KEY

Molar Mass Calculations

A mole is a standard unit of measurement for amount of a substance. For an element, one mole is equivalent to the mass of that element as it is listed on the periodic table, and thus represents its molar mass. For a compound, one must take the sum of all elements in the compound with respect to the number of atoms in order to obtain the molar mass.

Example: $CaCl_2$

1 mol = mass of Ca + 2 · (mass of Cl)
1 mol = 40.078g + 2 · (35.453g)
1 mol of $CaCl_2$ = 110.984 grams of $CaCl_2$
Therefore, we say that $CaCl_2$ has a molar mass of 110.984 g/mol.

Practice

1. nickel (II) sulfate $NiSO_4$

   154.76 g/mol

2. magnesium nitride Mg_3N_2

   100.93g/mol

3. phosphoric acid H_3PO_4

   98.00 g/mol

4. zinc acetate $Zn(C_2H_3O_2)_2$

   183.51 g/mol

5. dinitrogen pentoxide N_2O_5

   108.02g/mol

6. copper (I) nitrite $CuNO_2$

   109.56 g/mol

7. strontium hydroxide $Sr(OH)_2$

   121.64 g/mol

8. potassium phosphate K_3PO_4

   212.27g/mol

9. hydrochloric acid HCl

   36.46 g/mol

Mole Conversions Worksheet

There are three mole equalities:

1 mol = 6.02×10^{23} particles
1 mol = molar mass
1 mol = 22.4 L (for a gas at STP)

Mole-Particle Conversions

1. How many moles of magnesium is equivalent to 3.01×10^{22} atoms of magnesium?

$$\frac{3.01\times10^{22}\text{ atoms}}{} \left| \frac{1\text{ mol}}{6.02\times10^{23}\text{ atoms}} \right. = \boxed{0.0500\text{ mol Mg}}$$

2. How many molecules are there in 4.00 moles of glucose, $C_6H_{12}O_6$?

$$\frac{4.00\text{ mol}}{} \left| \frac{6.02\times10^{23}\text{ mlc}}{1\text{ mol}} \right. = \boxed{2.41\times10^{24}\text{ mlc } C_6H_{12}O_6}$$

3. How many moles are in 1.20×10^{25} atoms of phosphorus?

$$\frac{1.20\times10^{25}\text{ atoms}}{} \left| \frac{1\text{ mol}}{6.02\times10^{23}\text{ atoms}} \right. = \boxed{19.9\text{ mol P}}$$

4. How many atoms are in 0.750 moles of zinc?

$$\frac{0.750\text{ mol}}{} \left| \frac{6.02\times10^{23}\text{ atoms}}{1\text{ mol}} \right. = \boxed{4.52\times10^{23}\text{ atoms}}$$

5. How many molecules are in 0.400 moles of dinitrogen pentoxide?

$$\frac{0.400\text{ mol}}{} \left| \frac{6.02\times10^{23}\text{ mlc}}{1\text{ mol}} \right. = \boxed{2.41\times10^{23}\ N_2O_5}$$

Mole-Mass Conversions

1. How many moles are in 28.0 grams of carbon dioxide?

$$\frac{28.0\text{ g}}{} \left| \frac{1\text{ mol}}{44.01\text{ g}} \right. = \boxed{0.636\text{ mol } CO_2}$$

2. What is the mass of 5.00 moles of iron (III) oxide?

$$\frac{5.00\text{ mol}}{} \left| \frac{159.70\text{ g}}{1\text{ mol}} \right. = \boxed{799\text{ g } Fe_2O_3}$$

3. Find the number of moles of argon that is equivalent to 452 grams.

$$\frac{452\text{ g}}{} \left| \frac{1\text{ mol}}{39.95\text{ g}} \right. = \boxed{11.3\text{ mol Ar}}$$

4. Find the number of grams in 1.26×10^{-4} moles of acetic acid. $HC_2H_3O_2$

$$\frac{1.26\times10^{-4}\text{ mol} \mid 60.06\text{ g}}{\mid 1\text{ mol}} = \boxed{7.57\times10^{-3}\text{ g } HC_2H_3O_2}$$

5. Find the mass equivalent to 2.6 moles of lithium bromide.

$$\frac{2.6\text{ mol} \mid 86.84\text{ g}}{\mid 1\text{ mol}} = \boxed{230\text{ g LiBr}}$$

Mole-Volume Conversions

1. Determine the volume, in liters, occupied by 0.030 moles of a gas at STP.

$$\frac{0.030\text{ mol} \mid 22.4\text{ L}}{\mid 1\text{ mol}} = \boxed{0.67\text{ L of gas}}$$

2. How many moles of gaseous argon atoms are present in 11.2 L at STP?

$$\frac{11.2\text{ L} \mid 1\text{ mol}}{\mid 22.4\text{ L}} = \boxed{0.500\text{ mol Ar}}$$

3. What is the volume of 0.0520 moles of neon gas at STP?

$$\frac{0.0520\text{ mol} \mid 22.4\text{ L}}{\mid 1\text{ mol}} = \boxed{1.16\text{ L Ne}}$$

4. What is the volume of 1.2 moles of water vapor at STP?

$$\frac{1.2\text{ mol} \mid 22.4\text{ L}}{\mid 1\text{ mol}} = \boxed{27\text{ L } H_2O}$$

5. How many moles of gaseous sulfur trioxide are present in 2.50 L at STP?

$$\frac{2.50\text{ L} \mid 1\text{ mol}}{\mid 22.4\text{ L}} = \boxed{.112\text{ mol } SO_3}$$

