Chapter 3 The Mole — The Central Unit of Chemistry

3.1 Relative Atomic Mass

Warm Up, p. 108

1. dozen, litres, kilograms
2. b. volume
   c. mass

Quick Check, p. 108

1. One object's mass relative to another's
2. You must have the same number of candies in each bag.

Practice Problems — Determining Relative Atomic Mass, p. 110

1. $\frac{276\text{ g}}{26.4\text{ g}} = 10.5$
   The mass of an AA battery is 10.5 times the mass of a watch battery.

2. $\frac{2.683\text{ g Sr}}{0.490\text{ g O}} = 5.48$
   A strontium atom weighs 5.48 times as much as an oxygen atom.

3. a. 4.218 g DBr 0.337 g D = 3.881 g Br
   $\frac{0.337\text{ g D}}{3.881\text{ g Br}} \times 79.9\text{ u} = 6.94\text{ u}$

   b. Daltonium represents lithium.

Practice Problems — Determining Relative Atomic Mass (Non 1:1 Formulas), p. 111

1. $3 \times \frac{1.000\text{ g Al}}{14.100\text{ g I}} \times 126.9\text{ u} = 27.00\text{ u}$

2. $1.5 \times \frac{1.000\text{ g Al}}{14.100\text{ g I}} \times 126.9\text{ u} = 13.5\text{ u}$

3.1 Activity: The Relative Mass of Paper Clips, p. 112

For example:

Objects	Mass (g)
Small paper clips	5.6
Coupled paper clips	20.0
Large paper clips	14.4

1. $\dfrac{\text{Mass of some number of large paper clips}}{\text{Mass of the same number of small paper clips}} = \dfrac{14.4\ \text{g}}{5.6\ \text{g}} = 2.57$

   The mass of a large paper clip is 2.57 times the mass of a small paper clip.

4. 1.00 smu × 2.57 = 2.57 smu

7. All the paper clips of the same type may not weigh exactly the same.

3.1 Review Questions, p. 113

1. a. $\dfrac{2245\ \text{g}}{825\ \text{g}} = 2.72$ 2.72 × 1.00 mmu = 2.72 mmu

   b. The mass ratio of any equal number of identical items is the same.

2. a. 5.000 g NaCl – 1.965 g Na = 3.035 g Cl

   $\dfrac{1.965\ \text{g Na}}{3.035\ \text{g Cl}} = 0.6474$

   b. 0.6474 × 35.5 u = 23.0 u

3. a. 10.000 g ZuF – 8.503 g Zu = 1.497 g F

   $\dfrac{8.503\ \text{g Zu}}{1.497\ \text{g F}} \times 19.0\ \text{u} = 108\ \text{u}$

   b. silver

4. a. $\dfrac{2.037\ \text{g Zn}}{1.000\ \text{g S}} \times 32.1\ \text{u} = 65.4\ \text{u}$

   b. $2 \times \dfrac{2.037\ \text{g Zn}}{1.000\ \text{g S}} \times 32.1\ \text{u} = 130\ \text{u}$

   c. $0.667 \times \dfrac{2.037\ \text{g Zn}}{1.000\ \text{g S}} \times 32.1\ \text{u} = 43.8\ \text{u}$

5. a. $\frac{13.073 \text{ g Cu}}{1.647 \text{ g O}} \times 16.0 \text{ u} = 127 \text{ u}$

   b. $0.50 \times \frac{13.073 \text{ g Cu}}{1.647 \text{ g O}} \times 16.0 \text{ u} = 63.5 \text{ u}$

   c. $2.00 \times \frac{13.073 \text{ g Cu}}{1.647 \text{ g O}} \times 16.0 \text{ u} = 254 \text{ u}$

6. a. $\frac{25.0}{0.3864} = 64.7$

   b. 63.5 u Cu_2O

7. Al $\frac{25.0}{0.903} = 27.7$ (3% error)

   Mg $\frac{25.0}{1.05} = 23.8$ (–2% error)

   Ag $\frac{25.0}{0.23772} = 105$ (–3% error)

8.

Element	Mass of Gas (g)	Relative Atomic Mass (u)
H	0.210	1.0
Cl	7.455	**35.5**

9. A potassium atom weighs 39.1 times as much as a hydrogen atom.

10. a. 31.0 u
    b. 40.1 u
    c. 238 u

11. a. $\frac{628.2 \text{ g}}{213.1 \text{ g}} = 2.948$
    The mass of a knife is 2.948 times the mass of a fork.
    b. If eight knives weigh 2.948 times as much as eight forks then one knife will weigh 2.948 times as much as one fork.
    c. The average mass of a knife is 2.948 times the average mass of a fork.

12. For example: Weigh a pile containing one 10 g coin and two 20 g coins. If the pile weighs:
    49 g then the 10 g coin is actually 9 g
    48 g then the 20 g coin is actually 19 g
    50 g then the 30 g coin is actually 29 g

3.2 Introducing the Mole — The Central Unit of Chemistry

Warm Up, p. 115

1. the number of slurps per gulp
2. $15 \text{ gulps} \times \frac{4 \text{ slurps}}{1 \text{ gulp}} = 60 \text{ slurps}$
3. $20 \text{ slurps} \times \frac{1 \text{ gulp}}{5 \text{ slurps}} = 4 \text{ gulps}$

Quick Check, p. 116

1. a. For example: They both represent a number.
   b. For example: A dozen is known to be 12 of anything whereas we don't know exactly how many things are in a mole.
2. 35.5 g
3. 32.1 g

Practice Problems — Converting Moles to Number of Items, p. 117

1. $3.5 \text{ mol } Cr^{3+} \times \frac{6.02 \times 10^{23} \text{ ions } Cr^{3+}}{1 \text{ mol } Cr^{3+}} = 2.1 \times 10^{24} \text{ ions } Cr^{3+}$

2. $30.0 \text{ mol } H_2O \times \frac{6.02 \times 10^{23} \text{ molecules } H_2O}{1 \text{ mol } H_2O} = 1.81 \times 10^{25} \text{ molecules } H_2O$

3. $0.023 \text{ mol Na} \times \frac{6.02 \times 10^{23} \text{ atoms Na}}{1 \text{ mol Na}} = 1.4 \times 10^{22} \text{ atoms Na}$

Practice Problems — Converting Number of Items to Moles, p. 118

1. $1.81 \times 10^{22} \text{ atoms Ar} \times \frac{1 \text{ mol Ar}}{6.02 \times 10^{23} \text{ atoms Ar}} = 0.0301 \text{ mol Ar}$

2. $2.25 \times 10^{24} \text{ molecules } CO_2 \times \frac{1 \text{ mol } CO_2}{6.02 \times 10^{23} \text{ molecules } CO_2} = 3.74 \text{ mol } CO_2$

