Chapter 7 – Chemical Quantities

Chapter 7: 1 – 7, 9 – 11, 13 – 18, 19 – 26, 29 - 35

Practice Problems

1. What is the mass of 0.50 bushel of apples? *1 dozen apples = 2.0 kg apples = 0.20 bushel*

(0.50 bushel)(2.0 kg apples/ 0.20 bushel) = 5.0 kg

2. Assume a variety of apples has eight seeds in each. How many apple seeds in 14 kg of apples?

$$(14\ kg\ apples)\left(\frac{0.20\ bushel}{2.0\ kg}\right)\left(\frac{1\ doz\ apples}{0.20\ bushel}\right)\left(\frac{12\ apples}{1\ dozen}\right)\left(\frac{8\ seeds}{apple}\right) = 672\ apples$$

3. How many moles is 2.80 x 10^{24} atoms of silicon?

$$(2.80\ x\ 10^{24} atoms\ Si)\left(\frac{1\ mol\ Si}{6.02\ x\ 10^{23} atoms\ Si}\right) = 4.65\ mol\ Si$$

4. How many molecules is 0.360 mol of water?

$$(0.360\ mol\ H_2O)\left(\frac{6.02\ x\ 10^{23} molecules\ H_2O}{1\ mol\ H_2O}\right) = 2.17\ x\ 10^{23}\ molecules\ H_2O$$

5. How many atoms are there in 1.14 mol SO_3?

$$(1.14\ mol\ SO_3)\left(\frac{6.02\ x\ 10^{23} molecules\ SO_3}{1\ mol\ SO_3}\right)\left(\frac{4\ atoms}{1\ molecule\ SO_3}\right) = 2.75\ x\ 10^{24}\ atoms$$

6. How many moles are there in 4.65 x 10^{24} molecules of NO_2?

$$(4.65\ x\ 10^{24}\ molecules\ NO_2)\left(\frac{1\ mol\ NO_2}{6.02\ x\ 10^{23}\ molecules\ NO_2}\right) = 7.72\ moles\ NO_2$$

7. Find the gram molecular mass of each compound.

a. C_2H_6

$(2\ mol\ C)\left(\frac{12.0\ g\ C}{1\ mol\ C}\right) = 24.0\ g\ C;\ (6\ mol\ H)\left(\frac{1.01\ g\ H}{1\ mol\ H}\right) = 6.06g\ H;\ C_2H_6 = 30.1\ g$

b. PCl_3

$(1\ mol\ P)\left(\frac{31.0\ g\ P}{1\ mol\ P}\right) = 31.0\ g\ P;\ (3\ mol\ Cl)\left(\frac{35.5\ g\ Cl}{1\ mol\ Cl}\right) = 106.5\ g\ Cl;\ PCl_3 = 137.5\ g$

c. C_3H_7OH

$(3\ mol\ C)\left(\frac{12.0\ g\ C}{1\ mol\ C}\right) = 36.0\ g\ C;\ (8\ mol\ H)\left(\frac{1.01\ g\ H}{1\ mol\ H}\right) = 8.08g\ H;\ (1\ mol\ O)\left(\frac{16.0\ g\ O}{1\ mol\ O}\right) = 16.0\ g\ O;$

$C_3H_7OH = 60.1\ g$

d. N_2O_5

$(2\ mol\ N)\left(\frac{14.0\ g\ N}{1\ mol\ N}\right) = 28.0\ g\ N;\ (5\ mol\ O)\left(\frac{16.0\ g\ O}{1\ mol\ O}\right) = 80.0g\ O; N_2O_5 = 108\ g$

9. Calculate the gram formula mass of each ionic compound.

a. K_2O

$(2\ mol\ K)\left(\frac{39.1\ g\ K}{1\ mol\ K}\right) = 78.2\ g\ K;\ (1\ mol\ O)\left(\frac{16.0\ g\ O}{1\ mol\ O}\right) = 16.0 g\ O; K_2O =$ **94.2 g**

b. $CaSO_4$

$(1\ mol\ Ca)\left(\frac{40.1\ g\ Ca}{1\ mol\ Ca}\right) = 40.1\ g\ Ca;\ (1\ mol\ S)\left(\frac{32.1\ g\ S}{1\ mol\ S}\right) = 32.1\ g\ s: (4\ mol\ O)\left(\frac{16.0\ g\ O}{1\ mol\ O}\right) = 64.0\ g\ O;$