Mixed Conversions

1. How many gaseous oxygen molecules are in 3.36 L at STP?

$$\frac{3.36\text{ L} \mid 1\text{ mol} \mid 6.02\times10^{23}\text{ m/c}}{\mid 22.4\text{ L} \mid 1\text{ mol}} = \boxed{9.03\times10^{22}\text{ m/c } O_2}$$

2. Find the mass, in grams, of 2.00×10^{23} molecules of fluorine.

$$\frac{2.00\times10^{23}\text{ m/c} \mid 1\text{ mol} \mid 38.00\text{ g}}{\mid 6.02\times10^{23}\text{ m/c} \mid 1\text{ mol}} = \boxed{12.6\text{ g } F_2}$$

3. Determine the volume, in liters, occupied by 14.0 grams of nitrogen gas at STP.

$$\frac{14.0\text{ g} \mid 1\text{ mol} \mid 22.4\text{ L}}{\mid 28.02\text{ g} \mid 1\text{ mol}} = \boxed{11.2\text{ L } N_2}$$

4. Find the mass, in grams, of 1.00×10^{23} molecules of sodium iodide.

$$\frac{1.00\times10^{23}\text{ m/c}}{} \cdot \frac{1\text{ mol}}{6.02\times10^{23}\text{ m/c}} \cdot \frac{149.89\text{ g}}{1\text{ mol}} = \boxed{24.9\text{ g NaI}}$$

5. How many particles are present in a 1.43 gram sample of a molecular compound with a molar mass of 233 grams per mole?

$$\frac{1.43\text{ g}}{} \cdot \frac{1\text{ mol}}{233\text{ g}} \cdot \frac{6.02\times10^{23}\text{ particles}}{1\text{ mol}} = \boxed{3.69\times10^{21}\text{ particles}}$$

6. Aspartame is an artificial sweetener that is 160 times sweeter than sucrose (regular sugar) when dissolved in water. It is marketed by G.D. Searle as NutraSweet. The molecular formula of aspartame is $C_{14}H_{18}N_2O_5$.

   a. Calculate the molar mass of aspartame.

$$\boxed{294.34\text{ g/mol}}$$

   b. How many moles of aspartame is equivalent to 10.0 grams?

$$\frac{10.0\text{ g}}{} \cdot \frac{1\text{ mol}}{294.34\text{ g}} = \cancel{0.033}\ \boxed{0.0340\text{ mol aspartame}}$$

   c. What is the mass, in grams, of 1.56 moles of aspartame?

$$\frac{1.56\text{ mol}}{} \cdot \frac{294.34\text{ g}}{1\text{ mol}} = \boxed{459\text{ g aspartame}}$$

   d. How many molecules are present in 5.00 milligrams of aspartame?

$$\frac{5.00\text{ mg}}{} \cdot \frac{1\text{ g}}{1000\text{ mg}} \cdot \frac{1\text{ mol}}{294.34\text{ g}} \cdot \frac{6.02\times10^{23}\text{ m/c}}{1\text{ mol}} = \boxed{1.02\times10^{19}\text{ m/c aspartame}}$$

   e. How many atoms of nitrogen are in 1.20 grams of aspartame?

$$\frac{1.20\text{ g}}{} \cdot \frac{1\text{ mol}}{294.34\text{ g}} \cdot \frac{6.02\times10^{23}\text{ m/c}}{1\text{ mol}} \cdot \frac{2\text{ atoms N}}{1\text{ m/c}} = \boxed{4.91\times10^{21}\text{ atoms N}}$$

Percent Composition

Percent composition is used to determine how much each element contributes to the overall mass of the compound. This information is useful for determining formulas of unknown substances later on. Perform the following calculations, reporting the percent mass of each element.

1. NaCl

Na: $\frac{22.99}{58.44} \times 100 = \boxed{39.3\%}$ Cl: $100 - 39.3 = \boxed{60.7\%}$

2. SO_2

S: $\frac{32.07}{64.07} \times 100 = \boxed{50.1\%}$ O: $100 - 50.1 = \boxed{49.9\%}$

3. $NaNO_3$

Na: $\frac{22.99}{85.00} \times 100 = \boxed{27.0\%}$ N: $\frac{14.01}{85.00} \times 100 = \boxed{16.5\%}$ O: $100 - 27.0 - 16.5 = \boxed{56.5\%}$

4. $Zn_3(PO_4)_2$

Zn: $\frac{3(65.41)}{386.17} \times 100 = \boxed{50.8\%}$ P: $\frac{2(30.97)}{386.17} \times 100 = \boxed{16.0\%}$ O: $100 - 50.8 - 16.0 = \boxed{33.2\%}$

5. $Pb(OH)_2$

Pb: $\frac{207.19}{241.21} \times 100 = \boxed{85.9\%}$ O: $\frac{32}{241.21} \times 100 = \boxed{13.3\%}$ H: $100 - 85.9 - 13.3 = \boxed{0.8\%}$

6. sulfurous acid H_2SO_3

H $\frac{2.02}{82.09} \times 100 = \boxed{2.5\%}$ S: $\frac{32.07}{82.09} \times 100 = \boxed{39.1\%}$ O: $100 - 2.5 - 39.1 = \boxed{58.4\%}$

7. phosphorus tribromide PBr_3

P: $\frac{30.97}{270.67} \times 100 = \boxed{11.4\%}$ Br: $100 - 11.4 = \boxed{88.6\%}$

8. barium hydroxide $Ba(OH)_2$

Ba: $\frac{137.33}{171.35} \times 100 = \boxed{80.1\%}$ O: $\frac{32}{171.35} \times 100 = \boxed{18.7\%}$ H: $100 - 80.1 - 18.7 = \boxed{1.2\%}$

9. aluminum nitrate $Al(NO_3)_3$

Al: $\frac{26.98}{213.01} \times 100 = \boxed{12.7\%}$ N: $\frac{3(14.01)}{213.01} \times 100 = \boxed{19.7\%}$ O: $100 - 12.7 - 19.7 = \boxed{67.6\%}$

