A.P. Chemistry Summer assignment 2020

https://misterchemistry.com

Welcome to AP chemistry! I look forward to meeting you in the fall. A little bit about this course: AP chemistry is equivalent to a beginning college chemistry class. The class culminates in early May with an AP chemistry exam. My mission is to have you ready to take that exam. In order to be ready to take the exam, there's a lot of material to cover in a short amount of time. In an effort to hit the ground running I'm assigning the first three chapters (1,2 and 3) over the summer. My AP chemistry course is centered around my web site, **misterchemistry.com.** At the website you'll find a pdf version of the book (*Chemistry The Central Science*), the lecture slides, lecture videos using the slides, and problem videos answers to the assigned chapter problems.

Here's how we're going to cover book chapters in this class:

- actively watch the lecture videos or read actively read the chapter

- practice doing the assigned chapter problems — *do the circled problems in the packet, and you'll find the answers to the questions on the website under* ***Problem Videos***

Actively watching the lecture videos or reading the chapter involves:

- getting yourself a spiral notebook 100 pages or bigger to use exclusively for AP chemistry
- writing out the definitions of the key terms
- writing out and attempting the practice problems found in the body of the chapter
- making sketches of any meaningful diagrams

Points will be given in September for demonstrating actively watching the lecture video series 1-8 or actively reading chapters 1-3 *(you can and should do both).*

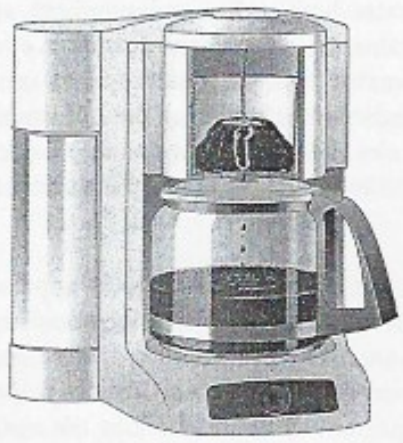
A short five or six question quiz involving questions from the chapter problems will be given to check for understanding.

The pattern of actively reading or watching and attempting problems before we cover the material in class will be repeated though out the year. This is so that class time can be more dedicated to discussing the topic,working through problems and doing laboratory activities, rather than listening to me lecture. We’re going to have fun, work hard and learn a lot next year. Have a good summer.

Sincerely,

Mr. Coulter

1.3 Describe the separation method(s) involved in brewing a cup of coffee. [Section 1.3]



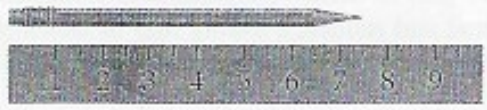
1.4 Identify each of the following as measurements of length, area, volume, mass, density, time, or temperature: (a) 25 ps, (b) 374.2 mg, (c) 77 K, (d) 100,000 km^2, (e) 1.06 μm, (f) 16 nm^2, (g) −78 °C, (h) 2.56 g/cm^3, (i) 28 cm^3. [Section 1.4]

1.5 (a) Three spheres of equal size are composed of aluminum (density = 2.70 g/cm^3), silver (density = 10.49 g/cm^3), and nickel (density = 8.90 g/cm^3). List the spheres from lightest to heaviest. (b) Three cubes of equal mass are composed of gold (density = 19.32 g/cm^3), platinum (density = 21.45 g/cm^3), and lead (density = 11.35 g/cm^3). List the cubes from smallest to largest. [Section 1.4]

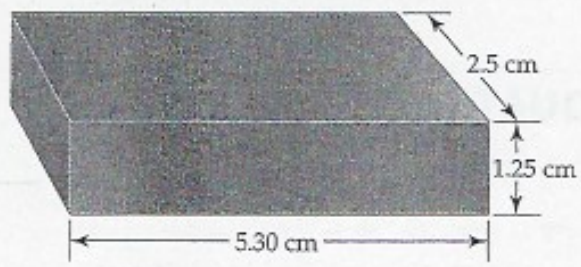
1.6 The following dartboards illustrate the types of errors often seen when one measurement is repeated several times. The bull's-eye represents the "true value," and the darts represent the experimental measurements. Which board best represents each of the following scenarios: (a) measurements both accurate and precise, (b) measurements precise but inaccurate, (c) measurements imprecise but yielding an accurate average? [Section 1.5]

(i) (ii) (iii)

1.7 (a) What is the length of the pencil in the following figure if the ruler reads in centimeters? How many significant figures are there in this measurement? (b) An automobile speedometer with circular scales reading both miles per hour and kilometers per hour is shown. What speed is indicated, in both units? How many significant figures are in the measurements? [Section 1.5]



1.8 (a) How many significant figures should be reported for the volume of the metal bar shown here? (b) If the mass of the bar is 104.72 g, how many significant figures should be reported when its density is determined using the calculated volume? [Section 1.5]



1.9 When you convert units, how do you decide which part of the conversion factor is in the numerator and which is in the denominator? [Section 1.6]

1.10 Show the steps to convert the speed of sound, 344 meters per second, into miles per hour. [Section 1.6]

CLASSIFICATION AND PROPERTIES OF MATTER (sections 1.2 and 1.3)

1.11 Classify each of the following as a pure substance or a mixture. If a mixture, indicate whether it is homogeneous or heterogeneous: (a) rice pudding, (b) seawater, (c) magnesium, (d) crushed ice.

1.12 Classify each of the following as a pure substance or a mixture. If a mixture, indicate whether it is homogeneous or heterogeneous: (a) air, (b) tomato juice, (c) iodine crystals, (d) sand.

1.13 Give the chemical symbol or name for the following elements, as appropriate: (a) sulfur, (b) gold, (c) potassium, (d) chlorine, (e) copper, (f) U, (g) Ni, (h) Na, (i) Al, (j) Si.

1.14 Give the chemical symbol or name for each of the following elements, as appropriate: (a) carbon, (b) nitrogen, (c) titanium, (d) zinc, (e) iron, (f) P, (g) Ca, (h) He, (i) Pb, (j) Ag.

1.15 A solid white substance A is heated strongly in the absence of air. It decomposes to form a new white substance B and a gas C. The gas has exactly the same properties as the product obtained when carbon is burned in an excess of oxygen. Based on these observations, can we determine whether solids A and B and gas C are elements or compounds? Explain your conclusions for each substance.

1.16 You are hiking in the mountains and find a shiny gold nugget. It might be the element gold, or it might be "fool's gold," which is a nickname for iron pyrite, FeS_2. What kinds of experiments could be done to determine if the shiny nugget is really gold?

1.17 In the process of attempting to characterize a substance, a chemist makes the following observations: The substance is a silvery white, lustrous metal. It melts at 649 °C and boils at 1105 °C. Its density at 20 °C is 1.738 g/cm^3. The substance burns in air, producing an intense white light. It reacts with chlorine to give a brittle white solid. The substance can be pounded into thin sheets or drawn into wires. It is a good conductor of electricity. Which of these characteristics are physical properties, and which are chemical properties?

1.18 Read the following description of the element zinc and indicate which are physical properties and which are chemical properties. Zinc is a silver-gray–colored metal that melts at 420 °C. When zinc granules are added to dilute sulfuric acid, hydrogen is given off and the metal dissolves. Zinc has a hardness on the Mohs scale of 2.5 and a density of 7.13 g/cm^3 at 25 °C. It reacts slowly with oxygen gas at elevated temperatures to form zinc oxide, ZnO.

1.19 Label each of the following as either a physical process or a chemical process: (a) rusting of a metal can, (b) boiling a cup of water, (c) pulverizing an aspirin, (d) digesting a candy bar, (e) exploding of nitroglycerin.

1.20 A match is lit and held under a cold piece of metal. The following observations are made: (a) The match burns. (b) The metal gets warmer. (c) Water condenses on the metal. (d) Soot (carbon) is deposited on the metal. Which of these occurrences are due to physical changes, and which are due to chemical changes?

1.21 Suggest a method of separating each of the following mixtures into two components: (a) sugar and sand, (b) oil and vinegar.

1.22 Three beakers contain clear, colorless liquids. One beaker contains pure water, another contains salt water, and another contains sugar water. How can you tell which beaker is which? (No tasting allowed!)

UNITS AND MEASUREMENT (section 1.4)

1.23 What exponential notation do the following abbreviations represent: (a) d, (b) c, (c) f, (d) μ, (e) M, (f) k, (g) n, (h) m, (i) p?

1.24 Use appropriate metric prefixes to write the following measurements without use of exponents: (a) 2.3×10^{-10} L, (b) 4.7×10^{-6} g, (c) 1.85×10^{-12} m, (d) 16.7×10^{6} s; (e) 15.7×10^{3} g, (f) 1.34×10^{-3} m, (g) 1.84×10^{2} cm.

1.25 Make the following conversions: (a) 72 °F to °C, (b) 216.7 °C to °F, (c) 233 °C to K, (d) 315 K to °F, (e) 2500 °F to K, (f) 0 K to °F.

1.26 (a) The temperature on a warm summer day is 87 °F. What is the temperature in °C? (b) Many scientific data are reported at 25 °C. What is this temperature in kelvins and in degrees Fahrenheit? (c) Suppose that a recipe calls for an oven temperature of 400 °F. Convert this temperature to degrees Celsius and to kelvins. (d) Liquid nitrogen boils at 77 K. Convert this temperature to degrees Fahrenheit and to degrees Celsius.

1.27 (a) A sample of tetrachloroethylene, a liquid used in dry cleaning that is being phased out because of its potential to cause cancer, has a mass of 40.55 g and a volume of 25.0 mL at 25 °C. What is its density at this temperature? Will tetrachloroethylene float on water? (Materials that are less dense than water will float.) (b) Carbon dioxide (CO_2) is a gas at room temperature and pressure. However, carbon dioxide can be put under pressure to become a "supercritical fluid" that is a much safer dry-cleaning agent than tetrachloroethylene. At a certain pressure, the density of supercritical CO_2 is 0.469 g/cm^3. What is the mass of a 25.0-mL sample of supercritical CO_2 at this pressure?

1.28 (a) A cube of osmium metal 1.500 cm on a side has a mass of 76.31 g at 25 °C. What is its density in g/cm^3 at this temperature? (b) The density of titanium metal is 4.51 g/cm^3 at 25 °C. What mass of titanium displaces 125.0 mL of water at 25 °C? (c) The density of benzene at 15 °C is 0.8787 g/mL. Calculate the mass of 0.1500 L of benzene at this temperature.

