

2 Chemical Formulas and Composition

Stoichiometry

- 2-1** (a) Stoichiometry is the description of the quantitative relationships among elements in a compound and among substances as they undergo chemical change.
 (b) Composition stoichiometry describes the quantitative relationships among elements in compounds, e.g., in water, H_2O , there are 2 hydrogen atoms for every 1 atom of oxygen. Reaction stoichiometry describes the quantitative relationships among substances as they undergo chemical changes. (Reaction stoichiometry will be discussed in Chapter 3.)

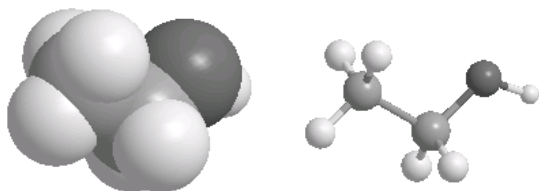
2-3 The common ions for each formula unit is listed below:

(a) MgCl_2 contains Mg^{2+} and Cl^- ions

(b) $(\text{NH}_4)_2\text{CO}_3$ contains NH_4^+ and CO_3^{2-} ions

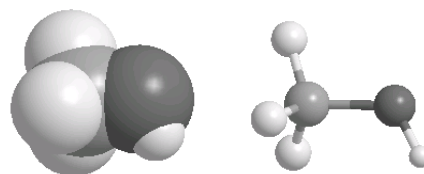
(c) $\text{Zn}(\text{NO}_3)_2$ contains Zn^{2+} and NO_3^- ions

2-5 Ethanol - $\text{CH}_3\text{CH}_2\text{OH}$



(space-filling; ball-and-stick)

Methanol - CH_3OH



(space-filling; ball-and-stick)

Both are composed of hydrogen, carbon, and oxygen. Both have an oxygen and hydrogen on the end. The ethanol molecule has an additional carbon and two hydrogens.

- 2-7** Organic compounds are those that contain carbon-to-carbon bonds, carbon-to-hydrogen bonds, or both. Organic formulas given in Table 2-1 include: acetic acid- CH_3COOH , methane- CH_4 , ethane- C_2H_6 , propane- C_3H_8 , butane- C_4H_{10} , pentane- C_5H_{12} , benzene- C_6H_6 , methanol- CH_3OH , ethanol- $\text{CH}_3\text{CH}_2\text{OH}$, acetone- CH_3COCH_3 , diethyl ether- $\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$.

2-9 Compounds from Table 2-1 that contain only carbon and hydrogen and are not shown in Figure 1-5:

Compound	Ball and stick model	Compound	Ball and stick model
acetic acid- CH_3COOH		acetone- CH_3COCH_3	
methanol- CH_3OH		diethyl ether- $\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$	

- 2-11** (a) Formula weight is the mass in atomic mass units of the simplest formula of an ionic compound and is found by adding the atomic weights of the atoms specified in the formula. The numerical amount for the formula weight is the equal to the numerical amount for the mass in grams of one mole of the substance.
 (b) Molecular weight is the mass in atomic mass units of one molecule of a substance that is molecular, rather than ionic. It is found by adding the atomic weights of the atoms specified in the formula. The numerical amount for the molecular weight is the equal to the numerical amount for the mass in grams of one mole of the substance.
 (c) Structural formula is the representation that shows how atoms are connected in a compound.
 (d) An ion is an atom or group of atoms that carries an electrical charge, which is caused by unequal numbers of protons and electrons. A positive ion is a cation. A negative ion is an anion.
- 2-13** The formulas for (a) through (d) are given in Table 2-1.
 (a) C_4H_{10} (b) $\text{CH}_3\text{CH}_2\text{OH}$ (c) SO_3 (d) CH_3COCH_3 (e) CCl_4
- 2-15** We can find most of the names of the appropriate ions in Table 2-2.
 (a) magnesium chloride (b) iron(II) nitrate (c) sodium sulfate
 (d) calcium hydroxide (e) iron(II) sulfate
- 2-17** Formulas are written to show the ions in the smallest ratio that gives no net charge. Compounds are electrically neutral.
 (a) NaOH , sodium hydroxide (b) $\text{Al}_2(\text{CO}_3)_3$, aluminum carbonate
 (c) Na_3PO_4 , sodium phosphate (d) $\text{Ca}(\text{NO}_3)_2$, calcium nitrate
 (e) FeCO_3 , iron(II) carbonate
- 2-19** (a) This chemical formula is incorrect. The atomic symbol for a potassium ion is K^+ , not P^+ . The correct chemical formula for potassium iodide is KI .
 (b) This chemical formula is correct.
 (c) The chemical formula is incorrect. The symbol for a silver ion is Ag^+ . The correct chemical formula for the carbonate ion is CO_3^{2-} . Therefore, the chemical formula for silver carbonate is Ag_2CO_3 .
- 2-21** (a) $\text{Al}(\text{OH})_3$ (b) MgCO_3 (c) ZnCO_3 (d) $(\text{NH}_4)_2\text{SO}_4$ (e) ZnSO_4
- 2-23** (a) CaCO_3 (b) $\text{Mg}(\text{OH})_2$ (c) CH_3COOH (d) NaOH (e) ZnO
- 2-25** $\frac{? \text{ amu}}{\text{atom}} \geq 58.693 \times 2 \geq 117.386 \text{ amu/atom}$. The atomic weight of tin is 118.710 amu/atom.
- Tin, Sn, is the element with an atomic weight slightly over 117.386 amu.
- 2-27** (a) *amu*—a measurement of mass that is equal to exactly 1/12 of the mass of an atom of carbon-12.
 (b) The mass of an atom of cobalt is almost twice that of an atom of aluminum (58.93/26.98).
- 2-29** Here we use the atomic weights to the number of places given in the periodic table in the inside front cover of the text.

