CHAPTER 8

Chemical Composition

CHAPTER ANSWERS

1. $100 \text{ washers} \times \frac{0.110 \text{ g}}{1 \text{ washer}} = 11.0 \text{ g}$ (assuming 100 washers is exact).

   $100. \text{ g} \times \frac{1 \text{ washer}}{0.110 \text{ g}} = 909 \text{ washers}$

2. $500. \text{ g} \times \frac{1 \text{ cork}}{1.63 \text{ g}} = 306.7 = 307 \text{ corks}$

   $500. \text{ g} \times \frac{1 \text{ stopper}}{4.31 \text{ g}} = 116 \text{ stoppers}$

   1 kg of corks contains $\left(1000 \text{g} \times \frac{1 \text{ cork}}{1.63 \text{ g}}\right) = 613.49 = 613 \text{ corks}$

   613 stoppers would weigh $\left(613 \text{ stoppers} \times \frac{4.31 \text{ g}}{1 \text{ stopper}}\right) = 2644 \text{ g} = 2640 \text{ g}$

   The ratio of the mass of a stopper to the mass of a cork is (4.31 g/1.63 g). So the mass of stoppers that contains the same number of stoppers as there are corks in 1000 g of corks is

   $1000 \text{ g} \times \frac{4.31 \text{ g}}{1.63 \text{ g}} = 2644 \text{ g} = 2640 \text{ g}.$

3. The *atomic mass unit* (amu) is defined by scientists to more simply describe relative masses on an atomic or molecular scale. One amu is equivalent to 1.66×10^{-24} g.

4. The average atomic mass takes into account the various isotopes of an element and the relative abundances in which those isotopes are found.

5.

   a. $278 \text{ Li atoms} \times \frac{6.941 \text{ amu}}{1 \text{ Li atom}} = 1930 \text{ amu}$

   b. $1 \times 10^6 \text{ C atoms} \times \frac{12.01 \text{ amu}}{1 \text{ C atom}} = 1.201 \times 10^7 \text{ amu} = 1 \times 10^7 \text{ amu}$

   c. $5 \times 10^{25} \text{ Na atoms} \times \frac{22.99 \text{ amu}}{1 \text{ Na atom}} = 1.150 \times 10^{27} \text{ amu} = 1 \times 10^{27} \text{ amu}$

   d. $1 \text{ Cd atom} \times \frac{112.4 \text{ amu}}{1 \text{ Cd atom}} = 112.4 \text{ amu}$

e. $6.022 \times 10^{23} \text{ Hg atoms} \times \frac{200.6 \text{ amu}}{1 \text{ Hg atom}} = 1.208 \times 10^{26} \text{ amu}$

6.

a. $40.08 \text{ amu Ca} \times \frac{1 \text{ Ca atom}}{40.08 \text{ amu}} = 1 \text{ Ca atom}$

b. $919.5 \text{ amu W} \times \frac{1 \text{ W atom}}{183.9 \text{ amu}} = 5 \text{ W atoms}$

c. $549.4 \text{ amu Mn} \times \frac{1 \text{ Mn atom}}{54.94 \text{ amu}} = 10 \text{ Mn atoms}$

d. $6345 \text{ amu I} \times \frac{1 \text{ I atom}}{126.9 \text{ amu}} = 50 \text{ I atoms}$

e. $2072 \text{ amu} \times \frac{1 \text{ Pb atom}}{207.2 \text{ amu}} = 10 \text{ Pb atoms}$

7. One sodium atom has a mass of 22.99 amu.

124 sodium atoms would weigh: $124 \text{ atoms} \times \frac{22.99 \text{ amu}}{1 \text{ atom}} = 2851 \text{ amu}$

344.85 amu represents: $344.85 \times \frac{1 \text{ atom}}{22.99 \text{ amu}} = 15 \text{ atoms}$.

8. One tin atom has a mass of 118.7 amu.

A sample containing 35 tin atoms would weigh: $35 \times \frac{118.7 \text{ amu}}{1 \text{ atom}} = 4155 \text{ amu}$

2967.5 amu of tin would represent: $2967.5 \text{ amu} \times \frac{1 \text{ tin atom}}{118.7 \text{ amu}} = 25 \text{ tin atoms}$.

9. Avogadro's number (6.022×10^{23} atoms; 1.00 mol)

10. 3 × Avogadro's number ($3 \times 6.022 \times 10^{23} = 1.807 \times 10^{24}$, 3.00 mol)

11. molar masses: Na, 22.99 g; K, 39.10 g

$11.50 \text{ g Na} \times \frac{1 \text{ mol Na}}{22.99 \text{ g}} = 0.5002 \text{ mol Na}$

$0.5002 \text{ mol Na} \times \frac{6.033 \times 10^{23}}{1 \text{ mol Na}} = 3.012 \times 10^{23} \text{ atoms}$

$0.5002 \text{ mol K} \times \frac{39.10 \text{ g}}{1 \text{ mol K}} = 19.56 \text{ g K}$

12. 32.00 g of O_2 (the molar mass of O_2) contains the same number of atoms as 28.02 g of N_2 (the molar mass of N_2). Each quantity represents Avogadro's number of its respective molecules.

13. The ratio of the atomic mass of H to the atomic mass of N is (1.008 amu/14.01 amu), and the mass of hydrogen is given by

$$7.00 \text{ g N} \times \frac{1.008 \text{ amu}}{14.01 \text{ amu}} = 0.504 \text{ g H.}$$

14. The ratio of the atomic mass of Co to the atomic mass of F is (58.93 amu/19.00 amu), and the mass of cobalt is given by

$$57.0 \text{ g} \times \frac{58.93 \text{ amu}}{19.00 \text{ amu}} = 177 \text{ g Co.}$$

15. The mass of a magnesium atom equals $3.82 \times 10^{-23} \text{g} \times \frac{24.31 \text{ amu Mg}}{22.99 \text{ amu Na}} = 4.04 \times 10^{-23} \text{g}$

16. 14.01 g of nitrogen atoms contains 6.022×10^{23} N atoms; therefore the mass of one nitrogen atom is given by

$$1 \text{ N atom} \times \frac{14.01 \text{ g}}{6.022 \times 10^{23} \text{ atoms}} = 2.32 \times 10^{-23} \text{ g}$$

17. 1 mol of He atoms = 4.003 g

$$4 \text{ mol of H atoms} \times \frac{1.008 \text{ g H}}{1 \text{ mol}} = 4.032 \text{ g}$$

4 mol of H atoms has a mass slightly larger than 1 mol of He atoms.

18. $0.50 \text{ mol O atoms} \times \frac{16.00 \text{ g}}{1 \text{ mol}} = 8.0 \text{ g O}$

$$4 \text{ mol H atoms} \times \frac{1.008 \text{ g H}}{1 \text{ mol}} = 4 \text{ g H}$$

Half a mole of O atoms weighs more than 4 moles of H atoms.

19.

a. $21.50 \text{ g As} \times \frac{1 \text{ mol}}{74.92 \text{ g}} = 0.2870 \text{ mol As}$

b. $9.105 \text{ g P} \times \frac{1 \text{ mol}}{30.97 \text{ g}} = 0.2940 \text{ mol P}$

c. $0.05152 \text{ g Ba} \times \frac{1 \text{ mol}}{137.3 \text{ g}} = 3.752 \times 10^{-4} \text{ mol Ba}$

d. $43.15 \text{ g C} \times \frac{1 \text{ mol}}{12.01 \text{ g}} = 3.593 \text{ mol C}$

e. $26.02 \text{ g Cr} \times \frac{1 \text{ mol}}{52.00 \text{ g}} = 0.5004 \text{ mol Cr}$

f. $1.951 \text{ g Pt} \times \frac{1 \text{ mol}}{195.1 \text{ g}} = 0.01000 \text{ mol Pt}$

g. $0.000375 \text{ g F} \times \frac{1 \text{ mol}}{19.00 \text{ g}} = 1.97 \times 10^{-5} \text{ mol F}$

20.

a. $66.50 \text{ g F} \times \frac{1 \text{ mol}}{19.00 \text{ g}} = 3.500 \text{ mol of F atoms}$

b. $401.2 \text{ mg Hg} \times \frac{1 \text{ mmol}}{200.6 \text{ mg}} = 2.000 \text{ mmol Hg}$ (1 mmol = 1/1000 mol)

c. $84.27 \text{ g Si} \times \frac{1 \text{ mol}}{28.09 \text{ g}} = 3.000 \text{ mol Si}$

d. $48.78 \text{ g Pt} \times \frac{1 \text{ mol}}{195.1 \text{ g}} = 0.2500 \text{ mol Pt}$

e. $2431 \text{ g Mg} \times \frac{1 \text{ mol}}{24.31 \text{ g}} = 100.0 \text{ mol Mg}$

f. $47.97 \text{ g} \times \frac{1 \text{ mol}}{95.94 \text{ g}} = 0.5000 \text{ mol Mo}$

21.