3. $9.27 \times 10^{22} \text{ formula units NaCl} \times \frac{1 \text{ mol NaCl}}{6.02 \times 10^{23} \text{ formula units NaCl}} = 0.154 \text{ mol NaCl}$

Practice Problems — Determining a Compound's Formula Mass and/or Molar Mass, p. 119

1. NO_2 1(14.0 u) + 2(16.0 u) = 46.0 u
2. $Na_2Cr_2O_7$ 2(23.0 g) + 2(52.0 g) + 7(16.0 g) = 262.0 g or 262.0 g/mol
3. Fe_2S_3 2(55.8 g) + 3(32.1 g) = 207.9 g or 207.9 g/mol

Practice Problems — Converting Moles to Mass, p. 120

1. $2.65 \text{ mol NaCl} \times \frac{58.5 \text{ g NaCl}}{1 \text{ mol NaCl}} = 155 \text{ g NaCl}$

2. $0.87 \text{ mol } NH_3 \times \frac{17.0 \text{ g } NH_3}{1 \text{ mol } NH_3} = 15 \text{ g } NH_3$

3. $2.0 \times 10^{12} \text{ mol } H_2SO_4 \times \frac{98.1 \text{ g } H_2SO_4}{1 \text{ mol } H_2SO_4} \times \frac{1 \text{ kg } H_2SO_4}{1000 \text{ g } H_2SO_4} \times \frac{1 \text{ tonne } H_2SO_4}{1000 \text{ g } H_2SO_4}$
   $= 2.0 \times 10^{8} \text{ tonnes } H_2SO_4$

Practice Problems — Converting Mass to Moles, p. 120

1. $62.2 \text{ g Au} \times \frac{1 \text{ mol Au}}{197.0 \text{ g Au}} = 0.316 \text{ mol Au}$

2. $3.88 \text{ g } CO_2 \times \frac{1 \text{ mol } CO_2}{44.0 \text{ g } CO_2} = 0.0882 \text{ mol } CO_2$

3. $500.0 \text{ mg } (NH_4)_2CO_3 \times \frac{1 \text{ g } (NH_4)_2CO_3}{1000 \text{ mg } (NH_4)_2CO_3} = 0.5000 \text{ g } (NH_4)_2CO_3$

   $0.5000 \text{ g } (NH_4)_2CO_3 \times \frac{1 \text{ mol } (NH_4)_2CO_3}{96.0 \text{ g } (NH_4)_2CO_3} = 0.00521 \text{ mol } (NH_4)_2CO_3$

3.2 Activity: A Mole of Pennies, p. 121

1. For example: 8.6×10^{17} km
2. For example: 1.5×10^{21} kg

3.2 Review Questions, p. 122

1. a. A quantity equal to the number of atoms in the atomic mass of any element expressed in grams
   b. $6.02214179 \times 10^{23}$
   c. Avogadro's number

2. a. 12.0 g
   b. 36.0 g
   c. 64.2 g

3. a. 55.8 g
   b. molar mass

4. a. 44.0 u
   b. 74.1 u
   c. 154.0 g

5. $3.2 \text{ mol C} \times \frac{6.02 \times 10^{23} \text{ atoms C}}{1 \text{ mol C}} = 1.9 \times 10^{24} \text{ atoms C}$

6. $0.0085 \text{ moles } C_2H_6 \times \frac{6.02 \times 10^{23} \text{ molecules } C_2H_6}{1 \text{ mol } C_2H_6} = 5.1 \times 10^{21} \text{ molecules } C_2H_6$

7. $1.4 \times 10^{18} \text{ atoms Ag} \times \frac{1 \text{ mol Ag}}{6.02 \times 10^{23} \text{ atoms Ag}} = 2.3 \times 10^{-6} \text{ mol Ag}$

8. $2.99 \text{ g Na} \times \frac{1 \text{ mol Na}}{23.0 \text{ g Na}} = 0.130 \text{ mol Na}$

9. $5.2 \text{ mol F} \times \frac{19.0 \text{ g F}}{1 \text{ mol F}} = 99 \text{ g F}$

10. $2.0 \text{ g Li} \times \frac{1 \text{ mol Li}}{6.9 \text{ g Li}} = 0.316 \text{ mol Li}$

11. $0.32 \text{ mol } NaNO_2 \times \frac{69.0 \text{ g } NaNO_2}{1 \text{ mol } NaNO_2} = 22 \text{ g } NaNO_2$

12. $0.058 \text{ g } C_8H_{10}N_4O_2 \times \frac{1 \text{ mol } C_8H_{10}N_4O_2}{194.0 \text{ g } C_8H_{10}N_4O_2} = 3.0 \times 10^{-4} \text{ mol } C_8H_{10}N_4O_2$

13. $0.725 \text{ mol } CO_2 \times \frac{6.02 \times 10^{23} \text{ molecules } CO_2}{1 \text{ mol } CO_2} = 4.36 \times 10^{23} \text{ molecules } CO_2$

14. $1.70 \times 10^{9} \text{ molecules Pher} \times \frac{1 \text{ mol Pher}}{6.02 \times 10^{23} \text{ molecules Pher}} = 2.82 \times 10^{-15} \text{ mol Pher}$

15. $1300 \text{ g Ti} \times \frac{1 \text{ mol Ti}}{47.9 \text{ g Ti}} = 27 \text{ mol Ti}$

16. $1.75 \text{ mol } CuSO_4, 5H_2O \times \frac{249.6 \text{ g } CuSO_4, 5H_2O}{1 \text{ mol } CuSO_4, 5H_2O} = 437 \text{ g } CuSO_4, 5H_2O$

17. $8.18 \times 10^6 \text{ mol } NH_3 \times \frac{17.0 \text{ g } NH_3}{1 \text{ mol } NH_3} \times \frac{1 \text{ tonne } NH_3}{1000 \text{ g } NH_3} = 1.39 \times 10^5 \text{ tonnes } NH_3$

18. $2.640 \times 10^3 \text{ g } (NH_4)PO_4 \times \frac{1 \text{ mol } (NH_4)PO_4}{47.9 \text{ g } (NH_4)PO_4} = 55 \text{ mol } (NH_4)PO_4$

19. $5.925 \text{ mol } SnCr_2O_7 \times \frac{334.7 \text{ g } SnCr_2O_7}{1 \text{ mol } SnCr_2O_7} = 1983 \text{ g } SnCr_2O_7$

3.3 The Wheel Model of Mole Conversions

Warm Up, p. 124

1. 15 g C
2. 1 mol Zn
3. 34 g CH_4

Practice Problems — Two Step Conversions, p. 126

1. $1 \times 10^{18} \text{ molecules } SO_2 \times \frac{1 \text{ mol } SO_2}{\mathbf{6.02 \times 10^{23}} \text{ molecules } SO_2} \times \frac{\mathbf{64.1} \text{ g } SO_2}{1 \text{ mol } SO_2} = \mathbf{1 \times 10^{-4}} \text{ g } SO_2$