10. iron (III) nitrate $Fe(NO_3)_3$

Fe: $\frac{55.85}{241.88} \times 100 = \boxed{23.1\%}$ N: $\frac{3(14.01)}{241.88} \times 100 = \boxed{17.4\%}$ O: $100 - 23.1 - 17.4 = \boxed{59.5\%}$

Empirical & Molecular Formulas

Empirical formulas use percent composition information to determine the ratio of elements in a compound. Empirical formulas give the simplest formula possible, which does not necessarily represent the actual formula of a molecule. From experimentally collected data about the actual mass of the sample, the molecular formula can be determined using the empirical formula. See the example below for calculating empirical and molecular formulas from given data:

Given: 27.3% carbon + 72.7% oxygen ; experimental mass = 88.02 g/mol

① Assume 100g of compound
② Convert to moles
③ Divide by smallest # of moles

$\frac{27.3g\,C \mid 1\,mol}{12.011g} = \frac{2.273\,mol\,C}{2.273} = 1$

$\frac{72.7g\,O \mid 1\,mol}{16.00g} = \frac{4.544\,mol\,O}{2.273} = 2$

$\boxed{CO_2}$ empirical

④ $\frac{\text{experimental}}{\text{empirical mass}}$ $\frac{88.02\,g/mol}{44.01\,g/mol} = 2$

⑤ multiply by factor from #4

$2(CO_2) = \boxed{C_2O_4}$ molecular

Determine the empirical formula:

1. 88.8% copper; 11.2% oxygen

$\frac{88.8g\,Cu \mid 1\,mol}{63.55g} = 1.40\,mol\,Cu$

$\frac{11.2g\,O \mid 1\,mol}{16.00g} = 0.70\,mol\,O$

$Cu_{\frac{1.40}{0.70}}O_{\frac{0.70}{0.70}}$ $\boxed{Cu_2O}$

2. 40.0% carbon; 6.7% hydrogen; 53.3% oxygen

$\frac{40.0g\,C \mid 1\,mol}{12.01g} = 3.33\,mol\,C$

$\frac{6.7g\,H \mid 1\,mol}{1.01g} = 6.63\,mol\,H$

$\frac{53.5g \mid 1\,mol}{16.00g} = 3.34\,mol\,O$

$C_{\frac{3.33}{3.33}}H_{\frac{6.63}{3.33}}O_{\frac{3.34}{3.33}}$ $\boxed{CH_2O}$

3. 82.40% nitrogen; 17.60% hydrogen

$\frac{82.40g\,N \mid 1\,mol}{14.01g} = 5.88\,mol\,N$

$\frac{17.60g\,H \mid 1\,mol}{1.01g} = 17.4\,mol$

$N_{\frac{5.88}{5.88}}H_{\frac{17.4}{5.88}}$ $\boxed{NH_3}$

4. 10.04% carbon; 0.84% hydrogen; 89.12% chlorine

$\frac{10.04g\,C \mid 1\,mol}{12.01g} = .836\,mol\,C$ $\frac{89.12g \mid 1\,mol}{35.45g} = 2.51\,mol\,Cl$

$\frac{0.84g\,H \mid 1\,mol}{1.01g} = 0.832\,mol\,H$

$C_{\frac{0.836}{0.832}}H_{\frac{0.832}{0.832}}Cl_{\frac{2.51}{0.832}}$ $\boxed{CHCl_3}$

5. 52.94% aluminum; 47.06% oxygen

$\frac{52.94g \mid 1\,mol}{26.98g} = 1.96\,mol\,Al$

$\frac{47.06g\,O \mid 1\,mol}{16.00g} = 2.94\,mol\,O$

$Al_{\frac{1.96}{1.96}}O_{\frac{2.94}{1.96}}$ $2(AlO_{1.5}) = \boxed{Al_2O_3}$

6. 65.1% scandium; 34.9% oxygen

$\frac{65.1g\,Sc \mid 1\,mol}{44.96g} = 1.45\,mol\,Sc$

$\frac{34.9g\,O \mid 1\,mol}{16.00g} = 2.18\,mol\,O$

$Sc_{\frac{1.45}{1.45}}O_{\frac{2.18}{1.45}}$ $2(ScO_{1.5})$ $\boxed{Sc_2O_3}$

7. 74.17% mercury; 25.83% chlorine

$\frac{74.17g\,Hg \mid 1\,mol}{200.59g} = .3698\,mol\,Hg$

$\frac{25.83g\,Cl \mid 1\,mol}{35.45g} = .729\,mol\,Cl$

$\boxed{HgCl_2}$

Determine the empirical and molecular formulas for each of the following.

1. 27.3% carbon; 72.7 oxygen; experimental molar mass is 132 g/mol.

$\frac{27.3g \mid 1 mol}{\mid 12.01g} = \frac{2.27 mol C}{2.27}$ $\boxed{CO_2}$ EF

$\frac{72.7g \mid 1 mol}{\mid 16.00g} = \frac{4.54 mol O}{2.27}$

$\frac{132 g/mol}{44.01 g/mol} = 3$

$3(CO_2)$

$\boxed{C_3O_6}$ MF

2. 92.3% carbon; 7.7% hydrogen; experimental molar mass is 78.1 g/mol.

$\frac{92.3g \mid 1 mol}{\mid 12.01g} = 7.69 mol C$

$\frac{7.7g \mid 1 mol}{\mid 1.01g} = 7.62 mol H$

$\boxed{CH}$ EF

$\frac{78.1 g/mol}{13.02 g/mol} = 6$

$6(CH)$

$\boxed{C_6H_6}$ MF

3. 94.12% sulfur; 5.88% hydrogen; experimental molar mass is 34.1 g/mol.