$$\begin{array}{rclcl}
 \text{(a)} & 1 \times \text{Ca} & = & 1 \times 40.078 & \text{amu} = 40.078 \text{ amu} \\
 & 1 \times \text{S} & = & 1 \times 32.066 & \text{amu} = 32.066 \text{ amu} \\
 & 4 \times \text{O} & = & 4 \times 15.9994 & \text{amu} = 63.9976 \text{ amu}
 \end{array}$$

$$\text{FW} = \boxed{136.142 \text{amu}}$$

$$\begin{array}{rclcl}
 \text{(b)} & 3 \times \text{C} & = & 3 \times 12.011 & \text{amu} = 36.033 \text{ amu} \\
 & 8 \times \text{H} & = & 8 \times 1.0079 & \text{amu} = 8.0632 \text{ amu}
 \end{array}$$

$$\text{FW} = \boxed{44.096 \text{amu}}$$

$$\begin{array}{rclcl}
 \text{(c)} & 6 \times \text{C} & = & 6 \times 12.011 & \text{amu} = 72.066 \text{ amu} \\
 & 8 \times \text{H} & = & 8 \times 1.0079 & \text{amu} = 8.0632 \text{ amu} \\
 & 1 \times \text{S} & = & 1 \times 32.066 & \text{amu} = 32.066 \text{ amu} \\
 & 2 \times \text{O} & = & 2 \times 15.9994 & \text{amu} = 31.9988 \text{ amu} \\
 & 2 \times \text{N} & = & 2 \times 14.0067 & \text{amu} = 28.0134 \text{ amu}
 \end{array}$$

$$\text{FW} = \boxed{172.207 \text{amu}}$$

$$\begin{array}{rclcl}
 \text{(d)} & 3 \times \text{U} & = & 3 \times 238.0289 & \text{amu} = 714.0867 \text{ amu} \\
 & 14 \times \text{O} & = & 14 \times 15.9994 & \text{amu} = 223.9916 \text{ amu} \\
 & 2 \times \text{P} & = & 2 \times 30.9738 & \text{amu} = 61.9476 \text{ amu}
 \end{array}$$

$$\text{FW} = \boxed{1000.0259 \text{amu}}$$

2-31 The ratio of masses present is $\frac{1.76 \text{ g Ba}}{0.487 \text{ g F}} = 3.614$ or $\frac{3.614 \text{ g Ba}}{1.0 \text{ g F}}$. Based on the formula BaF_2 , this

ratio represents $\frac{1 \text{ atom Ba}}{2 \text{ atoms F}}$. So the atomic mass ratio of Ba/F is $\frac{\text{AW Ba}}{\text{AW F}}$ or $\frac{3.614}{1.0/2} = \boxed{7.228}$

From a table of atomic weights, $\frac{\text{AW Ba}}{\text{AW F}} = \frac{137.33 \text{ amu}}{19.00 \text{ amu}} = \boxed{7.228}$

This calculation could not be done without knowledge of the formula or some other knowledge of the relative numbers of atoms present.

$$\textbf{2-33} \quad \underline{\hspace{1cm}} \text{ g H}_2\text{O}_2 = 1.24 \text{ mol H}_2\text{O}_2 \times \frac{34.02 \text{ g H}_2\text{O}_2}{1 \text{ mol H}_2\text{O}_2} = \boxed{42.2 \text{ g H}_2\text{O}_2}$$

$$\textbf{2-35} \quad \text{(a)} \quad \underline{\hspace{1cm}} \text{ Formula Units K}_2\text{CrO}_4 = 154.3 \text{ g K}_2\text{CrO}_4 \times \frac{1 \text{ mol K}_2\text{CrO}_4}{194.20 \text{ g K}_2\text{CrO}_4}$$

$$\times \frac{6.022 \times 10^{23} \text{ For. Units K}_2\text{CrO}_4}{1 \text{ mol K}_2\text{CrO}_4} = \boxed{4.785 \times 10^{23} \text{ Form. Units K}_2\text{CrO}_4}$$

$$\text{(b)} \quad \underline{\hspace{1cm}} \text{ K}^+ \text{ ions} = 4.785 \times 10^{23} \text{ Formula Units K}_2\text{CrO}_4 \times \frac{2 \text{ K}^+ \text{ ions}}{1 \text{ For. unit K}_2\text{CrO}_4} =$$

$$\boxed{9.570 \times 10^{23} \text{ K}^+ \text{ ions}}$$

$$(c) \quad \underline{?} \text{ CrO}_4^{2-} \text{ ions} = 4.785 \times 10^{23} \text{ Formula Units K}_2\text{CrO}_4 \times \frac{1 \text{ CrO}_4^{2-} \text{ ion}}{1 \text{ For. Unit K}_2\text{CrO}_4} =$$

$$\boxed{4.785 \times 10^{23} \text{ CrO}_4^{2-} \text{ ions}}$$

(d) Each formula unit contains 2 K, 1 Cr, and 4 O atoms, or 7 atoms total.

