% \text{ yield of } AlCl_3$$

28. Step 1: Write the balanced chemical equation.

$$Cu(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Cu(NO_3)_2(aq)$$

Step 2: Make mass $\rightarrow$ mole conversion.

$$20.0 \text{ g Cu} \times \frac{1 \text{ mol Cu}}{63.55 \text{ g Cu}} = 0.315 \text{ mol Cu}$$

Step 3: Make mole $\rightarrow$ mole conversion.

$$0.315 \text{ mol Cu} \times \frac{2 \text{ mol Ag}}{1 \text{ mol Cu}} = 0.630 \text{ mol Ag}$$

Step 4: Make mole $\rightarrow$ mass conversion.

$$0.630 \text{ mol Ag} \times \frac{107.9 \text{ g Ag}}{1 \text{ mol Ag}} = 68.0 \text{ g Ag}$$

68.0 g of Ag is the theoretical yield.

$$\% \text{ yield} = \frac{60.0 \text{ g Ag}}{68.0 \text{ g Ag}} \times 100 = 88.2\% \text{ yield of Ag}$$

29. Step 1: Write the balanced chemical equation.

$$Zn(s) + I_2(s) \rightarrow ZnI_2(s)$$

Step 2: Make mass $\rightarrow$ mole conversion.

$$125.0 \text{ g Zn} \times \frac{1 \text{ mol Zn}}{65.38 \text{ g Zn}} = 1.912 \text{ mol Zn}$$

Step 3: Make mole $\rightarrow$ mole conversion.

$$1.912 \text{ mol Zn} \times \frac{1 \text{ mol } ZnI_2}{1 \text{ mol Zn}} = 1.912 \text{ mol } ZnI_2$$

Step 4: Make mole $\rightarrow$ mass conversion.

$$1.912 \text{ mol } ZnI_2 \times \frac{319.2 \text{ g } ZnI_2}{1 \text{ mol } ZnI_2} = 610.3 \text{ g } ZnI_2$$

610.3 g of ZnI_2 is the theoretical yield.

$$\% \text{ yield} = \frac{515.6 \text{ g } ZnI_2}{610.3 \text{ g } ZnI_2} \times 100$$
$$= 84.48\% \text{ yield of } ZnI_2$$

Solutions

Chapter 13

1. $\frac{\text{Rate}_{\text{nitrogen}}}{\text{Rate}_{\text{neon}}} = \sqrt{\frac{20.2\ \text{g/mol}}{28.0\ \text{g/mol}}} = \sqrt{0.721} = 0.849$

2. $\frac{\text{Rate}_{\text{carbon monoxide}}}{\text{Rate}_{\text{carbon dioxide}}} = \sqrt{\frac{44.0\ \text{g/mol}}{28.0\ \text{g/mol}}}$

$= \sqrt{1.57}$

$= 1.25$

3. Rearrange Graham's law to solve for Rate_A.

$\text{Rate}_A = \text{Rate}_B \times \sqrt{\frac{\text{molar mass}_B}{\text{molar mass}_A}}$

$\text{Rate}_B = 3.6\ \text{mol/min}$

$\frac{\text{molar mass}_B}{\text{molar mass}_A} = 0.5$

$\text{Rate}_A = 3.6\ \text{mol/min} \times \sqrt{0.5}$

$= 3.6\ \text{mol/min} \times 0.71$

$= 2.5\ \text{mol/min}$

4. $P_{\text{hydrogen}} = P_{\text{total}} - P_{\text{helium}}$

$= 600\ \text{mm Hg} - 439\ \text{mm Hg}$

$= 161\ \text{mm Hg}$

5. $P_{\text{total}} = 5.00\ \text{kPa} + 4.56\ \text{kPa} + 3.02\ \text{kPa} + 1.20\ \text{kPa}$

$= 13.78\ \text{kPa}$

6. $P_{\text{carbon dioxide}} = 30.4\ \text{kPa} - (16.5\ \text{kPa} + 3.7\ \text{kPa})$

$= 30.4\ \text{kPa} - 20.2\ \text{kPa} = 10.2\ \text{kPa}$

Chapter 14

1. $V_2 = \frac{V_1P_1}{P_2} = \frac{(300.0\ \text{mL})(99.0\ \text{kPa})}{188\ \text{kPa}} = 158\ \text{mL}$

2. $P_2 = \frac{V_1P_1}{V_2} = \frac{(1.00\ \text{L})(0.988\ \text{atm})}{2.00\ \text{L}} = 0.494\ \text{atm}$

3. $V_2 = \frac{V_1P_1}{P_2} = \frac{(145.7\ \text{mL})(1.08\ \text{atm})}{1.43\ \text{atm}}$

$= 1.10 \times 10^2\ \text{mL}$

4. $P_2 = \frac{V_1P_1}{V_2} = \frac{(4.00\ \text{L})(0.980\ \text{atm})}{0.0500\ \text{L}} = 78.4\ \text{atm}$

5. $29.2\ \text{kPa} \times \frac{1\ \text{atm}}{101.3\ \text{kPa}} = 0.288\ \text{atm}$

$V_2 = \frac{V_1P_1}{P_2} = \frac{(0.220\ \text{L})(0.860\ \text{atm})}{0.288\ \text{atm}} = 0.657\ \text{L}$

6. $T_1 = 89°\text{C} + 273 = 362\ \text{K}$

$T_2 = \frac{T_1V_2}{V_1} = \frac{(362\ \text{K})(1.12\ \text{L})}{0.67\ \text{L}} = 605\ \text{K}$

$605 - 273 = 330°\text{C}$

7. $T_1 = 80.0°\text{C} + 273 = 353\ \text{K}$

$T_2 = 30.0°\text{C} + 273 = 303\ \text{K}$

$V_2 = \frac{V_1T_2}{T_1} = \frac{(3.00\ \text{L})(303\ \text{K})}{353\ \text{K}} = 2.58\ \text{L}$

8. $T_1 = 25°\text{C} + 273 = 298\ \text{K}$

$T_2 = 0.00°\text{C} + 273 = 273\ \text{K}$

$V_2 = \frac{V_1T_2}{T_1} = \frac{(0.620\ \text{L})(273\ \text{K})}{298\ \text{K}} = 0.57\ \text{L}$

9. $T_1 = 30.0°\text{C} + 273 = 303\ \text{K}$

$T_2 = \frac{T_1P_2}{P_1} = \frac{(303\ \text{K})(201\ \text{kPa})}{125\ \text{kPa}} = 487\ \text{K}$

$487\ \text{K} - 273 = 214°\text{C}$

10. $T_1 = 25.0°\text{C} + 273 = 298\ \text{K}$

$T_2 = 37.0°\text{C} + 273 = 310\ \text{K}$

$P_2 = \frac{P_1T_2}{T_1} = \frac{(1.88\ \text{atm})(310\ \text{K})}{298\ \text{K}} = 1.96\ \text{atm}$

11. $T_2 = 36.5°\text{C} + 273 = 309.5\ \text{K}$

$T_1 = \frac{T_2P_1}{P_2} = \frac{(309.5\ \text{K})(1.12\ \text{atm})}{2.56\ \text{atm}} = 135\ \text{K}$

$135\ \text{K} - 273 = -138°\text{C}$

12. $T_1 = 0.00°\text{C} + 273 = 273\ \text{K}$

$T_2 = \frac{T_1P_2}{P_1} = \frac{(273\ \text{K})(28.4\ \text{kPa})}{30.7\ \text{kPa}} = 252.5\ \text{K}$

$252.5\ \text{K} - 273 = -20.5°\text{C} = -21°\text{C}$

The temperature must be lowered by 21°C.