$CaSO_4 = 136.2\ g$

c. CuI_2

$(1\ mol\ Cu)\left(\frac{63.5\ g\ Cu}{1\ mol\ Cu}\right) = 63.5\ g\ Cu;\ (2\ mol\ I)\left(\frac{126.9\ g\ I}{1\ mol\ I}\right) = 253.8\ g\ I; CuI_2 = 317.3\ g$

10. Find the gram formula mass of each compound.

a. barium fluoride (BaF_2)

$(1\ mol\ Ba)\left(\frac{137.3\ g\ Ba}{1\ mol\ Ba}\right) = 137.3\ g\ Ba;\ (2\ mol\ F)\left(\frac{19.0\ g\ F}{1\ mol\ F}\right) = 38.0\ g\ F; BaF_2 = 175.3 g$

b. strontium chloride ($SrCl_2$)

$(1\ mol\ Sr)\left(\frac{87.62\ g\ Sr}{1\ mol\ Sr}\right) = 137.3\ g\ Sr;\ (2\ mol\ Cl)\left(\frac{35.5\ g\ Cl}{1\ mol\ Cl}\right) = 71.0 g\ Cl; SrCl_2 = 158.62\ g$

c. sodium hydrogen carbonate ($NaHCO_3$)

$(1\ mol\ Na)\left(\frac{23.0\ g\ Na}{1\ mol\ Na}\right) = 23.0\ g\ Na;\ (1\ mol\ H)\left(\frac{1.01\ g\ H}{1\ mol\ H}\right) = 1.01\ g\ H; (1\ mol\ C)\left(\frac{12.0\ g\ C}{1\ mol\ C}\right) = 12.0\ g\ C$

$(3\ mol\ O)\left(\frac{16.0\ g\ O}{1\ mol\ O}\right) = 48.0\ g\ O;\ NaHCO_3 = 84.0\ g$

d. aluminum sulfite ($Al_2[SO_3]_3$)

$(2\ mol\ Al)\left(\frac{27.0\ g\ Al}{1\ mol\ Al}\right) = 54.0\ g\ Al;\ (3\ mol\ S)\left(\frac{32.1\ g\ S}{1\ mol\ S}\right) = 96.3\ g\ S; (9\ mol\ O)\left(\frac{16.0\ g\ O}{1\ mol\ O}\right) = 144.0\ g\ O$

$Al_2(SO_3)_3 = 294\ g$

Section Review 7.1

11. Describe the relationship between Avogadro's number and one mole of any substance.

One mole of any substance is equal to Avogadro's number, 6.02×10^{23}. The substance could represent a mole of atoms, ionic formula units, or molecules.

13. How many oxygen atoms are in a representative particle of each substance?

a. ammonium nitrate (NH_4NO_3), a fertilizer 3 oxygen atoms

b. acetylsalicylic acid ($C_8H_8O_4$), the fever-reducing compound aspirin? 4 O atoms

c. ozone (O_3), a disinfectant 3 O atoms

d. nitroglycerine ($C_3H_5(NO_3)_3$), an explosive 9 O atoms

14. How many moles is each of the following?

a. 1.50 x 10^{23} molecules NH_3

$$(1.50\ x\ 10^{23}\ molecules\ NH_3)\left(\frac{1\ mol\ NH_3}{6.02\ x\ 10^{23} molecules}\right) = 0.249\ mol\ NH_3$$

b. 1 billion (1 x 10^9 molecules) O_2

$$(1\ x\ 10^{9}\ molecules\ O_2)\left(\frac{1\ mol\ O_2}{6.02\ x\ 10^{23} molecules}\right) = 1.66\ x\ 10^{-15}\ mol\ O_2$$

c. 6.02 x 10^{22} molecules Br_2

$$(6.02\ x\ 10^{22}\ molecules\ Br_2)\left(\frac{1\ mol\ Br_2}{6.02\ x\ 10^{23} molecules}\right) = 0.100\ mol\ Br_2$$

d. 4.81 x 10^{24} atoms Li

$$(4.81\ x\ 10^{24}\ atoms\ Li\ )\left(\frac{1\ mol\ \ Li}{6.02\ x\ 10^{23} molecules}\right) = 7.99\ mol\ Li$$

15. Distinguish among gram atomic mass, gram molecular mass, and gram formula mass.

Gram atomic mass is the atomic mass of an element expressed in grams. **Gram molecular mass** is the mass of a mole of a molecular element or compound. **Gram formula mass** is the mass of a mole of an ionic compound.