2. $2.1 \text{ g Br} \times \frac{1 \text{ mol Br}}{79.9 \text{ g Br}} \times \frac{6.02 \times 10^{23} \text{ atoms Br}}{1 \text{ mol Br}} = 1.6 \times 10^{22} \text{ atoms Br}$

3. $1 \text{ atom Ag} \times \frac{1 \text{ mol Ag}}{6.02 \times 10^{23} \text{ atoms Ag}} \times \frac{107.9 \text{ g Ag}}{1 \text{ mol Ag}} = 1.79 \times 10^{-22} \text{ g Ag}$

Practice Problems — One-, Two-, and Three-Step Conversions, p. 128

1. a. $\frac{2 \text{ mol O}}{1 \text{ mol } SO_2}$ b. $\frac{1 \text{ mol } C_2H_4}{4 \text{ mol H}}$

2. $14 \text{ g O} \times \frac{1 \text{ mol O}}{16.0 \text{ g O}} \times \frac{1 \text{ mol } KNO_3}{3 \text{ mol O}} = 0.29 \text{ mol } KNO_3$

3. $2.5 \text{ g } K_2Cr_2O_7 \times \frac{1 \text{ mol } K_2Cr_2O_7}{\mathbf{294.2} \text{ g } K_2Cr_2O_7} \times \frac{\mathbf{7} \text{ mol O}}{1 \text{ mol } K_2Cr_2O_7} \times \frac{6.02 \times 10^{23} \text{ atoms O}}{1 \text{ mol O}}$

   $= 3.6 \times 10^{22}$ atoms O

4. $1.23 \times 10^{24} \text{ f.units } Na_2S \times \frac{1 \text{ mol } Na_2S}{6.02 \times 10^{23} \text{ f.units } Na_2S} \times \frac{2 \text{ mol } Na^+}{1 \text{ mol } Na_2S} \times \frac{23.0 \text{ g } Na^+}{1 \text{ mol } Na^+}$

   $= 94.0 \text{ g } Na^+$

3.3 Activity: The Evaporation Rate of Water, p. 129

For example:

	Mass of Beaker and H_2O (g)	Time of Day
initial	68.623	8:50
final	68.555	9:20
change	0.068	30 min

1. $0.068 \text{ g } H_2O \times \frac{1 \text{ mol } H_2O}{18.0 \text{ g } H_2O} \times \frac{6.02 \times 10^{23} \text{ molecules } H_2O}{1 \text{ mol } H_2O} = 2.274 \times 10^{21} \text{ molecules } H_2O$

2. $30 \text{ min} \times \frac{60 \text{ s}}{1 \text{ min}} = 1800 \text{ s}$

3. $\frac{2.274 \times 10^{21} \text{ molecules } H_2O}{1800 \text{ s}} = 1 \times 10^{18} \text{ molecules } H_2O$

3.3 Review Questions, p. 130

1. $1.0 \times 10^{3} \text{ atoms Ag} \times \frac{1 \text{ mol Ag}}{6.02 \times 10^{23} \text{ atoms Ag}} \times \frac{107.9 \text{ g Ag}}{1 \text{ mol Ag}} = 1.8 \times 10^{-19} \text{ g Ag}$

2. $106.0 \text{ g C} \times \frac{1 \text{ mol C}}{12.0 \text{ g C}} \times \frac{6.02 \times 10^{23} \text{ atoms C}}{1 \text{ mol C}} = 5.32 \times 10^{24} \text{ atoms C}$

3. $1 \text{ atom Cl} \times \frac{1 \text{ mol Cl}}{6.02 \times 10^{23} \text{ atoms Cl}} \times \frac{35.5 \text{ g Cl}}{1 \text{ mol Cl}} = 5.90 \times 10^{-23} \text{ g Cl}$

4. $72.6 \text{ g } C_3H_8 \times \frac{1 \text{ mol } C_3H_8}{44.0 \text{ g } C_3H_8} \times \frac{6.02 \times 10^{23} \text{ molecules } C_3H_8}{1 \text{ mol } C_3H_8} = 9.93 \times 10^{23} \text{ molecules } C_3H_8$

5. a. $31.1 \text{ g Au} \times \frac{1 \text{ mol Au}}{197.0 \text{ g Au}} \times \frac{6.02 \times 10^{23} \text{ atoms Au}}{1 \text{ mol Au}} = 9.50 \times 10^{22} \text{ atoms Au}$

   b. $\frac{9.50 \times 10^{22} \text{ atoms Au}}{1.3 \times 10^{5} \text{ cents}} = 7.3 \times 10^{17} \text{ atoms Au per cent}$

6. a. $\frac{4 \text{ mol O}}{1 \text{ mol } N_2O_4}$ b. $\frac{1 \text{ mol } NO_2}{1 \text{ mol N}}$

7. $2.3 \text{ mol } CO_2 \times \frac{2 \text{ mol O}}{1 \text{ mol } CO_2} = 4.6 \text{ mol O}$

8. $52.4 \text{ mg } CaC_2O_4 \times \frac{1 \text{ g } CaC_2O_4}{1000 \text{ mg } CaC_2O_4} = 0.0524 \text{ g } CaC_2O_4$

$0.0524 \text{ g } CaC_2O_4 \times \frac{1 \text{ mol } CaC_2O_4}{128.1 \text{ g } CaC_2O_4} \times \frac{2 \text{ mol C}}{1 \text{ mol } CaC_2O_4} = 8.18 \times 10^{-4} \text{ mol C}$

9. $6.80 \times 10^{24} \text{ f.units } Na_3PO_4 \times \frac{1 \text{ mol } Na_3PO_4}{6.02 \times 10^{23} \text{ f.units } Na_3PO_4} \times \frac{3 \text{ mol } Na^+}{1 \text{ mol } Na_3PO_4}$

$= 33.9 \text{ mol } Na^+$

10. $1.4 \text{ mol O} \times \frac{1 \text{ mol } H_2SO_4}{4 \text{ mol O}} \times \frac{98.1 \text{ g } H_2SO_4}{1 \text{ mol } H_2SO_4} = 34 \text{ g } H_2SO_4$

11. $0.85 \text{ mol } C_8H_9NO_2 \times \frac{8 \text{ mol C}}{1 \text{ mol } C_8H_9NO_2} \times \frac{6.02 \times 10^{23} \text{ atoms C}}{1 \text{ mol C}} = 4.1 \times 10^{24} \text{ atoms C}$