a. $0.251 \text{ mol Li} \times \frac{6.941 \text{ g Li}}{1 \text{ mol Li}} = 1.74 \text{ g Li}$

b. $1.51 \text{ mol Al} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}} = 40.7 \text{ g Al}$

c. $8.75 \times 10^{-2} \text{ mol Pb} \times \frac{207.2 \text{ g Pb}}{1 \text{ mol Pb}} = 18.1 \text{ g Pb}$

d. $125 \text{ mol Cr} \times \frac{52.00 \text{ g Cr}}{1 \text{ mol Cr}} = 6.50 \times 10^{3} \text{ g Cr}$

e. $4.25 \times 10^{3} \text{ mol Fe} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol}} = 2.37 \times 10^{5} \text{ g Fe}$

f. $0.000105 \text{ mol Mg} \times \frac{24.31 \text{ g Mg}}{1 \text{ mol Mg}} = 2.55 \times 10^{-3} \text{ g Mg}$

22.

a. $1.76 \times 10^{-3} \text{ mol Cs} \times \frac{132.9 \text{ g}}{1 \text{ mol}} = 2.34 \times 10^{-1} \text{ g Cs}$

b. $0.0125 \text{ mol Ne} \times \frac{20.18 \text{ g}}{1 \text{ mol}} = 0.252 \text{ g Ne}$

c. $5.29 \times 10^{3} \text{ mol Pb} \times \frac{207.2 \text{ g}}{1 \text{ mol}} = 1.10 \times 10^{6} \text{ g Pb}$

d. $0.00000122 \text{ mol Na} \times \frac{22.99 \text{ g}}{1 \text{ mol}} = 2.80 \times 10^{-5} \text{ g Na}$

e. $5.51 \text{ millimol As} \times \frac{74.92 \text{ g}}{1 \text{ mol}} = 413 \text{ mg} = 0.413 \text{ g As}$

f. $8.72 \text{ mol C} \times \frac{12.01 \text{ g}}{1 \text{ mol}} = 105 \text{ g C}$

23.

a. $1.50 \text{ g Ag} \times \frac{6.022 \times 10^{23} \text{ Ag atoms}}{107.9 \text{ g Ag}} = 8.37 \times 10^{21} \text{ Ag atoms}$

b. $0.0015 \text{ mol Cu} \times \frac{6.022 \times 10^{23} \text{ Cu atoms}}{1 \text{ mol}} = 9.0 \times 10^{20} \text{ Cu atoms}$

c. $0.0015 \text{ g Cu} \times \frac{6.022 \times 10^{23} \text{ Cu atoms}}{63.55 \text{ g Cu}} = 1.4 \times 10^{19} \text{ Cu atoms}$

d. $2.00 \text{ kg} = 2.00 \times 10^{3} \text{ g}$

$2.00 \times 10^{3} \text{ g Mg} \times \frac{6.022 \times 10^{23} \text{ Mg atoms}}{24.31 \text{ g Mg}} = 4.95 \times 10^{25} \text{ Mg atoms}$

e. $1.000 \text{ oz} = 28.35 \text{ g}$

$2.34 \text{ oz} \times \frac{28.35 \text{ g}}{1.000 \text{ oz}} \times \frac{6.022 \times 10^{23} \text{ Ca atoms}}{40.08 \text{ g Ca}} = 9.97 \times 10^{23} \text{ Ca atoms}$

f. $2.34 \text{ g Ca} \times \frac{6.022 \times 10^{23} \text{ Ca atoms}}{40.08 \text{ g Ca}} = 3.52 \times 10^{22} \text{ Ca atoms}$

g. $2.34 \text{ mol Ca} \times \frac{6.022 \times 10^{23} \text{ Ca atoms}}{1 \text{ mol Ca}} = 1.41 \times 10^{24} \text{ Ca atoms}$

24.

a. $425 \text{ Na atoms} \times \frac{22.99 \text{ amu}}{1 \text{ Na atom}} = 9.77 \times 10^{3} \text{ amu}$

b. $425 \text{ Na atoms} \times \frac{22.99 \text{ g Na}}{6.022 \times 10^{23} \text{ Na atoms}} = 1.62 \times 10^{-20} \text{ g}$

c. $425 \text{ mol Na} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}} = 9.77 \times 10^{3} \text{ g}$

d. $425 \text{ mol Na} \times \frac{6.022 \times 10^{23} \text{ Na atoms}}{1 \text{ mol Na}} = 2.56 \times 10^{26} \text{ sodium atoms}$

e. $425 \text{ g Na} \times \frac{6.022 \times 10^{23} \text{ Na atoms}}{22.99 \text{ g Na}} = 1.11 \times 10^{25} \text{ sodium atoms}$

f. $425 \text{ g Na} \times \frac{1 \text{ mol Na}}{22.99 \text{ g Na}} = 18.5 \text{ mol Na}$

g. $425 \text{ g Na} \times \frac{24.31 \text{ g Mg}}{22.99 \text{ g Na}} = 449 \text{ g Mg}$

25. molar mass

26. The molar mass is calculated by summing the individual atomic masses of the atoms in the formula.

27.

a. Cr_2O_3, chromium(III) oxide

mass of 2 mol Cr = 2(52.00 g) = 104.00 g

mass of 3 mol O = 3(16.00 g) = 48.00 g

molar mass of Cr_2O_3 = (104.00 g + 48.00 g) = 152.00 g

b. $Cu(NO_3)_2$, copper(II) nitrate

mass of 1 mol Cu = 63.55 g = 63.55 g

mass of 4 mol N = 4(14.01 g) = 56.04 g

mass of 6 mol O = 6(16.00 g) = 96.00 g

molar mass of $Cu(NO_3)_2$ = (63.55 g + 56.04 g + 96.00 g) = 215.59 g

c. P_4O_6, tetraphosphorus hex(a)oxide

mass of 4 mol P = 4(30.97 g) = 123.9 g

mass of 6 mol O = 6(16.00) g = 96.00 g

molar mass of P_4O_6 = (123.9 g + 96.00 g) = 219.9 g

d. Bi_2O_3, bismuth(III) oxide

mass of 2 mol Bi = 2(209.0 g) = 418.0 g

mass of 3 mol O = 3(16.00 g) = 48.00 g

molar mass of Bi_2O_3 = (418.0 g + 48.00 g) = 466.0 g

e. CS_2, carbon disulfide

mass of 1 mol C = 12.01 g = 12.01 g

mass of 2 mol S = 2(32.07 g) = 64.14 g

molar mass of CS_2 = (12.01 g + 64.14 g) = 76.15 g

f. H_2SO_3, sulfurous acid

mass of 2 mol H = 2(1.008 g) = 2.016 g

mass of 1 mol S = 32.07 g = 32.07 g

mass of 3 mol O = 3(16.00 g) = 48.00 g

molar mass of H_2SO_3 = (2.016 g + 32.07 g + 48.00 g) = 82.11 g

28.

a. carbon monoxide

mass of 1 mol C = 12.01 g

mass of 1 mol O = 16.00 g

molar mass of CO = (12.01 g + 16.00 g) = 28.01 g

b. sodium carbonate

mass of 2 mol Na = 2(22.99 g) = 45.98 g

mass of 1 mol C = 12.01 g

mass of 3 mol O = 3(16.00 g) = 48.00 g

molar mass of Na_2CO_3 = (45.98 g + 12.01 g + 48.00 g) = 105.99 g

c. iron(III) nitrate/ferric nitrate

mass of 1 mol Fe = 55.85 g

mass of 3 mol N = 3(14.01 g) = 42.03 g

mass of 9 mol O = 9(16.00 g) = 96.00 g

molar mass of $Fe(NO_3)_3$ = (55.85 g + 42.03 g + 96.00 g) = 241.88 g

d. hydrogen iodide

mass of 1 mol H = 1.008 g

mass of 1 mol I = 126.9 g

molar mass of HI = 127.9 g

e. sulfur trioxide

mass of 1 mol S = 32.07 g

mass of 3 mol O = 3(16.00 g) = 48.00 g

molar mass of SO_3 = (32.07 g + 48.00 g) = 80.07 g

29.

a. $BaCl_2$

mass of 1 mol Ba = 137.3 g

mass of 2 mol Cl = 2(35.45 g) = 70.90 g

molar mass of $BaCl_2$ = (137.3 g + 70.90 g) = 208.2 g

b. $Al(NO_3)_3$

mass of 1 mol Al = 26.98 g

mass of 3 mol N = 3(14.01 g) = 42.03 g

mass of 9 mol O = 9(16.00 g) = 96.00 g

molar mass of $Al(NO_3)_3$ = (26.98 g + 42.03 g + 96.00 g) = 213.0 g

c. $FeCl_2$

mass of 1 mol Fe = 55.85 g

mass of 2 mol Cl = 2(35.45 g) = 70.90 g

molar mass of $FeCl_2$ = (55.85 g + 70.90 g) = 126.75 g

d. SO_2

mass of 1 mol S = 32.07 g

mass of 2 mol O = 2(16.00 g) = 32.00 g

molar mass of SO_2 = (32.07 g + 32.00 g) = 64.07 g

e. $Ca(C_2H_3O_2)_2$

mass of 1 mol Ca = 40.08 g

mass of 4 mol C = 4(12.01 g) = 48.04 g

mass of 6 mol H = 6(1.008 g) = 6.048 g

mass of 4 mol O = 4(16.00 g) = 64.00 g

molar mass of $Ca(C_2H_3O_2)_2$ = (40.08 g + 48.04 g + 6.048 g + 64.00 g) = 158.17 g