1.29 (a) To identify a liquid substance, a student determined its density. Using a graduated cylinder, she measured out a 45-mL sample of the substance. She then measured the mass of the sample, finding that it weighed 38.5 g. She knew that the substance had to be either isopropyl alcohol (density 0.785 g/mL) or toluene (density 0.866/mL). What are the calculated density and the probable identity of the substance? (b) An experiment requires 45.0 g of ethylene glycol, a liquid whose density is 1.114 g/mL. Rather than weigh the sample on a balance, a chemist chooses to dispense the liquid using a graduated cylinder. What volume of the liquid should he use? (c) A cubic piece of metal measures 5.00 cm on each edge. If the metal is nickel, whose density is 8.90 g/cm^3, what is the mass of the cube?

1.30 (a) After the label fell off a bottle containing a clear liquid believed to be benzene, a chemist measured the density of the liquid to verify its identity. A 25.0-mL portion of the liquid had a mass of 21.95 g. A chemistry handbook lists the density of benzene at 15 °C as 0.8787 g/mL. Is the calculated density in agreement with the tabulated value? (b) An experiment requires 15.0 g of cyclohexane, whose density at 25 °C is 0.7781 g/mL. What volume of cyclohexane should be used? (c) A spherical ball of lead has a diameter of 5.0 cm. What is the mass of the sphere if lead has a density of 11.34 g/cm^3? (The volume of a sphere is $(4/3)\pi r^3$ where r is the radius.)

1.31 In the year 2007, an estimated amount of 31 billion tons of carbon dioxide (CO_2) was emitted worldwide due to fossil fuel combustion and cement production. Express this mass of CO_2 in grams without exponential notation, using an appropriate metric prefix.

1.32 Silicon for computer chips is grown in large cylinders called "boules" that are 300 mm in diameter and 2 m in height. The density of silicon is 2.33 g/cm^3. Silicon wafers for making integrated circuits are sliced from a 2.0 m boule and are typically 0.75 mm thick and 300 mm in diameter. (a) How many wafers can be cut from a single boule? (b) What is the mass of a silicon wafer? (The volume of a cylinder is given by $\pi r^2 h$, where r is the radius and h is its height.)

UNCERTAINTY IN MEASUREMENT (section 1.5)

1.33 Indicate which of the following are exact numbers: (a) the mass of a piece of paper, (b) the volume of a cup of coffee, (c) the number of inches in a mile, (d) the number of ounces in a pound, (e) the number of microseconds in a week, (f) the number of pages in this book.

1.34 Indicate which of the following are exact numbers: (a) the mass of a 32-oz can of coffee, (b) the number of students in your chemistry class, (c) the temperature of the surface of the sun, (d) the mass of a postage stamp, (e) the number of milliliters in a cubic meter of water, (f) the average height of students in your school.

1.35 What is the number of significant figures in each of the following measured quantities? (a) 601 kg, (b) 0.054 s, (c) 6.3050 cm, (d) 0.0105 L, (e) 7.0500×10^{-3} m^3, (f) 400 g.

1.36 Indicate the number of significant figures in each of the following measured quantities: (a) 3.774 km, (b) 205 m^2, (c) 1.700 cm, (d) 350.00 K, (e) 307.080 g, (f) 1.3×10^3 m/s.

1.37 Round each of the following numbers to four significant figures, and express the result in standard exponential notation: (a) 102.53070, (b) 656,980, (c) 0.008543210, (d) 0.000257870, (e) −0.0357202.

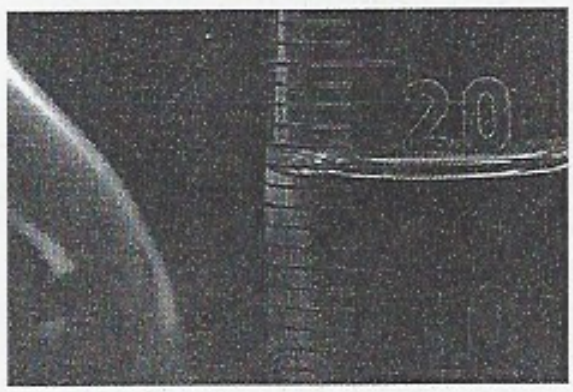
1.38 (a) The diameter of Earth at the equator is 7926.381 mi. Round this number to three significant figures, and express it in standard exponential notation. (b) The circumference of Earth through the poles is 40,008 km. Round this number to four significant figures, and express it in standard exponential notation.

1.39 Carry out the following operations, and express the answers with the appropriate number of significant figures.
(a) 14.3505 + 2.65
(b) 952.7 – 140.7389
(c) $(3.29 \times 10^4)(0.2501)$
(d) 0.0588/0.677

1.40 Carry out the following operations, and express the answer with the appropriate number of significant figures.
(a) 320.5 − (6104.5/2.3)
(b) $[(285.3 \times 10^5) - (1.200 \times 10^3)] \times 2.8954$
(c) $(0.0045 \times 20{,}000.0) + (2813 \times 12)$
(d) $863 \times [1255 - (3.45 \times 108)]$

1.41 You weigh an object on a balance and read the mass in grams according to the picture. How many significant figures are in this measurement?

1.42 You have a graduated cylinder that contains a liquid (see photograph). Write the volume of the liquid, in milliliters, using the proper number of significant figures.



DIMENSIONAL ANALYSIS (section 1.6)

1.43 Using your knowledge of metric units, English units, and the information on the back inside cover, write down the conversion factors needed to convert (a) mm to nm, (b) mg to kg, (c) km to ft, (d) $in.^3$ to cm^3.

1.44 Using your knowledge of metric units, English units, and the information on the back inside cover, write down the conversion factors needed to convert (a) μm to mm, (b) ms to ns, (c) mi to km, (d) ft^3 to L.

1.45 (a) A bumblebee flies with a ground speed of 15.2 m/s. Calculate its speed in km/h. (b) The lung capacity of the blue whale is 5.0×10^3 L. Convert this volume into gallons. (c) The Statue of Liberty is 151 ft tall. Calculate its height in meters. (d) Bamboo can grow up to 60.0 cm/day. Convert this growth rate into inches per hour.

1.46 (a) The speed of light in a vacuum is 2.998×10^8 m/s. Calculate its speed in miles per hour. (b) The Sears Tower in Chicago is 1454 ft tall. Calculate its height in meters. (c) The Vehicle Assembly Building at the Kennedy Space Center in Florida has a volume of 3,666,500 m^3. Convert this volume to liters and express the result in standard exponential notation. (d) An individual suffering from a high cholesterol level in her blood has 242 mg of cholesterol per 100 mL of blood. If the total blood volume of the individual is 5.2 L, how many grams of total blood cholesterol does the individual's body contain?

1.47 Perform the following conversions: (a) 5.00 days to s, (b) 0.0550 mi to m, (c) \$1.89/gal to dollars per liter, (d) 0.510 in./ms to km/hr, (e) 22.50 gal/min to L/s, (f) 0.02500 ft^3 to cm^3.

1.48 Carry out the following conversions: (a) 0.105 in. to mm, (b) 0.650 qt to mL, (c) 8.75 μm/s to km/hr, (d) 1.955 m^3 to yd^3, (e) \$3.99/lb to dollars per kg, (f) 8.75 lb/ft^3 to g/mL.

1.49 (a) How many liters of wine can be held in a wine barrel whose capacity is 31 gal? (b) The recommended adult dose of Elixophyllin®, a drug used to treat asthma, is 6 mg/kg of body mass. Calculate the dose in milligrams for a 185-lb person. (c) If an automobile is able to travel 400 km on 47.3 L of gasoline, what is the gas mileage in miles per gallon? (d) A pound of coffee beans yields 50 cups of coffee (4 cups = 1 qt). How many milliliters of coffee can be obtained from 1 g of coffee beans?

1.50 (a) If an electric car is capable of going 225 km on a single charge, how many charges will it need to travel from Seattle, Washington, to San Diego, California, a distance of 1257 mi, assuming that the trip begins with a full charge? (b) If a migrating loon flies at an average speed of 14 m/s, what is its average speed in mi/hr? (c) What is the engine piston displacement in liters of an engine whose displacement is listed as 450 $in.^3$? (d) In March 1989 the *Exxon Valdez* ran aground and spilled 240,000 barrels of crude petroleum off the coast of Alaska. One barrel of petroleum is equal to 42 gal. How many liters of petroleum were spilled?

SECTION 2.3 Atoms have a nucleus that contains **protons** and **neutrons; electrons** move in the space around the nucleus. The magnitude of the charge of the electron, 1.602×10^{-19} C, is called the **electronic charge**. The charges of particles are usually represented as multiples of this charge—an electron has a 1− charge, and a proton has a 1+ charge. The masses of atoms are usually expressed in terms of **atomic mass units** (1 amu = 1.66054×10^{-24} g). The dimensions of atoms are often expressed in units of **angstroms** (1 Å = 10^{-10} m).

Elements can be classified by **atomic number**, the number of protons in the nucleus of an atom. All atoms of a given element have the same atomic number. The **mass number** of an atom is the sum of the numbers of protons and neutrons. Atoms of the same element that differ in mass number are known as **isotopes**.

SECTION 2.4 The atomic mass scale is defined by assigning a mass of exactly 12 amu to a ^{12}C atom. The **atomic weight** (average atomic mass) of an element can be calculated from the relative abundances and masses of that element's isotopes. The **mass spectrometer** provides the most direct and accurate means of experimentally measuring atomic (and molecular) weights.

SECTION 2.5 The **periodic table** is an arrangement of the elements in order of increasing atomic number. Elements with similar properties are placed in vertical columns. The elements in a column are known as a **group**. The elements in a horizontal row are known as a **period**. The **metallic elements** (**metals**), which comprise the majority of the elements, dominate the left side and the middle of the table; the **nonmetallic elements** (**nonmetals**) are located on the upper right side. Many of the elements that lie along the line that separates metals from nonmetals are **metalloids**.

SECTION 2.6 Atoms can combine to form **molecules**. Compounds composed of molecules (**molecular compounds**) usually contain only nonmetallic elements. A molecule that contains two atoms is called a **diatomic molecule**. The composition of a substance is given by its **chemical formula**. A molecular substance can be represented by its **empirical formula**, which gives the relative numbers of atoms of each kind. It is usually represented by its **molecular formula**, however, which gives the actual numbers of each type of atom in a molecule. **Structural formulas** show the order in which the atoms in a molecule are connected. Ball-and-stick models and space-filling models are often used to represent molecules.