$$\underline{?} \text{ atoms} = 4.785 \times 10^{23} \text{ Formula units K}_2\text{CrO}_4 \times \frac{7 \text{ atoms}}{1 \text{ For. Unit K}_2\text{CrO}_4} = \boxed{3.350 \times 10^{24} \text{ atoms}}$$

$$\mathbf{2-37} \quad \frac{6.438 \text{ g Ne}}{20.1797 \text{ g Ne per mole}} = \boxed{0.3190 \text{ mole Ne}}$$

- 2-39** (a) No. The molecular formulas are different, so the mass of one mole of molecules (the molar mass) is different.
 (b) Yes. One mole of any kind of molecules contains Avogadro's number of molecules.
 (c) No. This is for the same reason given in (a).
 (d) No. The formulas are different, so there are different numbers of atoms per molecule and, hence, different total numbers of atoms in equal numbers of molecules.

2-41 Here we show values in the table on the right front inside cover. The bolded amounts represents the amounts the students fill in.

	Element	Formula	Mass of one mole of molecules
(a)	Br	Br ₂	159.808 g
(b)	O	O ₂	31.9988 g
(c)	P	P ₄	123.8952 g
(d)	Ne	Ne	20.1797 g
(e)	S	S₈	256.53 g
(f)	O	O₂	31.9988 g

$$\mathbf{2-43} \quad \underline{?} \text{ g/atom Cu} = \frac{63.546 \text{ g Cu}}{1 \text{ mol Cu}} \times \frac{1 \text{ mol Cu}}{6.022 \times 10^{23} \text{ atoms Cu}} = \boxed{1.055 \times 10^{-22} \text{ g/1 atom Cu}}$$

$$\mathbf{2-45} \quad \underline{?} \text{ molecules C}_3\text{H}_8 = 8.00 \times 10^6 \text{ molecules CH}_4 \times \frac{1 \text{ mol CH}_4}{6.022 \times 10^{23} \text{ molecules CH}_4} \times \frac{16.043 \text{ g CH}_4}{1 \text{ mol CH}_4}$$

$$\frac{1 \text{ mol CH}_4}{1 \text{ mol C}_3\text{H}_8} \times \frac{1 \text{ mol C}_3\text{H}_8}{44.096 \text{ g C}_3\text{H}_8} \times \frac{6.022 \times 10^{23} \text{ molecules C}_3\text{H}_8}{\text{mol C}_3\text{H}_8} = \boxed{2.91 \times 10^6 \text{ molecules C}_3\text{H}_8}$$

$$\mathbf{2-47} \quad \text{FW Fe}_3(\text{PO}_4)_2 = 357.49 \text{ amu}$$

$$\% \text{ Fe} = \frac{3 \times 55.85 \text{ amu Fe}}{357.49 \text{ amu}} \times 100\% = \boxed{46.8\% \text{ Fe}}$$

Element	Mass of Element	Moles of Element	Divide by Smallest
C	60.00	$\frac{60.00}{12.011} = 4.995 \text{ mol}$	$\frac{4.995}{1.667} = 3.00$
H	13.33	$\frac{13.33}{1.0079} = 13.23 \text{ mol}$	$\frac{13.23}{1.667} = 7.94$
O	26.67	$\frac{26.67}{15.9994} = 1.667 \text{ mol}$	$\frac{1.667}{1.667} = 1.00$
Total 100.00			

Smallest Whole-Number Ratio of Atoms is $\text{C}_3\text{H}_8\text{O}$, the simplest formula.

Formula weight of simplest formula = 60 amu.

Since the formula weight of the simplest formula (FW = 60.09 amu) is equal to the approximate molecular weight given, the molecular formula is the simplest formula, $\boxed{\text{C}_3\text{H}_8\text{O}}$

2-51 (a) % O = 100 % total – [9.79% H + 79.12% C] = 11.09% O

$$\text{So, MW} = \frac{2 \times 16.00 \text{ amu} \times 100}{11.09} = \boxed{288.5 \text{ amu}}$$

(b) % O = 100 % total – [9.79% H + 79.12% C] = 11.09% O

Element	Rel. Mass Element	Rel. No. of Atoms	Divide by Smallest	Multiply by 2
C	79.12	$\frac{79.12}{12.011} = 6.588$	$\frac{6.588}{0.6934} = 9.50$	19
H	9.79	$\frac{9.79}{1.0079} = 9.71$	$\frac{9.71}{0.6934} = 14.00$	28
O	11.09	$\frac{11.09}{15.994} = 0.6934$	$\frac{.6934}{0.6934} = 1.00$	2
Total 100.00				

The simplest formula is $\text{C}_{19}\text{H}_{28}\text{O}_2$. Given that each molecule contains two O atoms, the molecular formula is $\boxed{\text{C}_{19}\text{H}_{28}\text{O}_2}$. As a check on the MW calculated above, the MW of this formula is 288.2.