12. $100.0 \text{ g } HgCl_2 \times \frac{1 \text{ mol } HgCl_2}{271.6 \text{ g } HgCl_2} \times \frac{1 \text{ mol } Hg^{2+}}{1 \text{ mol } HgCl_2} \times \frac{6.02 \times 10^{23} \text{ ions } Hg^{2+}}{1 \text{ mol } Hg^{2+}}$

$= 2.22 \times 10^{23} \text{ ions } Hg^{2+}$

13. $8.3 \text{ g } CuCl_2 \times \frac{1 \text{ mol } CuCl_2}{134.5 \text{ g } CuCl_2} \times \frac{2 \text{ mol } Cl^-}{1 \text{ mol } CuCl_2} \times \frac{35.5 \text{ g } Cl^-}{1 \text{ mol } Cl^-} = 4.4 \text{ g } Cl^-$

14. $4.8 \times 10^{26} \text{ molecules } C_2H_5OH \times \frac{1 \text{ mol } C_2H_5OH}{6.02 \times 10^{23} \text{ molecules } C_2H_5OH} \times \frac{2 \text{ mol C}}{1 \text{ mol } C_2H_5OH} \times \frac{12.0 \text{ g C}}{1 \text{ mol C}}$

$= 1.9 \times 10^4 \text{ g C} = 19 \text{ kg C}$

15. $3.9 \times 10^{27} \text{ molecules HF} \times \frac{1 \text{ mol HF}}{6.02 \times 10^{23} \text{ molecules HF}} \times \frac{20.0 \text{ g HF}}{1 \text{ mol HF}} \times \frac{1 \text{ kg HF}}{1000 \text{ g HF}}$

$= 1.3 \times 10^2 \text{ kg HF}$

16. $1.44 \times 10^8 \text{ g } NO_2 \times \frac{1 \text{ mol } NO_2}{46.0 \text{ g } NO_2} \times \frac{2 \text{ mol O}}{1 \text{ mol } NO_2} \times \frac{6.02 \times 10^{23} \text{ atoms O}}{1 \text{ mol O}}$

$= 3.77 \times 10^{30} \text{ atoms O}$

17. $1.000 \times 10^{-3} \text{ g } CCl_4 \times \frac{1 \text{ mol } CCl_4}{154.0 \text{ g } CCl_4} \times \frac{6.02 \times 10^{23} \text{ molecules } CCl_4}{1 \text{ mol } CCl_4}$

$= 3.91 \times 10^{18} \text{ molecules } CCl_4$

18. $4.5 \text{ mol } C_3H_5(OH)_3 \times \frac{8 \text{ mol H}}{1 \text{ mol } C_3H_5(OH)_3} \times \frac{6.02 \times 10^{23} \text{ atoms H}}{1 \text{ mol H}} = 2.2 \times 10^{25} \text{ atoms H}$

19. $14.56 \text{ g NaHSO}_4 \times \frac{1 \text{ mol NaHSO}_4}{120.1 \text{ g NaHSO}_4} \times \frac{7 \text{ mol atoms}}{1 \text{ mol NaHSO}_4} \times \frac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol atoms}}$

$= 5.11 \times 10^{23}$ atoms

3.4 Molar Volume

Warm Up, p. 132

1. thousandth
2. millimoles (mmol)
3. litre
4. 32 mL
5. 0.0112 g

Quick Check, p. 132

1. the volume of the mole of a substance
2. size, spacing
3. spacing
4. increases

Practice Problems — Converting Moles to Volume or Volume to Moles, p. 134

1. $1.33 \text{ mol O}_2 \times \frac{22.4 \text{ L O}_2}{1 \text{ mol O}_2} = 29.8 \text{ L O}_2$

2. $9.5 \text{ L SO}_2 \times \frac{1 \text{ mol SO}_2}{22.4 \text{ L SO}_2} = 0.42 \text{ mol SO}_2$

3. $0.39 \text{ mol SiO}_2 \times \frac{22.8 \text{ cm}^3 \text{ SiO}_2}{1 \text{ mol SiO}_2} = 8.9 \text{ cm}^3 \text{ SiO}_2$

Practice Problems — Conversions: Volume to Number of Items or Mass; Mass to Volume, p. 136

1. $17 \text{ g H}_2\text{S} \times \frac{1 \text{ mol H}_2\text{S}}{34.1 \text{ g H}_2\text{S}} \times \frac{22.4 \text{ L H}_2\text{S}}{1 \text{ mol H}_2\text{S}} = 11 \text{ L H}_2\text{S}$

2. 22.4 L C_3H_8, 3 mol C, 12.0 g C answer 1.6 g C

3. $0.200 \text{ L } C_2H_6O_2 \times \frac{1 \text{ mol } C_2H_6O_2}{0.0559 \text{ L } C_2H_6O_2} \times \frac{6 \text{ mol H}}{1 \text{ mol } C_2H_6O_2} \times \frac{6.02 \times 10^{23} \text{ atoms H}}{1 \text{ mol H}}$

$= 1.29 \times 10^{25}$ atoms H

Practice Problems — Calculating Molar Volume and Density, p. 138

1. $1.33 \text{ g Au} \times \frac{1 \text{ cm}^3 \text{ Au}}{19.42 \text{ g Au}} = 639 \text{ cm}^3 \text{ Au}$

2. $12.7 \text{ mL Hg} \times \frac{13.534 \text{ g Hg}}{1 \text{ mL Hg}} = 172 \text{ g Hg}$

3. $\frac{46.0 \text{ g } C_2H_5OH}{1 \text{ mol } C_2H_5OH} \times \frac{1 \text{ mL } C_2H_5OH}{0.789 \text{ g } C_2H_5OH} = 58.3 \text{ mL/mol } C_2H_5OH$

3.4 Activity: The Atomic Radius of Aluminum, p. 139

1. 2.702 g/cm^3

2. $\frac{27.0 \text{ g Al}}{1 \text{ mol Al}} \times \frac{1 \text{ cm}^3 \text{ Al}}{2.702 \text{ g Al}} = 9.99 \text{ cm}^3\text{/mol Al}$

3. $0.74 \times \frac{9.99 \text{ cm}^3 \text{ Al}}{1 \text{ mol Al}} = 7.3945 \text{ cm}^3\text{/mol Al}$

4. $\frac{7.3945 \text{ cm}^3 \text{ Al}}{1 \text{ mol Al}} \times \frac{1 \text{ mol Al}}{6.02 \times 10^{23} \text{ atoms Al}} = 1.228 \times 10^{-23} \text{ cm}^3\text{/atom Al}$

5. $r^3 = \frac{1.228 \times 10^{-23} \text{ cm}^3}{4.1888} = 2.93 \times 10^{-24} \text{ cm}^3 \quad r = 1.43 \times 10^{-8} \text{ cm}$