$\frac{94.12g \mid 1 mol}{\mid 32.07g} = \frac{2.94 mol S}{2.94}$

$\frac{5.88g \mid 1 mol}{\mid 1.01g} = \frac{5.82 mol H}{2.94}$

$\boxed{SH_2}$ EF

$\frac{34.1 g/mol}{34.1 g/mol} = 1$

$\boxed{SH_2}$ MF

4. 30.43% nitrogen; 69.5% oxygen; experimental molar mass is 92.0 g/mol.

$\frac{30.43gN \mid 1 mol}{\mid 14.01g} = \frac{2.17 mol N}{2.17}$

$\frac{69.5g \mid 1 mol}{\mid 16.00g} = \frac{4.34 mol O}{2.17}$

$\boxed{NO_2}$ EF

$\frac{92.0 g/mol}{46.01 g/mol} = 2$

$2(NO_2)$

$\boxed{N_2O_4}$ MF

5. 73.8% carbon; 8.7% hydrogen; 17.5% nitrogen; experimental molar mass is 162.2 g/mol.

$\frac{73.8gC \mid 1 mol}{\mid 12.01g} = \frac{6.14 mol C}{1.25}$

$\frac{8.7gH \mid 1 mol}{\mid 1.01g} = \frac{8.61 mol H}{1.25}$

$\frac{17.5g \mid 1 mol}{\mid 14.01g} = \frac{1.25 mol N}{1.25}$

$\boxed{C_5H_7N}$ EF

$\frac{162.2 g/mol}{81.1 g/mol} = 2$

$2(C_5H_7N)$

$\boxed{C_{10}H_{14}N_2}$ MF

Practice with Ch. 11 Concepts – Honors Level

1. Determine the molar mass in each of the following quantities:

   a. formic acid (CH_2O_2)

   $12.01 + 2(1.01) + 2(16.00) = \boxed{46.03\ g/mol}$

   b. ammonium dichromate $(NH_4)_2Cr_2O_7$

   $2(14.01) + 8(1.01) + 2(52.00) + 7(16.00) = \boxed{252.10 g/mol}$

2. What is the mass, in grams, of each of the following quantities:

   a. 2.53 moles of lead (II) nitrate $Pb(NO_3)_2$

   $\frac{2.53\ mol \mid 331.21g}{\mid 1\ mol} = \boxed{837g\ Pb(NO_3)_2}$

   b. 2.66×10^{24} particles of potassium iodide

   $\frac{2.66\times10^{24}\ particles \mid 1\ mol \mid 166.00g}{\mid 6.02\times10^{23}\ p \mid 1\ mol} = \boxed{733g\ KI}$

   c. 78.4 L of nitrogen gas

   $\frac{78.4L \mid 1\ mol \mid 28.02g}{\mid 22.4L \mid 1\ mol} = \boxed{98.07g\ N_2}$

3. How many grams of copper (II) iodide are needed to get 8.00×10^{24} iodide **ions**?

   $\frac{8.00\times10^{24}\ I^-\ ions \mid 1\ mlc\ CuI_2 \mid 1\ mol \mid 317.35g}{\mid 2\ ions\ I^- \mid 6.02\times10^{23}\ mlc \mid 1\ mol} = \boxed{2.11\times10^3\ g\ CuI_2}$

4. If an element has 1.96×10^{22} atoms in 0.791 grams, what is its molar mass?

   $\frac{1.96\times10^{22}\ atoms \mid 1\ mol}{\mid 6.02\times10^{23}\ atoms} = 0.0326 mol$ $\qquad \frac{0.791g}{0.0326mol} = \boxed{24.3g/mol}$

5. Find the density of gold, in g/cm^3, when a cube measuring 0.787 inch by 3.15 inch by 1.57 inch contains 3.77×10^{24} atoms. (1 inch = 2.54 cm).

   $\frac{0.787in \mid 2.54cm}{\mid 1in} = 2.00cm$

   $\frac{3.15in \mid 2.54cm}{\mid 1in} = 8.00cm$

   $\frac{1.57in \mid 2.54cm}{\mid 1in} = 3.99cm$

   $(2.00)(8.00)(3.99) = 63.84cm^3$

   $\frac{3.77\times10^{24}\ atoms \mid 1\ mol \mid 196.97g}{\mid 6.02\times10^{23}\ atoms \mid 1\ mol} = 1230g$

   $\frac{1230g}{63.8cm^3} = \boxed{19.3g/cm^3}$

6. How many molecules of water would be present in a 15.0 mL sample, given that the density of water is 1.00 g/mL?

   $\frac{1.00g}{mL} = \frac{x}{15.0mL}$ $\qquad x = \frac{15.0g \mid 1\ mol \mid 6.02\times10^{23}\ mlc}{\mid 18.02g \mid 1\ mol} = \boxed{5.01\times10^{23}\ molecules\ H_2O}$

7. Determine the percent composition for each element in the following compounds:

   a. manganese (II) oxide MnO

$Mn: \frac{(54.94)}{70.94} \times 100 = \boxed{77.4\%\ Mn}$ $O: 100 - 77.4 = \boxed{22.6\%\ O}$

   b. propanol (C_3H_8O)

$C: \frac{3(12.01)}{60.11} \times 100 = \boxed{59.9\%\ C}$ $H: \frac{8(1.01)}{60.11} \times 100 = \boxed{13.4\%}$ $O: 100 - 59.9 - 13.4 = \boxed{26.7\%}$

   c. calcium phosphate $Ca_3(PO_4)_2$

$Ca: \frac{3(40.08)}{310.18} \times 100 = \boxed{38.8\%}$ $P: \frac{2(30.97)}{310.18} \times 100 = \boxed{20.0\%}$ $O: 100 - 38.8 - 20.0 = \boxed{81.2\%}$