2-53 (a)

Element	Rel. Mass Element	Rel. No. of Atoms	Divide by Smallest
Cu	30.03	$\frac{30.03}{63.55} = 0.4725$	$\frac{0.4725}{0.4725} = 1.00$
C	22.70	$\frac{22.70}{12.011} = 1.890$	$\frac{1.890}{0.4725} = 4.00$
H	1.91	$\frac{1.91}{1.008} = 1.895$	$\frac{1.895}{0.4725} = 4.01$
O	45.37	$\frac{45.37}{16.00} = 2.836$	$\frac{2.836}{0.4725} = 6.00$
Total 100.00			

The simplest formula is $\text{CuC}_4\text{H}_4\text{O}_6$

(b)

Element	Rel. Mass Element	Rel. No. of Atoms	Divide by Smallest
N	11.99	$\frac{11.99}{14.01} = 0.8558$	$\frac{0.8558}{0.8557} = 1.00$
O	13.70	$\frac{13.70}{16.00} = 0.8563^*$	$\frac{0.8563}{0.8557} = 1.00$
B	9.25	$\frac{9.25}{10.81} = 0.8557$	$\frac{0.8557}{0.8557} = 1.00$
F	65.06	$\frac{65.06}{19.00} = 3.424$	$\frac{3.424}{0.8557} = 4.00$
Total 100.00			

The simplest formula is NOBF_4

*More significant digits can be kept throughout the problem and rounded for the final answer.

2-55 (a)

Element	Mass of Element	Rel. No. of Atoms	Divide by Smallest
N	5.60	$\frac{5.60}{14.01} = 0.400$	$\frac{0.400}{0.400} = 1.00$
Cl	14.2	$\frac{14.2}{35.45} = 0.401$	$\frac{0.401}{0.400} = 1.00$
H	0.800	$\frac{0.800}{1.01} = 0.792$	$\frac{0.792}{0.400} = 1.98 \approx 2$

The simplest formula is NClH_2 or NH_2Cl

(b)

Element	Rel. Mass Element	Rel. No. of Atoms		Divide by Smallest	
N	26.2	$\frac{26.2}{14.01}$	= 1.87	$\frac{1.87}{1.87}$	= 1.00
Cl	66.4	$\frac{66.4}{35.45}$	= 1.87	$\frac{1.87}{1.87}$	= 1.00
H	7.5	$\frac{7.5}{1.01}$	= 7.43*	$\frac{7.43}{1.87}$	= 3.97 \approx 4
Total 100.00					

The simplest formula is $\boxed{\text{NCIH}_4 \text{ or } \text{NH}_4\text{Cl}}$

*More significant digits can be kept throughout the problem and rounded for the final answer.

2-57

Element	Rel. Mass Element	Rel. No. of Atoms		Divide by Smallest	
C	65.13	$\frac{65.13}{12.01}$	= 5.423	$\frac{5.422}{0.417}$	= 13.00
H	7.57	$\frac{7.57}{1.008}$	= 7.51	$\frac{7.51}{0.417}$	= 18.01
Cl	14.79	$\frac{14.79}{35.45}$	= 0.4172	$\frac{0.4172}{0.417}$	= 1.00
N	5.84	$\frac{5.84}{14.01}$	= 0.417	$\frac{0.417}{0.417}$	= 1.00
O	6.67	$\frac{6.67}{16.00}$	= 0.417	$\frac{0.417}{0.417}$	= 1.00
Total 100.00					

The simplest formula is $\boxed{\text{C}_{13}\text{H}_{18}\text{ClNO}}$

2-59

Element	Rel. Mass Element	Rel. No. of Atoms	Divide by Smallest
C	67.30	$\frac{67.30}{12.01} = 5.604$	$\frac{5.604}{0.330} = 17.00$
H	6.930	$\frac{6.930}{1.008} = 6.875$	$\frac{6.875}{0.330} = 20.83 \approx 21$
O	21.15	$\frac{21.15}{16.00} = 1.322$	$\frac{1.322}{0.330} = 4.01$
N	4.62	$\frac{4.62}{14.01} = 0.330$	$\frac{0.330}{0.330} = 1.00$
Total 100.00			