30.

a. aluminum fluoride

mass of 1 mol Al = 26.98 g

mass of 3 mol F = 3(19.00 g) = 57.00 g

molar mass of AlF_3 = (26.98 g + 57.00 g) = 83.98 g

b. sodium phosphate

mass of 3 mol Na = 3(22.99 g) = 68.97 g

mass of 1 mol P = 30.97 g

mass of 4 mol O = 4(16.00 g) = 64.00 g

molar mass of Na_3PO_4 = (68.97 g + 30.97 g + 64.00 g) = 163.94 g

c. magnesium carbonate

mass of 1 mol Mg = 24.31 g

mass of 1 mol C = 12.01 g

mass of 3 mol O = 3(16.00 g) = 48.00 g

molar mass of $MgCO_3$ = (24.31 g + 12.01 g + 48.00 g) = 84.32 g

d. lithium hydrogen carbonate/lithium bicarbonate

mass of 1 mol Li = 6.941 g

mass of 1 mol H = 1.008 g

mass of 1 mol C = 12.01 g

mass of 3 mol O = 3(16.00 g) = 48.00 g

molar mass of $LiHCO_3$ = (6.941 g + 1.008 g + 12.01 g + 48.00 g) = 67.96 g

e. chromium(III) oxide/chromic oxide

mass of 2 mol Cr = 2(52.00 g) = 104.0 g

mass of 3 mol O = 3(16.00 g) = 48.00 g

molar mass of Cr_2O_4 = 152.0 g

31.

a. molar mass of NO_2 = 46.01 g; 21.4 mg = 0.0214 g

$$0.0214 \text{ g } NO_2 \times \frac{1 \text{ mol}}{46.01 \text{ g}} = 4.65 \times 10^{-4} \text{ mol } NO_2$$

b. molar mass of $Cu(NO_3)_2$ = 187.6 g

$$1.56 \text{ g } Cu(NO_3)_2 \times \frac{1 \text{ mol}}{187.6 \text{ g}} = 8.32 \times 10^{-3} \text{ mol } Cu(NO_3)_2$$

c. molar mass of CS_2 = 76.15 g

$$2.47 \text{ g } CS_2 \times \frac{1 \text{ mol}}{76.15 \text{ g}} = 0.0324 \text{ mol}$$

d. molar mass of $Al_2(SO_4)_3$ = 342.2 g

$$5.04 \text{ g } Al_2(SO_4)_3 \times \frac{1 \text{ mol}}{342.2 \text{ g}} = 0.0147 \text{ mol } Al_2(SO_4)_3$$

e. molar mass of $PbCl_2$ = 278.1 g

$$2.99 \text{ g} \times \frac{1 \text{ mol}}{278.1 \text{ g}} = 0.0108 \text{ mol } PbCl_2$$

f. molar mass of $CaCO_3$ = 100.09 g

$$62.4 \text{ g } CaCO_3 \times \frac{1 \text{ mol}}{100.09 \text{ g}} = 0.623 \text{ mol } CaCO_3$$

32.

a. molar mass NaCl = 58.44 g; 52.1 mg = 0.0521 g

$$0.0521 \text{ g} \times \frac{1 \text{ mol}}{58.44 \text{ g}} = 8.92 \times 10^{-4} \text{ mol}$$

b. molar mass $MgCO_3$ = 84.32 g

$$10.5\text{ g} \times \frac{1\text{ mol}}{84.32\text{ g}} = 0.125\text{ mol}$$

c. molar mass Al_2O_3 = 101.96 g

$$4.00\text{ g} \times \frac{1\text{ mol}}{101.96\text{ g}} = 0.0392\text{ mol}$$

d. molar mass of Fe_2O_3 = 159.7 g

$$24.1\text{ g} \times \frac{1\text{ mol}}{159.7\text{ g}} = 0.151\text{ mol}$$

e. millimolar mass of Li_2CO_3 = 73.89 mg

$$125\text{ mg} \times \frac{1\text{ mmol}}{73.89\text{ mg}} = 1.69\text{ mmol} = 1.69 \times 10^{-3}\text{ mol}$$

f. molar mass of Fe = 55.85 g; 2.25 kg = 2250 g

$$2250\text{ g} \times \frac{1\text{ mol}}{55.85\text{ g}} = 40.3\text{ mol}$$

33.

a. molar mass $MgCl_2$ = 95.21 g

$$41.5\text{ g} \times \frac{1\text{ mol}}{95.21\text{ g}} = 0.436\text{ mol}$$

b. molar mass Li_2O = 29.88 g; 135 mg = 0.135 g

$$0.135\text{ g} \times \frac{1\text{ mol}}{29.88\text{ g}} = 4.52 \times 10^{-3}\text{ mol} = 4.52\text{ mmole}$$

c. molar mass Cr = 52.00 g; 1.21 kg = 1210 g

$$1210\text{ g} \times \frac{1\text{ mol}}{52.00\text{ g}} = 23.3\text{ mol}$$

d. molar mass H_2SO_4 = 98.09 g

$$62.5\text{ g} \times \frac{1\text{ mol}}{98.09\text{ g}} = 0.637\text{ mol}$$

e. molar mass C_6H_6 = 78.11 g

$$42.7\text{ g} \times \frac{1\text{ mol}}{78.11\text{ g}} = 0.547\text{ mol}$$

f. molar mass H_2O_2 = 34.02 g

$$135\text{ g} \times \frac{1\text{ mol}}{34.02\text{ g}} = 3.97\text{ mol}$$

34.

a. molar mass of NaH_2PO_4 = 120.0 g

$$4.26 \times 10^{-3} \text{ g} \times \frac{1 \text{ mol}}{120.0 \text{ g}} = 3.55 \times 10^{-5} \text{ mol}$$

b. molar mass of CuCl = 99.00 g

$$521 \text{ g} \times \frac{1 \text{ mol}}{99.00 \text{ g}} = 5.26 \text{ mol}$$

c. molar mass of Fe = 55.85 g

$$151 \text{ kg} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol}}{55.85 \text{ g}} = 2.70 \times 10^3 \text{ mol}$$

d. molar mass of SrF_2 = 125.6 g

$$8.76 \text{ g} \times \frac{1 \text{ mol}}{125.6 \text{ g}} = 0.0697 \text{ mol}$$

e. molar mass of Al = 26.98 g

$$1.26 \times 10^4 \text{ g} \times \frac{1 \text{ mol}}{26.98 \text{ g}} = 467 \text{ mol}$$

35.

a. molar mass $AlCl_3$ = 133.3 g

$$1.25 \text{ mol} \times \frac{133.3 \text{ g}}{1 \text{ mol}} = 167 \text{ g}$$

b. molar mass $NaHCO_3$ = 84.01 g

$$3.35 \text{ mol} \times \frac{84.01 \text{ g}}{1 \text{ mol}} = 281 \text{ g}$$

c. molar mass HBr = 80.91 g

$$4.25 \text{ mmol} \times \frac{80.91 \text{ mg}}{1 \text{ mmol}} = 344 \text{ mg} = 0.344 \text{ g}$$

d. molar mass U = 238.0 g

$$1.31 \times 10^{-3} \text{ mol} \times \frac{238.0 \text{ g}}{1 \text{ mol}} = 0.312 \text{ g}$$

e. molar mass CO_2 = 44.01 g

$$0.00104 \text{ mol} \times \frac{44.01 \text{ g}}{1 \text{ mol}} = 0.0458 \text{ g}$$

f. molar mass Fe = 55.85 g

$$1.49 \times 10^2 \text{ mol Fe} \times \frac{55.85 \text{ g}}{1 \text{ mol}} = 8.32 \times 10^3 \text{ g}$$

36.

a. molar mass of CO = 28.01 g

$$0.00471 \text{ mol} \times \frac{28.01 \text{ g}}{1 \text{ mol}} = 0.132 \text{ g}$$

b. molar mass of $AuCl_3$ = 303.4 g

$$1.75 \times 10^{-6} \text{ mol } AuCl_3 \times \frac{303.4 \text{ g}}{1 \text{ mol}} = 5.31 \times 10^{-4} \text{ g}$$

c. molar mass of $FeCl_3$ = 162.2 g

$$228 \text{ mol } FeCl_3 \times \frac{162.2 \text{ g}}{1 \text{ mol}} = 3.70 \times 10^{4} \text{ g}$$

d. molar mass of K_3PO_4 = 212.3 g; 2.98 millimol = 0.00298 mol

$$0.00298 \text{ mol } K_3PO_4 \times \frac{212.3 \text{ g}}{1 \text{ mol}} = 0.633 \text{ g}$$

e. molar mass of LiCl = 42.39 g

$$2.71 \times 10^{-3} \text{ mol LiCl} \times \frac{42.39 \text{ g}}{1 \text{ mol}} = 0.115 \text{ g}$$

f. molar mass of NH_3 = 17.03 g

$$6.55 \text{ mol } NH_3 \times \frac{17.03 \text{ g}}{1 \text{ mol}} = 112 \text{ g}$$