SECTION 2.7 Atoms can either gain or lose electrons, forming charged particles called **ions**. Metals tend to lose electrons, becoming positively charged ions (**cations**). Nonmetals tend to gain electrons, forming negatively charged ions (**anions**). Because **ionic compounds** are electrically neutral, containing both cations and anions, they usually contain both metallic and nonmetallic elements. Atoms that are joined together, as in a molecule, but carry a net charge are called **polyatomic ions**. The chemical formulas used for ionic compounds are empirical formulas, which can be written readily if the charges of the ions are known. The total positive charge of the cations in an ionic compound equals the total negative charge of the anions.

SECTION 2.8 The set of rules for naming chemical compounds is called **chemical nomenclature**. We studied the systematic rules used for naming three classes of inorganic substances: ionic compounds, acids, and binary molecular compounds. In naming an ionic compound, the cation is named first and then the anion. Cations formed from metal atoms have the same name as the metal. If the metal can form cations of differing charges, the charge is given using Roman numerals. Monatomic anions have names ending in *-ide*. Polyatomic anions containing oxygen and another element (**oxyanions**) have names ending in *-ate* or *-ite*.

SECTION 2.9 **Organic chemistry** is the study of compounds that contain carbon. The simplest class of organic molecules is the **hydrocarbons**, which contain only carbon and hydrogen. Hydrocarbons in which each carbon atom is attached to four other atoms are called **alkanes**. Alkanes have names that end in *-ane*, such as methane and ethane. Other organic compounds are formed when an H atom of a hydrocarbon is replaced with a functional group. An **alcohol**, for example, is a compound in which an H atom of a hydrocarbon is replaced by an OH functional group. Alcohols have names that end in *-ol*, such as methanol and ethanol. Compounds with the same molecular formula but a different bonding arrangement of their constituent atoms are called **isomers**.

KEY SKILLS

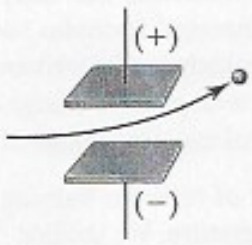
- Describe the basic postulates of Dalton's atomic theory. (Section 2.1)
- Describe the key experiments that led to the discovery of electrons and to the nuclear model of the atom. (Section 2.2)
- Describe the structure of the atom in terms of protons, neutrons, and electrons. (Section 2.3)
- Describe the electrical charge and relative masses of protons, neutrons, and electrons. (Section 2.3)
- Use chemical symbols together with atomic number and mass number to express the subatomic composition of isotopes. (Section 2.3)
- Understand how atomic weights relate to the masses of individual atoms and to their natural abundances. (Section 2.4)
- Describe how elements are organized in the periodic table by atomic number and by similarities in chemical behavior, giving rise to periods and groups. (Section 2.5)
- Describe the locations of metals and nonmetals in the periodic table. (Section 2.5)
- Distinguish between molecular substances and ionic substances in terms of their composition. (Sections 2.6 and 2.7)
- Distinguish between empirical formulas and molecular formulas. (Section 2.6)
- Describe how molecular formulas and structural formulas are used to represent the compositions of molecules. (Section 2.6)
- Explain how ions are formed by the gain or loss of electrons and be able to use the periodic table to predict the charges of common ions. (Section 2.7)
- Write the empirical formulas of ionic compounds, given the charges of their component ions. (Section 2.7)
- Write the name of an ionic compound given its chemical formula, or write the chemical formula given its name. (Section 2.8)
- Name or write chemical formulas for binary inorganic compounds and for acids. (Section 2.8)
- Identify organic compounds and name simple alkanes and alcohols. (Section 2.9)

EXERCISES

VISUALIZING CONCEPTS

These exercises are intended to probe your understanding of key concepts rather than your ability to utilize formulas and perform calculations. Exercises with red exercise numbers have answers in the back of the book.

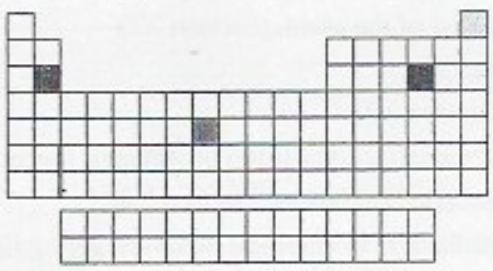
2.1 A charged particle is caused to move between two electrically charged plates, as shown here.



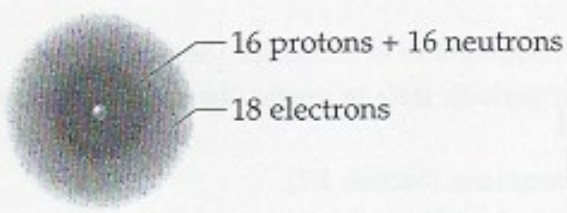
(a) Why does the path of the charged particle bend? (b) What is the sign of the electrical charge on the particle? (c) As the charge on the plates is increased, would you expect the bending to increase, decrease, or stay the same? (d) As the mass of the particle is increased while the speed of the particles remains the same, would you expect the bending to increase, decrease, or stay the same? [Section 2.2]

2.2 The following diagram is a representation of 20 atoms of a fictitious element, which we will call nevadium (Nv). The red spheres are ^{293}Nv, and the blue spheres are ^{295}Nv. (a) Assuming that this sample is a statistically representative sample of the element, calculate the percent abundance of each element. (b) If the mass of ^{293}Nv is 293.15 amu and that of ^{295}Nv is 295.15 amu, what is the atomic weight of Nv? [Section 2.4]

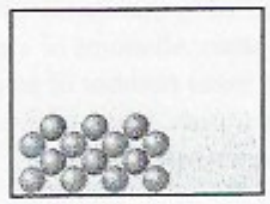
2.3 Four of the boxes in the following periodic table are colored. Which of these are metals and which are nonmetals? Which one is an alkaline earth metal? Which one is a noble gas? [Section 2.5]



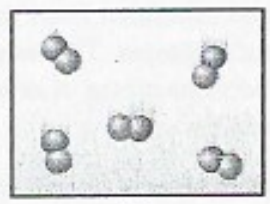
2.4 Does the following drawing represent a neutral atom or an ion? Write its complete chemical symbol including mass number, atomic number, and net charge (if any). [Sections 2.3 and 2.7]



2.5 Which of the following diagrams most likely represents an ionic compound, and which represents a molecular one? Explain your choice. [Sections 2.6 and 2.7]

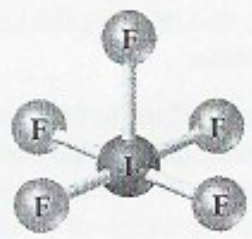


(i)

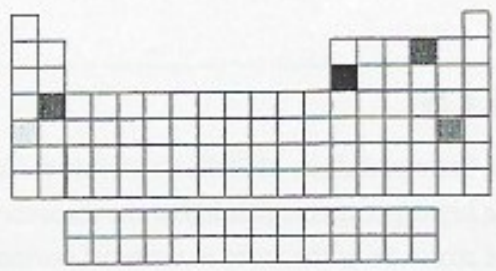


(ii)

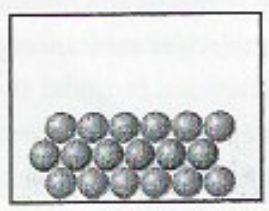
2.6 Write the chemical formula for the following compound. Is the compound ionic or molecular? Name the compound. [Sections 2.6 and 2.8]



2.7 Five of the boxes in the following periodic table are colored. Predict the charge on the ion associated with each of these elements. [Section 2.7]



2.8 The following diagram represents an ionic compound in which the red spheres represent cations and blue spheres represent anions. Which of the following formulas is consistent with the drawing: KBr, K_2SO_4, $Ca(NO_3)_2$, $Fe_2(SO_4)_3$? Name the compound. [Sections 2.7 and 2.8]



These exercises are divided into sections that deal with specific topics in the chapter. The exercises are grouped in pairs, with the answers given in the back of the book to the odd-numbered exercises, as indicated by the red exercise numbers. Those exercises whose numbers appear in brackets are more challenging than the nonbracketed exercises.

ATOMIC THEORY AND THE DISCOVERY OF ATOMIC STRUCTURE (sections 2.1–2.2)

2.9 How does Dalton's atomic theory account for the fact that when 1.000 g of water is decomposed into its elements, 0.111 g of hydrogen and 0.889 g of oxygen are obtained regardless of the source of the water?

2.10 Hydrogen sulfide is composed of two elements: hydrogen and sulfur. In an experiment, 6.500 g of hydrogen sulfide is fully decomposed into its elements. (a) If 0.384 g of hydrogen is obtained in this experiment, how many grams of sulfur must be obtained? (b) What fundamental law does this experiment demonstrate? (c) How is this law explained by Dalton's atomic theory?

2.11 A chemist finds that 30.82 g of nitrogen will react with 17.60 g, 35.20 g, 70.40 g, or 88.00 g of oxygen to form four different compounds. (a) Calculate the mass of oxygen per gram of nitrogen in each compound. (b) How do the numbers in part (a) support Dalton's atomic theory?

2.12 In a series of experiments, a chemist prepared three different compounds that contain only iodine and fluorine and determined the mass of each element in each compound:

Compound	Mass of Iodine (g)	Mass of Fluorine (g)
1	4.75	3.56
2	7.64	3.43
3	9.41	9.86

(a) Calculate the mass of fluorine per gram of iodine in each compound. (b) How do the numbers in part (a) support the atomic theory?

2.13 Summarize the evidence used by J. J. Thomson to argue that cathode rays consist of negatively charged particles.

2.14 An unknown particle is caused to move between two electrically charged plates, as illustrated in Figure 2.8. Its path is deflected by a smaller magnitude in the opposite direction from that of a beta particle. What can you conclude about the charge and mass of this unknown particle?

2.15 How did Rutherford interpret the following observations made during his α-particle scattering experiments? (a) Most α particles were not appreciably deflected as they passed through the gold foil. (b) A few α particles were deflected at very large angles. (c) What differences would you expect if beryllium foil were used instead of gold foil in the α-particle scattering experiment?