6. $1.43 \times 10^{-8} \text{ cm} \times \frac{1 \text{ m}}{100 \text{ cm}} \times \frac{1 \times 10^9 \text{ nm}}{1 \text{ m}} = 0.143 \text{ nm}$

3.4 Review Questions, p. 140

1. $0.250 \text{ mol } C_8H_{18} \times \frac{82.4 \text{ mL } C_8H_{18}}{1 \text{ mol } C_8H_{18}} = 20.6 \text{ mL } C_8H_{18}$

2. $2.4 \text{ L air} \times \frac{1 \text{ mol air}}{22.4 \text{ L air}} = 0.11 \text{ mol air}$

3. $2.75 \text{ L } N_2 \times \frac{1 \text{ mol } N_2}{22.4 \text{ L } N_2} = 0.123 \text{ mol } N_2$

4. $5.0 \text{ L air} \times \frac{21 \text{ L } O_2}{100 \text{ L air}} \times \frac{1 \text{ mol } O_2}{22.4 \text{ L } O_2} = 0.047 \text{ mol } O_2$

5. $2.57 \text{ L } P_2O_5 \times \frac{1 \text{ mol } P_2O_5}{22.4 \text{ L } P_2O_5} \times \frac{142.0 \text{ g } P_2O_5}{1 \text{ mol } P_2O_5} = 16.3 \text{ g } P_2O_5$

6. $\frac{0.935 \text{ g}}{525 \text{ mL}} \times \frac{22400 \text{ mL}}{1 \text{ mol}} = 39.9 \text{ g/mol}$ (Argon)

7. $1400 \text{ L } C_2H_2 \times \frac{1 \text{ mol } C_2H_2}{22.4 \text{ L } C_2H_2} \times \frac{6.02 \times 10^{23} \text{ molecules } C_2H_2}{1 \text{ mol } C_2H_2} = 3.8 \times 10^{25} \text{ molecules } C_2H_2$

8. $5 \times 10^{19} \text{ molecules } PH_3 \times \frac{1 \text{ mol } PH_3}{6.02 \times 10^{23} \text{ molecules } PH_3} \times \frac{22.4 \text{ L } PH_3}{1 \text{ mol } PH_3} = 0.002 \text{ L } PH_3$

$0.002 \text{ L } PH_3 \times \frac{1000 \text{ mL}}{1 \text{ L}} = 2 \text{ mL } PH_3$

9. $9100 \text{ g } C_3H_8 \times \frac{1 \text{ mol } C_3H_8}{44.0 \text{ g } C_3H_8} \times \frac{22.4 \text{ L } C_3H_8}{1 \text{ mol } C_3H_8} = 4600 \text{ L } C_3H_8$

10. (3.7) $0.355 \text{ L } CO_2 \times \frac{1 \text{ mol } CO_2}{22.4 \text{ L } CO_2} \times \frac{44.0 \text{ g } CO_2}{1 \text{ mol } CO_2} = 2.6 \text{ g } CO_2$

11. $83.9 \text{ L } NH_3 \times \frac{1 \text{ mol } NH_3}{22.4 \text{ L } NH_3} \times \frac{3 \text{ mol H}}{1 \text{ mol } NH_3} = 11.2 \text{ mol H}$

12. $3.84 \text{ L } N_2O \times \frac{1 \text{ mol } N_2O}{22.4 \text{ L } N_2O} \times \frac{2 \text{ mol N}}{1 \text{ mol } N_2O} \times \frac{14.0 \text{ g N}}{1 \text{ mol N}} = 4.80 \text{ g N}$

13. $27.2 \text{ L } N_2O_4 \times \frac{1 \text{ mol } N_2O_4}{22.4 \text{ L } N_2O_4} \times \frac{4 \text{ mol O}}{1 \text{ mol } N_2O_4} \times \frac{6.02 \times 10^{23} \text{ atoms O}}{1 \text{ mol O}}$

$= 2.92 \times 10^{24} \text{ atoms O}$

14. $15 \text{ mL } C_4H_{10} \times \frac{0.601 \text{ g } C_4H_{10}}{1 \text{ mL } C_4H_{10}} = 9.0 \text{ g } C_4H_{10}$

15. $\frac{200.6 \text{ g Hg}}{1 \text{ mol Hg}} \times \frac{1 \text{ mL Hg}}{13.546 \text{ g Hg}} = 14.81 \text{ mL/mol Hg}$

16. $5.0\ cm^3\ Au \times \frac{19.42\ g\ Au}{1\ cm^3\ Au} \times \frac{1\ mol\ Au}{197.0\ g\ Au} = 0.49\ mol\ Au$

17. $15.0\ mL\ Br_2 \times \frac{3.53\ g\ Br_2}{1\ mL\ Br_2} \times \frac{1\ mol\ Br_2}{159.8\ g\ Br_2} \times \frac{6.02 \times 10^{23}\ molecules\ Br_2}{1\ mol\ Br_2}$

$= 1.99 \times 10^{23}\ molecules\ Br_2$

3.5 Composition Analysis — Determining Formulas

Warm Up, p. 142

1. 72 u
2. 29u
3. For example: more ways of creating the fragment
   For example: weaker bonds are broken to create fragment

Practice Problems — Determining Percentage Composition, p. 143

1.

13 C	(13 × 12.0 g)/mol	= 156.0 g/mol	= 75.7%
18 H	(18 × 1.0 g)/mol	= 18.0 g/mol	= 8.7%
2 O	(2 × 16.0 g)/mol	= 32.0 g/mol	= 15.5%
		206.0 g/mol	99.9%

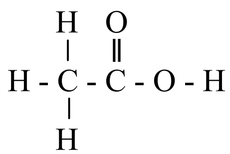
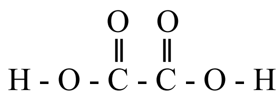
2.

2 N	(2 × 14.0 g)/mol	= 28.0 g/mol	= 21.2%
8 H	(8 × 1.0 g)/mol	= 18.0 g/mol	= 6.1%
1 S	(1 × 32.0 g)/mol	= 32.1 g/mol	= 24.3%
4 O	(4 × 16.0 g)/mol	= 64.0 g/mol	= 48.4%
		132.1 g/mol	100.0%

3.