8. Determine the empirical formula for a sample that has the following percent composition:

   a. 5.93% hydrogen and 94.07% sulfur

$\frac{5.93g \mid 1 mol}{\mid 1.01g} = \frac{5.87 mol}{2.94}$ $\boxed{H_2S}$

$\frac{94.07g \mid 1 mol}{\mid 32.01g} = \frac{2.94 mol}{2.94}$

   b. 80.68% mercury, 12.87% oxygen, and 6.45% sulfur

$\frac{80.68g \mid 1 mol}{\mid 200.59g} = .402 mol\ Hg$ $\frac{6.45g \mid 1 mol}{\mid 32.01g} = .201 mol\ S$ $\boxed{Hg_2SO_4}$

$\frac{12.87g \mid 1 mol}{\mid 16.00g} = .804 mol\ O$

9. A 48.30 gram sample of a compound containing aluminum and iodine in a fixed ratio contains 3.20 grams of aluminum. What is the empirical formula of the compound?

$\frac{3.20g \mid 1 mol}{\mid 26.98g} = \frac{.119 mol\ Al}{.119}$ $\boxed{AlO_3}$

$48.30 - 3.20 = \frac{45.1g \mid 1 mol}{\mid 126.90g} = \frac{.355 mol\ I}{.119}$

10. Determine the empirical formula for caffeine, given that a sample contains 49.47 grams of carbon, 28.85 grams of nitrogen, 16.48 grams of oxygen, and 5.20 grams of hydrogen.

$\frac{49.47g \mid 1 mol}{\mid 12.01g} = \frac{4.12 mol\ C}{1.03}$ $\frac{16.48g \mid 1 mol}{\mid 16.00g} = \frac{1.03 mol\ O}{1.03}$ $\boxed{C_4N_2OH_5}$

$\frac{28.85g \mid 1 mol}{\mid 14.01g} = \frac{2.06 mol\ N}{1.03}$ $\frac{5.20g \mid 1 mol}{\mid 1.01g} = \frac{5.15 mol\ H}{1.03}$

11. If the molar mass of caffeine is determined to be 194.19 g/mol, what is caffeine's molecular formula? (use information from #10 also)

$\frac{194.19\ g/mol}{97.11\ g/mol} = 2$ $2(C_4N_2OH_5)$

$\boxed{C_8N_4O_2H_{10}}$

Ch. 11 Practice II – Honors Level

1. Determine the mass of 8.234×10^{22} formula units of ammonium nitrate. $(NH_4)_2NO_3$

$$\frac{8.234\times10^{22}\text{ f.u.}}{} \left|\frac{1\text{ mol}}{6.02\times10^{23}\text{ f.u.}}\right| \frac{98.11\text{ g}}{1\text{ mol}} = \boxed{13.42\text{ g } (NH_4)_2NO_3}$$

2. How many molecules are in a 15.0 grams sample of magnesium oxide?

$$\frac{15.0\text{ g MgO}}{} \left|\frac{1\text{ mol}}{40.31\text{ g}}\right| \frac{6.02\times10^{23}\text{ m/c}}{1\text{ mol}} = \boxed{2.24\times10^{23}\text{ m/c MgO}}$$

3. How many hydrogen atoms are in 8.25 grams of ammonia (NH_3)?

$$\frac{8.25\text{ g } NH_3}{} \left|\frac{1\text{ mol}}{17.04\text{ g}}\right| \frac{6.02\times10^{23}\text{ m/c}}{1\text{ mol}} \left|\frac{3\text{ H atoms}}{1\text{ m/c}}\right. = \boxed{8.74\times10^{23}\text{ atoms H}}$$

4. What is the molar mass of a compound that contains 2.25×10^{23} molecules in 14.45 grams of the compound?

$$\frac{2.25\times10^{23}\text{ m/c}}{} \left|\frac{1\text{ mol}}{6.02\times10^{23}\text{ m/c}}\right. = .374\text{ mol} \qquad \frac{14.45\text{ g}}{.374\text{ mol}} = \boxed{38.7\text{ g/mol}}$$

5. Lead has a density of 12.3 g/cm^3. What volume would 9.40×10^{24} atoms occupy?

$$\frac{9.40\times10^{24}\text{ atoms}}{} \left|\frac{1\text{ mol}}{6.02\times10^{23}\text{ atoms}}\right| \frac{207.19\text{ g}}{1\text{ mol}} = 3235\text{ g} \qquad \frac{12.3\text{ g}}{\text{cm}^3} = \frac{3240\text{ g}}{x}$$

$$V = \boxed{263\text{ cm}^3}$$

6. Find the percent composition for each element in sodium sulfate.
Na_2SO_4

$$Na: \frac{2(22.99)}{141.99}\times100 = \boxed{32.4\%} \qquad S: \frac{32.01}{141.99}\times100 = \boxed{22.5\%} \qquad O: 100-32.4-22.5 = \boxed{45.1\%}$$

7. Determine the percent of carbon in copper phthalocyanine, $Cu(C_8H_4N_2)_4$.

$$\frac{32(12.01)}{576.11}\times100 = \boxed{66.7\%}$$

8. Determine the mass of carbon found in 135 grams of silver oxalate.

$Ag_2C_2O_4$

$\frac{2(12.01)}{303.76} \times 100 = 7.9\%$

$\frac{7.9}{100} = \frac{x}{135}$

$x = \boxed{10.7 g\ C}$

9. Determine the empirical formula of a compound that contains 0.89 grams K, 1.18 grams Cr, and 1.27 grams O.

$0.89 g\ K \left| \frac{1 mol}{39.10 g} \right. = 0.0228 mol\ K$

$1.18 g\ Cr \left| \frac{1 mol}{52.00 g} \right. = 0.0227 mol\ Cr$

$1.27 g\ O \left| \frac{1 mol}{16.00 g} \right. = 0.0794 mol\ O$

$2(KCrO_{3.5})$

$\boxed{K_2Cr_2O_7}$

10. Use the following data to determine the empirical formula of the compound:

Mass of crucible (g)	15.00
Mass of crucible + iron (g)	24.68
Mass of crucible + iron oxide compound (g)	28.85