2.16 Millikan determined the charge on the electron by studying the static charges on oil drops falling in an electric field (Figure 2.5). A student carried out this experiment using several oil drops for her measurements and calculated the charges on the drops. She obtained the following data:

Droplet	Calculated Charge (C)
A	1.60×10^{-19}
B	3.15×10^{-19}
C	4.81×10^{-19}
D	6.31×10^{-19}

(a) What is the significance of the fact that the droplets carried different charges? (b) What conclusion can the student draw from these data regarding the charge of the electron? (c) What value (and to how many significant figures) should she report for the electronic charge?

MODERN VIEW OF ATOMIC STRUCTURE; ATOMIC WEIGHTS (sections 2.3–2.4)

2.17 The radius of an atom of gold (Au) is about 1.35 Å. (a) Express this distance in nanometers (nm) and in picometers (pm). (b) How many gold atoms would have to be lined up to span 1.0 mm? (c) If the atom is assumed to be a sphere, what is the volume in cm^3 of a single Au atom?

2.18 An atom of rhodium (Rh) has a diameter of about 2.7×10^{-8} cm. (a) What is the radius of a rhodium atom in angstroms (Å) and in meters (m)? (b) How many Rh atoms would have to be placed side by side to span a distance of 6.0 μm? (c) If you assume that the Rh atom is a sphere, what is the volume in m^3 of a single atom?

2.19 Answer the following questions without referring to Table 2.1: (a) What are the main subatomic particles that make up the atom? (b) What is the relative charge (in multiples of the electronic charge) of each of the particles? (c) Which of the particles is the most massive? (d) Which is the least massive?

2.20 Determine whether each of the following statements is true or false. If false, correct the statement to make it true: (a) The nucleus has most of the mass and comprises most of the volume of an atom. (b) Every atom of a given element has the same number of protons. (c) The number of electrons in an atom equals the number of neutrons in the atom. (d) The protons in the nucleus of the helium atom are held together by a force called the strong nuclear force.

2.21 (a) Define atomic number and mass number. (b) Which of these can vary without changing the identity of the element?

2.22 (a) Which two of the following are isotopes of the same element: $^{31}_{16}X$, $^{31}_{15}X$, $^{32}_{16}X$? (b) What is the identity of the element whose isotopes you have selected?

2.23 How many protons, neutrons, and electrons are in the following atoms: (a) ^{40}Ar, (b) ^{65}Zn, (c) ^{70}Ga, (d) ^{80}Br, (e) ^{184}W, (f) ^{243}Am?

2.24 Each of the following isotopes is used in medicine. Indicate the number of protons and neutrons in each isotope: (a) phosphorus-32, (b) chromium-51, (c) cobalt-60, (d) technetium-99, (e) iodine-131, (f) thallium-201.

2.25 Fill in the gaps in the following table, assuming each column represents a neutral atom.

Symbol	^{52}Cr				
Protons		25			82
Neutrons		30	64		
Electrons			48	86	
Mass no.				222	207

2.26 Fill in the gaps in the following table, assuming each column represents a neutral atom.

Symbol	^{65}Zn				
Protons		38			92
Neutrons		58	49		
Electrons			38	36	
Mass no.				81	235

2.27 Write the correct symbol, with both superscript and subscript, for each of the following. Use the list of elements inside the front cover as needed: (a) the isotope of platinum that contains 118 neutrons, (b) the isotope of krypton with mass number 84, (c) the isotope of arsenic with mass number 75, (d) the isotope of magnesium that has an equal number of protons and neutrons.

2.28 One way in which Earth's evolution as a planet can be understood is by measuring the amounts of certain isotopes in rocks. One quantity recently measured is the ratio of ^{129}Xe to ^{130}Xe in some minerals. In what way do these two isotopes differ from one another? In what respects are they the same?

2.29 (a) What isotope is used as the standard in establishing the atomic mass scale? (b) The atomic weight of boron is reported as 10.81, yet no atom of boron has the mass of 10.81 amu. Explain.

2.30 (a) What is the mass in amu of a carbon-12 atom? (b) Why is the atomic weight of carbon reported as 12.011 in the table of elements and the periodic table in the front inside cover of this text?

2.31 Only two isotopes of copper occur naturally, ^{63}Cu (atomic mass = 62.9296 amu; abundance 69.17%) and ^{65}Cu (atomic mass = 64.9278 amu; abundance 30.83%). Calculate the atomic weight (average atomic mass) of copper.

2.32 Rubidium has two naturally occurring isotopes, rubidium-85 (atomic mass = 84.9118 amu; abundance = 72.15%) and rubidium-87 (atomic mass = 86.9092 amu; abundance = 27.85%). Calculate the atomic weight of rubidium.

2.33 (a) In what fundamental way is mass spectrometry related to Thomson's cathode-ray experiments (Figure 2.4)? (b) What are the labels on the axes of a mass spectrum? (c) To measure the mass spectrum of an atom, the atom must first lose one or more electrons. Why is this so?

2.34 (a) The mass spectrometer in Figure 2.12 has a magnet as one of its components. What is the purpose of the magnet? (b) The atomic weight of Cl is 35.5 amu. However, the mass spectrum of Cl (Figure 2.13) does not show a peak at this mass. Explain. (c) A mass spectrum of phosphorus (P) atoms shows only a single peak at a mass of 31. What can you conclude from this observation?

2.35 Naturally occurring magnesium has the following isotopic abundances:

Isotope	Abundance	Atomic mass (amu)
^{24}Mg	78.99 %	23.98504
^{25}Mg	10.00 %	24.98584
^{26}Mg	11.01 %	25.98259

(a) What is the average atomic mass of Mg? (b) Sketch the mass spectrum of Mg.

2.36 Mass spectrometry is more often applied to molecules than to atoms. We will see in Chapter 3 that the *molecular weight* of a molecule is the sum of the atomic weights of the atoms in the molecule. The mass spectrum of H_2 is taken under conditions that prevent decomposition into H atoms. The two naturally occurring isotopes of hydrogen are ^{1}H (atomic mass = 1.00783 amu; abundance 99.9885%) and ^{2}H (atomic mass = 2.01410 amu; abundance 0.0115%). (a) How many peaks will the mass spectrum have? (b) Give the relative atomic masses of each of these peaks. (c) Which peak will be the largest and which the smallest?

THE PERIODIC TABLE; MOLECULES AND IONS (sections 2.5–2.7)

2.37 For each of the following elements, write its chemical symbol, locate it in the periodic table, give its atomic number, and indicate whether it is a metal, metalloid, or nonmetal: (a) chromium, (b) helium, (c) phosphorus, (d) zinc, (e) magnesium, (f) bromine, (g) arsenic.

2.38 Locate each of the following elements in the periodic table; give its name and atomic number, and indicate whether it is a metal, metalloid, or nonmetal: (a) Li, (b) Sc, (c) Ge, (d) Yb, (e) Mn, (f) Sb, (g) Xe.

2.39 For each of the following elements, write its chemical symbol, determine the name of the group to which it belongs (Table 2.3), and indicate whether it is a metal, metalloid, or nonmetal: (a) potassium, (b) iodine, (c) magnesium, (d) argon, (e) sulfur.

2.40 The elements of group 4A show an interesting change in properties moving down the group. Give the name and chemical symbol of each element in the group and label it as a nonmetal, metalloid, or metal.

2.41 What can we tell about a compound when we know the empirical formula? What additional information is conveyed by the molecular formula? By the structural formula? Explain in each case.

2.42 Two compounds have the same empirical formula. One substance is a gas, whereas the other is a viscous liquid. How is it possible for two substances with the same empirical formula to have markedly different properties?

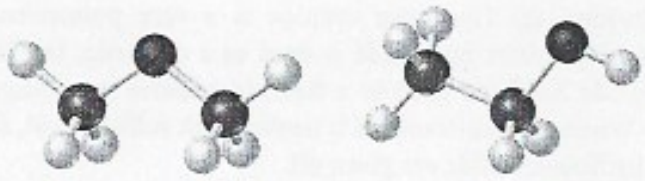
2.43 Write the empirical formula corresponding to each of the following molecular formulas: (a) Al_2Br_6, (b) C_8H_{10}, (c) $C_4H_8O_2$, (d) P_4O_{10}, (e) $C_6H_4Cl_2$, (f) $B_3N_3H_6$.

2.44 Determine the molecular and empirical formulas of the following: (a) the organic solvent *benzene*, which has six carbon atoms and six hydrogen atoms; (b) the compound *silicon tetrachloride*, which has a silicon atom and four chlorine atoms and is used in the manufacture of computer chips; (c) the reactive substance *diborane*, which has two boron atoms and six hydrogen atoms; (d) the sugar called *glucose*, which has six carbon atoms, twelve hydrogen atoms, and six oxygen atoms.

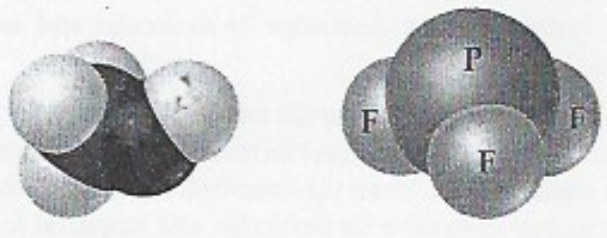
2.45 How many hydrogen atoms are in each of the following: (a) C_2H_5OH, (b) $Ca(CH_3COO)_2$, (c) $(NH_4)_3PO_4$?

2.46 How many of the indicated atoms are represented by each chemical formula: (a) carbon atoms in $C_2H_5COOCH_3$, (b) oxygen atoms in $Ca(ClO_4)_2$, (c) hydrogen atoms in $(NH_4)_2HPO_4$?