The simplest formula is $\boxed{\text{C}_{17}\text{H}_{21}\text{O}_4\text{N}}$

2-61 (a) FW $\text{C}_{14}\text{H}_{18}\text{N}_2\text{O}_5 = 294.34$ amu

$$\% \text{ C} = \frac{14 \times 12.011 \text{ amu C}}{294.34 \text{ amu}} \times 100\% = \boxed{57.13\% \text{ C}}$$

$$\% \text{ H} = \frac{18 \times 1.01 \text{ amu H}}{294.34 \text{ amu}} \times 100\% = \boxed{6.18\% \text{ H}}$$

$$\% \text{ N} = \frac{2 \times 14.01 \text{ amu N}}{294.34 \text{ amu}} \times 100\% = \boxed{9.520\% \text{ N}}$$

$$\% \text{ O} = \frac{5 \times 16.00 \text{ amu O}}{294.34 \text{ amu}} \times 100\% = \boxed{27.18\% \text{ O}}$$

(b) FW $\text{SiC} = 40.097$ amu

$$\% \text{ Si} = \frac{1 \times 28.086 \text{ amu Si}}{40.097 \text{ amu}} \times 100\% = \boxed{70.05\% \text{ Si}}$$

$$\% \text{ C} = \frac{1 \times 12.011 \text{ amu C}}{40.097 \text{ amu}} \times 100\% = \boxed{29.95\% \text{ C}}$$

(c) FW $\text{C}_9\text{H}_8\text{O}_4 = 180.17$ amu

$$\% \text{ C} = \frac{9 \times 12.01 \text{ amu C}}{180.17 \text{ amu}} \times 100\% = \boxed{59.99\% \text{ C}}$$

$$\% \text{ H} = \frac{8 \times 1.01 \text{ amu H}}{180.17 \text{ amu}} \times 100\% = \boxed{4.48\% \text{ H}}$$

$$\% \text{ O} = \frac{4 \times 16.00 \text{ amu O}}{180.17 \text{ amu}} \times 100\% = \boxed{35.52\% \text{ O}}$$

- 2-63** (a) Hydrogen peroxide's actual formula is H_2O_2 ; however, its simplest formula or lowest whole number ratio is HO .
- (b) Water's actual formula is H_2O , while its simplest formula is also H_2O .
- (c) Ethylene glycol's actual formula is $\text{C}_2\text{H}_6\text{O}_2$; however, its simplest formula is CH_3O .

2-65

$$\text{?g C} = 2.92 \text{ g CO}_2 \times \frac{12.01 \text{ g C}}{44.010 \text{ g CO}_2} = 0.797 \text{ g C}$$

$$\text{?g H} = 1.22 \text{ g H}_2\text{O} \times \frac{2(1.008 \text{ g H})}{18.0152 \text{ g H}_2\text{O}} = 0.137 \text{ g H}$$

$$\text{?g O} = 1.20 \text{ g} - 0.797 \text{ g} - 0.137 \text{ g} = 0.27 \text{ g O}$$

Element	Mass of Element	Rel. No. of Atoms	Divide by Smallest
C	0.797	$\frac{0.797}{12.01} = 0.0664$	$\frac{0.0664}{0.0169} = 3.93 \approx 4$
H	0.137	$\frac{0.137}{1.008} = 0.136$	$\frac{0.136}{0.0169} = 8.05$
O	0.27	$\frac{0.27}{16.00} = 0.0169$	$\frac{0.0169}{0.0169} = 1.00$

The simplest formula is $\boxed{\text{C}_4\text{H}_8\text{O}}$

2-67

$$\text{?mol C} = 4.839 \text{ g CO}_2 \times \frac{12.011 \text{ g C}}{44.010 \text{ g CO}_2} = 1.321 \text{ g C}$$

$$\text{?g H} = 3.959 \text{ g H}_2\text{O} \times \frac{2(1.0079 \text{ g H})}{18.0152 \text{ g H}_2\text{O}} = 0.4430 \text{ g H}$$

$$\text{?g N} = 3.302 \text{ g} - (1.321 + 0.4430) = 1.538 \text{ g N}$$

Element	Mass of Element	Rel. No. of Atoms	Divide by Smallest
C	1.321	$\frac{1.321}{12.01} = 0.1100$	$\frac{0.1100}{0.1098} = 1.002 \approx 1$
H	0.4430	$\frac{0.4430}{1.008} = 0.4395$	$\frac{0.4395}{0.1098} = 4.003 \approx 4$
N	1.538	$\frac{1.538}{14.0067} = 0.1098$	$\frac{0.1098}{0.1098} = 1.00$

The simplest formula is $\boxed{\text{CH}_4\text{N}}$, which has a molar mass of 30.049 g/mol

The actual substance has a molar mass of 60.10 g/mol $\frac{60.10}{30.049} = 2$

The molecular formula is $\boxed{\text{C}_2\text{H}_8\text{N}_2}$,

$$\text{2-69} \quad \underline{?} \text{ g Mg} = 0.104 \text{ g MgO} \times \frac{24.3 \text{ g Mg}}{40.31 \text{ g MgO}} = 0.0627 \text{ g Mg}$$

$$\underline{?} \text{ g H} = 0.0231 \text{ g H}_2\text{O} \times \frac{2 \times 1.01 \text{ g H}}{18.02 \text{ g H}_2\text{O}} = 0.00259 \text{ g H}$$

$$\underline{?} \text{ g Si} = 0.155 \text{ g SiO}_2 \times \frac{28.1 \text{ g Si}}{60.1 \text{ g SiO}_2} = 0.0725 \text{ g Si}$$

$$\underline{?} \text{ g O} = 0.301 \text{ g total} - [0.0627 \text{ g Mg} + 0.00259 \text{ g H} + 0.0725 \text{ g Si}] = 0.163 \text{ g O}$$