1 Mg	(1 × 24.3 g)/mol	= 24.3 g/mol	
1 S	(1 × 32.0 g)/mol	= 32.1 g/mol	
4 O	(4 × 16.0 g)/mol	= 64.0 g/mol	
		120.4 g/mol	
7 H_2O	(7 × 18.0 g)/mol	= 126.0 g/mol	= 51.1%
		246.4 g/mol	

Quick Check, p. 144

Structural Formula	Molecular Formula	Empirical Formula
	$C_2H_4O_2$	CH_2O
	$C_2H_2O_4$	CHO_2

Practice Problems — Determining an Empirical Formula, p. 145

1. $18.7 \text{ g Li} \times \frac{1 \text{ mol Li}}{6.9 \text{ g Li}} = 2.7101 \text{ mol Li}$

   $16.3 \text{ g C} \times \frac{1 \text{ mol C}}{12.0 \text{ g C}} = 1.3583 \text{ mol C}$

   $65.5 \text{ g O} \times \frac{1 \text{ mol O}}{16.0 \text{ g O}} = 4.0938 \text{ mol O}$

   Li_2CO_3

2. $9.93 \text{ g C} \times \frac{1 \text{ mol C}}{12.0 \text{ g C}} = 0.8275 \text{ mol C}$

   $58.6 \text{ g Cl} \times \frac{1 \text{ mol Cl}}{35.5 \text{ g Cl}} = 1.6507 \text{ mol Cl}$

   $31.4 \text{ g F} \times \frac{1 \text{ mol F}}{19.0 \text{ g F}} = 1.6526 \text{ mol F}$

   CCl_2F_2

3. $5.723 \text{ g Ag} \times \frac{1 \text{ mol Ag}}{107.9 \text{ g Ag}} = 0.8275 \text{ mol C}$

   $0.852 \text{ g S} \times \frac{1 \text{ mol S}}{32.1 \text{ g S}} = 1.6507 \text{ mol Cl}$

   $1.695 \text{ g O} \times \frac{1 \text{ mol O}}{16.0 \text{ g O}} = 0.1059 \text{ mol O}$

   Ag_2SO_4

Practice Problems — Determining a Molecular Formula, p. 147

1. 1C (1 × 12.0 g)/mol = 12.0 g/mol
   2H (2 × 1.0 g)/mol = 2.0 g/mol
   1O (1 × 16.0 g)/mol = 16.0 g/mol
   = 30.0 g/mol

   $\frac{60.0 \text{ g/mol}}{30.0 \text{ g/mol}} = 2$

   2 (CH_2O) = $C_2H_4O_2$

2. 3 C (1 × 12.0 g)/mol = 36.0 g/mol
   4 H (4 × 1.0 g)/mol = 4.0 g/mol
   = 40.0 g/mol

   80.0 g/mol, 120.0 g/mol because they are both multiples of 40 g/mol

3. $4.51 \text{ g C} \times \frac{1 \text{ mol C}}{12.0 \text{ g C}} = 0.3758 \text{ mol C}$

   $1.13 \text{ g H} \times \frac{1 \text{ mol H}}{1.0 \text{ g H}} = 1.13 \text{ mol H}$

   $6.01 \text{ g O} \times \frac{1 \text{ mol O}}{16.0 \text{ g O}} = 0.3756 \text{ mol O}$

   CH_3O

   1 C (1 × 12.0 g)/mol = 12.0 g/mol
   3 H (3 × 1.0 g)/mol = 3.0 g/mol
   1 O (1 × 16.0 g)/mol = 16.0 g/mol
   = 31.0 g/mol

   $\frac{62.0 \text{ g/mol}}{31.0 \text{ g/mol}} = 2$

   2 (CH_3O) = $C_2H_6O_2$

3.5 Activity: Determining the Empirical Formula of Butane from the Percentage Composition of Its Model, p. 148

1. For example:

   $19.202 \text{ g C} \times \frac{1 \text{ doz C}}{14.4 \text{ g C}} = 1.3335 \text{ doz C}$

   $18.733 \text{ g H} \times \frac{1 \text{ doz H}}{5.6 \text{ g H}} = 3.3452 \text{ doz H}$

2. $\frac{3.3452 \text{ doz H}}{1.3335 \text{ doz C}} = 2.5$ $CH_{2.5}$

3. 2

4. 2 ($CH_{2.5}$) = C_2H_5

5. C_4H_{10}

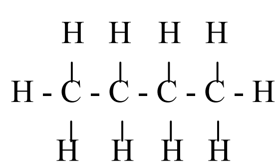
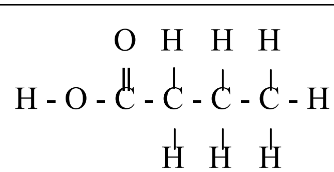
3.5 Review Questions, p. 149

1. 10 C (10 × 12.0 g)/mol = 120.0 g/mol = 76.9%
   20 H (20 × 1.0 g)/mol = 20.0 g/mol = 12.8%
   1 O (1 × 16.0 g)/mol = 16.0 g/mol = 10.3%
   156.0 g/mol 100.0%

2. 1 Na (1 × 23.0 g)/mol = 23.0 g/mol
   2 C (2 × 12.0 g)/mol = 24.0 g/mol
   3 H (3 × 1.0 g)/mol = 3.0 g/mol
   2 O (2 × 16.0 g)/mol = 32.0 g/mol
   82.0 g/mol
   $3H_2O$ (3 × 18.0 g)/mol = 54.0 g/mol = 39.7%
   136.0 g/mol

3. 7 C (7 × 12.0 g)/mol = 84.0 g/mol
   5 H (5 × 1.0 g)/mol = 5.0 g/mol
   6 O (6 × 16.0 g)/mol = 96.0 g/mol
   3 N (3 × 14.0 g)/mol = 42.0 g/mol = 18.5%
   227 g/mol

4.

Structural Formula	Molecular Formula	Empirical Formula
	C_4H_{10}	C_2H_5
	$C_4H_8O_2$	C_2H_4O

5. a. Many compounds have the same empirical formula
   b. Its molar mass

6. $BaCO_3$

7. 1.4844 g C × $\frac{1 \text{ mol C}}{}$ = 0.1237 mol C

$$12.0\ \text{g C}$$

$$0.1545\ \text{g H} \times \frac{1\ \text{mol H}}{1.0\ \text{g H}} = 0.1545\ \text{mol H}$$

$$0.4947\ \text{g O} \times \frac{1\ \text{mol O}}{16.0\ \text{g O}} = 0.0309\ \text{mol O}$$

$$0.8661\ \text{g N} \times \frac{1\ \text{mol N}}{14.0\ \text{g N}} = 0.0619\ \text{mol N}$$

$C_4H_5ON_2$

8. $$0.0285\ \text{mol Al} \times \frac{27.0\ \text{g Al}}{1\ \text{mol Al}} = 0.7695\ \text{g Al} = 1.8\%\ \text{Al}$$

$$0.8740\ \text{mol Si} \times \frac{28.1\ \text{g Si}}{1\ \text{mol Si}} = 24.5594\ \text{g Si} = 58.2\%\ \text{Si}$$

$$0.0975\ \text{mol Yb} \times \frac{173.0\ \text{g Yb}}{1\ \text{mol Yb}} = 16.8675\ \text{g Yb} = \underline{40.0\%}\ \text{Yb}$$

$$100.0\%$$

b. For example: If Heliomolar was introduced in 1984, the person did not die before 1984 or perhaps Heliomolar was only used in certain countries.