2.47 Write the molecular and structural formulas for the compounds represented by the following molecular models:

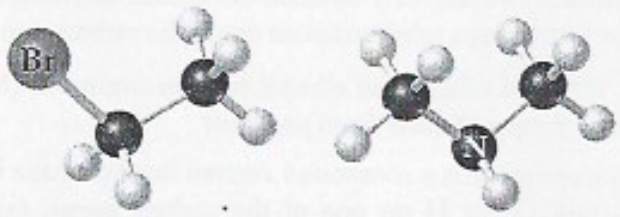


(a) (b)

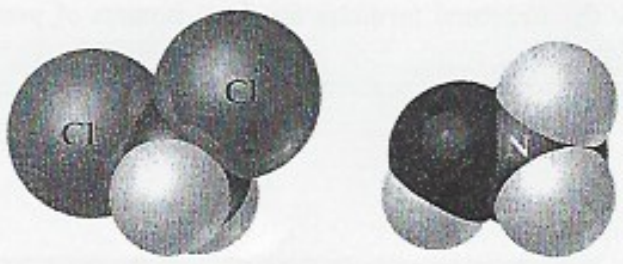


(c) (d)

2.48 Write the molecular and structural formulas for the compounds represented by the following models:



(a) (b)



(c) (d)

2.49 Fill in the gaps in the following table:

Symbol	$^{59}Co^{3+}$			
Protons		34	76	80
Neutrons		46	116	120
Electrons		36		78
Net charge			2+	

2.50 Fill in the gaps in the following table:

Symbol	$^{31}P^{3-}$			
Protons		34	50	
Neutrons		45	69	118
Electrons			46	76
Net charge		2−		3+

2.51 Each of the following elements is capable of forming an ion in chemical reactions. By referring to the periodic table, predict the charge of the most stable ion of each: (a) Mg, (b) Al, (c) K, (d) S, (e) F.

2.52 Using the periodic table, predict the charges of the ions of the following elements: (a) Ga, (b) Sr, (c) As, (d) Br, (e) Se.

2.53 Using the periodic table to guide you, predict the chemical formula and name of the compound formed by the following elements: (a) Ga and F, (b) Li and H, (c) Al and I, (d) K and S.

2.54 The most common charge associated with scandium in its compounds is 3+. Indicate the chemical formulas you would expect for compounds formed between scandium and (a) iodine, (b) sulfur, (c) nitrogen.

2.55 Predict the chemical formula for the ionic compound formed by (a) Ca^{2+} and Br^-, (b) K^+ and CO_3^{2-}, (c) Al^{3+} and CH_3COO^-, (d) NH_4^+ and SO_4^{2-}, (e) Mg^{2+} and PO_4^{3-}.

2.56 Predict the chemical formulas of the compounds formed by the following pairs of ions: (a) Cr^{3+} and Br^-, (b) Fe^{3+} and O^{2-}, (c) Hg_2^{2+} and CO_3^{2-}, (d) Ca^{2+} and ClO_3^-, (e) NH_4^+ and PO_4^{3-}.

2.57 Complete the table by filling in the formula for the ionic compound formed by each pair of cations and anions, as shown for the first pair.

Ion	K^+	NH_4^+	Mg^{2+}	Fe^{3+}
Cl^-	KCl			
OH^-				
CO_3^{2-}				
PO_4^{3-}				

2.58 Complete the table by filling in the formula for the ionic compound formed by each pair of cations and anions, as shown for the first pair.

Ion	Na^+	Ca^{2+}	Fe^{2+}	Al^{3+}
O^{2-}	Na_2O			
NO_3^-				
SO_4^{2-}				
AsO_4^{3-}				

2.59 Predict whether each of the following compounds is molecular or ionic: (a) B_2H_6, (b) CH_3OH, (c) $LiNO_3$, (d) Sc_2O_3, (e) CsBr, (f) NOCl, (g) NF_3, (h) Ag_2SO_4.

2.60 Which of the following are ionic, and which are molecular? (a) PF_5, (b) NaI, (c) SCl_2, (d) $Ca(NO_3)_2$, (e) $FeCl_3$, (f) LaP, (g) $CoCO_3$, (h) N_2O_4.

NAMING INORGANIC COMPOUNDS; ORGANIC MOLECULES (sections 2.8–2.9)

2.61 Give the chemical formula for (a) chlorite ion, (b) chloride ion, (c) chlorate ion, (d) perchlorate ion, (e) hypochlorite ion.

2.62 Selenium, an element required nutritionally in trace quantities, forms compounds analogous to sulfur. Name the following ions: (a) SeO_4^{2-}, (b) Se^{2-}, (c) HSe^-, (d) $HSeO_3^-$.

2.63 Give the names and charges of the cation and anion in each of the following compounds: (a) CaO, (b) Na_2SO_4, (c) $KClO_4$, (d) $Fe(NO_3)_2$, (e) $Cr(OH)_3$.

2.64 Give the names and charges of the cation and anion in each of the following compounds: (a) CuS, (b) Ag_2SO_4, (c) $Al(ClO_3)_3$, (d) $Co(OH)_2$, (e) $PbCO_3$.

2.65 Name the following ionic compounds: (a) Li_2O, (b) $FeCl_3$, (c) NaClO, (d) $CaSO_3$, (e) $Cu(OH)_2$, (f) $Fe(NO_3)_2$, (g) $Ca(CH_3COO)_2$, (h) $Cr_2(CO_3)_3$, (i) K_2CrO_4, (j) $(NH_4)_2SO_4$.

2.66 Name the following ionic compounds: (a) KCN, (b) $NaBrO_2$, (c) $Sr(OH)_2$, (d) CoS, (e) $Fe_2(CO_3)_3$, (f) $Cr(NO_3)_3$, (g) $(NH_4)_2SO_3$, (h) NaH_2PO_4, (i) $KMnO_4$, (j) $Ag_2Cr_2O_7$.

2.67 Write the chemical formulas for the following compounds: (a) aluminum hydroxide, (b) potassium sulfate, (c) copper(I) oxide, (d) zinc nitrate, (e) mercury(II) bromide, (f) iron(III) carbonate, (g) sodium hypobromite.

2.68 Give the chemical formula for each of the following ionic compounds: (a) sodium phosphate, (b) zinc nitrate, (c) barium bromate, (d) iron(II) perchlorate, (e) cobalt(II) hydrogen carbonate, (f) chromium(III) acetate, (g) potassium dichromate.

2.69 Give the name or chemical formula, as appropriate, for each of the following acids: (a) $HBrO_3$, (b) HBr, (c) H_3PO_4, (d) hypochlorous acid, (e) iodic acid, (f) sulfurous acid.

2.70 Provide the name or chemical formula, as appropriate, for each of the following acids: (a) hydroiodic acid, (b) chloric acid, (c) nitrous acid, (d) H_2CO_3, (e) $HClO_4$, (f) CH_3COOH

2.71 Give the name or chemical formula, as appropriate, for each of the following binary molecular substances: (a) SF_6, (b) IF_5, (c) XeO_3, (d) dinitrogen tetroxide, (e) hydrogen cyanide, (f) tetraphosphorus hexasulfide.

2.72 The oxides of nitrogen are very important components in urban air pollution. Name each of the following compounds: (a) N_2O, (b) NO, (c) NO_2, (d) N_2O_5, (e) N_2O_4.

2.73 Write the chemical formula for each substance mentioned in the following word descriptions (use the front inside cover to find the symbols for the elements you don't know). (a) Zinc carbonate can be heated to form zinc oxide and carbon dioxide. (b) On treatment with hydrofluoric acid, silicon dioxide forms silicon tetrafluoride and water. (c) Sulfur dioxide reacts with water to form sulfurous acid. (d) The substance phosphorus trihydride, commonly called phosphine, is a toxic gas. (e) Perchloric acid reacts with cadmium to form cadmium(II) perchlorate. (f) Vanadium(III) bromide is a colored solid.

2.74 Assume that you encounter the following sentences in your reading. What is the chemical formula for each substance mentioned? (a) Sodium hydrogen carbonate is used as a deodorant. (b) Calcium hypochlorite is used in some bleaching solutions. (c) Hydrogen cyanide is a very poisonous gas. (d) Magnesium hydroxide is used as a cathartic. (e) Tin(II) fluoride has been used as a fluoride additive in toothpastes. (f) When cadmium sulfide is treated with sulfuric acid, fumes of hydrogen sulfide are given off.

2.75 (a) What is a hydrocarbon? (b) Butane is the alkane with a chain of four carbon atoms. Write a structural formula for this compound and determine its molecular and empirical formulas.

2.76 (a) What ending is used for the names of alkanes? (b) Hexane is an alkane whose structural formula has all its carbon atoms in a straight chain. Draw the structural formula for this compound and determine its molecular and empirical formulas. (*Hint:* You might need to refer to Table 2.6.)

2.77 (a) What is a functional group? (b) What functional group characterizes an alcohol? (c) With reference to Exercise 2.75, write a structural formula for 1-butanol, the alcohol derived from butane, by making a substitution on one of the carbon atoms.

2.78 (a) What do ethane and ethanol have in common? (b) How does 1-propanol differ from propane?

2.79 Chloropropane is a compound derived from propane by substituting Cl for H on one of the carbon atoms. (a) Draw the structural formulas for the two isomers of chloropropane. (b) Suggest names for these two compounds.

2.80 Draw the structural formulas for three isomers of pentane, C_5H_{12}.

ADDITIONAL EXERCISES

These exercises are not divided by category, although they are roughly in the order of the topics in the chapter. They are not paired.

2.81 Suppose a scientist repeats the Millikan oil-drop experiment but reports the charges on the drops using an unusual (and imaginary) unit called the *warmomb* (wa). The scientist obtains the following data for four of the drops:

Droplet	Calculated Charge (wa)
A	3.84×10^{-8}
B	4.80×10^{-8}
C	2.88×10^{-8}
D	8.64×10^{-8}

(a) If all the droplets were the same size, which would fall most slowly through the apparatus? (b) From these data, what is the best choice for the charge of the electron in warmombs? (c) Based on your answer to part (b), how many electrons are there on each of the droplets? (d) What is the conversion factor between warmombs and coulombs?

CHAPTER SUMMARY AND KEY TERMS

INTRODUCTION AND SECTION 3.1 The study of the quantitative relationships between chemical formulas and chemical equations is known as **stoichiometry**. One of the important concepts of stoichiometry is the law of conservation of mass, which states that the total mass of the products of a chemical reaction is the same as the total mass of the reactants. The same numbers of atoms of each type are present before and after a chemical reaction. A balanced **chemical equation** shows equal numbers of atoms of each element on each side of the equation. Equations are balanced by placing coefficients in front of the chemical formulas for the **reactants** and **products** of a reaction, *not* by changing the subscripts in chemical formulas.

SECTION 3.2 Among the reaction types described in this chapter are (1) **combination reactions**, in which two reactants combine to form one product; (2) **decomposition reactions**, in which a single reactant forms two or more products; and (3) **combustion reactions** in oxygen, in which a hydrocarbon or related compound reacts with O_2 to form CO_2 and H_2O.