Element	Mass of Element	Rel. No. of Atoms	Divide by Smallest
Mg	0.0627	$\frac{0.0627}{24.3} = 0.00258$	$\frac{0.00258}{0.00258} = 1.00$
H	0.00259	$\frac{0.00259}{1.01} = 0.00256$	$\frac{0.00256}{0.00258} = 1.00$
Si	0.0725	$\frac{0.0725}{28.1} = 0.00258$	$\frac{0.00258}{0.00258} = 1.00$
O	0.163	$\frac{0.163}{16.00} = 0.0102$	$\frac{0.0102}{0.00258} = 3.96 \approx 4$

The simplest formula is MgHSiO_4

2-71 Calculate the amount of O for a given amount of H in each compound:

$$\text{In H}_2\text{O:} \quad \frac{1 \times 16.00 \text{ amu O}}{2 \times 1.01 \text{ amu H}} = 7.92 \text{ amu O/amu H}$$

$$\text{In H}_2\text{O}_2: \quad \frac{2 \times 16.00 \text{ amu O}}{2 \times 1.01 \text{ amu H}} = 15.84 \text{ amu O/amu H}$$

The mass of O in these two compounds is in the ratio 7.92 : 15.84 or 1 : 2. The masses of O that combine with a fixed mass of H in the two compounds are in the ratio of small whole numbers, 1 : 2. Alternatively, the masses of H that combine with a fixed mass of O could be compared.

2-73 If the M_2O substance is 73.4% M by mass, then it is 26.6% Oxygen by mass.

$$\text{This means that if you had one mole of M}_2\text{O:} \quad 26.6 = \frac{15.9994 \text{ g O}}{x \text{ g M}_2\text{O}} \times 100$$

or that 60.148 would be the grams of M_2O in a mole.

$$60.148 - 15.9994 = 44.15 \text{ as the mass of the 2 M atoms; each M is } 22.07 \text{ g/mol}$$

$$\text{So for MO:} \quad \underline{?} \% \text{ M in MO} = \frac{22.07 \text{ g M}}{22.07 + 15.9994 \text{ g MO}} \times 100 = 58.0 \% \text{ M in MO}$$

2-75 Note: The mass (or weight) ratio in *any* units is the same as that deduced in amu or grams, e.g.,

$$\frac{63.55 \text{ amu Cu}}{183.54 \text{ amu CuFeS}_2} \quad \text{or} \quad \frac{63.55 \text{ lb Cu}}{183.54 \text{ lb CuFeS}_2}$$

$$\underline{\hspace{1cm}} \text{ lb Cu} = 6.63 \text{ lb CuFeS}_2 \times \frac{63.55 \text{ lb Cu}}{183.54 \text{ lb CuFeS}_2} = 2.2956 = \boxed{2.30 \text{ lb Cu}}$$

2-77 (a) FW $\text{CuSO}_4 = 159.62 \text{ amu}$

$$\underline{\hspace{1cm}} \text{ g Cu} = 253 \text{ g CuSO}_4 \times \frac{63.55 \text{ g Cu}}{159.62 \text{ g CuSO}_4} = \boxed{101 \text{ g Cu}}$$

(b) FW $\text{CuSO}_4 \cdot 5\text{H}_2\text{O} = 249.72$

$$\underline{\hspace{1cm}} \text{ g Cu} = 573 \text{ g CuSO}_4 \cdot 5\text{H}_2\text{O} \times \frac{63.55 \text{ g Cu}}{249.72 \text{ g CuSO}_4 \cdot 5\text{H}_2\text{O}} = \boxed{146 \text{ g Cu}}$$

$$\mathbf{2-79} \quad \underline{\hspace{1cm}} \text{ g Cu}_3(\text{CO}_3)_2(\text{OH})_2 = 685 \text{ g Cu} \times \frac{344.69 \text{ g Cu}_3(\text{CO}_3)_2(\text{OH})_2}{3 \times 63.55 \text{ g Cu}} = \boxed{1.24 \times 10^3 \text{ g Cu}_3(\text{CO}_3)_2(\text{OH})_2}$$