24.68 − 15.00 = 9.68 g iron
28.85 − 24.68 = 4.17 g oxygen

$9.68 g\ Fe \left| \frac{1 mol}{55.85 g} \right. = .173 mol\ Fe$

$4.17 g\ O \left| \frac{1 mol}{16.00 g} \right. = .261 mol\ O$

$2(FeO_{1.5})$ $\boxed{Fe_2O_3}$

11. A fat is composed of 76.5% carbon, 11.3% oxygen, and 12.2% hydrogen. What is its molecular formula if it has a molar mass of 847 g/mol?

$76.5 g\ C \left| \frac{1 mol}{12.01 g} \right. = 6.37 mol\ C$

$11.3 g\ O \left| \frac{1 mol}{16.00 g} \right. = .706 mol\ O$

$12.2 g\ H \left| \frac{1 mol}{1.01 g} \right. = 12.08 mol\ H$

$C_9H_{17}O$

$\frac{847 g/mol}{141.26 g/mol} = 6(C_9H_{17}O)$

$\boxed{C_{54}H_{102}O_6}$

Hydrate Problems

1. A 50.00 gram sample of hydrated manganese (II) chloride yields 31.75 grams of the anhydrous compound after heating. Determine the chemical formula and the name of the hydrate.

$50.00g - 31.75g = \frac{18.25g\ H_2O \mid 1\ mol}{\mid 18.02g} = \frac{1.01\ mol\ H_2O}{0.252\ mol}$ $\boxed{MnCl_2 \cdot 4H_2O}$

$\frac{31.75g \mid 1\ mol}{\mid 125.84g} = \frac{0.252\ mol}{0.252\ mol}$

2. Cerium (III) iodide occurs as a hydrate with a composition of 76.3% of cerium (III) iodide and 23.7% water. Determine the chemical formula of the hydrate.

$\frac{76.3g \mid 1mol}{\mid 520.82g} = .146\ mol$ $\boxed{CeI_3 \cdot 9H_2O}$

$\frac{23.7g \mid 1mol}{\mid 18.02g} = 1.32mol$

3. A hydrate with a molar mass of 174.37 grams has 31.0% water. Find the formula of this hydrate containing 13.9% magnesium, 4.1% hydrogen, 17.8% phosphorus, and 64.2% oxygen.

69% anhydrate × 174.37 g/mol = 120.32 g/mol = MM anhydrate

$\frac{13.9g \mid 1mol}{\mid 24.31g} = .57mol\ Mg$ $\frac{64.2g \mid 1mol}{\mid 16.00g} = 4.02mol\ O$ $\frac{31.0g\ H_2O \mid 1\ mol}{\mid 18.02g} = 1.720\ mol\ H_2O$

$\frac{4.1g \mid 1mol}{\mid 1.01g} = 4.06mol\ H$

MgH_7PO_7
$- \quad H_6\ O_3\ (3H_2O)$
$\boxed{MgHPO_4} \rightarrow \boxed{MgHPO_4 \cdot 3H_2O} \leftarrow \boxed{3H_2O}$

$\frac{69.0g \mid 1mol}{\mid 120.32g} = .570\ mol\ anh.$

$\frac{17.8g \mid 1mol}{\mid 30.97g} = .57mol\ P$

4. A calcium chloride hydrate has a mass of 4.72 grams. After heating, the mass of the anhydrate is found to be 3.56 grams. Determine the formula of the hydrate.

$4.72 - 3.56 = \frac{1.16g\ H_2O \mid 1\ mol}{\mid 18.02g} = 0.064\ mol$ $\boxed{CaCl_2 \cdot 2H_2O}$

$\frac{3.56g\ CaCl_2 \mid 1mol}{\mid 111.16g} = 0.032\ mol$

5. A sample of copper (II) sulfate hydrate has a mass of 3.97 grams. After heating, the anhydrate has a mass of 2.54 grams. Determine the formula of the hydrate.

$3.97 - 2.54 = \frac{1.43g\ H_2O \mid 1mol}{\mid 18.02g} = 0.0794\ mol$

$\frac{2.54g\ CuSO_4 \mid 1mol}{\mid 159.56g} = 0.0159mol$

$\boxed{CuSO_4 \cdot 5H_2O}$

6. A sample of sodium carbonate hydrate has a mass of 8.85 grams. It loses 1.28 grams when heated. Find the formula of the hydrate.

$8.85-1.28 = 7.57g \text{ anhyrous} \left| \frac{1 mol}{105.99g} \right. = 0.0714 \text{ mol}$

$1.28g \left| \frac{1 mol}{18.02g} \right. = 0.0710 \text{ mol}$

$\boxed{Na_2CO_3 \cdot 1H_2O}$

7. A hydrate is determined to be 45.43% water and 54.57% $CoCl_2$. Find the chemical formula and the name of this hydrate.

$45.43g \left| \frac{1 mol}{18.02g} \right. = 2.52 \text{ mol } H_2O$

$\boxed{CoCl_2 \cdot 6H_2O}$

$54.57g \left| \frac{1 mol}{129.83g} \right. = .420 \text{ mol}$

8. A 17.44 gram sample of a zinc sulfate hydrate is heated in a crucible to drive off all water of hydration. After heating, the anhydrous compound has a mass of 9.79 grams. Determine the formula of this hydrate.