SECTION 3.3 Much quantitative information can be determined from chemical formulas and balanced chemical equations by using atomic weights. The **formula weight** of a compound equals the sum of the atomic weights of the atoms in its formula. If the formula is a molecular formula, the formula weight is also called the **molecular weight**. Atomic weights and formula weights can be used to determine the elemental composition of a compound.

SECTION 3.4 A mole of any substance is **Avogadro's number** (6.02×10^{23}) of formula units of that substance. The mass of a **mole** of atoms, molecules, or ions (the **molar mass**) equals the formula weight of that material expressed in grams. The mass of one molecule of H_2O, for example, is 18 amu, so the mass of 1 mol of H_2O is 18 g. That is, the molar mass of H_2O is 18 g/mol.

SECTION 3.5 The empirical formula of any substance can be determined from its percent composition by calculating the relative number of moles of each atom in 100 g of the substance. If the substance is molecular in nature, its molecular formula can be determined from the empirical formula if the molecular weight is also known.

SECTIONS 3.6 AND 3.7 The mole concept can be used to calculate the relative quantities of reactants and products in chemical reactions. The coefficients in a balanced equation give the relative numbers of moles of the reactants and products. To calculate the number of grams of a product from the number of grams of a reactant, first convert grams of reactant to moles of reactant. Then use the coefficients in the balanced equation to convert the number of moles of reactant to moles of product. Finally, convert moles of product to grams of product.

A **limiting reactant** is completely consumed in a reaction. When it is used up, the reaction stops, thus limiting the quantities of products formed. The **theoretical yield** of a reaction is the quantity of product calculated to form when all of the limiting reactant reacts. The actual yield of a reaction is always less than the theoretical yield. The **percent yield** compares the actual and theoretical yields.

KEY SKILLS

- Balance chemical equations. (Section 3.1)
- Predict the products of simple combination, decomposition, and combustion reactions. (Section 3.2)
- Calculate formula weights. (Section 3.3)
- Convert grams to moles and moles to grams using molar masses. (Section 3.4)
- Convert number of molecules to moles and moles to number of molecules using Avogadro's number. (Section 3.4)
- Calculate the empirical and molecular formulas of a compound from percentage composition and molecular weight. (Section 3.5)
- Calculate amounts, in grams or moles, of reactants and products for a reaction. (Section 3.6)
- Calculate the percent yield of a reaction. (Section 3.7)

KEY EQUATIONS

- $$\%\ \text{element} = \frac{\left(\begin{array}{c}\text{number of atoms}\\ \text{of that element}\end{array}\right)\left(\begin{array}{c}\text{atomic weight}\\ \text{of element}\end{array}\right)}{(\text{formula weight of compound})} \times 100\%$$ [3.10]

  This is the formula to calculate the mass percentage of each element in a compound. The sum of all the percentages of all the elements in a compound should add up to 100%.

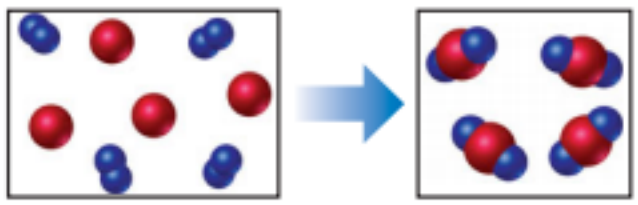
- $$\%\ \text{yield} = \frac{(\text{actual yield})}{(\text{theoretical yield})} \times 100\%$$ [3.14]

  This is the formula to calculate the percent yield of a reaction. The percent yield can never be more than 100%.

EXERCISES

VISUALIZING CONCEPTS

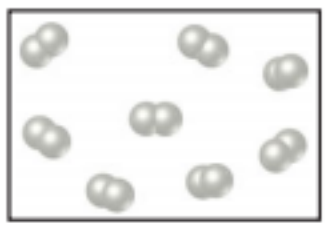
3.1 The reaction between reactant A (blue spheres) and reactant B (red spheres) is shown in the following diagram:



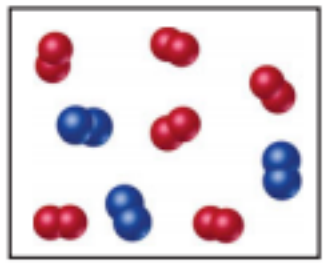
Based on this diagram, which equation best describes the reaction? [Section 3.1]

(a) $A_2 + B \longrightarrow A_2B$
(b) $A_2 + 4\,B \longrightarrow 2\,AB_2$
(c) $2\,A + B_4 \longrightarrow 2\,AB_2$
(d) $A + B_2 \longrightarrow AB_2$

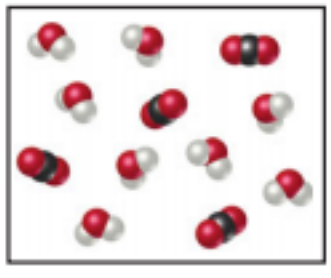
3.2 Under appropriate experimental conditions, H_2 and CO undergo a combination reaction to form CH_3OH. The following drawing represents a sample of H_2. Make a corresponding drawing of the CO needed to react completely with the H_2. How did you arrive at the number of CO molecules in your drawing? [Section 3.2]



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]

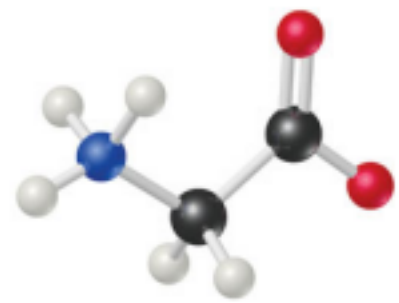


3.4 The following diagram represents the collection of CO_2 and H_2O molecules formed by complete combustion of a hydrocarbon. What is the empirical formula of the hydrocarbon? [Section 3.2]

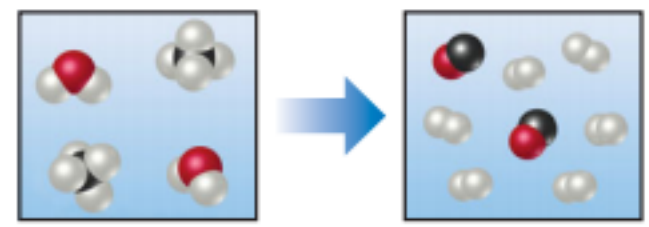


3.5 Glycine, an amino acid used by organisms to make proteins, is represented by the following molecular model.

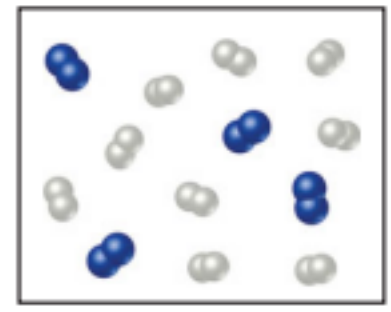
(a) Write its molecular formula.
(b) Determine its molar mass.
(c) Calculate the mass of 3 moles of glycine.
(d) Calculate the percent nitrogen by mass in glycine. [Sections 3.3 and 3.5]



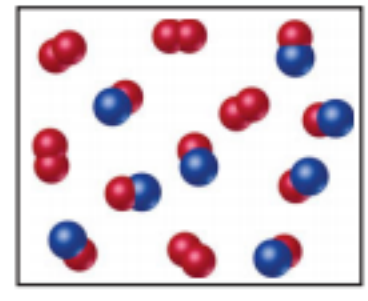
3.6 The following diagram represents a high-temperature reaction between CH_4 and H_2O. Based on this reaction, how many moles of each product can be obtained starting with 4.0 mol CH_4? [Section 3.6]



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]



3.8 Nitrogen monoxide and oxygen react to form nitrogen dioxide. Consider the mixture of NO and O_2 shown in the accompanying diagram. The blue spheres represent N, and the red ones represent O. (a) Draw a representation of the product mixture, assuming that the reaction goes to completion. What is the limiting reactant in this case? (b) How many NO_2 molecules would you draw as products if the reaction had a percent yield of 75%? [Section 3.7]



BALANCING CHEMICAL EQUATIONS (section 3.1)

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?

3.10 (a) What is the difference between adding a subscript 2 to the end of the formula for CO to give CO_2 and adding a coefficient in front of the formula to give 2 CO? (b) Is the following chemical equation, as written, consistent with the law of conservation of mass?

$$3\ Mg(OH)_2(s) + 2\ H_3PO_4(aq) \longrightarrow Mg_3(PO_4)_2(s) + 6\ H_2O(l)$$

Why or why not?

3.11 Balance the following equations:

(a) $CO(g) + O_2(g) \longrightarrow CO_2(g)$

(b) $N_2O_5(g) + H_2O(l) \longrightarrow HNO_3(aq)$

(c) $CH_4(g) + Cl_2(g) \longrightarrow CCl_4(l) + HCl(g)$

(d) $Al_4C_3(s) + H_2O(l) \longrightarrow Al(OH)_3(s) + CH_4(g)$

(e) $C_5H_{10}O_2(l) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$

(f) $Fe(OH)_3(s) + H_2SO_4(aq) \longrightarrow Fe_2(SO_4)_3(aq) + H_2O(l)$

(g) $Mg_3N_2(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + (NH_4)_2SO_4(aq)$

3.12 Balance the following equations:

(a) $Li(s) + N_2(g) \longrightarrow Li_3N(s)$

(b) $TiCl_4(l) + H_2O(l) \longrightarrow TiO_2(s) + HCl(aq)$

(c) $NH_4NO_3(s) \longrightarrow N_2(g) + O_2(g) + H_2O(g)$

(d) $Ca_3P_2(s) + H_2O(l) \longrightarrow Ca(OH)_2(aq) + PH_3(g)$

(e) $Al(OH)_3(s) + H_2SO_4(aq) \longrightarrow Al_2(SO_4)_3(aq) + H_2O(l)$

(f) $AgNO_3(aq) + Na_2CO_3(aq) \longrightarrow Ag_2NO_3(s) + Na_2CO_3(aq)$

(g) $C_2H_5NH_2(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g) + N_2(g)$

3.13 Write balanced chemical equations to correspond to each of the following descriptions: (a) Solid calcium carbide, CaC_2, reacts with water to form an aqueous solution of calcium hydroxide and acetylene gas, C_2H_2. (b) When solid potassium chlorate is heated, it decomposes to form solid potassium chloride and oxygen gas. (c) Solid zinc metal reacts with sulfuric acid to form hydrogen gas and an aqueous solution of zinc sulfate. (d) When liquid phosphorus trichloride is added to water, it reacts to form aqueous phosphorous acid, $H_3PO_3(aq)$, and aqueous hydrochloric acid. (e) When hydrogen sulfide gas is passed over solid hot iron(III) hydroxide, the resultant reaction produces solid iron(III) sulfide and gaseous water.