37.

a. molar mass of C_2H_6O = 46.07 g

$$0.251 \text{ mol} \times \frac{46.07 \text{ g}}{1 \text{ mol}} = 11.6 \text{ g } C_2H_6O$$

b. molar mass of CO_2 = 44.01 g

$$1.26 \text{ mol} \times \frac{44.01 \text{ g}}{1 \text{ mol}} = 55.5 \text{ g } CO_2$$

c. molar mass of $AuCl_3$ = 303.4 g

$$9.31 \times 10^{-4} \text{ mol} \times \frac{303.4 \text{ g}}{1 \text{ mol}} = 0.282 \text{ g } AuCl_3$$

d. molar mass of $NaNO_3$ = 85.00 g

$$7.74 \text{ mol} \times \frac{85.00 \text{ g}}{1 \text{ mol}} = 658 \text{ g } NaNO_3$$

e. molar mass of Fe = 55.85 g

$$0.000357 \text{ mol} \times \frac{55.85 \text{ g}}{1 \text{ mol}} = 0.0199 \text{ g Fe}$$

38.

a. molar mass NaOCl = 74.44 g

$$0.00421 \text{ mol} \times \frac{74.44 \text{ g}}{1 \text{ mol}} = 0.313 \text{ g}$$

b. molar mass BaH_2 = 139.3 g

$$0.998 \text{ mol} \times \frac{139.3 \text{ g}}{1 \text{ mol}} = 139 \text{ g}$$

c. molar mass AlF_3 = 83.98 g

$$1.99 \times 10^{-2} \text{ mol} \times \frac{83.98 \text{ g}}{1 \text{ mol}} = 1.67 \text{ g}$$

d. molar mass $MgCl_2$ = 95.21 g

$$0.119 \text{ mol} \times \frac{95.21 \text{ g}}{1 \text{ mol}} = 11.3 \text{ g}$$

e. molar mass Pb = 207.2 g

$$225 \text{ mol} \times \frac{207.2 \text{ g}}{1 \text{ mol}} = 4.66 \times 10^4 \text{ g}$$

f. molar mass CO_2 = 44.01 g

$$0.101 \text{ mol} \times \frac{44.01 \text{ g}}{1 \text{ mol}} = 4.45 \text{ g}$$

39.

a. 4.75 millimol = 0.00475 mol

$$0.00475 \text{ mol} \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 2.86 \times 10^{21} \text{ molecules}$$

b. molar mass of PH_3 = 33.99 g

$$4.75 \text{ g} \times \frac{6.022 \times 10^{23} \text{ molecules}}{33.99 \text{ g}} = 8.42 \times 10^{22} \text{ molecules}$$

c. molar mass of $Pb(C_2H_3O_2)_2$ = 325.3 g

$$1.25 \times 10^{-2} \text{ g} \times \frac{6.022 \times 10^{23} \text{ formula units}}{325.3 \text{ g}} = 2.31 \times 10^{19} \text{ formula units}$$

d. $$1.25 \times 10^{-2} \text{ mol} \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}} = 7.53 \times 10^{21} \text{ formula units}$$

e. If the sample contains a total of 5.40 mol of carbon, then because each benzene contains six carbons, there must be (5.40/6) = 0.900 mol of benzene present.

$$0.900 \text{ mol} \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 5.42 \times 10^{23} \text{ molecules}$$

40.

a. $6.37 \text{ mol CO} \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 3.84 \times 10^{24} \text{ molecules CO}$

b. molar mass of CO = 28.01 g

$6.37 \text{ g} \times \frac{6.022 \times 10^{23} \text{ molecules}}{28.01 \text{ g}} = 1.37 \times 10^{23} \text{ molecules CO}$

c. molar mass of H_2O = 18.02 g

$2.62 \times 10^{-6} \text{ g} \times \frac{6.022 \times 10^{23} \text{ molecules}}{18.02 \text{ g}} = 8.76 \times 10^{16} \text{ molecules } H_2O$

d. $2.62 \times 10^{-6} \text{ g} \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 1.58 \times 10^{18} \text{ molec. } H_2O$

e. molar mass of C_6H_6 = 78.11 g

$5.23 \text{ g} \times \frac{6.022 \times 10^{23} \text{ molecules}}{78.11 \text{ g}} = 4.03 \times 10^{22} \text{ molecules } C_6H_6$

41.

a. molar mass of C_2H_6O = 46.07 g

$1.271 \text{ g} \times \frac{1 \text{ mol}}{46.07 \text{ g}} = 0.02759 \text{ mol } C_2H_6O$

$0.02759 \text{ mol } C_2H_6O \times \frac{2 \text{ mol C}}{1 \text{ mol } C_2H_6O} = 0.05518 \text{ mol C}$

b. molar mass of $C_6H_4Cl_2$ = 147.0 g

$3.982 \text{ g} \times \frac{1 \text{ mol}}{147.0 \text{ g}} = 0.027088 \text{ mol } C_6H_4Cl_2$

$0.027088 \text{ mol } C_6H_4Cl_2 \times \frac{6 \text{ mol C}}{1 \text{ mol } C_6H_4Cl_2} = 0.1625 \text{ mol C}$

c. molar mass of C_3O_2 = 68.03 g

$0.4438 \text{ g} \times \frac{1 \text{ mol}}{68.03 \text{ g}} = 0.0065236 \text{ mol } C_3O_2$

$0.0065236 \text{ mol } C_3O_2 \times \frac{3 \text{ mol C}}{1 \text{ mol } C_3O_2} = 0.01957 \text{ mol C}$

d. molar mass of CH_2Cl_2 = 84.93 g

$$2.910\text{ g} \times \frac{1\text{ mol}}{84.93\text{ g}} = 0.034264\text{ mol } CH_2Cl_2$$

$$0.034264\text{ mol } CH_2Cl_2 \times \frac{1\text{ mol C}}{1\text{ mol } CH_2Cl_2} = 0.03426\text{ mol C}$$

42.

a. molar mass of Na_2SO_4 = 142.1 g

$$2.01\text{ g } Na_2SO_4 \times \frac{1\text{ mol } Na_2SO_4}{142.1\text{ g}} \times \frac{1\text{ mol S}}{1\text{ mol } Na_2SO_4} = 0.0141\text{ mol S}$$

b. molar mass of Na_2SO_3 = 126.1 g

$$2.01\text{ g } Na_2SO_3 \times \frac{1\text{ mol } Na_2SO_3}{126.1\text{ g}} \times \frac{1\text{ mol S}}{1\text{ mol } Na_2SO_3} = 0.0159\text{ mol S}$$

c. molar mass of Na_2S = 78.05 g

$$2.01\text{ g } Na_2S \times \frac{1\text{ mol } Na_2S}{78.05\text{ g}} \times \frac{1\text{ mol S}}{1\text{ mol } Na_2S} = 0.0258\text{ mol S}$$

d. molar mass of $Na_2S_2O_3$ = 158.1 g

$$2.01\text{ g } Na_2S_2O_3 \times \frac{1\text{ mol } Na_2S_2O_3}{158.1\text{ g}} \times \frac{1\text{ mol S}}{1\text{ mol } Na_2S} = 0.0127\text{ mol S}$$

43. molar

44. less than

45.

a. mass of H present = 1.008 g = 1.008 g

mass of Cl present = 35.45 g = 35.45 g

mass of O present = 3(16.00 g) = 48.00 g

molar mass of $HClO_3$ = 84.46 g

$$\%\text{ H} = \frac{1.008\text{ g H}}{84.46\text{ g}} \times 100 = 1.193\%\text{ H}$$

$$\%\text{ Cl} = \frac{35.45\text{ g Cl}}{84.46\text{ g}} \times 100 = 41.97\%\text{ Cl}$$

$$\%\text{ O} = \frac{48.00\text{ g O}}{84.46\text{ g}} \times 100 = 56.83\%\text{ O}$$

b. mass of U present = 238.0 g = 238.0 g

mass of F present = 4(19.00 g) = 76.00 g

molar mass of UF_4 = 314.0 g

$$\% \text{ U} = \frac{238.0 \text{ g U}}{314.0 \text{ g}} \times 100 = 75.80\% \text{ U}$$

$$\% \text{ F} = \frac{76.00 \text{ g F}}{314.0 \text{ g}} \times 100 = 24.20\% \text{ F}$$

c. mass of Ca present = 40.08 g = 40.08 g

mass of H present = 2(1.008 g) = 2.016 g

molar mass of CaH_2 = 42.10 g

$$\% \text{ Ca} = \frac{40.08 \text{ g C}}{42.10 \text{ g}} \times 100 = 95.21\% \text{ Ca}$$

$$\% \text{ H} = \frac{2.016 \text{ g H}}{42.10 \text{ g}} \times 100 = 4.789\% \text{ H}$$