$17.44-9.79 = 7.65g \left| \frac{1 mol}{18.02g} \right. = .425 \text{ mol } H_2O$

$9.79g \left| \frac{1 mol}{161.42g} \right. = .0606 \text{ mol}$

$\boxed{ZnSO_4 \cdot 7H_2O}$

9. Use the following data to find the formula of a lead (II) acetate hydrate.

Mass of crucible (g)	20.00
Mass of crucible + hydrate (g)	21.04
Mass of crucible + anhydrate (g)	20.99

$21.04-20.99 = 0.05g \text{ } H_2O \text{ } \cancel{\text{anhydrate}} \left| \frac{1 mol}{\cancel{325.29g} \text{ } 18.02} \right. = 2.77 \times 10^{-3} \text{ mol}$

$0.99g \text{ anhydrate} \left| \frac{1 mol}{325.29g} \right. = 3.04 \times 10^{-3} \text{ mol}$

$\boxed{Pb(C_2H_3O_2)_2 \cdot 1H_2O}$

Chapter 11 Review

1. Calculate the number of moles of $FeSO_4$ in 25.6 grams of this compound.

$$\frac{25.6\,g\,FeSO_4}{} \left| \frac{1\,mol}{151.86\,g} \right. = \boxed{0.169\,mol}$$

2. Calculate the number of liters of NO_2 gas at STP in 79.7 grams of this compound.

$$\frac{79.7\,g}{} \left| \frac{1\,mol}{46.01\,g} \right| \frac{22.4\,L}{1\,mol} = \boxed{38.8\,L}$$

3. How many chloride ions are there in 2.19 grams of aluminum chloride?

$$\frac{2.19\,g}{} \left| \frac{1\,mol}{133.33\,g} \right| \frac{6.02\times10^{23}\,m/c}{1\,mol} \left| \frac{3\,ions\,Cl^-}{1\,m/c} \right. = \boxed{2.70\times10^{22}\,ions\,Cl^-}$$

4. How many atoms of carbon are in 19.1 grams of glucose?

$$\frac{19.1\,g}{} \left| \frac{1\,mol}{180.18\,g} \right| \frac{6.02\times10^{23}\,m/c}{1\,mol} \left| \frac{6\,atoms\,C}{1\,m/c} \right. = \boxed{3.83\times10^{23}\,atoms\,C}$$

5. Determine the following for 45.2 grams of the compound $PtCl_2(NH_3)_2$:
   a. number of moles of nitrogen
   b. number of atoms of nitrogen
   c. mass percent (percent composition) of nitrogen
   d. actual mass of nitrogen in the compound

a $$\frac{45.2\,g}{} \left| \frac{1\,mol}{300.06\,g} \right| \frac{2\,mol\,N}{1\,mol\,cmpd} = \boxed{.301\,mol\,N}$$

b $$\frac{.301\,mol}{} \left| \frac{6.02\times10^{23}\,atoms}{1\,mol} \right. = \boxed{1.81\times10^{23}\,atoms\,N}$$

c $$\frac{2(14.01)}{300.06} \times 100 = \boxed{9.34\%}$$

d $$\frac{9.34}{100} = \frac{x}{45.2} \quad \boxed{4.22\,g\,N}$$

6. Determine the empirical formula of a compound composed of 23.1% aluminum, 15.4% carbon, and 61.5% oxygen.

$$\frac{23.1\,g\,Al}{} \left| \frac{1\,mol}{26.98\,g} \right. = .856\,mol\,Al$$

$$\frac{15.4\,\cancel{12.01}\,g\,C}{} \left| \frac{1\,mol}{12.01\,g} \right. = 1.26\,mol\,C$$

$$\frac{61.5\,g\,O}{} \left| \frac{1\,mol}{16.00\,g} \right. = 3.84\,mol\,O$$

$$2(AlC_{1.5}O_{4.5})$$

$$Al_2C_3O_9$$

$$\boxed{Al_2(CO_3)_3}$$

7. To find the experimental empirical formula of a compound, a student heats a piece of magnesium and collects the following data. Determine the empirical formula for oxide of magnesium that is produced.

Length of magnesium strip	35.00 cm
Mass of empty crucible	20.74 g
Mass of 2.00 meters of magnesium	1.44 g
Mass of crucible + oxide of magnesium product	21.17 g

$\frac{1.44 g}{2.00 m} = \frac{x}{.035 m}$ $x = .0252 g\ Mg \left| \frac{1 mol}{24.305 g} \right. = .00104$ mol

$21.17 - 20.74 g = .43 g\ MgO$

$.43 - \cancel{.0252} = \cancel{.405} g\ O \left| \frac{1 mol}{16.00 g} \right. = .0253$ mol
.0104 .420

$2(MgO_{2.5})$

$\boxed{Mg_2O_5}$

8. Vitamin C is composed of 40.92% carbon, 4.580% hydrogen, and 54.50% oxygen. Its molar mass is 176.0 g/mol. Calculate its molecular formula.

$40.92 g\ C \left| \frac{1 mol}{12.01 g} \right. = 3.41$ mol C

$4.580 g\ H \left| \frac{1 mol}{1.01 g} \right. = 4.53$ mol H

$54.50 g\ O \left| \frac{1 mol}{16.00 g} \right. = 3.41$ mol

$3(CH_{1.3}O)$

$\boxed{C_3H_4O_3}$

9. A compound is found to contain 36.84% and 63.16% oxygen. If the molar mass is 152.0 g/mol, determine the molecular formula of the compound.