3.14 Write balanced chemical equations to correspond to each of the following descriptions: (a) When sulfur trioxide gas reacts with water, a solution of sulfuric acid forms. (b) Boron sulfide, $B_2S_3(s)$, reacts violently with water to form dissolved boric acid, H_3BO_3, and hydrogen sulfide gas. (c) Phosphine, $PH_3(g)$, combusts in oxygen gas to form water vapor and solid tetraphosphorus decaoxide. (d) When solid mercury(II) nitrate is heated, it decomposes to form solid mercury(II) oxide, gaseous nitrogen dioxide, and oxygen. (e) Copper metal reacts with hot concentrated sulfuric acid solution to form aqueous copper(II) sulfate, sulfur dioxide gas, and water.

PATTERNS OF CHEMICAL REACTIVITY (section 3.2)

3.15 (a) When the metallic element sodium combines with the nonmetallic element bromine, $Br_2(l)$, how can you determine the chemical formula of the product? How do you know whether the product is a solid, liquid, or gas at room temperature? Write the balanced chemical equation for the reaction. (b) When a hydrocarbon burns in air, what reactant besides the hydrocarbon is involved in the reaction? What products are formed? Write a balanced chemical equation for the combustion of benzene, $C_6H_6(l)$, in air.

3.16 (a) Determine the chemical formula of the product formed when the metallic element aluminum combines with the nonmetallic element bromine, Br_2. Write the balanced chemical equation for the reaction. (b) What products form when a compound containing C, H, and O is completely combusted in air? Write a balanced chemical equation for the combustion of acetone, $C_3H_6O(l)$, in air.

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.

3.18 Write a balanced chemical equation for the reaction that occurs when (a) calcium metal undergoes a combination reaction with $O_2(g)$; (b) copper(II) hydroxide decomposes into copper(II) oxide and water when heated; (c) heptane, $C_7H_{16}(l)$, burns in air; (d) methyl tert-butyl ether, $C_5H_{12}O(l)$, burns 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) $K_2O(s) + H_2O(l) \longrightarrow KOH(aq)$

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

(a) $PbCO_3(s) \longrightarrow PbO(s) + CO_2(g)$

(b) $C_2H_4(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$

(c) $Mg(s) + N_2(g) \longrightarrow Mg_3N_2(s)$

(d) $C_7H_8O_2(l) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$

(e) $Al(s) + Cl_2(g) \longrightarrow AlCl_3(s)$

FORMULA WEIGHTS (section 3.3)

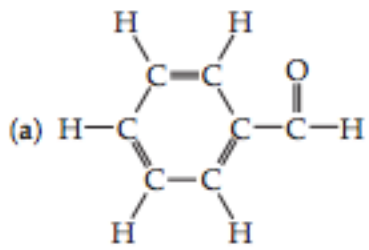
3.21 Determine the formula weights of each of the following compounds: (a) nitric acid, HNO_3; (b) $KMnO_4$; (c) $Ca_3(PO_4)_2$; (d) quartz, SiO_2; (e) gallium sulfide, (f) chromium(III) sulfate, (g) phosphorus trichloride.

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.

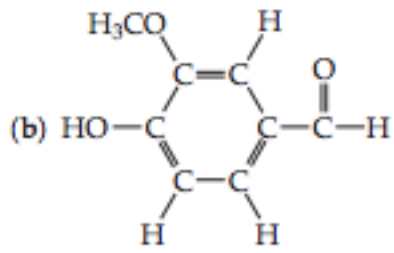
3.23 Calculate the percentage by mass of oxygen in the following compounds: (a) morphine, $C_{17}H_{19}NO_3$; (b) codeine, $C_{18}H_{21}NO_3$ (c) cocaine, $C_{17}H_{21}NO_4$; (d) tetracycline, $C_{22}H_{24}N_2O_8$; (e) digitoxin, $C_{41}H_{64}O_{13}$; (f) vancomycin, $C_{66}H_{75}Cl_2N_9O_{24}$.

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.

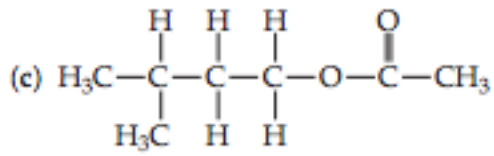
3.25 Based on the following structural formulas, calculate the percentage of carbon by mass present in each compound:



(a) Benzaldehyde (almond fragrance)

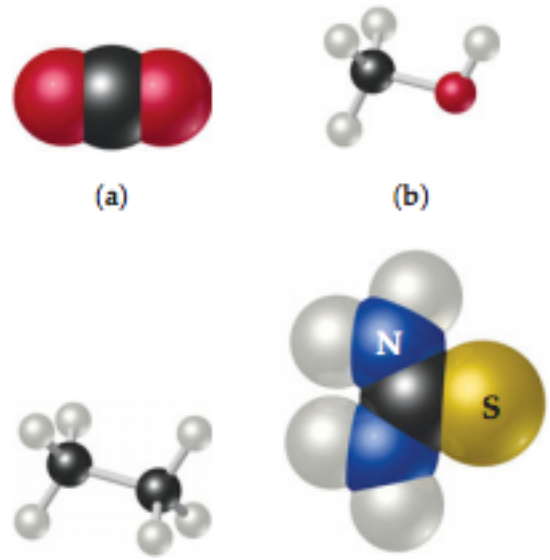


(b) Vanillin (vanilla flavor)



(c) Isopentyl acetate (banana flavor)

3.26 Calculate the percentage of carbon by mass in each of the compounds represented by the following models:



(a) (b) (c) (d)

AVOGADRO'S NUMBER AND THE MOLE (section 3.4)

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?

3.28 (a) What is the mass, in grams, of a mole of ^{12}C? (b) How many carbon atoms are present in a mole of ^{12}C?

3.29 Without doing any detailed calculations (but using a periodic table to give atomic weights), rank the following samples in order of increasing number of atoms: 0.50 mol H_2O, 23 g Na, 6.0×10^{23} N_2 molecules.

3.30 Without doing any detailed calculations (but using a periodic table to give atomic weights), rank the following samples in order of increasing number of atoms: 9.0×10^{23} molecules of H_2O_2, 2.0 mol CH_4, 16 g O_2.

3.31 What is the mass, in kilograms, of an Avogadro's number of people, if the average mass of a person is 160 lb? How does this compare with the mass of Earth, 5.98×10^{24} kg?

3.32 If Avogadro's number of pennies is divided equally among the 300 million men, women, and children in the United States, how many dollars would each receive? How does this compare with the gross domestic product (GDP) of the United States, which was $14.4 trillion in 2008? (The GDP is the total market value of the nation's goods and services.)

3.33 Calculate the following quantities:
(a) mass, in grams, of 0.105 mole of sucrose ($C_{12}H_{22}O_{11}$)
(b) moles of $Zn(NO_3)_2$ in 143.50 g of this substance
(c) number of molecules in 1.0×10^{-6} mol CH_3CH_2OH
(d) number of N atoms in 0.410 mol NH_3

3.34 Calculate the following quantities:
(a) mass, in grams, of 1.50×10^{-2} mol of CdS
(b) number of moles of NH_4Cl in 86.6 g of this substance
(c) number of molecules in 8.447×10^{-2} mol C_6H_6
(d) number of O atoms in 6.25×10^{-3} mol $Al(NO_3)_3$

3.35 (a) What is the mass, in grams, of 2.50×10^{-3} mol of ammonium phosphate?
(b) How many moles of chloride ions are in 0.2550 g of aluminum chloride?

(c) What is the mass, in grams, of 7.70×10^{20} molecules of caffeine, $C_8H_{10}N_4O_2$?
(d) What is the molar mass of cholesterol if 0.00105 mol has a mass of 0.406 g?

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 1.50×10^{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?

3.37 The molecular formula of allicin, the compound responsible for the characteristic smell of garlic, is $C_6H_{10}OS_2$. (a) What is the molar mass of allicin? (b) How many moles of allicin are present in 5.00 mg of this substance? (c) How many molecules of allicin are in 5.00 mg of this substance? (d) How many S atoms are present in 5.00 mg of allicin?

3.38 The molecular formula of aspartame, the artificial sweetener marketed as NutraSweet®, is $C_{14}H_{18}N_2O_5$. (a) What is the molar mass of aspartame? (b) How many moles of aspartame are present in 1.00 mg of aspartame? (c) How many molecules of aspartame are present in 1.00 mg of aspartame? (d) How many hydrogen atoms are present in 1.00 mg of aspartame?

3.39 A sample of glucose, $C_6H_{12}O_6$, contains 1.250×10^{21} carbon atoms. (a) How many atoms of hydrogen does it contain? (b) How many molecules of glucose does it contain? (c) How many moles of glucose does it contain? (d) What is the mass of this sample in grams?

3.40 A sample of the male sex hormone testosterone, $C_{19}H_{28}O_2$, contains 3.88×10^{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 2.0×10^{-6} g/L. How many moles of vinyl chloride in each liter does this represent? How many molecules per liter?

3.42 At least 25 μg of tetrahydrocannabinol (THC), the active ingredient in marijuana, is required to produce intoxication. The molecular formula of THC is $C_{21}H_{30}O_2$. How many moles of THC does this 25 μg represent? How many molecules?

EMPIRICAL FORMULAS (section 3.5)

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.

