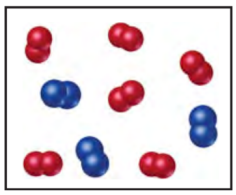
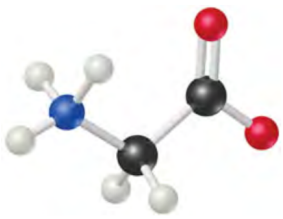
# Chemical Reactions and Stoichiometry Problem Set

**3.3** The following diagram represents the collection of elements formed by a decomposition reaction. **(a)** If the blue spheres represent N atoms and the red ones represent O atoms, what was the empirical formula of the original compound? **(b)** Could you draw a diagram representing the molecules of the compound that had been decomposed? Why or why not? [Section 3.2]

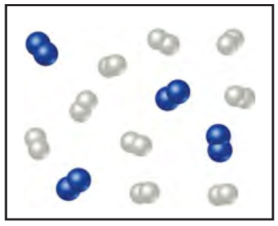


**3.5** Glycine, an amino acid used by organisms to make proteins, is represented by the following molecular model.

**(a)** Write its molecular formula.
**(b)** Determine its molar mass.
**(c)** Calculate the mass of 3 moles of glycine.
**(d)** Calculate the percent nitrogen by mass in glycine. [Sections 3.3 and 3.5]



**3.7** Nitrogen ($N_2$) and hydrogen ($H_2$) react to form ammonia ($NH_3$). Consider the mixture of $N_2$ and $H_2$ shown in the accompanying diagram. The blue spheres represent N, and the white ones represent H. Draw a representation of the product mixture, assuming that the reaction goes to completion. How did you arrive at your representation? What is the limiting reactant in this case? [Section 3.7]



**3.9** **(a)** What scientific principle or law is used in the process of balancing chemical equations? **(b)** In balancing equations, why should you not change subscripts in chemical formulas? **(c)** How would you write out liquid water, water vapor, aqueous sodium chloride, and solid sodium chloride in chemical equations?

**3.17** Write a balanced chemical equation for the reaction that occurs when **(a)** $Mg(s)$ reacts with $Cl_2(g)$; **(b)** barium carbonate decomposes into barium oxide and carbon dioxide gas when heated; **(c)** the hydrocarbon styrene, $C_8H_8(l)$, is combusted in air; **(d)** dimethylether, $CH_3OCH_3(g)$, is combusted in air.

**3.19** Balance the following equations and indicate whether they are combination, decomposition, or combustion reactions:

**(a)** $C_3H_6(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$
**(b)** $NH_4NO_3(s) \longrightarrow N_2O(g) + H_2O(g)$
**(c)** $C_5H_6O(l) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$
**(d)** $N_2(g) + H_2(g) \longrightarrow NH_3(g)$
**(e)** $K_2O(s) + H_2O(l) \longrightarrow KOH(aq)$

**3.22** Determine the formula weights of each of the following compounds: **(a)** nitrous oxide, $N_2O$, known as laughing gas and used as an anesthetic in dentistry; **(b)** benzoic acid, $HC_7H_5O_2$, a substance used as a food preservative; **(c)** $Mg(OH)_2$, the active ingredient in milk of magnesia; **(d)** urea, $(NH_2)_2CO$, a compound used as a nitrogen fertilizer; **(e)** isopentyl acetate, $CH_3CO_2C_5H_{11}$, responsible for the odor of bananas.

**3.24** Calculate the percentage by mass of the indicated element in the following compounds: **(a)** carbon in acetylene, $C_2H_2$, a gas used in welding; **(b)** hydrogen in ascorbic acid, $HC_6H_7O_6$, also known as vitamin C; **(c)** hydrogen in ammonium sulfate, $(NH_4)_2SO_4$, a substance used as a nitrogen fertilizer; **(d)** platinum in $PtCl_2(NH_3)_2$, a chemotherapy agent called cisplatin; **(e)** oxygen in the female sex hormone estradiol, $C_{18}H_{24}O_2$; **(f)** carbon in capsaicin, $C_{18}H_{27}NO_3$, the compound that gives the hot taste to chili peppers.

**3.27** **(a)** What is Avogadro's number, and how is it related to the mole? **(b)** What is the relationship between the formula weight of a substance and its molar mass?

**3.36** **(a)** What is the mass, in grams, of 1.223 mol of iron(III) sulfate?
**(b)** How many moles of ammonium ions are in 6.955 g of ammonium carbonate?
**(c)** What is the mass, in grams, of $1.50 \times 10^{21}$ molecules of aspirin, $C_9H_8O_4$?
**(d)** What is the molar mass of diazepam (Valium®) if 0.05570 mol has a mass of 15.86 g?