13. $T_1 = 22.0°\text{C} + 273 = 295\ \text{K}$

$T_2 = 44.6°\text{C} + 273 = 318\ \text{K}$

$P_2 = \frac{P_1T_2}{P_1} = \frac{(660\ \text{torr})(318\ \text{K})}{295\ \text{K}} = 711\ \text{torr}$

$711\ \text{torr} - 660\ \text{torr} = 51\ \text{torr more}$

19. $T_1 = 36°C + 273 = 309\ K$

$T_2 = 28°C + 273 = 301\ K$

$V_2 = \frac{P_1T_2V_1}{P_2T_1} = \frac{(0.998\ atm)(301\ K)(2.1\ L)}{(0.900\ atm)(309\ K)} = 2.3\ L$

20. $T_1 = 0.00°C + 273 = 273\ K$

$T_2 = 30.00°C + 273 = 303\ K$

$P_2 = \frac{V_1T_2P_1}{V_2T_1} = \frac{(30.0\ mL)(303\ K)(1.00\ atm)}{(20.0\ mL)(273\ K)}$

$= 1.66\ atm$

21. $T_1 = 22.0°C + 273 = 295\ K$

$T_2 = 100.0°C + 273 = 373\ K$

$V_1 = \frac{V_2T_1P_2}{T_2P_1} = \frac{(0.224\ mL)(295\ K)(1.23\ atm)}{(373\ K)(1.02\ atm)}$

$= 0.214\ mL$

22. $T_1 = 5.0°C + 273 = 278\ K$

$T_2 = 2.09°C + 273 = 275\ K$

$V_2 = \frac{P_1T_2V_1}{P_2T_1} = \frac{(1.30\ atm)(275\ K)(46.0\ mL)}{(1.52\ atm)(278\ K)}$

$= 39\ mL$

23. $P_1 = \frac{V_2T_1P_2}{V_1T_2} = \frac{(0.644\ L)(298\ K)(32.6\ kPa)}{(0.766\ L)(303\ K)} =$

$= 27.0\ kPa$

24. $2.4\ mol \times \frac{22.4\ L}{mol} = 54\ L$

25. $0.0459\ mol \times \frac{22.4\ L}{mol} = 1.03\ L$

26. $1.02\ mol \times \frac{22.4\ L}{mol} = 22.8\ L$

27. $2.00\ L \times \frac{1\ mol}{22.4\ L} = 0.0893\ mol$

28. Set up problem as a ratio.

$\frac{?\ mol\ He}{0.865\ L} = \frac{0.0226\ mol\ He}{0.460\ L}$

Solve for mol He.

$?\ mol\ He = \frac{0.0226\ mol\ He}{0.460\ L} \times 0.865\ L$

$= 0.0425\ mol\ He$

29. $1.0\ L \times \frac{1\ mol}{22.4\ L} = 0.045\ mol$

$0.045\ mol \times \frac{44.0\ g}{mol} = 2.0\ g$

30. $0.00922\ g \times \frac{1\ mol}{2.016\ g} = 0.00457\ mol$

$0.00457\ mol \times \frac{22.4\ L}{mol} = 0.102\ L$ or $102\ mL$

31. $0.416\ g \times \frac{1\ mol}{83.8\ g} = 0.00496\ mol$

$0.00496\ mol \times \frac{22.4\ L}{mol} = 0.111\ L$

32. $0.860\ g - 0.205\ g = 0.655\ g$ He remaining

Set up problem as a ratio.

$\frac{V}{0.655\ g} = \frac{19.2\ L}{0.860\ g}$

Solve for V.

$V = \frac{(19.2\ L)(0.655\ g)}{0.860\ g} = 14.6\ L$

33. $4.5\ kg \times \frac{1000\ g}{1\ kg} \times \frac{1\ mol}{28.0\ g} \times \frac{22.4\ L}{1\ mol} = 3.6 \times 10^3\ L$

41. $n = \frac{PV}{RT} = \frac{(3.81\ atm)(0.44\ L)}{\left(0.0821\ \frac{L \cdot atm}{mol \cdot K}\right)(298\ K)}$

$= 6.9 \times 10^{-3}\ mol$

42. $143\ kPa \times \frac{1.00\ atm}{101.3\ kPa} = 1.41\ atm$

$T = \frac{PV}{nR} = \frac{(1.41\ atm)(1.00\ L)}{(2.49\ mol)\left(0.0821\frac{L \cdot atm}{mol \cdot K}\right)} = 6.90\ K$

$6.90\ K - 273 = -266°C$

43. $V = \frac{nRT}{P} = \frac{(0.323\ mol)\left(0.0821\ \frac{L \cdot atm}{mol \cdot K}\right)(265\ K)}{0.900\ atm}$

$= 7.81\ L$

44. $T = 20.0°C + 273 = 293\ K$

$P = \frac{nRT}{V} = \frac{(0.108\ mol)\left(0.0821\frac{L \cdot atm}{mol \cdot K}\right)(293\ K)}{0.505\ L}$

$= 5.14\ atm$

45. $T = \frac{PV}{nR} = \frac{(0.988\ atm)(1.20\ L)}{(0.0470\ mol)\left(0.0821\frac{L \cdot atm}{mol \cdot K}\right)} = 307\ K$

46. $117\ kPa \times \frac{1.00\ atm}{101.3\ kPa} = 1.15\ atm$

$T = 35.1°C + 273 = 308\ K$

$m = \frac{PMV}{RT} = \frac{(1.15\ atm)(70.0\ g/mol)(2.00\ L)}{\left(0.0821\frac{L \cdot atm}{mol \cdot K}\right)(308\ K)}$

$= 6.39\ g$

47. $T = 22.0°C + 273 = 295\ K$

$m = \frac{MPV}{RT} = \frac{(28.0\ g/mol)(1.00\ atm)(0.600\ L)}{\left(0.0821\frac{L \cdot atm}{mol \cdot K}\right)(295\ K)}$

$= 0.694\ g$

Solutions

48. $D = \frac{PM}{RT} = \frac{(1.00 \text{ atm})(44.0 \text{ g/mol})}{\left(0.0821\frac{\text{L·atm}}{\text{mol·K}}\right)(273 \text{ K})} = 1.96 \text{ g/L}$

49. $T = 25.0°\text{C} + 273 = 298 \text{ K}$

$M = \frac{DRT}{P} = \frac{(1.09 \text{ g/L})\left(0.0821\frac{\text{L·atm}}{\text{mol·K}}\right)(298 \text{ K})}{1.02 \text{ atm}}$

$= 26.1 \text{ g/mol}$

50. $D = \frac{MP}{RT} = \frac{(39.9 \text{ g/mol})(1.00 \text{ atm})}{\left(0.0821\frac{\text{L·atm}}{\text{mol·K}}\right)(273 \text{ K})} = 1.78 \text{ g/L}$

56. $S(s) + O_2(g) \rightarrow SO_2(g)$

$3.5 \text{ L } SO_2 \times + \frac{1 \text{ volume } O_2}{1 \text{ volume } SO_2} = 3.5 \text{ L } O_2$

57. $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

$5.00 \text{ L } O_2 \times \frac{2 \text{ volumes } H_2}{1 \text{ volume } O_2} = 10.0 \text{ L } H_2$

58. $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

$34.0 \text{ L } O_2 \times \frac{1 \text{ volume } C_3H_8}{5 \text{ volumes } O_2} = 6.80 \text{ L } C_3H_8$

59. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

$2.36 \text{ L } CH_4 \times \frac{2 \text{ volumes } O_2}{1 \text{ volume } CH_4} = 4.72 \text{ L } O_2$

60. $0.100 \text{ L } N_2O \times \frac{1 \text{ mol}}{22.4 \text{ L}} = 0.00446 \text{ mol } N_2O$

$0.00446 \text{ mol } N_2O \times \frac{1 \text{ mol } NH_4NO_3}{1 \text{ mol } N_2O}$

$= 0.00446 \text{ mol } NH_4NO_3$

$0.00446 \text{ mol } NH_4NO_3 \times 80.0 \text{ g/mol}$

$= 0.357 \text{ g } NH_4NO_3$

61. $2.38 \text{ kg} \times \frac{1000 \text{ g}}{\text{kg}} \times \frac{1 \text{ mol } CaCO_3}{100.0 \text{ g}} \times$

$\frac{1 \text{ mol } CO_2}{1 \text{ mol } CaCO_3} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 533 \text{ L } CO_2$

62. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

$n = \frac{PV}{RT} = \frac{(1.00 \text{ atm})(10.5 \text{ L})}{\left(0.0821\frac{\text{L·atm}}{\text{mol·K}}\right)(473 \text{ K})}$

$= 0.271 \text{ mol } CH_4$

$0.271 \text{ mol } CH_4 \times \frac{2 \text{ mol } H_2O}{1 \text{ mol } CH_4} = 0.541 \text{ mol } H_2O$

63. $52.0 \text{ g Fe} \times \frac{1 \text{ mol Fe}}{55.85 \text{ g Fe}} \times \frac{3 \text{ mol } O_2}{4 \text{ mol Fe}} \times \frac{22.4 \text{ L}}{1 \text{ mol}}$

$= 15.6 \text{ L } O_2$

64. $2K(s) + Cl_2(g) \rightarrow 2KCl(s)$

$0.204 \text{ g K} \times \frac{1 \text{ mol K}}{39.1 \text{ g K}} \times \frac{1 \text{ mol } Cl_2}{2 \text{ mol K}} \times \frac{22.4 \text{ L}}{1 \text{ mol}}$

$= 0.0584 \text{ L } Cl_2$

Chapter 15

1. $S_1 = \frac{0.55 \text{ g}}{1.0 \text{ L}} = 0.55 \text{ g/L}$

$S_2 = P_2 \times \frac{S_1}{P_1} = 110.0 \text{ kPa} \times \frac{0.55 \text{ g/L}}{20.0 \text{ kPa}} = 3.0 \text{ g/L}$

2. $S_2 = \frac{1.5 \text{ g}}{1.0 \text{ L}} = 1.5 \text{ g/L}$

$P_2 = \frac{S_2}{S_1} \times P_1 = \frac{1.5 \text{ g/L}}{0.66 \text{ g/L}} \times 10.0 \text{ atm} = 23 \text{ atm}$

8. 600 mL H_2O × 1.0 g/mL = 600 g H_2O

$\frac{20 \text{ g } NaHCO_3}{600 \text{ g } H_2O + 20 \text{ g } NaHCO_3} \times 100 = 3\%$

9. $3.62\% = 100 \times \frac{\text{mass NaOCl}}{1500.0 \text{ g}}$

mass NaOCl = 54.3 g

10. 1500.0 g − 54.3 g = 1445.7 g solvent

11. $\frac{35 \text{ mL}}{115 \text{ mL} + 35 \text{ mL}} \times 100 = 23\%$

12. $30.0\% = 100 \times \frac{\text{volume ethanol}}{\text{volume solution}}$

volume ethanol = 0.300 × (volume solution) = 0.300 × 100.0 mL

volume ethanol = 30.0 mL

volume water = 100.0 mL − 30.0 mL = 70.0 mL

13. $\frac{24 \text{ mL}}{24 \text{ mL} + 1100 \text{ mL}} \times 100 = 2.1\%$

14. mol $C_6H_{12}O_6$ = $40.0 \text{ g} \times \frac{1 \text{ mol}}{180.16 \text{ g}} = 0.222 \text{ mol}$

$\text{molarity} = \frac{\text{mol } C_6H_{12}O_6}{1.5 \text{ L solution}} = \frac{0.222 \text{ mol}}{1.5 \text{ L}} = 0.148M$

15. mol NaOCl = $9.5 \text{ g} \times \frac{1 \text{ mol}}{74.44 \text{ g}} = 0.128 \text{ mol}$

$\text{molarity} = \frac{\text{mol NaOCl}}{1.00 \text{ L solution}} = \frac{0.128 \text{ mol}}{1.00 \text{ L}} = 0.128M$

16. mol KBr = $1.55 \text{ g} \times \frac{1 \text{ mol}}{119.0 \text{ g}} = 0.0130 \text{ mol KBr}$

$\text{molarity} = \frac{\text{mol KBr}}{1.60 \text{ L solution}} = \frac{0.0130 \text{ mol}}{01.60 \text{ L}}$

$= 8.13 \times 10^{-3}M$

17. mol $CaCl_2$ = (0.10M)(1.0 L) = (0.10 mol/L)(1.0 L)

= 0.10 mol $CaCl_2$

mass $CaCl_2$ = $0.10 \text{ mol } CaCl_2 \times \frac{110.98 \text{ g}}{1 \text{ mol}}$

= 11 g $CaCl_2$

18. mol NaOH = (2M)(1 L) = (2 mol/L)(1 L) = 2 mol

mass NaOH = $2 \text{ mol NaOH} \times \frac{40.00 \text{ g}}{1 \text{ mol}}$

= 80 g NaOH

19. mol $CaCl_2$ = $500.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times 0.20M$

$= 500.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{0.20 \text{ mol}}{1 \text{ L}}$

= 0.10 mol

mass $CaCl_2$ = $0.10 \text{ mol } CaCl_2 \times \frac{110.98 \text{ g}}{1 \text{ mol}}$

= 11 g $CaCl_2$

20. mol NaOH = $250 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times 3.0M$

$= 250 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{3.0 \text{ mol}}{1 \text{ L}}$

= 0.75 mol

mass NaOH = $0.75 \text{ mol NaOH} \times \frac{40.00 \text{ g}}{1 \text{ mol}}$

= 3.0×10^1 g NaOH

21. $(3.00M)V_1 = (1.25M)(0.300 \text{ L})$

$V_1 = \frac{(1.25M)(0.300 \text{ L})}{3.00M} = 0.125 \text{ L} = 125 \text{ mL}$

22. $(5.0M)V_1 = (0.25M)(100.0 \text{ mL})$

$V_1 = \frac{(0.25M)(100.0 \text{ mL})}{5.0M} = 5.0 \text{ mL}$

23. $(3.5M)(20.0 \text{ mL}) = M_2(100.0 \text{ mL})$

$M_2 = \frac{(3.5M)(20.0 \text{ mL})}{100.0 \text{ mL}} = 0.70M$

24. mol Na_2SO_4 = $10.0 \text{ g } Na_2SO_4 \times \frac{1 \text{ mol}}{142.04 \text{ g}}$

= 0.0704 mol Na_2SO_4

$\text{molality} = \frac{0.0704 \text{ mol } Na_2SO_4}{1000.0 \text{ g } H_2O} = 0.0704m$

25. mol $C_{10}H_8$ = $30.0 \text{ g } C_{10}H_8 \times \frac{1 \text{ mol}}{128.16 \text{ g}}$

= 0.234 mol $C_{10}H_8$

$\text{molality} = \frac{0.234 \text{ mol } C_{10}H_8}{500.0 \text{ g toluene}} \times \frac{1000.0 \text{ g toluene}}{1.0000 \text{ kg toluene}}$

$= 0.468m$

26. $22.8\% = \frac{\text{mass NaOH}}{\text{mass NaOH} + \text{mass } H_2O} \times 100$

Assume 100.0 g sample.

Then, mass NaOH = 22.8 g and mass H_2O = 100.0 g − (mass NaOH) = 77.2 g

mol NaOH = $22.8 \text{ g} \times \frac{1 \text{ mol}}{40.00 \text{ g}} = 0.570 \text{ mol NaOH}$

mol H_2O = $77.2 \text{ g} \times \frac{1 \text{ mol}}{18.02 \text{ g}} = 4.28 \text{ mol } H_2O$

mol fraction NaOH = $\frac{\text{mol NaOH}}{\text{mol NaOH} + \text{mol } H_2O}$

$= \frac{0.570 \text{ mol NaOH}}{0.570 \text{ mol NaOH} + 4.28 \text{ mol } H_2O} = \frac{0.570}{4.85}$

= 0.118

The mole fraction of NaOH is 0.118.

27. $0.21 = \frac{\text{mol NaCl}}{\text{mol NaCl} + \text{mol } H_2O}$

$0.21(\text{mol NaCl}) + 0.21(\text{mol } H_2O) = \text{mol NaCl}$

$0.79(\text{mol NaCl}) = 0.21(\text{mol } H_2O)$

$\text{mol } H_2O = 100.0 \text{ mL} \times \frac{1.0 \text{ g}}{1 \text{ mL}} \times \frac{1 \text{ mol}}{18.016 \text{ g}}$

$= 5.55 \text{ mol } H_2O$

Therefore, $\text{mol NaCl} = \frac{0.21 \times 5.55 \text{ mol}}{0.79}$

$= 1.48 \text{ mol}$

$\text{mass NaCl} = 1.48 \text{ mol} \times 58.44 \text{ g/mol} = 86.5 \text{ g}$

The mass of dissolved NaCl is 86.5 g.