9. 1 N (1 × 14.0 g)/mol = 14.0 g/mol
2 H (2 × 1.0 g)/mol = 2.0 g/mol
16.0 g/mol

$$\frac{32.1\ \text{g/mol}}{16.0\ \text{g/mol}} = 2.01$$

$2\ (NH_2) = N_2H_4$

10. $$1.080\ \text{g C} \times \frac{1\ \text{mol C}}{12.0\ \text{g C}} = 0.090\ \text{mol C}$$

$$0.121\ \text{g H} \times \frac{1\ \text{mol H}}{1.0\ \text{g H}} = 0.121\ \text{mol H}$$

$$1.439\ \text{g O} \times \frac{1\ \text{mol O}}{16.0\ \text{g O}} = 0.090\ \text{mol O}$$

$3\ (CH_{1.34}O) = C_3H_4O_3$

3 C (3 × 12.0 g)/mol = 36.0 g/mol
4 H (4 × 1.0 g)/mol = 4.0 g/mol
3 O (3 × 16.0 g)/mol = 48.0 g/mol
88.0 g/mol

$$\frac{176.1\ \text{g/mol}}{88.0\ \text{g/mol}} = 2.00$$

$2\ (C_3H_4O_3) = C_6H_8O_6$

11. $92.29 \text{ g C} \times \frac{1 \text{ mol C}}{12.0 \text{ g C}} = 7.69 \text{ mol C}$

$7.71 \text{ g H} \times \frac{1 \text{ mol H}}{1.0 \text{ g H}} = 7.71 \text{ mol H}$ CH

1 C (1 × 12.0 g)/mol = 12.0 g/mol
1 H (1 × 1.0 g)/mol = 1.0 g/mol
13.0 g/mol

$\frac{78.0 \text{ g/mol}}{13.0 \text{ g/mol}} = 6.00$

6 (CH) = C_6H_6

12. a. 0.273 × 44.0u = 12.0u
b. Yes, this is carbon's atomic mass.

3.6 Molar Concentration

Warm Up, p. 151

1. For example: pop, apple juice, vinegar
2. For example: vitamins, calcium ions, acids
3. For example: bathroom, garage

Quick Check, p. 152

1. For example: Many chemicals are dispensed in solution.
For example: Most chemical reactions occur in solution.
2. 2 mol of NaOH per litre of solution
3. Molar concentrations allow chemists to directly compare the number of particles in the same volume of different solutions.

Practice Problems — Converting Moles of Solute into Volume of Solution, p. 153

1. $0.72 \text{ L soln} \times \frac{2.5 \text{ mol NaOH}}{1 \text{ L soln}} = 1.8 \text{ mol NaOH}$

2. $0.500 \text{ L soln} \times \frac{0.154 \text{ mol NaCl}}{1 \text{ L soln}} = 0.0770 \text{ mol NaCl}$

3. $3.0 \text{ mol HCl} \times \frac{1 \text{ L soln}}{0.60 \text{ mol HCl}} = 5.0 \text{ L soln}$

4. $1.0 \times 10^{-3} \text{ mol methanethiol} \times \frac{1 \text{ L urine}}{4.0 \times 10^{-8} \text{ mol methanethiol}} = 25000 \text{ L urine}$

Practice Problems — Converting Volume of Solution into Mass of Solute and Determining Molar Concentration, p. 154

1. $0.500 \text{ L soln} \times \frac{1.5 \text{ mol } CaCl_2}{1 \text{ L soln}} \times \frac{111.1 \text{ g } CaCl_2}{1 \text{ mol } CaCl_2} = 83 \text{ g } CaCl_2$

   Measure out 83 g $CaCl_2$ and add water up to 0.500 L soln.

2. $0.055 \text{ L soln} \times \frac{0.20 \text{ mol KCl}}{1 \text{ L soln}} \times \frac{74.6 \text{ g KCl}}{1 \text{ mol KCl}} = 0.82 \text{ g KCl}$

3. $1.8 \text{ g } AgNO_3 \times \frac{1 \text{ mol } AgNO_3}{169.0 \text{ g } AgNO_3} = 0.01059 \text{ mol } AgNO_3$

   $\frac{0.01059 \text{ mol } AgNO_3}{0.075 \text{ L soln}} = 0.14 \text{ M } AgNO_3$

Practice Problems — Three-Step Conversion: Volume of Solution to Number of Ions, p. 157

1. $CaCl_2(s) \longrightarrow Ca^{2+}(aq) + 2Cl^-(aq)$ 1.5 M Ca^{2+} and 3.0 M Cl^-

2. $Na_3PO_4(s) \longrightarrow 3Na^+(aq) + PO_4^{3-}(aq)$ 0.20 M Na_3PO_4

3. $Li_3PO_4(s) \longrightarrow 3Li^+(aq) + PO_4^{3-}(aq)$ $[Li^+] = 3[PO_4^{3-}]$

4. $0.75 \text{ L soln} \times \frac{2.8 \text{ mol } K^+}{1 \text{ L soln}} \times \frac{39.1 \text{ g } K^+}{1 \text{ mol } K^+} = 82 \text{ g } K^+$

5. $0.525 \text{ L soln} \times \frac{3.0 \text{ mol } Fe(NO_3)_3}{1 \text{ L soln}} \times \frac{3 \text{ mol } NO_3^-}{1 \text{ mol } Fe(NO_3)_3} \times \frac{6.02 \times 10^{23} \text{ ions } NO_3^-}{1 \text{ mol } NO_3^-}$

   $= 2.8 \times 10^{24} \text{ ions } NO_3^-$

3.6 Activity: Building a Scale Model of a Solution, p. 158

1. $\frac{1000 \text{ g } H_2O}{1 \text{ L } H_2O} \times \frac{1 \text{ mol } H_2O}{18.0 \text{ g } H_2O} = \frac{55.6 \text{ mol } H_2O}{1 \text{ L } H_2O}$

2. 1 M Na^+, 1 M Cl^-
3. 54 H_2O, 1 Na^+, 1 Cl^-
4. Note to teacher: Airsoft B.B.'s are not too expensive (6 mm dia.)
   If you want the particle sizes to be roughly to scale then the Cl^- ions should be double the diameter of the Na^+ ions and the H_2O molecules.
6. For example: The particles are not moving in the model
   For example: The particles are much larger in the model
   For example: The particles in the model appear to be solid as opposed to having a cloud like shell