**3.40** A sample of the male sex hormone testosterone, $C_{19}H_{28}O_2$, contains $3.88 \times 10^{21}$ hydrogen atoms. **(a)** How many atoms of carbon does it contain? **(b)** How many molecules of testosterone does it contain? **(c)** How many moles of testosterone does it contain? **(d)** What is the mass of this sample in grams?

**3.41** The allowable concentration level of vinyl chloride, $C_2H_3Cl$, in the atmosphere in a chemical plant is $2.0 \times 10^{-6}$ g/L. How many moles of vinyl chloride in each liter does this represent? How many molecules per liter?

**3.43** Give the empirical formula of each of the following compounds if a sample contains **(a)** 0.0130 mol C, 0.0390 mol H, and 0.0065 mol O; **(b)** 11.66 g iron and 5.01 g oxygen; **(c)** 40.0% C, 6.7% H, and 53.3% O by mass.

**3.45** Determine the empirical formulas of the compounds with the following compositions by mass:
**(a)** 10.4% C, 27.8% S, and 61.7% Cl
**(b)** 21.7% C, 9.6% O, and 68.7% F
**(c)** 32.79% Na, 13.02% Al, and the remainder F

**3.48** The compound $XCl_4$ contains 75.0% Cl by mass. What is the element X?

**3.49** What is the molecular formula of each of the following compounds?
**(a)** empirical formula $CH_2$, molar mass = 84 g/mol
**(b)** empirical formula $NH_2Cl$, molar mass = 51.5 g/mol

**3.53** **(a)** Combustion analysis of toluene, a common organic solvent, gives 5.86 mg of $CO_2$ and 1.37 mg of $H_2O$. If the compound contains only carbon and hydrogen, what is its empirical formula? **(b)** Menthol, the substance we can smell in mentholated cough drops, is composed of C, H, and O. A 0.1005-g sample of menthol is combusted, producing 0.2829 g of $CO_2$ and 0.1159 g of $H_2O$. What is the empirical formula for menthol? If menthol has a molar mass of 156 g/mol, what is its molecular formula?

**3.58** Epsom salts, a strong laxative used in veterinary medicine, is a hydrate, which means that a certain number of water molecules are included in the solid structure. The formula for Epsom salts can be written as $MgSO_4 \cdot xH_2O$, where $x$ indicates the number of moles of $H_2O$ per mole of $MgSO_4$. When 5.061 g of this hydrate is heated to 250 °C, all the water of hydration is lost, leaving 2.472 g of $MgSO_4$. What is the value of $x$?

**3.65** Aluminum sulfide reacts with water to form aluminum hydroxide and hydrogen sulfide. **(a)** Write the balanced chemical equation for this reaction. **(b)** How many grams of aluminum hydroxide are obtained from 14.2 g of aluminum sulfide?

**3.68** The complete combustion of octane, $C_8H_{18}$, the main component of gasoline, proceeds as follows:

$$2\,C_8H_{18}(l) + 25\,O_2(g) \longrightarrow 16\,CO_2(g) + 18\,H_2O(g)$$

**(a)** How many moles of $O_2$ are needed to burn 1.50 mol of $C_8H_{18}$?
**(b)** How many grams of $O_2$ are needed to burn 10.0 g of $C_8H_{18}$?
**(c)** Octane has a density of 0.692 g/mL at 20 °C. How many grams of $O_2$ are required to burn 15.0 gal of $C_8H_{18}$ (the capacity of an average fuel tank)?

**3.80** Solutions of sulfuric acid and lead(II) acetate react to form solid lead(II) sulfate and a solution of acetic acid. If 5.00 g of sulfuric acid and 5.00 g of lead(II) acetate are mixed, calculate the number of grams of sulfuric acid, lead(II) acetate, lead(II) sulfate, and acetic acid present in the mixture after the reaction is complete.

**(d)** How many grams of $CO_2$ are produced when 15.0 gal of $C_8H_{18}$ are combusted?

**3.81** When benzene ($C_6H_6$) reacts with bromine ($Br_2$), bromobenzene ($C_6H_5Br$) is obtained:

$$C_6H_6 + Br_2 \longrightarrow C_6H_5Br + HBr$$

**(a)** When 30.0 g of benzene reacts with 65.0 g of bromine, what is the theoretical yield of bromobenzene? **(b)** If the actual yield of bromobenzene is 42.3 g, what is the percentage yield?