33. $\Delta T_b = 0.512°C/m \times 0.625m = 0.320°C$
$T_b = 100°C + 0.320°C = 100.320°C$
$\Delta T_f = 1.86°C/m \times 0.625m = 1.16°C$
$T_f = 0.0°C - 1.16°C = -1.16°C$

34. $\Delta T_b = 1.22°C/m \times 0.40m = 0.49°C$
$T_b = 78.5°C + 0.49°C = 79.0°C$
$\Delta T_f = 1.99°C/m \times 0.40m = 0.80°C$
$T_f = -114.1°C - 0.80°C = -114.9°C$

35. $1.12°C = 0.512°C/m \times m$
$m = 2.19m$

36. $0.500 \text{ mol/1 kg} = 0.500m$
$\Delta T_b = 2.53°C/m \times 0.500m = 1.26°C$

Chapter 16

1. 142 Calories = 142 kcal
$142 \text{ kcal} \times \frac{1000 \text{ cal}}{1 \text{ kcal}} = 142\,000 \text{ cal}$

2. $86.5 \text{ kJ} \times \frac{1 \text{ kcal}}{4.184 \text{ kJ}} = 20.7 \text{ kcal}$

3. $256 \text{ J} \times \frac{1 \text{ cal}}{4.184 \text{ J}} \times \frac{1 \text{ kcal}}{1000 \text{ cal}} = 6.12 \times 10^{-2} \text{ kcal}$

4. $q = c \times m \times \Delta T$
$q = 2.44 \text{ J/(g·°C)} \times 34.4 \text{ g} \times 53.8°C = 4.52 \times 10^3 \text{ J}$

5. $q = c \times m \times \Delta T$
$276 \text{ J} = 0.129 \text{ J/(g·°C)} \times 4.50 \text{ g} \times \Delta T$
$\Delta T = 475°C$

$\Delta T = T_f - T_i$
Because the gold gains heat, let $\Delta T = +475°C$
$475 °C = T_f - 25.0°C$
$T_f = 5.00 \times 10^2 °C$

6. $q = c \times m \times \Delta T$
$5696 \text{ J} = c \times 155 \text{ g} \times 15.0°C$
$c = 2.45 \text{ J/(g · °C)}$
The specific heat is very close to the value for ethanol.

12. $q = c \times m \times \Delta T$
$9750 \text{ J} = 4.184 \text{ J/(g·°C)} \times 335 \text{ g} \times \Delta T$
$\Delta T = 6.96°C$

Because the water lost heat, let $\Delta T = -6.96°C$
$\Delta T = -6.96°C = T_f - 65.5°C$
$T_f = 58.5°C$

13. $q = c \times m \times \Delta T$

$5650 \text{ J} = 4.184 \text{ J/(g·°C)} \times m \times 26.6°C$

$m = 50.8 \text{ g}$

20. $25.7 \text{ g } CH_3OH \times \frac{1 \text{ mol } CH_3OH}{32.04 \text{ g } CH_3OH} \times \frac{3.22 \text{ kJ}}{1 \text{ mol } CH_3OH}$
$= 2.58 \text{ kJ}$

21. $275 \text{ g } NH_3 \times \frac{1 \text{ mol } NH_3}{17.03 \text{ g } NH_3} \times \frac{23.3 \text{ kJ}}{1 \text{ mol } NH_3} = 376 \text{ kJ}$

22. $12\,880 \text{ kJ} = m \times \frac{1 \text{ mol } CH_4}{16.04 \text{ g } CH_4} \times \frac{891 \text{ kJ}}{1 \text{ mol } CH_4}$
$m = 12\,880 \text{ kJ} \times \frac{16.04 \text{ g } CH_4}{1 \text{ mol } CH_4} \times \frac{1 \text{ mol } CH_4}{891 \text{ kJ}}$
$m = 232 \text{ g } CH_4$

28. Add the first equation to the second equation reversed.

$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$	$\Delta H = -566.0 \text{ kJ}$
$2NO(g) \rightarrow N_2(g) + O_2(g)$	$\Delta H = -180.6 \text{ kJ}$
$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N2(g)$	$\Delta H = -746.6 \text{ kJ}$

Solutions

CONTENTS

29. Add the first equation to the second equation reversed and tripled.

$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s) \quad \Delta H = -3352$ kJ
$3MnO_2(s) \rightarrow 3Mn(s) + 3O_2(g) \quad \Delta H = +1563$ kJ

$4Al(s) + 3MnO_2(s) \rightarrow 2Al_2O_3(s) + 3Mn(s) \quad \Delta H = -1789$ kJ

30. a. One mole of $O_2(g)$ in the first equation cancels the $O_2(g)$ in the second equation.

$2[\frac{1}{2} N_2(g) + O_2(g) \rightarrow NO_2(g)]$
$2[NO(g) \rightarrow \frac{1}{2} O_2(g) + \frac{1}{2} N_2(g)]$

$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

b. $H_2(g) + S(s) + 2O_2(g) \rightarrow H_2SO_4(l)$
$SO_3(g) \rightarrow S(s) + \frac{3}{2}O_2(g)$
$H_2O(l) \rightarrow H_2(g) + \frac{1}{2}O_2(g)$

$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(l)$

31. a. $\Delta H^\circ_{rxn} = \Sigma \Delta H_f^\circ$ (products) $- \Sigma \Delta H_f^\circ$ (reactants)
$\Delta H^\circ_{rxn} = (-635.1 \text{ kJ} - 393.509 \text{ kJ}) - (-1206.9 \text{ kJ})$
$= 178.3$ kJ

b. $\Delta H^\circ_{rxn} = (-128.2 \text{ kJ}) - (-74.81 \text{ kJ}) = -53.4$ kJ

c. $\Delta H^\circ_{rxn} = 2(33.18 \text{ kJ}) - (0 \text{ kJ}) = 66$ kJ

d. $\Delta H^\circ_{rxn} = 2(-285.830 \text{ kJ}) - 2(-187.8 \text{ kJ}) = -196.1$ kJ

e. $\Delta H^\circ_{rxn} = [4(33.18 \text{ kJ}) + 6(-285.830 \text{ kJ})] - 4(-46.11) \text{ kJ} = -1397.82$ kJ

38. a. ΔS_{system} is negative because the system's entropy decreases.

b. ΔS_{system} is negative because the system's entropy decreases.

c. ΔS_{system} is positive because the system's entropy increases.

d. ΔS_{system} is negative because the system's entropy decreases.