Practice Problems

16. Find the mass, in grams, of each.

a. 3.32 mol K

$$(3.32\ mol\ M\ )\left(\frac{39.1\ g\ K}{1\ mol\ K}\right) = 130.\ g\ K$$

b. 4.52 x 10^{-3} mol $C_{20}H_{42}$

$$(4.52\ x\ 10^{-3}\ mol\ C_{20}H_{42}\ )\left(\frac{282\ g\ C_{20}H_{42}}{1\ mol\ C_{20}H_{42}}\right) = 1.27\ g\ C_{20}H_{42}$$

c. 0.0112 mol K_2CO_3

$$(0.0112\ mol\ K_2CO_3\ )\left(\frac{138.2\ g\ K_2CO_3}{1\ mol\ K_2CO_3}\right) = 1.55\ g\ K_2CO_3$$

17. Calculate the mass, in grams of 2.50 mol of each substance.

a. sodium sulfate (Na_2SO_4)

$$(2.50\ mol\ Na_2SO_4\ )\left(\frac{142.1\ g\ Na_2SO_4}{1\ mol\ Na_2SO_4}\right) = 355\ g\ Na_2SO_4$$

b. iron(II) hydroxide ($Fe[OH]_2$)

$$(2.50\ mol\ Fe(OH)_2)\left(\frac{89.8\ g\ Fe(OH)_2}{1\ mol\ Fe(OH)_2}\right) = 225\ g\ Fe(OH)_2$$

18. Find the number of moles in each quantity.

a. 3.70 x 10^{-1} g B

$$(3.70\ x\ 10^{-1}\ g\ B)\left(\frac{1\ mol\ B}{10.8\ g\ B}\right) = 0.0343\ mol\ B$$

b. 27.4 g TiO_2

$$(27.4\ g\ TiO_2)\left(\frac{1\ mol\ TiO_2}{60.1\ g\ TiO_2}\right) = 0.456\ mol\ TiO_2$$

c. 847 g $(NH_4)_2CO_3$

$$(847\ g\ (NH_4)_2CO_3)\left(\frac{1\ mol\ (NH_4)_2CO_3}{98.0\ g\ (NH_4)_2CO_3}\right) = 8.64\ mol\ (NH_4)_2CO_3$$

20. What is the volume at STP of these gases?

a. 3.20 x 10^{-3} mol CO_2

$$(3.20\ x\ 10^{-3}\ mol\ CO_2)\left(\frac{22.4\ L\ CO_2}{1\ mol\ CO_2}\right) = 0.0717\ L\ CO_2$$

b. 0.960 mole CH_4

$$(0.960\ mol\ CH_4)\left(\frac{22.4\ L\ CH_4}{1\ mol\ CH_4}\right) = 21.5\ L\ CH_4$$

c. 3.70 mol N_2

$$(3.70\ mol\ N_2)\left(\frac{22.4\ L\ N_2}{1\ mol\ N_2}\right) = 82.9\ L\ N_2$$

21. Assuming STP, how many moles are in these volumes?

a. 67.2 L SO_2

$$(67.2\ L\ SO_2)\left(\frac{1\ mol\ SO_2}{22.4\ L}\right) = 3.00\ mol\ SO_2$$

b. 0.880 L He

$$(0.880\ L\ \ He)\left(\frac{1\ mol\ He}{22.4\ L}\right) = 0.0393\ mol\ He$$

c. 1.00 x 10^3 L C_2H_6

$$(1.00\ x\ 10^3\ L\ C_2H_6)\left(\frac{1\ mol\ C_2H_6}{22.4\ L}\right) = 44.6\ mol\ C_2H_6$$

22. A gaseous compound composed of sulfur and oxygen that is linked to the formation of acid rain has a density of 3.58 g/ L at STP. What is the molar mass of this gas?

$$\left(\frac{3.58\ g}{L}\right)\left(\frac{22.4\ L}{1\ mol}\right) = 80.2\frac{g}{mol}$$

23. What is the density of krypton gas at STP?

$$\left(\frac{83.80\ g\ Kr}{mol\ Kr}\right)\left(\frac{1\ mol\ Kr}{22.4\ L}\right) = 3.74\frac{g}{L}$$