2-81 Formula weights: $\text{CaWO}_4 = 287.93$; $\text{FeWO}_4 = 303.70$

$$\underline{\hspace{1cm}} \text{ g CaWO}_4 = 657 \text{ g FeWO}_4 \times \frac{183.85 \text{ g W}}{303.70 \text{ g FeWO}_4} \times \frac{287.93 \text{ g CaWO}_4}{183.85 \text{ g W}} = \boxed{623 \text{ g CaWO}_4}$$

$$\mathbf{2-83} \quad \underline{\hspace{1cm}} \text{ g Pb} = 110.5 \text{ g ore} \times \frac{10.0 \text{ g PbS}}{100.0 \text{ g ore}} \times \frac{207.2 \text{ g Pb}}{239.26 \text{ g PbS}} = \boxed{9.569 \text{ g Pb/110.5 g ore}}$$

$$\mathbf{2-85} \quad \underline{\hspace{1cm}} \text{ g Sr(NO}_3)_2 = 267.7 \text{ g sample} \times \frac{88.2 \text{ g Sr(NO}_3)_2}{100.0 \text{ g sample}} = 236.1 \text{ g Sr(NO}_3)_2 \text{ present}$$

The formula weight of $\text{Sr(NO}_3)_2$ is 211.63 g/mol.

$$(a) \quad \underline{\hspace{1cm}} \text{ g Sr} = 236.1 \text{ g Sr(NO}_3)_2 \times \frac{87.62 \text{ g Sr}}{211.63 \text{ g Sr(NO}_3)_2} = \boxed{97.75 \text{ g Sr}}$$

$$(b) \quad \underline{\hspace{1cm}} \text{ g N} = 236.1 \text{ g Sr(NO}_3)_2 \times \frac{2 \times 14.0 \text{ g N}}{211.63 \text{ g Sr(NO}_3)_2} = \boxed{31.24 \text{ g N}}$$

$$\mathbf{2-87} \quad (a) \quad \underline{\hspace{1cm}} \text{ g CH}_3\text{COOH} = 143.7 \text{ g vinegar} \times \frac{5.0 \text{ g CH}_3\text{COOH}}{100 \text{ g vinegar}} = \boxed{7.2 \text{ g CH}_3\text{COOH}}$$

$$(b) \quad \underline{\hspace{1cm}} \text{ lb CH}_3\text{COOH} = 143.7 \text{ lb vinegar} \times \frac{5.0 \text{ lb CH}_3\text{COOH}}{100 \text{ lb vinegar}} = \boxed{7.2 \text{ lb acetic acid}}$$

$$(c) \quad \underline{\hspace{1cm}} \text{ g NaCl} = 34.0 \text{ g solution} \times \frac{5.0 \text{ g NaCl}}{100 \text{ g solution}} = \boxed{1.7 \text{ g NaCl}}$$

- 2-89** Assume you spend one dollar to purchase each substance. To get the lb of nitrogen per dollar:

$$\frac{? \text{ lb } (\text{NH}_4)_2\text{SO}_4}{\$} = \frac{20 \text{ lb } (\text{NH}_4)_2\text{SO}_4}{\$ 7.00} \times \frac{2 \times 14.01 \text{ lb N}}{132.15 \text{ lb } (\text{NH}_4)_2\text{SO}_4} = \boxed{0.6058 \text{ lb N per dollar for } (\text{NH}_4)_2\text{SO}_4}$$

$$\frac{? \text{ lb } \text{CH}_4\text{N}_2\text{O}}{\$} = \frac{6 \text{ lb } \text{CH}_4\text{N}_2\text{O}}{\$ 21.00} \times \frac{2 \times 14.01 \text{ lb N}}{60.06 \text{ lb } \text{CH}_4\text{N}_2\text{O}} = \boxed{0.133 \text{ lb N per dollar for } \text{CH}_4\text{N}_2\text{O}}$$

$(\text{NH}_4)_2\text{SO}_4$ has more N for the dollar.

- 2-91** The chemical formula for calcium carbonate is CaCO_3 , and its molar mass is 100.09 g/mol. The mass of CaCO_3 needed to supply 1200 mg of Ca per day =

$$? \text{ g } \text{CaCO}_3/\text{day} = \frac{1200 \text{ mg Ca}}{1 \text{ day}} \times \frac{1 \text{ g Ca}}{1000 \text{ mg Ca}} \times \frac{100.09 \text{ g } \text{CaCO}_3}{40.08 \text{ g Ca}} = 3.0 \text{ g } \text{CaCO}_3/\text{day}$$

- 2-93** Let x = atomic weight of metal M.

$$(a) \quad \% \text{ M} = \frac{\text{mass M}}{\text{mass M} + \text{mass O}} \times 100\% = \frac{2x}{2x + (3 \times \text{AW O})} \times 100\%$$

$$52.9\% = \frac{2x}{2x + (3 \times 16.00)} \times 100$$

$$\frac{52.9}{100} = \frac{2x}{2x + 48} ; \quad 1.058x + 25.39 = 2x ; \quad 0.942x = 25.39$$

$$x = \boxed{27.0 \text{ amu}}$$

(b) The metal is probably aluminum (atomic weight 26.98) .