39. a. $\Delta G_{system} = \Delta H_{system} - T\Delta S_{system}$
$\Delta G_{system} = -75\,900 \text{ J} - (273 \text{ K})(138 \text{ J/K})$
$\Delta G_{system} = -75\,900 \text{ J} - 37\,700 \text{ J} = -113\,600 \text{ J}$
spontaneous reaction

b. $\Delta G_{system} = \Delta H_{system} - T\Delta S_{system}$
$\Delta G_{system} = -27\,600 \text{ J} - (535 \text{ K})(-55.2 \text{ J/K})$
$\Delta G_{system} = -27\,600 \text{ J} + 29\,500 \text{ J} = 1900 \text{ J}$
nonspontaneous reaction

c. $\Delta G_{system} = \Delta H_{system} - T\Delta S_{system}$
$\Delta G_{system} = 365\,000 \text{ J} - (388 \text{ K})(-55.2 \text{ J/K})$
$\Delta G_{system} = 365\,000 \text{ J} + 21\,400 \text{ J} = 386\,000 \text{ J}$
nonspontaneous reaction

Chapter 17

1. Average reaction rate =

$$-\frac{[H_2] \text{ at time } t_2 - [H_2] \text{ at time } t_1}{t_2 - t_1} = -\frac{\Delta[H_2]}{\Delta t}$$

$$\text{Average reaction rate} = -\frac{0.020M - 0.030M}{4.00 \text{ s} - 0.00 \text{ s}}$$

$$= -\frac{-0.010M}{4.00 \text{ s}} = 0.0025 \text{ mol/(L·s)}$$

2. Average reaction rate =

$$-\frac{[Cl_2] \text{ at time } t_2 - [Cl_2] \text{ at time } t_1}{t_2 - t_1} = -\frac{\Delta[Cl_2]}{\Delta t}$$

$$\text{Average reaction rate} = -\frac{0.040M - 0.050M}{4.00 \text{ s} - 0.00 \text{ s}}$$

$$= -\frac{-0.010M}{4.00 \text{ s}} = 0.0025 \text{ mol/(L·s)}$$

3. Average reaction rate =

$$\frac{[HCl] \text{ at time } t_2 - [HCl] \text{ at time } t_1}{t_2 - t_1} = \frac{\Delta[HCl]}{\Delta t}$$

$$\text{Average reaction rate} = \frac{0.020M - 0.000M}{4.00 \text{ s} - 0.00 \text{ s}}$$

$$= \frac{0.020M}{4.00 \text{ s}} = 0.0050 \text{ mol/(L·s)}$$

16. Rate $= k[A]^3$

17. Examining trials 1 and 2, doubling [A] has no effect on the rate; therefore, the reaction is zero order in A. Examining trials 2 and 3, doubling [B] doubles the rate; therefore, the reaction is first order in B. Rate $= k[A]^0[B] = k[B]$

18. Examining trials 1 and 2, doubling $[CH_3CHO]$ increases the rate by a factor of four. Examining trials 2 and 3, doubling $[CH_3CHO]$ again increases the rate by a factor of four. Therefore, the reaction is second order in CH_3CHO.
Rate $= k[CH_3CHO]^2$

24. $[NO] = 0.00500M$
$[H_2] = 0.00200M$
$k = 2.90 \times 10^2 \text{ L}^2/(\text{mol}^2\text{·s})$

Rate $= k\,[NO]^2[H_2]$
$= [2.90 \times 10^2 \text{ L}^2/(\text{mol}^2\text{·s})](0.00500M)^2 (0.00200M)$
$= [2.90 \times 10^2 \cancel{\text{L}^2}/(\cancel{\text{mol}^2}\text{·s})](0.00500 \cancel{\text{mol}/\text{L}})^2 (0.00200 \text{ mol/L})$
$= 1.45 \times 10^{-5}$ mol/(L·s)

Solutions

25. $[NO] = 0.0100M$

$[H_2] = 0.00125M$

$k = 2.90 \times 10^2\ L^2/(mol^2{\cdot}s)$

$$\text{Rate} = k\,[NO]^2[H_2]$$

$$= [2.90 \times 10^2\ L^2/(mol^2{\cdot}s)]\,(0.0100M)^2(0.00125M)$$

$$= [2.90 \times 10^2\ \cancel{L^2}/(\cancel{mol^2}{\cdot}s)]\,(0.0100\ \cancel{mol/L})^2\,(0.00125\ mol/L)$$

$$= 3.63 \times 10^{-5}\ mol/(L{\cdot}s)$$

26. $[NO] = 0.00446M$

$[H_2] = 0.00282M$

$k = 2.90 \times 10^2\ L^2/(mol^2{\cdot}s)$

$$\text{Rate} = k\,[NO]^2[H_2]$$

$$= [2.90 \times 10^2\ L^2/(mol^2{\cdot}s)](0.00446M)^2(0.00282M)$$

$$= [2.90 \times 10^2\ \cancel{L^2}/(\cancel{mol^2}{\cdot}s)](0.00446\ \cancel{mol/L})^2\,(0.00282mol/L)$$

$$\text{Rate} = 1.63 \times 10^{-5}\ mol/(L{\cdot}s)$$

Chapter 18

1. a. $K_{eq} = \dfrac{[NO_2]^2}{[N_2O_4]}$

b. $K_{eq} = \dfrac{[CH_4][H_2O]}{[CO][H_2]^3}$

c. $K_{eq} = \dfrac{[H_2]^2[S_2]}{[H_2S]^2}$

2. a. $K_{eq} = [C_{10}H_8(g)]$

b. $K_{eq} = [CO_2(g)]$

c. $K_{eq} = [H_2O(g)]$

d. $K_{eq} = \dfrac{[H_2(g)][CO(g)]}{[H_2O(g)]}$

e. $K_{eq} = \dfrac{[CO_2(g)]}{[CO(g)]}$

3. $K_{eq} = \dfrac{[NO_2]^2}{[N_2O_4]} = \dfrac{(0.0627)^2}{(0.0185)} = 0.213$

4. $K_{eq} = \dfrac{[CH_4][O_2H]}{[CO][H_2]^3} = \dfrac{(0.0387)(0.0387)}{(0.0613)(0.1839)^3} = 3.93$

16. a. $K_{eq} = \dfrac{[CH_3OH]}{[CO][H_2]^2}$

$$10.5 = \frac{(1.32)}{[CO](0.933)^2}$$

$[CO] = 0.144M$

b. $K_{eq} = \dfrac{[CH_3OH]}{[CO][H_2]^2}$

$$10.5 = \frac{(0.325)}{(1.09)[H_2]^2}$$

$[H_2] = 0.169M$

c. $K_{eq} = \dfrac{[CH_3OH]}{[CO][H_2]^2}$

$$10.5 = \frac{[CH_3OH]}{(3.85)(0.0661)^2}$$

$[CH_3OH] = 0.177M$

17. a. $PbCrO_4(s) \rightleftharpoons Pb^{2+}(aq) + CrO_4^{2-}(aq)$

s mol/L dissolves — *s* mol/L — *s* mol/L

$K_{sp} = [Pb^{2+}][CrO_4^{2-}]$

$2.3 \times 10^{-13} = (s)(s) = s^2$

$s = \sqrt{2.3 \times 10^{-13}} = 4.8 \times 10^{-7}M$

b. $AgCl(s) \rightleftharpoons Ag^{+}(aq) + Cl^{-}(aq)$

s mol/L dissolves — *s* mol/L — *s* mol/L

$K_{sp} = [Ag^+][Cl^-]$

$1.8 \times 10^{-10} = (s)(s) = s^2$

$s = \sqrt{1.8 \times 10^{-10}} = 1.3 \times 10^{-5}M$

c. $CaCO_3(s) \rightleftharpoons Ca^{2+}(aq) + CO_3^{2-}(aq)$

s mol/L dissolves — *s* mol/L — *s* mol/L

$K_{sp} = [Ca^{2+}][CO_3^{2-}]$

$3.4 \times 10^{-9} = (s)(s) = s^2$

$s = \sqrt{3.4 \times 10^{-9}} = 5.8 \times 10^{-5}M$

d. $CaSO_4(s) \rightleftharpoons Ca^{2+}(aq) + SO_4^{2-}(aq)$

s mol/L dissolves — *s* mol/L — *s* mol/L

$K_{sp} = [Ca^{2+}][SO_4^{2-}]$

$4.9 \times 10^{-5} = (s)(s) = s^2$

$s = \sqrt{4.9 \times 10^{-5}} = 7.0 \times 10^{-3}M$

18. a. $AgBr(s) \rightleftharpoons Ag^{+}(aq) + Br^{-}(aq)$

s mol/L dissolves — *s* mol/L — *s* mol/L

$K_{sp} = [Ag^+][Br^-]$

$5.4 \times 10^{-13} = (s)(s) = s^2$

$s = \sqrt{5.4 \times 10^{-13}} = 7.3 \times 10^{-7}M = [Ag^+]$

b. $CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2F^{-}(aq)$

s mol/L dissolves — *s* mol/L — 2*s* mol/L

$[CaF_2] = \frac{1}{2}[F^-]$

$K_{sp} = [Ca^{2+}][F^-]^2$

$3.5 \times 10^{-11} = (s)(2s)^2 = 4s^3$

$s = \sqrt[3]{\dfrac{3.5 \times 10^{-11}}{4}} = 2.1 \times 10^{-4}M$

$\frac{1}{2}[F^-] = 2.1 \times 10^{-4}M$

$[F^-] = 4.2 \times 10^{-4}M$

c. $Ag_2CrO_4(s) \rightleftharpoons 2Ag^+(aq) + CrO_4^{2-}(aq)$
s mol/L dissolves   2*s* mol/L   *s* mol/L