d. mass of Ag present =2(107.9 g) = 215.8 g

mass of S present = 32.07 g = 32.07 g

molar mass of Ag_2S = 247.9 g

$$\% \text{ Ag} = \frac{215.8 \text{ g Ag}}{247.9 \text{ g}} \times 100 = 87.06\% \text{ Ag}$$

$$\% \text{ S} = \frac{32.07 \text{ g S}}{247.9 \text{ g}} \times 100 = 12.94\% \text{ S}$$

e. mass of Na present = 22.99 g = 22.99 g

mass of H present = 1.008 g = 1.008 g

mass of S present = 32.07 g = 32.07 g

mass of O present = 3(16.00 g) = 48.00 g

molar mass of $NaHSO_3$ = 104.07 g

$$\% \text{ Na} = \frac{22.99 \text{ g Na}}{104.07 \text{ g}} \times 100 = 22.09\% \text{ Na}$$

$$\% \text{ H} = \frac{1.008 \text{ g H}}{104.07 \text{ g}} \times 100 = 0.9686\% \text{ H}$$

$$\% \text{ S} = \frac{32.07 \text{ g S}}{104.07 \text{ g}} \times 100 = 30.82\% \text{ S}$$

$$\% \text{ O} = \frac{48.00 \text{ g O}}{104.07 \text{ g}} \times 100 = 46.12\% \text{ O}$$

f. mass of Mn present = 54.94 g = 54.94 g

mass of O present = 2(16.00 g) = 32.00 g

molar mass of MnO_2 = 86.94 g

$$\% \text{ Mn} = \frac{54.94 \text{ g Mn}}{86.94 \text{ g}} \times 100 = 63.19\% \text{ Mn}$$

$$\% \text{ S} = \frac{32.00 \text{ g O}}{86.94 \text{ g}} \times 100 = 36.81\% \text{ O}$$

46.

a. mass of Cu present = 2(63.55 g) = 127.1 g

mass of O present = 16.00 g

molar mass of Cu_2O = 143.1 g

$$\% \text{ Cu} = \frac{127.1 \text{ g Cu}}{143.1 \text{ g}} \times 100 = 88.82\% \text{ Cu}$$

$$\% \text{ O} = \frac{16.00 \text{ g O}}{143.1 \text{ g}} \times 100 = 11.18\% \text{ O}$$

b. mass of Cu present = 63.55 g

mass of O present = 16.00 g

molar mass of CuO = 79.55 g

$$\% \text{ Cu} = \frac{63.55 \text{ g Cu}}{79.55 \text{ g}} \times 100 = 79.89\% \text{ Cu}$$

$$\% \text{ O} = \frac{16.00 \text{ g O}}{79.55 \text{ g}} \times 100 = 20.11\% \text{ O}$$

c. mass of Fe present = 55.85 g

mass of O present = 16.00 g

molar mass of FeO = 71.85 g

$$\% \text{ Fe} = \frac{55.85 \text{ g Fe}}{71.85 \text{ g}} \times 100 = 77.73\% \text{ Fe}$$

$$\% \text{ O} = \frac{16.00 \text{ g O}}{71.85 \text{ g}} \times 100 = 22.27\% \text{ O}$$

d. mass of Fe present = 2(55.85 g) = 111.7 g

mass of O present = 3(16.00 g) = 48.00 g

molar mass of Fe_2O_3 = 159.7 g

$$\% \text{ Fe} = \frac{111.7 \text{ g Fe}}{159.7 \text{ g}} \times 100 = 69.94\% \text{ Fe}$$

$$\% \text{ O} = \frac{48.00 \text{ g O}}{159.7 \text{ g}} \times 100 = 30.06\% \text{ O}$$

e. mass of N present = 14.01 g

mass of O present = 16.00 g

molar mass of NO = 30.01 g

$$\% \text{ N} = \frac{14.01 \text{ g N}}{30.01 \text{ g}} \times 100 = 46.68\% \text{ N}$$

$$\% \text{ O} = \frac{16.00 \text{ g O}}{30.01 \text{ g}} \times 100 = 53.32\% \text{ O}$$

f. mass of N present = 14.01 g

mass of O present = 2(16.00 g) = 32.00 g

molar mass of NO_2 = 46.01 g

$$\% \text{ N} = \frac{14.01 \text{ g N}}{46.01 \text{ g}} \times 100 = 30.45\% \text{ N}$$

$$\% \text{ O} = \frac{32.00 \text{ g O}}{46.01 \text{ g}} \times 100 = 69.55\% \text{ O}$$

47.

a. molar mass of CH_4 = 16.04 g

$$\% \text{ C} = \frac{12.01 \text{ g C}}{16.04 \text{ g}} \times 100 = 74.88\% \text{ C}$$

b. molar mass $NaNO_3$ = 85.00 g

$$\% \text{ Na} = \frac{22.99 \text{ g Na}}{85.00 \text{ g}} \times 100 = 27.05\% \text{ Na}$$

c. molar mass of CO = 28.01 g

$$\% \text{ C} = \frac{12.01 \text{ g C}}{28.01 \text{ g}} \times 100 = 42.88\% \text{ C}$$

d. molar mass of NO_2 = 46.01 g

$$\% \text{ N} = \frac{14.01 \text{ g N}}{46.01 \text{ g}} \times 100 = 30.45\% \text{ N}$$

e. molar mass of $C_8H_{18}O$ = 130.2 g

$$\% C = \frac{96.08 \text{ g C}}{130.2 \text{ g}} \times 100 = 73.79\% \text{ C}$$

f. molar mass of $Ca_3(PO_4)_2$ = 310.1 g

$$\% Ca = \frac{120.2 \text{ g Ca}}{310.1 \text{ g}} \times 100 = 38.76\% \text{ Ca}$$

g. molar mass of $C_{12}H_{10}O$ = 170.2 g

$$\% C = \frac{144.1 \text{ g C}}{170.2 \text{ g}} \times 100 = 84.67\% \text{ C}$$

h. molar mass of $Al(C_2H_3O_2)_3$ = 204.1 g

$$\% Al = \frac{26.98 \text{ g Al}}{204.1 \text{ g}} \times 100 = 13.22\% \text{ Al}$$

48.

a. molar mass of $CuBr_2$ = 223.4

$$\% Cu = \frac{63.55 \text{ g Cu}}{223.4 \text{ g}} \times 100 = 28.45\% \text{ Cu}$$

b. molar mass of CuBr = 143.5 g

$$\% Cu = \frac{63.55 \text{ g Cu}}{143.5 \text{ g}} \times 100 = 44.29\% \text{ Cu}$$

c. molar mass of $FeCl_2$ = 126.75 g

$$\% Fe = \frac{55.85 \text{ g Fe}}{126.75} \times 100 = 44.06\% \text{ Fe}$$

d. molar mass of $FeCl_3$ = 162.2 g

$$\% Fe = \frac{55.85 \text{ g Fe}}{162.2 \text{ g}} \times 100 = 34.43\% \text{ Fe}$$

e. molar mass of CoI_2 = 312.7 g

$$\% Co = \frac{58.93 \text{ g Co}}{312.7 \text{ g}} \times 100 = 18.85\% \text{ Co}$$

f. molar mass of CoI_3 = 439.6 g

$$\% Co = \frac{58.93 \text{ g Co}}{439.6 \text{ g}} \times 100 = 13.41\% \text{ Co}$$

g. molar mass of SnO = 134.7 g

$$\% Sn = \frac{118.7 \text{ g Sn}}{134.7 \text{ g}} \times 100 = 88.12\% \text{ Sn}$$

h. molar mass of SnO_2 = 150.7 g

$$\% \text{ Sn} = \frac{118.7 \text{ g Sn}}{150.7 \text{ g}} \times 100 = 78.77\% \text{ Sn}$$

49.

a. molar mass of $C_6H_{10}O_4$ = 146.1 g

$$\% \text{ C} = \frac{72.06 \text{ g C}}{146.1 \text{ g}} \times 100 = 49.32\% \text{ C}$$

b. molar mass of NH_4NO_3 = 80.05 g

$$\% \text{ N} = \frac{28.02 \text{ g N}}{80.05 \text{ g}} \times 100 = 35.00\% \text{ N}$$

c. molar mass of $C_8H_{10}N_4O_2$ = 194.2 g

$$\% \text{ C} = \frac{96.09 \text{ g C}}{194.2 \text{ g}} \times 100 = 49.47\% \text{ C}$$

d. molar mass of ClO_2 = 67.45 g

$$\% \text{ Cl} = \frac{35.45 \text{ g Cl}}{67.45 \text{ g}} \times 100 = 52.56\% \text{ Cl}$$

e. molar mass of $C_6H_{11}OH$ = 100.2 g

$$\% \text{ C} = \frac{72.06 \text{ g C}}{100.2 \text{ g}} \times 100 = 71.92\% \text{ C}$$

f. molar mass of $C_6H_{12}O_6$ = 180.2 g

$$\% \text{ C} = \frac{72.06 \text{ g C}}{180.2 \text{ g}} \times 100 = 39.99\% \text{ C}$$

g. molar mass of $C_{20}H_{42}$ = 282.5 g

$$\% \text{ C} = \frac{240.2 \text{ g C}}{282.5 \text{ g}} \times 100 = 85.03\% \text{ C}$$

h. molar mass of C_2H_5OH = 46.07 g

$$\% \text{ C} = \frac{24.02 \text{ g C}}{46.07 \text{ g}} \times 100 = 52.14\% \text{ C}$$