Section Review 7.2

24. Find the mass in grams of each quantity:

a. 0.720 mol Be

$$(0.720\ mol\ Be)\left(\frac{9.01\ g\ Be}{1\ mol\ Be}\right) = 6.48\ g\ Be$$

b. 2.40 mol N_2

$$(2.40\ mol\ N_2)\left(\frac{28.0\ g\ N_2}{1\ mol\ N_2}\right) = 67.2\ g\ N_2$$

c. 0.160 mol H_2O_2

$$(0.160\ mol\ H_2O_2)\left(\frac{34.0\ g\ H_2O_2}{1\ mol\ H_2O_2}\right) = 5.44\ g\ H_2O_2$$

d. 5.08 mol $Ca(NO_3)_2$

$$(5.08\ mol\ Ca(NO_3)_2)\left(\frac{164.09\ g\ Ca(NO_3)_2}{1\ mol\ Ca(NO_3)_2}\right) = 8.34\ x\ 10^2\ g\ Ca(NO_3)_2$$

25. Calculate the following:

a. The number of molecules in 60.0 g NO_2.

$$(60.0\ g\ NO_2)\left(\frac{1\ mol\ NO_2}{46.0\ g\ NO_2}\right)\left(\frac{6.02\ molecules\ NO_2}{1\ mol\ NO_2}\right) = 7.85\ x\ 10^{23}\ molecules\ NO_2$$

b. The volume, in liters, of 3.24 x 10^{22} molecules Cl_2 at STP.

$$(3.24\ x\ 10^{22}\ molecules\ Cl_2)\left(\frac{1\ mol\ Cl_2}{6.02\ x\ 10^{23} molecules\ Cl_2}\right)\left(\frac{22.4\ L\ Cl_2}{1\ mol\ Cl_2}\right) = 1.21\ L\ Cl_2$$

c. The mass, in grams, of 18.0 L CH_4 at STP.

$$(18.0\ L\ CH_4)\left(\frac{1\ mol\ CH_4}{22.4\ L\ CH_4}\right)\left(\frac{16.0\ g\ CH_4}{1\ mol\ CH_4}\right) = 12.9\ g\ CH_4$$

26. Would three balloons, each containing the same number of molecules of a different gas at STP, have the same mass or the same volume? Explain.

All three balloons would have the same volume, because equal numbers of gas particles at STP occupy the same amount of space. The masses would be different, however.

Practice Problems

29. Calculate the percent composition of the following:

a. When 9.03 g Mg combines completely with 3.48 g N to form a compound.

$\%\ Mg = \left(\frac{9.03\ g\ Mg}{12.51\ g\ compound}\right)(100) = 72.2\%$ $\%\ N = \left(\frac{3.48\ g\ N}{12.51\ g\ compound}\right)(100) = 27.8\%$

b. When 29.0 g Ag combines completely with 4.30 g S to form a compound.

$\%\ Ag = \left(\frac{29.0\ g\ Ag}{33.3\ g\ compound}\right)(100) = 87.1\%$ $\%\ S = \left(\frac{4.30\ g\ S}{33.3\ g\ compound}\right)(100) = 12.9\%$

30. When a 14.2 g sample of mercury(II) oxide is decomposed into its elements by heating, 13.2 g Hg is obtained. What is the percent composition of this compound?

$\%\ Hg = \left(\frac{13.2\ g\ Hg}{14.2\ g\ compound}\right)(100) = 93\%$ $\%\ O = \left(\frac{1.0\ g\ O}{14.2\ g\ compound}\right)(100) = 7\%$

31. Calculate the percent composition of these compounds.

a. ethane (C_2H_6)

$\%\ C = \left(\frac{2\ (12.0g\ C)}{30.0\ g\ compound}\right)(100) = 80\%$ $\%\ H = \left(\frac{6\ (1.01\ g\ H)}{30.0\ g\ compound}\right)(100) = 20\%$

b. sodium bisulfate ($NaHSO_4$)

$\%\ Na = \left(\frac{23.0\ g\ Na}{120.1\ g\ compound}\right)(100) = 19.1\%$ $\%\ H = \left(\frac{1.01\ g\ H}{120.1\ g\ compound}\right)(100) = 0.8\%$

$\%\ S = \left(\frac{32.1\ g\ S}{120.1\ g\ compound}\right)(100) = 26.7\%$ $\%\ O = \left(\frac{3\ (16.0\ g\ O)}{120.1\ g\ compound}\right)(100) = 53.3\%$

c. ammonium chloride (NH_4Cl)

$\%\ N = \left(\frac{14.0\ g\ N}{53.3\ g\ compound}\right)(100) = 26.1\%$ $\%\ H = \left(\frac{4.04\ g\ H}{53.3\ g\ compound}\right)(100) = 7.6\%$