$[Ag_2CrO_4] = \frac{1}{2}[Ag^+]$

$K_{sp} = [Ag^+]^2[CrO_4^{2-}]$

$1.1 \times 10^{-12} = (2s)^2(s) = 4s^3$

$s = \sqrt[3]{\frac{1.1 \times 10^{-12}}{4}} = 6.5 \times 10^{-5}M$

$\frac{1}{2}[Ag^+] = 6.5 \times 10^{-5}M$

$[Ag^+] = 1.3 \times 10^{-4}M$

d. $PbI_2(s) \rightleftharpoons Pb^{2+}(aq) + 2I^-(aq)$
s mol/L dissolves   *s* mol/L   2*s* mol/L

$K_{sp} = [Pb^{2+}][I^-]^2$

$9.8 \times 10^{-9} = (s)(2s)^2 = 4s^3$

$s = \sqrt[3]{\frac{9.8 \times 10^{-9}}{4}} = 1.3 \times 10^{-3}M$

19. a. $PbF_2(s) \rightleftharpoons Pb^{2+}(aq) + 2F^-(aq)$

$Q_{sp} = [Pb^{2+}][F^-]^2 = (0.050M)(0.015M)^2$
$= 1.12 \times 10^{-5}$

$K_{sp} = 3.3 \times 10^{-8}$

$Q_{sp} > K_{sp}$ so a precipitate will form.

b. $Ag_2SO_4(s) \rightleftharpoons 2Ag^+(aq) + SO_4^{2-}(aq)$

$Q_{sp} = [Ag^+]^2[SO_4^{2-}] = (0.0050M)^2(0.125M)$
$= 3.1 \times 10^{-6}$

$K_{sp} = 1.2 \times 10^{-5}$

$Q_{sp} < K_{sp}$ so no precipitate will form.

c. $Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$

$Q_{sp} = [Mg^{2+}][OH^-]^2 = (0.10M)(0.00125M)^2$
$= 1.56 \times 10^{-7}$

$K_{sp} = 5.6 \times 10^{-12}$

$Q_{sp} > K_{sp}$ so a precipitate will form.

Chapter 19

1. a. $Mg(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2(g)$
b. $2Al(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + 3H_2(g)$
c. $CaCO_3(s) + 2HBr(aq) \rightarrow CaBr_2(aq) + H_2O(l) + CO_2(g)$
d. $KHCO_3(s) + HCl(aq) \rightarrow KCl(aq) + H_2O(l) + CO_2(g)$

2.

Acid	Conjugate base	Base	Conjugate acid
a. NH_4^+	NH_3	OH^-	H_2O
b. HBr	Br^-	H_2O	H_3O^+
c. H_2O	OH^-	CO_3^{2-}	HCO_3^-
d. HSO_4^-	SO_4^{2-}	H_2O	H_3O^+

3. a. $H_2Se(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HSe^-(aq)$
$HSe^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + Se^{2-}(aq)$

b. $H_3AsO_4(aq) + H_2O(l) \quad H_3O^+(aq) + H_2AsO_4^-(aq)$

$H_2AsO_4^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HAsO_4^{2-}(aq)$

$HAsO_4^{2-}(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + AsO_4^{3-}(aq)$

c. $H_2SO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HSO_3^-(aq)$
$HSO_3^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + SO_3^{2-}(aq)$

10. a. $HClO_2(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + ClO_2-(aq)$

$K_a = \frac{[H_3O^+][ClO_2^-]}{[HClO_2]}$

b. $HNO_2(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + NO_2^-(aq)$

$K_a = \frac{[H_3O^+][NO_2^-]}{[HNO_2]}$

c. $HIO_2(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + IO^-(aq)$

$K_a = \frac{[H_3O^+][IO^-]}{[HIO]}$

11. a. $C_6H_{13}NH_2(aq) + H_2O(l) \rightleftharpoons C_6H_{13}NH_3^+(aq) + OH^-(aq)$

$K_b = \frac{[C_6H_{13}NH_3^+][OH^-]}{[C_6H_{13}NH_2]}$

b. $C_3H_7NH_2(aq) + H_2O(l) \rightleftharpoons C_3H_7NH_3+(aq) + OH^-(aq)$

$K_b = \frac{[C_3H_7NH_3^+][OH^-]}{[C_3H_7NH_2]}$

c. $CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + OH^-(aq)$

$K_b = \frac{[HCO_3^-][OH^-]}{[CO_3^{2-}]}$

d. $HSO_3^-(aq) + H_2O(l) \rightleftharpoons H_2SO_3(aq) + OH^-(aq)$

Solutions

$$K_b = \frac{[H_2SO_3^-][OH^-]}{[HSO_3^-]}$$

18. a. $[H^+] = 1.0 \times 10^{-13}M$

$K_w = [H^+][OH^-]$

$1.0 \times 10^{-14} = (1.0 \times 10^{-13})[OH^-]$

$$\frac{1.0 \times 10^{-14}}{1.0 \times 10^{-13}} = \frac{(1.0 \times 10^{-13})[OH^-]}{1.0 \times 10^{-13}}$$

$[OH^-] = 1.0 \times 10^{-1}M$

$[OH^-] > [H^+]$, so the solution is basic.

b. $[OH^-] = 1.0 \times 10^{-7}M$

$K_w = [H^+][OH^-]$

$1.0 \times 10^{-14} = [H^+](1.0 \times 10^{-7})$

$$\frac{1.0 \times 10^{-14}}{1.0 \times 10^{-7}} = \frac{[H^+](1.0 \times 10^{-7})}{1.0 \times 10^{-7}}$$

$[H^+] = 1.0 \times 10^{-7}M$

$[OH^-] = [H^+]$, so the solution is neutral.

c. $[OH^-] = 1.0 \times 10^{-3}M$

$K_w = [H+][OH^-]$

$1.0 \times 10^{-14} = [H^+](1.0 \times 10^{-3})$

$$\frac{1.0 \times 10^{-14}}{1.0 \times 10^{-3}} = \frac{[H^+](1.0 \times 10^{-3})}{1.0 \times 10^{-3}}$$

$[H^+] = 1.0 \times 10^{-11}M$

$[OH^-] > [H^+]$, so the solution is basic.

19. a. $pH = -\log(1.0 \times 10^{-2}) = -(-2.00) = 2.00$

b. $pH = -\log(3.0 \times 10^{-6}) = -(-5.52) = 5.52$

c. $K_w = [H^+][OH^-] = [H^+](8.2 \times 10^{-6})$

$$[H^+] = \frac{1.0 \times 10^{-14}}{8.2 \times 10^{-6}} = 1.2 \times 10^{-9}$$

$pH = -\log(1.2 \times 10^{-9}) = -(-8.92) = 8.92$

20. a. $pOH = -\log(1.0 \times 10^{-6}) = -(-6.00) = 6.00$
$pH = 14.00 - pOH = 14.00 - 6.00 = 8.00$

b. $pOH = -\log(6.5 \times 10^{-4}) = -(-3.19) = 3.19$
$pH = 14.00 - pOH = 14.00 - 3.19 = 10.81$

c. $pH = -\log(3.6 \times 10^{-9}) = -(-8.44) = 8.44$
$pOH = 14.00 - pH = 14.00 - 8.44 = 5.56$

d. $pH = -\log(0.025) = -(-1.60) = 1.60$
$pOH = 14.00 - pH = 14.00 - 1.60 = 12.40$