50.

a. molar mass of $FeCl_3$ = 162.2 g

$$\% \text{ Fe} = \frac{55.85 \text{ g Fe}}{162.2 \text{ g}} \times 100 = 34.43\% \text{ Fe}$$

b. molar mass of OF_2 = 54.00 g

$$\%\ O = \frac{16.00\ g\ O}{54.00} \times 100 = 29.63\%\ O$$

c. molar mass of C_6H_6 = 78.11 g

$$\%\ C = \frac{72.06\ g\ C}{78.11\ g} \times 100 = 92.25\%\ C$$

d. molar mass of NH_4ClO_4 = 117.5 g

$$\%\ N = \frac{14.01\ g\ N}{117.5\ g} \times 100 = 11.92\%\ N$$

e. molar mass of Ag_2O = 231.8 g

$$\%\ Ag = \frac{215.8\ g\ Ag}{231.8\ g} \times 100 = 93.10\%\ Ag$$

f. molar mass of $CoCl_2$ = 129.83 g

$$\%\ Co = \frac{58.93\ g\ Co}{129.83\ g} \times 100 = 45.39\%\ Co$$

g. molar mass of N_2O_4 = 92.02 g

$$\%\ N = \frac{28.02\ g\ N}{92.02\ g} \times 100 = 30.45\%\ N$$

h. molar mass of $MnCl_2$ = 125.84 g

$$\%\ Mn = \frac{54.94\ g\ Mn}{125.8\ g} \times 100 = 43.66\%\ Mn$$

51.

a. molar mass of NH_4I = 144.94 g

$$4.25\ g \times \frac{1\ mol\ NH_4I}{144.94\ g} \times \frac{1\ mol\ NH_4^+}{1\ mol\ NH_4I} = 0.0293\ mol\ NH_4^+$$

molar mass of NH_4^+ = 18.04 g

$$0.0293\ mol\ NH_4^+ \times \frac{18.04\ g\ NH_4^+}{1\ mol\ NH_4^+} = 0.529\ g\ NH_4^+$$

b. $$6.31\ mol\ (NH_4)_2S \times \frac{2\ mol\ NH_4^+}{1\ mol\ (NH_4)_2S} = 12.6\ mol\ NH_4^+$$

molar mass of NH_4^+ = 18.04 g

$$12.6\ mol\ NH_4^+ \times \frac{18.04\ g\ NH_4^+}{1\ mol\ NH_4^+} = 227\ g\ NH_4^+\ ion$$

c. molar mass of Ba_3P_2 = 473.8 g

$$9.71\ g \times \frac{1\ mol\ Ba_3P_2}{473.8\ g} \times \frac{3\ mol\ Ba^{2+}}{1\ mol\ Ba_3P_2} = 0.0615\ mol\ Ba^{2+}$$

molar mass of Ba^{2+} = 137.3 g

$$0.0615\ mol\ Ba^{2+} \times \frac{137.3\ g\ Ba^{2+}}{1\ mol\ Ba^{2+}} = 8.44\ g\ Ba^{2+}$$

d. $$7.63\ mol\ Ca_3(PO_4)_2 \times \frac{3\ mol\ Ca^{2+}}{1\ mol\ Ca_3(PO_4)_2} = 22.9\ mol\ Ca^{2+}$$

molar mass of Ca^{2+} = 40.08 g

$$22.9\ mol\ Ca^{2+} \times \frac{40.08\ g\ Ca^{2+}}{1\ mol\ Ca^{2+}} = 918\ g\ Ca^{2+}$$

52.

a. molar mass of NH_4Cl = 53.49 g; molar mass of NH_4^+ ion = 18.04 g

$$\%\ NH_4^+ = \frac{18.04\ g\ NH_4^+}{53.49\ g\ NH_4Cl} \times 100 = 33.73\%\ NH_4^+$$

b. molar mass of $CuSO_4$ = 159.62 g; molar mass of Cu^{2+} = 63.55 g

$$\%\ Cu^{2+} = \frac{63.55\ g\ Cu^{2+}}{159.62\ g\ CuSO_4} \times 100 = 39.81\%\ Cu^{2+}$$

c. molar mass of $AuCl_3$ = 303.4 g; molar mass of Au^{3+} ion = 197.0 g

$$\%\ Au^{3+} = \frac{197.0\ g\ Au^{3+}}{303.4\ g\ AuCl_3} \times 100 = 64.93\%\ Au^{3+}$$

d. molar mass of $AgNO_3$ = 169.9 g; molar mass of Ag^+ ion = 107.9 g

$$\%\ Ag^+ = \frac{107.9\ g\ Ag^+}{169.9\ g\ AgNO_3} \times 100 = 63.51\%\ Ag^+$$

53. To determine the *empirical* formula of a new compound, the composition of the compound by mass must be known. To determine the *molecular* formula of the compound, the molar mass of the compound must also be known.

54. The empirical formula indicates the smallest whole number ratio of the number and type of atoms present in a molecule. For example, NO_2 and N_2O_4 both have two oxygen atoms for every nitrogen atom and therefore have the same empirical formula

55.

a. NaO

b. $C_4H_3O_2$

c. $C_{12}H_{12}N_2O_3$ is already the empirical formula.

d. C_2H_3Cl

56.

a. yes (Each of these has the empirical formula CH.)

b. no (The number of hydrogen atoms is wrong.)

c. yes (Both have the empirical formula NO_2.)

d. no (The number of hydrogen and oxygen atoms is wrong.)

57. Assume we have 100.0 g of the compound so that the percentages become masses.

$$46.46 \text{ g Li} \times \frac{1 \text{ mol}}{6.941 \text{ g}} = 6.694 \text{ mol Li}$$

$$53.54 \text{ g O} \times \frac{1 \text{ mol}}{16.00 \text{ g}} = 3.346 \text{ mol O}$$

Dividing both of these numbers of moles by the smaller number of moles (3.346 mol O) gives

$$\frac{6.694 \text{ mol Li}}{3.346 \text{ mol}} = 2.000 \text{ mol Li}$$

$$\frac{3.346 \text{ mol O}}{3.346} = 1.000 \text{ mol O}$$

The empirical formula is Li_2O.

58. Assume we have 100.0 g of the compound so that the percentages become masses.

$$98.55 \text{ g Ba} \times \frac{1 \text{ mol}}{137.3 \text{ g}} = 0.7178 \text{ mol Ba}$$

$$1.447 \text{ g H} \times \frac{1 \text{ mol}}{1.008 \text{ g}} = 1.4355 \text{ mol H}$$

Dividing both of these numbers of moles by the smaller number of moles (0.7178 mol Ba) gives

$$\frac{0.7178 \text{ mol Ba}}{0.7178} = 1.000 \text{ mol Ba}$$

$$\frac{1.4355 \text{ mol H}}{0.7178 \text{ mol}} = 2.000 \text{ mol H}$$

The empirical formula is BaH_2.

59. $$0.2322 \text{ g C} \times \frac{1 \text{ mol}}{12.01 \text{ g}} = 0.01933 \text{ mol C}$$

$$0.05848 \text{ g H} \times \frac{1 \text{ mol}}{1.008 \text{ g}} = 0.05802 \text{ mol H}$$

$$0.3091 \text{ g O} \times \frac{1 \text{ mol}}{16.00 \text{ g}} = 0.01932 \text{ mol O}$$

Dividing each number of moles by the smallest number of moles (0.01932 mol C) gives

$$\frac{0.01933 \text{ mol C}}{0.01932 \text{ mol}} = 1.001 \text{ mol C}$$

$$\frac{0.05802 \text{ mol H}}{0.01932 \text{ mol}} = 3.003 \text{ mol H}$$

$$\frac{0.01932 \text{ mol O}}{0.01932 \text{ mol}} = 1.000 \text{ mol O}$$

The empirical formula is CH_3O.

60. Assume we have 100.0 g of the compound, so that the percentages become masses.

$$28.03 \text{ g Ca} \times \frac{1 \text{ mol}}{40.08 \text{ g}} = 0.6994 \text{ mol Ca}$$

$$22.38 \text{ g O} \times \frac{1 \text{ mol}}{16.00 \text{ g}} = 1.3988 \text{ mol O}$$

$$49.59 \text{ g Cl} \times \frac{1 \text{ mol}}{35.45 \text{ g}} = 1.3989 \text{ mol Cl}$$

Dividing each number of moles by the smallest number of moles (0.6994 mol Ca) gives

$$\frac{0.6994 \text{ mol Ca}}{0.6994 \text{ mol}} = 1.000 \text{ mol Ca}$$

$$\frac{1.3988 \text{ mol O}}{0.6994 \text{ mol}} = 2.000 \text{ mol O}$$

$$\frac{1.3939 \text{ mol Cl}}{0.6994 \text{ mol}} = 2.000 \text{ mol Cl}$$

The empirical formula is CaO_2Cl_2, which is more commonly written as $Ca(OCl)_2$.