$36.84 g\ N \left| \frac{1 mol}{14.01 g} \right. = 2.63$ mol N

$63.16 g\ O \left| \frac{1 mol}{16.00 g} \right. = 3.95$ mol O

$2(NO_{1.5})$ N_2O_3

$\frac{152.0 g/mol}{76.02 g/mol} = 2$

$\boxed{N_4O_6}$

10. 1.000 gram of the hydrate of cobalt (II) chloride was heated until all of the water was driven off. After heating, 0.546 grams of the anhydrate remained. What is the formula of this hydrate?

$1.000 g - 0.546 = .454 g\ H_2O \left| \frac{1 mol}{18.02 g} \right. = .025$ mol

$.546 g\ CoCl_2 \left| \frac{1 mol}{129.83 g} \right. = .00421$ mol

$\boxed{CoCl_2 \cdot 6H_2O}$

Chapter 11 Review II

1. Calculate the number of grams of $FeSO_4$ in 8.54×10^{25} molecules of this compound.

$$\frac{8.54\times10^{25}\,\text{m/c}}{} \left|\frac{1\text{ mol}}{6.02\times10^{23}\,\text{m/c}}\right| \frac{151.86\text{g}}{1\text{ mol}} = \boxed{21500\text{g}}$$

2. Calculate the number of microliters of O_2 gas at STP in 16.59 grams of this compound.

$$\frac{16.59\text{ g}}{} \left|\frac{1\text{ mol}}{32.00\text{g}}\right| \frac{22.4\text{L}}{1\text{ mol}} \left|\frac{1\times10^{6}\,\mu\text{L}}{1\text{L}}\right. = \boxed{1.161\times10^{7}\,\mu\text{L}}$$

3. How many grams of dinitrogen trioxide are present when you have 6.80×10^{22} atoms of nitrogen?

$$\frac{6.80\times10^{22}\text{ atoms N}}{} \left|\frac{1\text{ m/c }N_2O_3}{2\text{ atoms N}}\right| \frac{1\text{ mol}}{6.02\times10^{23}\text{ m/c}} \left|\frac{76.02\text{ g}}{1\text{ mol}}\right. = \boxed{4.29\text{g }N_2O_3}$$

4. Determine the molar mass of a substance with a mass of 7.95 grams that contains 1.5×10^{23} molecules.

$$\frac{1.5\times10^{23}\text{ m/c}}{} \left|\frac{1\text{ mol}}{6.02\times10^{23}\text{ m/c}}\right. = .25\text{mol} \qquad \frac{7.95\text{g}}{.25\text{mol}} = \boxed{32\text{ g/mol}}$$

5. Determine the following for 860.0 milligrams of acetaminophen ($C_8H_9NO_2$)
   a. number of moles of acetaminophen
   b. number of atoms of carbon
   c. mass percent (percent composition) of carbon
   d. actual mass of carbon in the compound

a) $$\frac{860.0\text{mg}}{} \left|\frac{1\text{ mol}}{151.18\text{g}}\right| \frac{1\text{ g}}{1\times10^{3}\text{mg}} = \boxed{5.689\times10^{-3}\text{ mol}}$$

b) $$\frac{5.689\times10^{-3}\text{ mol}}{} \left|\frac{6.02\times10^{23}\text{ m/c}}{1\text{ mol}}\right| \frac{8\text{ atoms C}}{1\text{ m/c}} = \boxed{2.740\times10^{22}\text{ atoms C}}$$

c) $$\frac{8(12.011)}{151.18} \times 100 = \boxed{63.6\%\text{ C}}$$

d) $$\frac{63.6}{100} = \frac{x}{.8600\text{g}} \qquad x = \boxed{.5466\text{g or }546.6\text{mg}}$$

6. Caffeine has the following percent composition: carbon 49.48%, hydrogen 5.19%, oxygen 16.48% and nitrogen 28.85%. Its molecular weight is 194.19 g/mol. What is its molecular formula?

$\frac{49.48 g C \mid 1 mol}{\mid 12.01 g} = \frac{4.12 mol C}{1.03}$ $C_4H_5ON_2 \Rightarrow EF$

$\frac{5.19 g H \mid 1 mol}{\mid 1.01 g} = \frac{5.14 mol H}{1.03}$ $\frac{194.19 g/mol}{97.11 g/mol} = 2$

$\frac{28.85 g N \mid 1 mol}{\mid 14.01 g} = \frac{2.06 mol N}{1.03}$ $\boxed{C_8H_{10}N_4O_2}$

$\frac{16.48 g O \mid 1 mol}{\mid 16.00 g} = \frac{1.03 mol O}{1.03}$

7. Given that a sample of lead contains 1.20×10^{24} atoms and during water displacement, the water level increases from 45.0 mL to 81.4 mL, determine the density of lead.

81.4 − 45.0 = 36.4 mL = volume

$\frac{1.20 \times 10^{24} atoms \mid 1 mol \mid 207.19 g}{\mid 6.02 \times 10^{23} atoms \mid 1 mol} = 413.0 g$

$\frac{413.0 g}{36.4 mL} = \boxed{11.3 g/cm^3}$

8. Given the lab data below, determine the number of waters of hydration present.

Mass of crucible: 18.050 grams

Mass of crucible + magnesium carbonate hydrate: 33.720 grams

Mass of crucible + magnesium carbonate anhydrate: 25.63 grams

$33.720 - 25.63 = \frac{8.09 g H_2O \mid 1 mol}{\mid 18.02 g} = \frac{.449 mol H_2O}{.0899}$

$25.63 - 18.050 = \frac{7.58 g MgCO_3 \mid 1 mol}{\mid 84.32 g} = \frac{.0899 mol MgCO_3}{.0899}$

$\boxed{MgCO_3 \cdot 5H_2O}$