$\%\ Cl = \left(\frac{35.5\ g\ Cl}{53.3\ g\ compound}\right)(100) = 66.3\%$

32. Calculate the percent nitrogen in these common fertilizers.

a. $CO(NH_2)_2$ the compound has a gram molecular weight of 60 g

$\%\ N = \left(\frac{2\ (14.0\ g\ N)}{60.0\ g\ compound}\right)(100) = 46.7\%$

b. NH_3 the compound has a gram molecular weight of 17.0 g

$\%\ N = \left(\frac{14.0\ g\ N}{17.0\ g\ compound}\right)(100) = 82.4\%$

c. NH_4NO_3 the compound has a gram molecular weight of 80.0 g

$\%\ N = \left(\frac{2\ (14.0\ g\ N)}{80.0\ g\ compound}\right)(100) = 35\%$

33. Using data from Problem 31, calculate the mass of hydrogen in each of the following.

a. 350 g C_2H_6

$$350\ g\ C_2H_6 \left(\frac{20\ g\ H}{100.0\ g\ compound}\right)(100) = 70.0\ g\ H$$

b. 20.3 g $NaHSO_4$

$$20.3\ g\ NaHSO_4 \left(\frac{0.8\ g\ H}{100.0\ g\ compound}\right)(100) = 0.162\ g\ H$$

c. 2.14 g NH_4Cl

$$2.14\ g\ NH_4 \left(\frac{7.6\ g\ H}{100.0\ g\ compound}\right)(100) = 0.163\ g\ H$$

34. Calculate the grams of nitrogen in 125 g of each fertilizer.

a. $CO(NH_2)_2$

$$125\ g\ CO(NH_2)_2 \left(\frac{46.7\ g\ N}{100.0\ g\ compound}\right)(100) = 58.4\ g\ N$$

b. NH_3

$$125\ g\ NH_3 \left(\frac{82.4\ g\ N}{100.0\ g\ compound}\right)(100) = 103\ g\ N$$

c. NH_4NO_3

$$125\ g\ NH_4NO_3 \left(\frac{35.0\ g\ N}{100.0\ g\ compound}\right)(100) = 43.8\ g\ N$$

35. Calculate the empirical formula of each compound.

a. 94.1% O, 5.9% H

$$94.1\ g\ O \left(\frac{1\ mol\ O}{16.0\ g\ O}\right) = 5.88\ mol\ O;\ \ 5.9\ g\ H\ \left(\frac{1\ mol\ H}{1.01\ g\ H}\right) = \ 5.84\ mol\ H;$$

Mole ratio: $O_{5.88}H_{5.84}$ Empirical formula is OH

b. 79.8% C, 20.2% H

$$79.8\ g\ C \left(\frac{1\ mol\ C}{12.0\ g\ C}\right) = 6.65\ mol\ C;\ \ 20.2\ g\ H\ \left(\frac{1\ mol\ H}{1.01\ g\ H}\right) = 20\ mol\ H;$$

Mole ratio: $C_{6.65}H_{20}$ Empirical formula is CH_3

c. 67.6% Hg, 10.8% S, 21.6% O

$$67.6\ g\ Hg \left(\frac{1\ mol\ Hg}{200.6\ g\ Hg}\right) = 0.337\ mol\ Hg;\ 10.8\ g\ S \left(\frac{1\ mol\ S}{32.1\ g\ S}\right) = 0.336\ mol\ S;$$

$$21.6\ g\ O\ \left(\frac{1\ mol\ O}{16.0\ g\ O}\right) = 1.35\ mol\ O$$

Mole ratio: $Hg_{.337}S_{.336}O_{1.35}$ Empirical formula: $HgSO_4$

d. 27.59% C, 1.15% H, 16.09% N, 55.17% O

$$27.59\ g\ C \left(\frac{1\ mol\ C}{12.0\ g\ C}\right) = 2.3\ mol\ C;\ 1.15\ g\ H \left(\frac{1\ mol\ H}{1.01\ g\ H}\right) = 1.14\ mol\ H;$$

$$16.09\ g\ N\ \left(\frac{1\ mol\ N}{14.0\ g\ N}\right) = 1.15\ g\ N;\ \ 55.17\ g\ O\ \left(\frac{1\ mol\ O}{16.0\ g\ O}\right) = 3.44\ mol\ O$$

Mole ratio: $C_{2.3}H_{1.14}N_{1.15}O_{3.44}$ Empirical formula: C_2HNO_3

Step 1. Convert percentages into moles.

Step 2. Write the mole ratio. For 35a, it is:

$O_{5.88}H_{5.84}$

Step 3. Determine the whole-number ratio, for 35a, it is nearly 1:1, so the empirical formula is OH. If you need more assistance with this, go to page 193 in the text.