21. a. $[H^+] = \text{antilog}(-2.37) = 4.3 \times 10^{-3}M$
$pOH = 14.00 - pH = 14.00 - 2.37 = 11.63$
$[OH^-] = \text{antilog}(-11.63) = 2.3 \times 10^{-12}M$

b. $[H^+] = \text{antilog}(-11.05) = 8.9 \times 10^{-12}M$
$pOH = 14.00 - pH = 14.00 - 11.05 = 2.95$
$[OH^-] = \text{antilog}(-2.95) = 1.1 \times 10^{-3}M$

c. $[H^+] = \text{antilog}(-6.50) = 3.2 \times 10^{-7}M$
$pOH = 14.00 - pH = 14.00 - 6.50 = 7.50$

$[OH^-] = \text{antilog}(-7.50) = 3.2 \times 10^{-8}M$

22. a. $$[H^+] = [HI] \times \frac{1 \text{ mol } H^+}{1 \text{ mol HI}} = 1.0M$$

$pH = -\log(1.0) = 0.00$

b. $$[H^+] = [HNO_3] \times \frac{1 \text{ mol } H^+}{1 \text{ mol } HNO_3} = 0.050M$$

$pH = -\log(0.050) = 1.30$

c. $$[OH^-] = [KOH] \times \frac{1 \text{ mol } OH^-}{1 \text{ mol KOH}} = 1.0M$$

$pOH = -\log(1.0) = 0.00$

$pH = 14.00 - 0.00 = 14.00$

d. $$[OH^-] = [Mg(OH)_2] \times \frac{2 \text{ mol } OH^-}{1 \text{ mol } Mg(OH)_2}$$

$= 4.8 \times 10^{-5}M$

$pOH = -\log(4.8 \times 10^{-5}) = 4.32$

$pH = 14.00 - 4.32 = 9.68$

23. a. $$K_a = \frac{[H^+][H_2AsO_4]}{[H_3AsO_4]}$$

$[H^+] = \text{antilog}(-1.50) = 3.2 \times 10^{-2}M$

$[H_3AsO_4] = [H^+] = 3.2 \times 10^{-2}M$

$[H_3AsO_4] = 0.220M - 3.2 \times 10^{-2}M = 0.188M$

$$K_a = \frac{(3.2 \times 10^{-2})(3.2 \times 10^{-2})}{0.188}$$

$= 5.4 \times 10^{-3}$

b. $$K_a = \frac{[H^+][ClO_2^-]}{[HClO_2]}$$

$[H^+] = \text{antilog}(-1.80) = 1.6 \times 10^{-2}M$

$[ClO_2] = [H^+] = 1.6 \times 10^{-2}M$

$[HClO_2] = 0.0.0400M - 1.6 \times 10^{-2}M$
$= 0.024M$

$$K_a = \frac{(1.6 \times 10^{-2})(1.6 \times 10^{-2})}{0.024}$$

$= 1.1 \times 10^{-2}$

29. a. $HNO_3(aq) + CsOH(aq) \rightarrow CsNO_3(aq) + H_2O(l)$
b. $2HBr(aq) + Ca(OH)_2(aq) \rightarrow CaBr_2(aq) + 2H_2O(l)$
c. $H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$
d. $CH_3COOH(aq) + NH_4OH(aq) \rightarrow$
$CH_3COONH_4(aq) + H_2O(l)$

30. $26.4\ \cancel{\text{mL}}\ \text{HBr} \times \frac{1\ \cancel{\text{L}}}{1000\ \cancel{\text{mL}}} \times \frac{0.250\ \text{mol HBr}}{1\ \cancel{\text{L}}\ \text{HBr}}$

$= 6.60 \times 10^{-3}$ mol HBr

$6.60 \times 10^{-3}\ \cancel{\text{mol HBr}} \times \frac{1\ \text{mol CsOH}}{1\ \cancel{\text{mol HBr}}}$

$= 6.60 \times 10^{-3}$ mol CsOH

$M_{\text{CsOH}} = \frac{6.60 \times 10^{-3}\ \text{mol CsOH}}{0.0300\ \text{L CsOH}} = 0.220M$

31. $43.33\ \cancel{\text{mL}}\ \text{KOH} \times \frac{1\ \cancel{\text{L}}}{1000\ \cancel{\text{mL}}} \times \frac{0.1000\ \text{mol KOH}}{1\ \cancel{\text{L}}\ \text{KOH}}$

$= 4.333 \times 10^{-3}$ mol KOH

$4.333 \times 10^{-3}\ \cancel{\text{mol}}\ \text{KOH} \times \frac{1\ \text{mol HNO}_3}{1\ \cancel{\text{mol}}\ \text{KOH}}$

$= 4.333 \times 10^{-3}$ mol HNO_3

$M_{\text{HNO}_3} = \frac{4.333 \times 10^{-3}\ \text{mol HNO}_3}{0.02000\ \text{L HNO}_3} = 0.2167M$

32. $49.90\ \cancel{\text{mL}}\ \text{HCl} \times \frac{1\ \cancel{\text{L}}}{1000\ \cancel{\text{mL}}} \times \frac{0.5900\ \text{mol HCl}}{1\ \cancel{\text{L}}\ \text{HCl}}$

$= 2.944 \times 10^{-2}$ mol HCl

$2.944 \times 10^{-2}\ \cancel{\text{mol}}\ \text{HCl} \times \frac{1\ \text{mol NH}_3}{1\ \cancel{\text{mol}}\ \text{HCl}}$

$= 2.944 \times 10^{-2}$ mol NH_3

$M_{\text{NH3}} = \frac{2.944 \times 10^{-2}\ \text{mol NH}_3}{0.02500\ \text{L NH}_3} = 1.178M$

33. a. $NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$
The solution is acidic.

b. $CH_3COO^-(aq) + H_2O(l) \rightleftharpoons CH_3COOH(aq) + OH^-(aq)$
The solution is basic.

c. $SO_4^{2-}(aq) + H_2O(l) \rightleftharpoons HSO_4^-(aq) + OH^-(aq)$
The solution is neutral.

d. $CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + OH^-(aq)$
The solution is basic.

Chapter 20

1. a. reduction
b. oxidation
c. oxidation
d. reduction

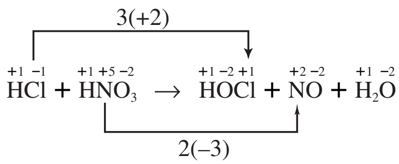
2. a. oxidized: bromide ion
reduced: chlorine
b. oxidized: cerium
reduced: copper(II) ion
c. oxidized: zinc
reduced: oxygen

3. a. oxidizing agent: iodine
reducing agent: magnesium
b. oxidizing agent: hydrogen ion
reducing agent: sodium
c. oxidizing agent: chlorine
reducing agent: hydrogen sulfide

4. a. +7
b. +5
c. +3

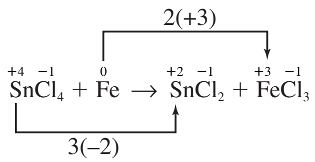
5. a. −3
b. +5
c. +6

12.



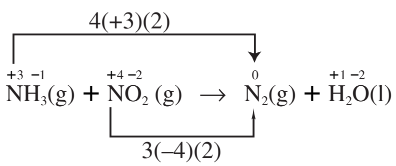
$3HCl + 2HNO_3 \rightarrow 3HOCl + 2NO + H_2O$

13.



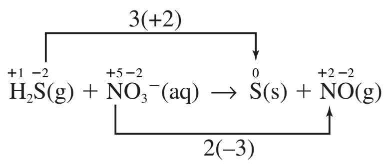
$3SnCl_4 + 2Fe \rightarrow 3SnCl_2 + 2FeCl_3$

14.



$8NH_3(g) + 6NO_2(g) \rightarrow 7N_2(g) + 12H_2O(l)$

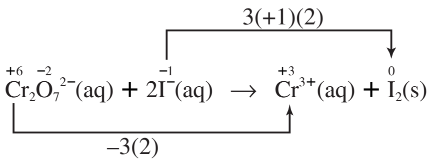
15.