61. The mass of chlorine in the reaction is 6.280 – 1.271 = 5.009 g Cl.

$$1.271 \text{ g Al} \times \frac{1 \text{ mol}}{26.98 \text{ g}} = 0.04711 \text{ mol Al}$$

$$5.009 \text{ g Cl} \times \frac{1 \text{ mol}}{35.45 \text{ g}} = 0.1413 \text{ mol Cl}$$

Dividing each of these number of moles by the smaller (0.04711 mol Al) gives

$$\frac{0.04711 \text{ mol Al}}{0.04711 \text{ mol}} = 1.000 \text{ mol Al}$$

$$\frac{0.1413 \text{ mol Cl}}{0.04711 \text{ mol}} = 3.000 \text{ mol Cl}$$

The empirical formula is $AlCl_3$.

62. Consider 100.0 g of the compound.

$$29.16\text{ g N} \times \frac{1\text{ mol}}{14.01\text{ g}} = 2.081\text{ mol N}$$

$$8.392\text{ g H} \times \frac{1\text{ mol}}{1.008\text{ g}} = 8.325\text{ mol H}$$

$$12.50\text{ g C} \times \frac{1\text{ mol}}{12.01\text{ g}} = 1.041\text{ mol C}$$

$$49.95\text{ g O} \times \frac{1\text{ mol}}{16.00\text{ g}} = 3.122\text{ mol O}$$

Dividing each number of moles by the smallest (1.041 mol C) gives

$$\frac{2.081\text{ mol N}}{1.041\text{ mol}} = 1.999\text{ mol N}$$

$$\frac{8.325\text{ mol H}}{1.041\text{ mol}} = 7.997\text{ mol H}$$

$$\frac{1.041\text{ mol C}}{1.041\text{ mol}} = 1.000\text{ mol C}$$

$$\frac{3.121\text{ mol O}}{1.041\text{ mol}} = 2.998\text{ mol O}$$

The empirical formula is $N_2H_8CO_3$ [i.e., $(NH_4)_2CO_3$].

63. $$3.269\text{ g Zn} \times \frac{1\text{ mol}}{65.38\text{ g}} = 0.05000\text{ mol Zn}$$

$$0.800\text{ g O} \times \frac{1\text{ mol}}{16.00\text{ g}} = 0.0500\text{ mol O}$$

Because the two components are present in equal amounts on a molar basis, the empirical formula must be simply ZnO.

64. Consider 100.0 g of the compound.

$$55.06\text{ g Co} \times \frac{1\text{ mol}}{58.93\text{ g}} = 0.9343\text{ mol Co}$$

If the sulfide of cobalt is 55.06% Co, then it is 44.94% S by mass.

$$44.94\text{ g S} \times \frac{1\text{ mol}}{32.07\text{ g}} = 1.401\text{ mol S}$$

Dividing each number of moles by the smaller (0.9343 mol Co) gives

$$\frac{0.09343 \text{ mol Co}}{0.9343} = 1.000 \text{ mol Co}$$

$$\frac{1.401 \text{ mol S}}{0.9343 \text{ mol}} = 1.500 \text{ mol S}$$

Multiplying by two to convert to whole numbers of moles gives the empirical formula for the compound as Co_2S_3.

65. The amount of fluorine that reacted with the aluminum sample must be (3.89 g – 1.25 g) = 2.64 g of fluorine

$$1.25 \text{ g Al} \times \frac{1 \text{ mol}}{26.98 \text{ g}} = 0.04633 \text{ mol Al}$$

$$2.64 \text{ g F} \times \frac{1 \text{ mol}}{19.00 \text{ g}} = 0.1389 \text{ mol F}$$

Dividing each number of moles by the smaller number of moles gives

$$\frac{0.04633 \text{ mol Al}}{0.04633 \text{ mol}} = 1.000 \text{ mol Al}$$

$$\frac{0.1389 \text{ mol F}}{0.04633 \text{ mol}} = 2.999 \text{ mol F}$$

The empirical formula is just AlF_3.

66. $$2.50 \text{ g Al} \times \frac{1 \text{ mol}}{26.98 \text{ g}} = 0.09266 \text{ mol Al}$$

$$5.28 \text{ g F} \times \frac{1 \text{ mol}}{19.00 \text{ g}} = 0.2779 \text{ mol F}$$

Dividing each number of moles by the smaller number of moles gives

$$\frac{0.09266 \text{ mol Al}}{0.09266 \text{ mol}} = 1.000 \text{ mol Al}$$

$$\frac{0.2779 \text{ mol F}}{0.09266 \text{ mol}} = 2.999 \text{ mol F}$$

The empirical formula is just AlF_3. Note the similarity between this problem and question 65; they differ in the way the data is given. In question 65, you were given the mass of the product and first had to calculate how much fluorine had reacted.

67. Consider 100.0 g of the compound.

$$67.61 \text{ g U} \times \frac{1 \text{ mol}}{238.0 \text{ g}} = 0.2841 \text{ mol U}$$

$$32.39 \text{ g F} \times \frac{1 \text{ mol}}{19.00 \text{ g}} = 1.705 \text{ mol F}$$

Dividing each number of moles by the smaller number of moles (0.2841 mol U) gives

$$\frac{0.2841 \text{ mol U}}{0.2841 \text{ mol}} = 1.000 \text{ mol U}$$

$$\frac{1.705 \text{ mol F}}{0.2841 \text{ mol}} = 6.000 \text{ mol F}$$

The empirical formula is UF_6.

68. Consider 100.0 g of the compound.

$$32.13 \text{ g Al} \times \frac{1 \text{ mol}}{26.98 \text{ g}} = 1.191 \text{ mol Al}$$

$$67.87 \text{ g F} \times \frac{1 \text{ mol}}{19.00 \text{ g}} = 3.572 \text{ mol F}$$

Dividing each number of moles by the smaller number (1.191 mol Al) gives

$$\frac{1.191 \text{ mol Al}}{1.191 \text{ mol}} = 1.000 \text{ mol Al}$$

$$\frac{3.572 \text{ mol F}}{1.191 \text{ mol}} = 2.999 \text{ mol F}$$

The empirical formula is AlF_3. Compare this question to questions 65 and 66: the three questions illustrate the different forms in which data for calculating empirical formulas may occur.

69. Consider 100.0 g of the compound.

$$33.88 \text{ g Cu} \times \frac{1 \text{ mol}}{63.55 \text{ g}} = 0.5331 \text{ mol Cu}$$

$$14.94 \text{ g N} \times \frac{1 \text{ mol}}{14.01 \text{ g}} = 1.066 \text{ mol N}$$

$$51.18 \text{ g O} \times \frac{1 \text{ mol}}{16.00 \text{ g}} = 3.199 \text{ mol O}$$

Dividing each number of moles by the smallest number of moles (0.5331 mol Cu) gives

$$\frac{0.5331 \text{ mol Cu}}{0.5331 \text{ mol}} = 1.000 \text{ mol Cu}$$

$$\frac{1.066 \text{ mol N}}{0.5331 \text{ mol}} = 2.000 \text{ mol N}$$

$$\frac{3.199 \text{ mol O}}{0.5331 \text{ mol}} = 6.001 \text{ mol O}$$

The empirical formula is CuN_2O_6 [i.e., $Cu(NO_3)_2$].

70. Consider 100.0 g of the compound.

$$59.78 \text{ g Li} \times \frac{1 \text{ mol}}{6.941 \text{ g}} = 8.613 \text{ mol Li}$$

$$40.22 \text{ g N} \times \frac{1 \text{ mol}}{14.01 \text{ g}} = 2.871 \text{ mol N}$$

Dividing each number of moles by the smaller number of moles (2.871 mol N) gives

$$\frac{8.613 \text{ mol Li}}{2.871 \text{ mol}} = 3.000 \text{ mol Li}$$

$$\frac{2.871 \text{ mol N}}{2.871 \text{ mol}} = 1.000 \text{ mol N}$$

The empirical formula is Li_3N.

71. Consider 100.0 g of the compound.

$$66.75 \text{ g Cu} \times \frac{1 \text{ mol}}{63.55 \text{ g}} = 1.050 \text{ mol Cu}$$

$$10.84 \text{ g P} \times \frac{1 \text{ mol}}{30.97 \text{ g}} = 0.3500 \text{ mol P}$$

$$22.41 \text{ g O} \times \frac{1 \text{ mol}}{16.00 \text{ g}} = 1.401 \text{ mol O}$$

Dividing each number of moles by the smallest number of moles (0.3500 mol P) gives

$$\frac{1.050 \text{ mol Cu}}{0.3500 \text{ mol}} = 3.000 \text{ mol Cu}$$

$$\frac{0.3500 \text{ mol P}}{0.3500} = 1.000 \text{ mol P}$$

$$\frac{1.401 \text{ mol O}}{0.3500 \text{ mol}} = 4.003 \text{ mol O}$$

The empirical formula is thus Cu_3PO_4.