3.6 Review Questions, 159

1. 1.5 mol HCl per 1 L soln

2. $0.0050 \text{ L DM} \times \frac{0.011 \text{ mol DM}}{1 \text{ L syrup}} = 5.5 \times 10^{-5} \text{ mol DM}$

3. $0.075 \text{ mol } Ca^{2+} \times \frac{1 \text{ L soln}}{0.20 \text{ mol } Ca^{2+}} = 0.37 \text{ or } 0.38 \text{ L soln}$

4. $5.00 \times 10^{-13} \text{ L soln} \times \frac{1.2 \times 10^{-2} \text{ mol } Na^+}{1 \text{ L soln}} \times \frac{6.02 \times 10^{23} \text{ ions } Na^+}{1 \text{ mol } Na^+} = 3.6 \times 10^{9} \text{ ions } Na^+$

5. a. $0.10 \text{ g } C_8H_{10}N_4O_2 \times \frac{1 \text{ mol } C_8H_{10}N_4O_2}{194.0 \text{ g } C_8H_{10}N_4O_2} = 5.155 \times 10^{-4} \text{ mol } C_8H_{10}N_4O_2$

   $\frac{5.155 \times 10^{-4} \text{ mol } C_8H_{10}N_4O_2}{0.296 \text{ L soln}} = 1.7 \times 10^{-3} \text{ M } C_8H_{10}N_4O_2$

   b. $42.6 \text{ g } C_6H_{12}O_6 \times \frac{1 \text{ mol } C_6H_{12}O_6}{180.0 \text{ g } C_6H_{12}O_6} = 0.237 \text{ mol } C_6H_{12}O_6$

   $\frac{0.237 \text{ mol } C_6H_{12}O_6}{0.355 \text{ L soln}} = 0.667 \text{ M } C_6H_{12}O_6$

6. $5.0 \text{ L blood} \times \frac{4.0 \times 10^{-3} \text{ mol } C_6H_{12}O_6}{1 \text{ L blood}} \times \frac{180.0 \text{ g } C_6H_{12}O_6}{1 \text{ mol } C_6H_{12}O_6} = 3.6 \text{ g } C_6H_{12}O_6$

7. $0.250 \text{ L soln} \times \frac{0.50 \text{ mol NaNO}_3}{1 \text{ L soln}} \times \frac{85.0 \text{ g NaNO}_3}{1 \text{ mol NaNO}_3} = 11 \text{ g NaNO}_3$

Measure out 11 g $NaNO_3$ and add water up to 250 mL soln

8. $0.3000 \text{ L soln} \times \frac{4.5 \times 10^{-4} \text{ mol O}_2}{1 \text{ L soln}} \times \frac{22.4 \text{ L O}_2}{1 \text{ mol O}_2} = 3.0 \times 10^{-3} \text{ L O}_2$

$3.0 \times 10^{-3} \text{ L O}_2 \times \frac{1000.0 \text{ mL}}{1 \text{ L}} = 3.0 \text{ mL O}_2$

9. a. $Fe_2(Cr_2O_7)_3(s) \longrightarrow 2Fe^{3+}(aq) + 3Cr_2O_7^{2-}(aq)$ 0.70 M Fe^{3+} and 1.0 or 1.1 M $Cr_2O_7^{2-}$

b. $Sr(CN)_2(s) \longrightarrow Sr^{2+}(aq) + 2CN^-(aq)$ 1.6 M Sr^{2+} and 3.2 M CN^-

10. $FeCl_3(s) \longrightarrow Fe^{3+}(aq) + 3Cl^-(aq)$ 0.013 M $FeCl_3$

11. a.

$Fe_2(SO_4)_3(s)$	$\longrightarrow$	$2Fe^{3+}(aq)$ +	$3SO_4^{2-}(aq)$
	dissolves to form	1.5 M	?
	dissolves to form	1.5 M	**2.3 M**

$1.5 \text{ M Fe}^{3+} \times \frac{3 \text{ M SO}_4^{2-}}{2 \text{ M Fe}^{3+}} = 2.2 \text{ or } 2.3 \text{ M SO}_4^{2-}$

b.

$Fe_2(SO_4)_3(s)$	$\longrightarrow$	$2Fe^{3+}(aq)$ +	$3SO_4^{2-}(aq)$
	dissolves to form	?	3.0 M
	dissolves to form	**2.0 M**	3.0 M

$3.0 \text{ M SO}_4^{2-} \times \frac{2 \text{ M Fe}^{3+}}{3 \text{ M SO}_4^{2-}} = 2.0 \text{ M Fe}^{3+}$

12. a. $ZnCrO_4(s) \longrightarrow Zn^{2+}(aq) + CrO_4^{2-}(aq)$ $[Zn^{2+}] = [CrO_4^{2-}]$
b. $Sr(OH)_2(s) \longrightarrow Sr^{2+}(aq) + 2OH^-(aq)$ $[OH^-] = 2[Sr^{2+}]$

13. $0.250 \text{ L soln} \times \frac{3.14 \times 10^{-2} \text{ mol Ca}^{2+}}{1 \text{ L soln}} \times \frac{40.1 \text{ g Ca}^{2+}}{1 \text{ mol Ca}^{2+}} = 0.31 \text{ g Ca}^{2+}$

14. $1.5 \text{ L soln} \times \frac{3.0 \text{ mol } Na_2CO_3}{1 \text{ L soln}} \times \frac{2 \text{ mol } Na^+}{1 \text{ mol } Na_2CO_3} \times \frac{6.02 \times 10^{23} \text{ ions } Na^+}{1 \text{ mol } Na^+}$

$= 5.4 \times 10^{24} \text{ ions } Na^+$

15. $\frac{0.0050 \text{ L}}{145 \text{ drops}} \times 1 \text{ drop} = 3.45 \times 10^{-5} \text{ L}$

$3.45 \times 10^{-5} \text{ L soln} \times \frac{0.10 \text{ mol } FeBr_3}{1 \text{ L soln}} \times \frac{3 \text{ mol } Br^-}{1 \text{ mol } FeBr_3} \times \frac{79.9 \text{ g } Br^-}{1 \text{ mol } Br^-}$

$= 8.3 \times 10^{-4} \text{ g } Br^-$

16. $0.049 \text{ g P} \times \frac{1 \text{ mol P}}{31.0 \text{ g P}} \times \frac{1 \text{ mol } H_3PO_4}{1 \text{ mol P}} = 1.581 \times 10^{-3} \text{ mol } H_3PO_4$

$\frac{1.581 \times 10^{-3} \text{ mol } H_3PO_4}{0.355 \text{ L soln}} = 4.4 \times 10^{-3} \text{ M } H_3PO_4$ or $4.4 \text{ mM } H_3PO_4$

17.