- 2-95** $\text{MW} = 6.5 \times 10^4 \text{ g/mol}$ or $6.5 \times 10^4 \text{ amu/molecule}$

$$\frac{? \text{ Fe atoms}}{\text{molecule}} = \frac{6.5 \times 10^4 \text{ amu hemoglobin}}{1 \text{ molecule}} \times \frac{0.35 \text{ amu Fe}}{100 \text{ amu hemoglobin}} \times \frac{1 \text{ Fe atom}}{55.85 \text{ amu Fe}} = 4.1$$

There are 4 iron atoms per hemoglobin molecule .

- 2-97** $\text{FW } \text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2 = 1004.64 \text{ amu}$

$$(a) \quad \% \text{ Ca} = \frac{10 \times 40.08 \text{ amu Ca}}{1004.64 \text{ amu}} \times 100\% = \boxed{39.89\% \text{ Ca}}$$

$$(b) \quad \% \text{ P} = \frac{6 \times 30.97 \text{ amu P}}{1004.64 \text{ amu}} \times 100\% = \boxed{18.50\% \text{ P}}$$

- 2-99** For the cations given, the group number is the same as the charge. Rubidium would likely form a 1+ ion since it is in group 1. The formula for the cation formed from the barium atom would be: Ba^{2+} . The formula for the anion formed from the nitrogen atom would be: N^{3-} .

- 2-101** The new and old values for Avogadro's number are the same up to 7 significant digits; both are equal to 6.022141×10^{23} , but differ in the next digit. The uncertainty only has 2 significant digits ($1.5 \times$

10^{17}). If the uncertainty were subtracted from 6.0221415×10^{23} , the result would be 6.0221414×10^{23} , so with the uncertainty, the two numbers are the same to 7 significant digits (6.0221415×10^{23} and 602,214,141,070,409,084,099,072).

2-103 All have the same empirical formula, CH_2O , which has a formula weight (FW) of 30.0 amu.

	Molecular Formula	Molecular Weight (amu)	Ratio With Empirical FW
Acetic Acid	$\text{C}_2\text{H}_4\text{O}_2$	60.0 amu	2
Erythrulose	$\text{C}_4\text{H}_8\text{O}_4$	120.0 amu	4
Formaldehyde	CH_2O	30.0 amu	1
Lactic Acid	$\text{C}_3\text{H}_6\text{O}_3$	90.0 amu	3
Ribose	$\text{C}_5\text{H}_{10}\text{O}_5$	150.0 amu	5

2-105 There is insufficient information since the oxygen used in combustion comes from the air in addition to the oxygen in the sample.

$$\text{2-107} \quad \% \text{ Ag in Ag}_2\text{O} = \frac{2 \times 107.87 \text{ g Ag}}{231.74 \text{ g Ag}_2\text{O}} \times 100\% = 93.10\% \text{ Ag}$$

$$\% \text{ Ag in Ag}_2\text{S} = \frac{2 \times 107.87 \text{ g Ag}}{247.8 \text{ g Ag}_2\text{S}} \times 100\% = 87.06\% \text{ Ag}$$

Recommend that, if the ores are the same price and if they contain the same mass percent of the silver compounds, the silver oxide be used. However, in an actual situation, the price and concentration of the desired compound would probably be the determining factors. Pure Ag_2O and Ag_2S both contain a very high percentage of silver.

$$\text{2-109} \quad 1 \text{ picomole} \times \frac{1 \times 10^{-12} \text{ mole}}{1 \text{ picomole}} \times \frac{6.022 \times 10^{23} \text{ pennies}}{1 \text{ mole}} \times \frac{1/16 \text{ in}}{\text{penny}} \times \frac{1 \text{ ft}}{12 \text{ in}} \times \frac{1 \text{ mile}}{5280 \text{ ft}}$$

$$= 5.9 \times 10^5 \text{ miles which is greater than 222,000 miles}$$

Yes , it will reach the moon .

$$\text{2-111} \quad \text{? MW or g/mol of B}_{12} = \frac{100 \text{ g B}_{12}}{4.35 \text{ g Co}} \times \frac{58.93 \text{ g Co}}{1 \text{ mol Co}} \times \frac{1 \text{ mol Co}}{1 \text{ mol B}_{12}} = \boxed{1.35 \times 10^3 \text{ g/mol B}_{12}}$$

2-113 % O = 100 % total – 92.83% Pb = 7.17% O

Element	Rel. Mass Element	Rel. No. of Atoms	Divide by Smallest
Pb	92.83	$\frac{92.83}{207.2} = 0.4480$	$\frac{0.4480}{0.448} = 1.00$
O	7.17	$\frac{7.17}{16.00} = 0.448$	$\frac{0.448}{0.448} = 1.00$
Total 100.00			

The simplest formula is PbO

2-115 0.050 mL H₂O = 0.050 cm³ H₂O, since 1 mL = 1cm³

$$\begin{aligned} \text{? molecules of H}_2\text{O} &= 0.050 \text{ cm}^3 \text{ H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.02 \text{ g H}_2\text{O}} \times \frac{6.022 \times 10^{23} \text{ molecules H}_2\text{O}}{1 \text{ mol H}_2\text{O}} \\ &= \boxed{1.7 \times 10^{21} \text{ molecules H}_2\text{O}} \end{aligned}$$