72. Consider 100.0 g of the compound.

$$15.77 \text{ g Al} \times \frac{1 \text{ mol}}{26.98 \text{ g}} = 0.5845 \text{ mol Al}$$

$$28.11 \text{ g S} \times \frac{1 \text{ mol}}{32.07 \text{ g}} = 0.8765 \text{ mol S}$$

$$56.12 \text{ g O} \times \frac{1 \text{ mol}}{16.00 \text{ g}} = 3.508 \text{ mol O}$$

Dividing each number of moles by the smallest number of moles (0.5845 mol Al) gives

$$\frac{0.5845 \text{ mol Al}}{0.5845 \text{ mol}} = 1.000 \text{ mol Al}$$

$$\frac{0.8765 \text{ mol S}}{0.5845 \text{ mol}} = 1.500 \text{ mol S}$$

$$\frac{3.508 \text{ mol O}}{0.5845 \text{ mol}} = 6.002 \text{ mol O}$$

Multiplying these relative numbers of moles by two to give whole numbers gives the empirical formula as $Al_2S_3O_{12}$ [i.e., $Al_2(SO_4)_3$].

73. The compound must contain 1.00 mg of lithium and 2.73 mg of fluorine.

$$1.00 \text{ mg Li} \times \frac{1 \text{ mmol}}{6.941 \text{ mg}} = 0.144 \text{ mmol Li}$$

$$2.73 \text{ mg F} \times \frac{1 \text{ mmol}}{19.00 \text{ mg}} = 0.144 \text{ mol F}$$

The empirical formula of the compound is LiF.

74. Compound 1: Assume 100.0 g of the compound.

$$22.55 \text{ g P} \times \frac{1 \text{ mol}}{30.97 \text{ g}} = 0.7281 \text{ mol P}$$

$$77.45 \text{ g Cl} \times \frac{1 \text{ mol}}{35.45 \text{ g}} = 2.185 \text{ mol Cl}$$

Dividing each number of moles by the smaller (0.7281 mol P) indicates that the formula of Compound 1 is PCl_3.

Compound 2: Assume 100.0 g of the compound.

$$14.87 \text{ g P} \times \frac{1 \text{ mol}}{30.97 \text{ g}} = 0.4801 \text{ mol P}$$

$$85.13 \text{ g Cl} \times \frac{1 \text{ mol}}{35.45 \text{ g}} = 2.401 \text{ mol Cl}$$

Dividing each number of moles by the smaller (0.4801 mol P) indicates that the formula of Compound 2 is PCl_5.

75. The *empirical formula* of a compound represents only the smallest whole number relationship between the number and type of atoms in a compound, whereas the *molecular formula* represents the actual number of atoms of each type in a true molecule of the substance. Many compounds (for example, H_2O) have the same empirical and molecular formulas.

76. If only the empirical formula is known, the molar mass of the substance must be determined before the molecular formula can be calculated.

77. Assume that we have 100.00 g of the compound; then 78.14 g will be boron, and 21.86 g will be hydrogen.

$$78.14 \text{ g B} \times \frac{1 \text{ mol}}{10.81 \text{ g}} = 7.228 \text{ mol B}$$

$$21.86 \text{ g H} \times \frac{1 \text{ mol}}{1.008 \text{ g}} = 21.69 \text{ mol H}$$

Dividing each number of moles by the smaller number (7.228 mol B) gives the empirical formula as BH_3. The empirical molar mass of BH_3 would be [10.81 g + 3(1.008 g)] = 13.83 g. This is approximately half of the indicated actual molar mass, and therefore the molecular formula must be B_2H_6.

78. empirical formula mass of CH = 13 g

$$n = \frac{\text{molar mass}}{\text{empirical formula mass}} = \frac{78 \text{ g}}{13 \text{ g}} = 6$$

The molecular formula is $(CH)_6$ or C_6H_6.

79. empirical formula mass of CH_2 = 14

$$n = \frac{\text{molar mass}}{\text{empirical formula mass}} = \frac{84 \text{ g}}{14 \text{ g}} = 6$$

molecular formula is $(CH_2)_6 = C_6H_{12}$.

80. empirical formular mass of C_2H_5O = 46 g

$$n = \frac{\text{molar mass}}{\text{empirical formula mass}} = \frac{90 \text{ g}}{46 \text{ g}} = \sim 2$$

molecular formula is $(C_2H_5O)_2 = C_4H_{10}O_2$

81. Consider 100.0 g of the compound.

$$42.87 \text{ g C} \times \frac{1 \text{ mol}}{12.01 \text{ g}} = 3.570 \text{ mol C}$$

$$3.598 \text{ g H} \times \frac{1 \text{ mol}}{1.008 \text{ g}} = 3.569 \text{ mol H}$$

$$28.55 \text{ g O} \times \frac{1 \text{ mol}}{16.00 \text{ g}} = 1.784 \text{ mol O}$$

$$25.00 \text{ g N} \times \frac{1 \text{ mol}}{14.01 \text{ g}} = 1.784 \text{ mol N}$$

Dividing each number of moles by the smallest number of moles (1.784 mol O or N) gives

$$\frac{3.570 \text{ mol C}}{1.784 \text{ mol}} = 2.001 \text{ mol C}$$

$$\frac{3.569 \text{ mol H}}{1.784 \text{ mol}} = 2.001 \text{ mol H}$$

$$\frac{1.784 \text{ mol O}}{1.784 \text{ mol}} = 1.000 \text{ mol O}$$

$$\frac{1.784 \text{ mol N}}{1.784 \text{ mol}} = 1.000 \text{ mol N}$$

The empirical formula of the compound is C_2H_2ON, and the empirical formula mass of C_2H_2ON is 56.

$$n = \frac{\text{molar mass}}{\text{empirical formula mass}} = \frac{168 \text{ g}}{56 \text{ g}} = 3$$

The molecular formula is $(C_2H_2ON)_3 = C_6H_6O_3N_3$.

82. For NO_2, molar mass = 14.01 + 2(16.00) = 46.01 g.

$$\% \text{N} = \frac{14.01 \text{ g N}}{46.01 \text{ g}} \times 100 = 30.45\% \text{ N}$$

$$\% \text{O} = \frac{2(16.00 \text{ g O})}{46.01 \text{ g}} \times 100 = 69.55\% \text{ O}$$

For N_2O_4, molar mass = 2(14.01 g) + 4(16.00 g) = 92.02 g.

$$\% \text{N} = \frac{2(14.01 \text{ g N})}{92.02 \text{ g}} \times 100 = 30.45\% \text{ N}$$

$$\% \text{O} = \frac{4(16.00 \text{ g O})}{92.02 \text{ g}} \times 100 = 69.55\% \text{ O}$$

83.

[1]	c	[6]	d
[2]	e	[7]	a
[3]	j	[8]	g
[4]	h	[9]	i
[5]	b	[10]	f

84.

5.00 g Al	0.185 mol	1.12×10^{23} atoms
0.140 g Fe	0.00250 mol	1.51×10^{21} atoms
2.7×10^{2} g Cu	4.3 mol	2.6×10^{24} atoms
0.00250 g Mg	1.03×10^{-4} mol	6.19×10^{19} atoms
0.062 g Na	2.7×10^{-3} mol	1.6×10^{21} atoms
3.95×10^{-18} g U	1.66×10^{-20} mol	1.00×10^{4} atoms

85.

4.24 g	0.0543 mol	3.27×10^{22} molec.	3.92×10^{23} atoms
4.04 g	0.224 mol	1.35×10^{23} molec.	4.05×10^{23} atoms
1.98 g	0.0450 mol	2.71×10^{22} molec.	8.13×10^{22} atoms
45.9 g	1.26 mol	7.59×10^{23} molec.	1.52×10^{24} atoms
126 g	6.99 mol	4.21×10^{24} molec.	1.26×10^{25} atoms
0.297 g	0.00927 mol	5.58×10^{21} molec.	3.35×10^{22} atoms

86. mass of 2 mol X = 2(41.2 g) = 82.4 g

mass of 1 mol Y = 57.7 g = 57.7 g

mass of 3 mol Z = 3(63.9 g) = 191.7 g

molar mass of X_2YZ_3 = 331.8 g

$$\%\,X = \frac{82.4\text{ g}}{331.8\text{ g}} \times 100 = 24.8\%\ X$$

$$\%\,Y = \frac{57.7\text{ g}}{331.8\text{ g}} \times 100 = 17.4\%\ Y$$

$$\%\,Z = \frac{191.7\text{ g}}{331.8\text{ g}} \times 100 = 57.8\%\ Z$$

If the molecular formula were actually $X_4Y_2Z_6$, the percentage composition would be the same, and the *relative* mass of each element present would not change. The molecular formula is always a whole-number multiple of the empirical formula.

87. magnesium/nitrogen compound: mass of nitrogen = 1.2791 g – 0.9240 = 0.3551 g N

$$0.9240\text{ g Mg} \times \frac{1\text{ mol}}{24.31\text{ g}} = 0.03801\text{ mol Mg}$$

$$0.3551\text{ g N} \times \frac{1\text{ mol}}{14.01\text{ g}} = 0.02535\text{ mol N}$$