$2H^+(aq) + 3H_2S(g) + 2NO_3^-(aq) \rightarrow 3S(s) + 2NO(g) + 4H_2O(l)$

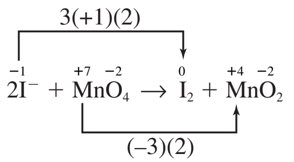
Solutions

16.



$14H^+(aq) + Cr_2O_7^{2-}(aq) + 6I^-(aq) \rightarrow$
$2Cr^{3+}(aq) + 3I_2(s) + 7H_2O(l)$

17.



$6I^-(aq) + 2MnO_4^-(aq) + 4H_2O(l) \rightarrow$
$3I_2(s) + 2MnO_2(s) + 8OH^-(aq)$

24. $2I^-(aq) \rightarrow I_2(s) + 2e^-$ (oxidation)

$14H^+(aq) + 6e^- + Cr_2O7_2^-(aq) \rightarrow$
$2Cr_3^+(aq) + 7H_2O(l)$ (reduction)

Multiply oxidation half-reaction by 3 and add to reduction half-reaction

$14H^+(aq) + 6e^- + Cr_2O_7^{2-}(aq) + 6I^-(aq) \rightarrow$
$3I_2(s) + 2Cr^{3+}(aq) + 7H_2O(l) + 6e^-$

$14H^+(aq) + Cr_2O_7^{2-}(aq) + 6I^-(aq) \rightarrow$
$3I_2(s) + 2Cr^{3+}(aq) + 7H_2O(l)$

25. $Mn^{2+}(aq) + 4H_2O(l) \rightarrow$
$MnO_4^-(aq) + 5e^- + 8H^+(aq)$ (oxidation)

$BiO_3^-(aq) + 3e^- + 6H^+(aq) \rightarrow$
$Bi^{2+}(aq) + 3H_2O(l)$ (reduction)

Multiply oxidation half-reaction. Multiply reduction half-reaction by 5 and add to oxidation half-reaction.

$3Mn^2+(aq) + 12H_2O(l) + 5BiO_3^-(aq) + 15e^- +$
$30H^+(aq) \rightarrow 3MnO_4^-(aq) + 15e^- + 24H^+(aq) +$
$5Bi^{2+}(aq) + 15H_2O(l)$

$3Mn^{2+}(aq) + 5BiO_3^-(aq) + 6H^+(aq) \rightarrow$
$3MnO_4^-(aq) + 5Bi^{2+}(aq) + 3H_2O(l)$

26. $6OH^-(aq) + N_2O(g) \rightarrow 2NO_2^-(aq) + 4e^- + 3H_2O(l)$
(oxidation)

$ClO^-(aq) + 2e^- + H_2O(l) \rightarrow Cl^-(aq) + 2OH^-(aq)$
(reduction)

Multiply reduction half-reaction by 2 and add to oxidation half-reaction.

$6OH^-(aq) + N_2O(g) + 2ClO^-(aq) + 4e^- + 2H_2O(l)$
$\rightarrow 2NO_2^-(aq) + 4e^- + 3H_2O(l) + 2Cl^-(aq) +$
$4OH^-(aq)$

$N_2O(g) + 2ClO^-(aq) + 2OH^-(aq) \rightarrow 2NO_2^-(aq) +$
$2Cl^-(aq) + H_2O(l)$

Chapter 21

1. $Pt^{2+}(aq) + Sn(s) \rightarrow Pt(s) + Sn^{2+}(aq)$
$E^0_{cell} = 1.18\ V - (-0.1375\ V)$
$E^0_{cell} = 1.32\ V$
$Sn|Sn^{2+}||Pt^{2+}|Pt$

2. $3Co^{2+}(aq) + 2Cr(s) \rightarrow 3Co(s) + 2Cr^{3+}(aq)$
$E^0_{cell} = (-0.28\ V) - (-0.744\ V)$
$E^0_{cell} = 0.46\ V$
$Cr|Cr^{3+}||Co^{2+}|Co$

3. $Hg^{2+}(aq) + Cr(s) \rightarrow Hg(l) + Cr^{2+}(aq)$
$E^0_{cell} = 0.851\ V - (-0.913\ V)$
$E^0_{cell} = 1.764\ V$
$Cr|Cr^{2+}||Hg^{2+}|Hg$

4. $E^0_{cell} = (0.521\ V) - (-0.1375\ V)$
$E^0_{cell} = 0.659\ V$
$E^0_{cell} > 0$ spontaneous

5. $E^0_{cell} = (-0.1262\ V) - (-2.372\ V)$
$E^0_{cell} = 2.246\ V$
$E^0_{cell} > 0$ spontaneous

6. $E^0_{cell} = (0.920\ V) - (1.507\ V)$
$E^0_{cell} = -0.587\ V$
$E^0_{cell} < 0$ not spontaneous

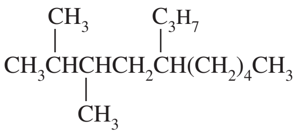
7. $E^0_{cell} = (-0.28\ V) - 2.010\ V$
$E^0_{cell} = -2.29\ V$
$E^0_{cell} < 0$ not spontaneous

Solutions

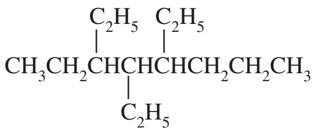
Chapter 22

1. a. 2,4-dimethylhexane
b. 2,4,7-trimethylnonane
c. 2,2,4-trimethylpentane

2. a.

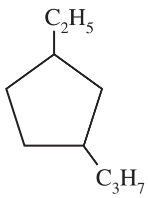


b.

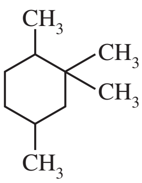


10. a. methylcyclopentane
b. 2-ethyl-1,4-dimethylcyclohexane
c. 1,3-diethylcyclobutane

11. a.



b.



18. a. 4-methyl-2-pentene
b. 2,2,6-trimethyl-3-octene

19. $CH_2{=}CHC{=}CHCH_3$

Chapter 23

1. 2,3-difluorobutane

2. 1-bromo-5-chloropentane

3. 1,3-dibromo-2-chlorobenzene

Chapter 24

No practice problems

Chapter 25

6. ${}^{15}_{8}O \rightarrow {}^{0}_{1}\beta + {}^{15}_{7}N$

7. ${}^{231}_{90}Th \rightarrow {}^{231}_{91}Pa + {}^{0}_{-1}\beta$, beta decay

8. ${}^{97}_{40}Zr \rightarrow {}^{0}_{-1}\beta + {}^{97}_{41}Nb$

9. a. ${}^{142}_{61}Pm + {}^{0}_{-1}e \rightarrow {}^{142}_{60}Nd$

b. ${}^{218}_{84}Po \rightarrow {}^{4}_{2}He + {}^{214}_{82}Pb$

c. ${}^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$

15. ${}^{27}_{13}Al + {}^{1}_{0}n \rightarrow {}^{24}_{11}Na + {}^{4}_{2}He$

16. ${}^{239}_{94}Pu + {}^{4}_{2}He \rightarrow {}^{242}_{96}Cm + {}^{1}_{0}n$

17. amount remaining $= (10.0 \text{ mg})\left(\frac{1}{2}\right)^{n}$

For $n = 1$, amount remaining $= (10.0 \text{ mg})\left(\frac{1}{2}\right)^{1}$ $= 5.00$ mg

For $n = 2$, amount remaining $= (10.0 \text{ mg})\left(\frac{1}{2}\right)^{2}$ $= 2.50$ mg

For $n = 3$, amount remaining $= (10.0 \text{ mg})\left(\frac{1}{2}\right)^{3}$ $= 1.25$ mg

18. amount remaining $= 25.0$ mg

$= (\text{initial amount})\left(\frac{1}{2}\right)^{5}$

initial amount $= (25.0 \text{ mg})(2)^5 = 8.00 \times 10^2$ mg

19. half-life $= 163.7\ \mu s$

$n = (818\ \mu s) \times \frac{1 \text{ half-life}}{163.7\ \mu s} = 5.00$ half-lives

amount remaining $= (1.0 \text{ g})\left(\frac{1}{2}\right)^{5.00} = 0.031$ g

Chapter 26

No practice problems

Solutions