3.44 Determine the empirical formula of each of the following compounds if a sample contains (a) 0.104 mol K, 0.052 mol C, and 0.156 mol O; (b) 5.28 g Sn and 3.37 g F; (c) 87.5% N and 12.5% H 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

3.46 Determine the empirical formulas of the compounds with the following compositions by mass:
(a) 55.3% K, 14.6% P, and 30.1% O
(b) 24.5% Na, 14.9% Si, and 60.6% F
(c) 62.1% C, 5.21% H, 12.1% N, and the remainder O

3.47 A compound whose empirical formula is XF_3 consists of 65% F by mass. What is the atomic mass of X?

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

3.50 What is the molecular formula of each of the following compounds?
(a) empirical formula HCO_2, molar mass = 90.0 g/mol
(b) empirical formula C_2H_4O, molar mass = 88 g/mol

3.51 Determine the empirical and molecular formulas of each of the following substances:
(a) Styrene, a compound substance used to make Styrofoam® cups and insulation, contains 92.3% C and 7.7% H by mass and has a molar mass of 104 g/mol.
(b) Caffeine, a stimulant found in coffee, contains 49.5% C, 5.15% H, 28.9% N, and 16.5% O by mass and has a molar mass of 195 g/mol.
(c) Monosodium glutamate (MSG), a flavor enhancer in certain foods, contains 35.51% C, 4.77% H, 37.85% O, 8.29% N, and 13.60% Na, and has a molar mass of 169 g/mol.

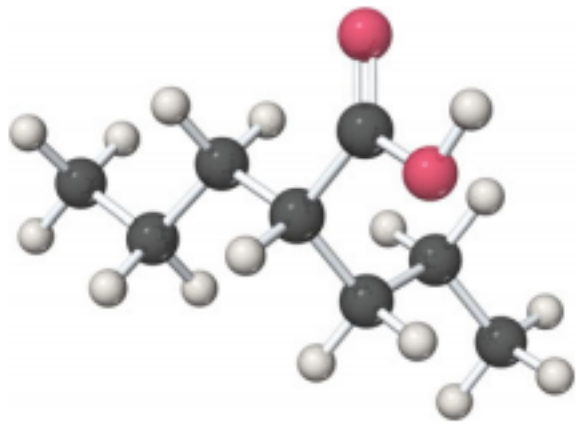
3.52 Determine the empirical and molecular formulas of each of the following substances:
(a) Ibuprofen, a headache remedy, contains 75.69% C, 8.80% H, and 15.51% O by mass, and has a molar mass of 206 g/mol.
(b) Cadaverine, a foul-smelling substance produced by the action of bacteria on meat, contains 58.55% C, 13.81% H, and 27.40% N by mass; its molar mass is 102.2 g/mol.
(c) Epinephrine (adrenaline), a hormone secreted into the bloodstream in times of danger or stress, contains 59.0% C, 7.1% H, 26.2% O, and 7.7% N by mass; its MW is about 180 amu.

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?

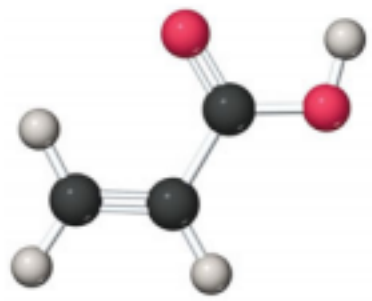
3.54 (a) The characteristic odor of pineapple is due to ethyl butyrate, a compound containing carbon, hydrogen, and oxygen. Combustion of 2.78 mg of ethyl butyrate produces 6.32 mg of CO_2 and 2.58 mg of H_2O. What is the empirical formula of the compound? (b) Nicotine, a component of tobacco, is composed of C, H, and N. A 5.250-mg sample of nicotine was combusted, producing 14.242 mg of CO_2 and 4.083 mg of

H_2O. What is the empirical formula for nicotine? If nicotine has a molar mass of 160 ± 5 g/mol, what is its molecular formula?

3.55 Valproic acid, used to treat seizures and bipolar disorder, is composed of C, H, and O. A 0.165-g sample is combusted in an apparatus such as that shown in Figure 3.14. The gain in mass of the H_2O absorber is 0.166 g, whereas that of the CO_2 absorber is 0.403 g. What empirical formula for valproic acid do these results indicate? Is this empirical formula consistent with the molecular model shown here?



3.56 Propenoic acid, as shown here,



is a reactive organic liquid used in the manufacture of plastics, coatings, and adhesives. An unlabeled container is thought to contain this acid. A 0.2033-g sample is combusted in an apparatus such as that shown in Figure 3.14. The gain in mass of the H_2O absorber is 0.102 g, whereas that of the CO_2 absorber is 0.374 g. Is this analysis consistent with the contents of the container being propenoic acid?

3.57 Washing soda, a compound used to prepare hard water for washing laundry, is a hydrate, which means that a certain number of water molecules are included in the solid structure. Its formula can be written as $Na_2CO_3 \cdot xH_2O$, where x is the number of moles of H_2O per mole of Na_2CO_3. When a 2.558-g sample of washing soda is heated at 25 °C, all the water of hydration is lost, leaving 0.948 g of Na_2CO_3. What is the value of x?

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?

CALCULATIONS BASED ON CHEMICAL EQUATIONS (section 3.6)

3.59 Why is it essential to use balanced chemical equations when determining the quantity of a product formed from a given quantity of a reactant?

3.60 What parts of balanced chemical equations give information about the relative numbers of moles of reactants and products involved in a reaction?

3.61 Hydrofluoric acid, HF(*aq*), cannot be stored in glass bottles because compounds called silicates in the glass are attacked by the HF(*aq*). Sodium silicate (Na_2SiO_3), for example, reacts as follows:

$$Na_2SiO_3(s) + 8\,HF(aq) \longrightarrow H_2SiF_6(aq) + 2\,NaF(aq) + 3\,H_2O(l)$$

(a) How many moles of HF are needed to react with 0.300 mol of Na_2SiO_3?
(b) How many grams of NaF form when 0.500 mol of HF reacts with excess Na_2SiO_3?
(c) How many grams of Na_2SiO_3 can react with 0.800 g of HF?

3.62 The reaction between potassium superoxide, KO_2, and CO_2,

$$4\,KO_2 + 2\,CO_2 \longrightarrow 2K_2CO_3 + 3\,O_2$$

is used as a source of O_2 and absorber of CO_2 in self-contained breathing equipment used by rescue workers.

(a) How many moles of O_2 are produced when 0.400 mol of KO_2 reacts in this fashion?
(b) How many grams of KO_2 are needed to form 7.50 g of O_2?
(c) How many grams of CO_2 are used when 7.50 g of O_2 are produced?

3.63 Several brands of antacids use $Al(OH)_3$ to react with stomach acid, which contains primarily HCl:

$$Al(OH)_3(s) + HCl(aq) \longrightarrow AlCl_3(aq) + H_2O(l)$$

(a) Balance this equation.
(b) Calculate the number of grams of HCl that can react with 0.500 g of $Al(OH)_3$.
(c) Calculate the number of grams of $AlCl_3$ and the number of grams of H_2O formed when 0.500 g of $Al(OH)_3$ reacts.
(d) Show that your calculations in parts (b) and (c) are consistent with the law of conservation of mass.

3.64 An iron ore sample contains Fe_2O_3 together with other substances. Reaction of the ore with CO produces iron metal:

$$Fe_2O_3(s) + CO(g) \longrightarrow Fe(s) + CO_2(g)$$

(a) Balance this equation.
(b) Calculate the number of grams of CO that can react with 0.350 kg of Fe_2O_3.
(c) Calculate the number of grams of Fe and the number of grams of CO_2 formed when 0.350 kg of Fe_2O_3 reacts.
(d) Show that your calculations in parts (b) and (c) are consistent with the law of conservation of mass.

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?

3.66 Calcium hydride reacts with water to form calcium hydroxide and hydrogen gas. (a) Write a balanced chemical equation for the reaction. (b) How many grams of calcium hydride are needed to form 4.500 g of hydrogen?

3.67 Automotive air bags inflate when sodium azide, NaN_3, rapidly decomposes to its component elements:

$$2\,NaN_3(s) \longrightarrow 2\,Na(s) + 3\,N_2(g)$$

(a) How many moles of N_2 are produced by the decomposition of 1.50 mol of NaN_3?
(b) How many grams of NaN_3 are required to form 10.0 g of nitrogen gas?
(c) How many grams of NaN_3 are required to produce 10.0 ft^3 of nitrogen gas, about the size of an automotive air bag, if the gas has a density of 1.25 g/L?

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

3.69 A piece of aluminum foil 1.00 cm square and 0.550 mm thick is allowed to react with bromine to form aluminum bromide.

(a) How many moles of aluminum were used? (The density of aluminum is 2.699 g/cm^3.) (b) How many grams of aluminum bromide form, assuming the aluminum reacts completely?

3.70 Detonation of nitroglycerin proceeds as follows:

$$4\,C_3H_5N_3O_9(l) \longrightarrow 12\,CO_2(g) + 6\,N_2(g) + O_2(g) + 10\,H_2O(g)$$

(a) If a sample containing 2.00 mL of nitroglycerin (density = 1.592 g/mL) is detonated, how many total moles of gas are produced? (b) If each mole of gas occupies 55 L under the conditions of the explosion, how many liters of gas are produced? (c) How many grams of N_2 are produced in the detonation?

LIMITING REACTANTS (section 3.7)

3.71 (a) Define the terms *limiting reactant* and *excess reactant*. (b) Why are the amounts of products formed in a reaction determined only by the amount of the limiting reactant? (c) Why should you base your choice of which compound is the limiting reactant on its number of initial moles, not on its initial mass in grams?

3.72 (a) Define the terms *theoretical yield*, *actual yield*, and *percent yield*. (b) Why is the actual yield in a reaction almost always less than the theoretical yield? (c) Can a reaction ever have 110% actual yield?

3.73 A manufacturer of bicycles has 4815 wheels, 2305 frames, and 2255 handlebars. (a) How many bicycles can be manufactured using these parts? (b) How many parts of each kind are left over? (c) Which part limits the production of bicycles?

3.74 A bottling plant has 126,515 bottles with a capacity of 355 mL, 108,500 caps, and 48,775 L of beverage. (a) How many bottles can be filled and capped? (b) How much of each item is left over? (c) Which component limits the production?

3.75 Sodium hydroxide reacts with carbon dioxide as follows:

$$2\,NaOH(s) + CO_2(g) \longrightarrow Na_2CO_3(s) + H_2O(l)$$

Which is the limiting reactant when 1.85 mol NaOH and 1.00 mol CO_2 are allowed to react? How many moles of Na_2CO_3 can be produced? How many moles of the excess reactant remain after the completion of the reaction?

3.76 Aluminum hydroxide reacts with sulfuric acid as follows:

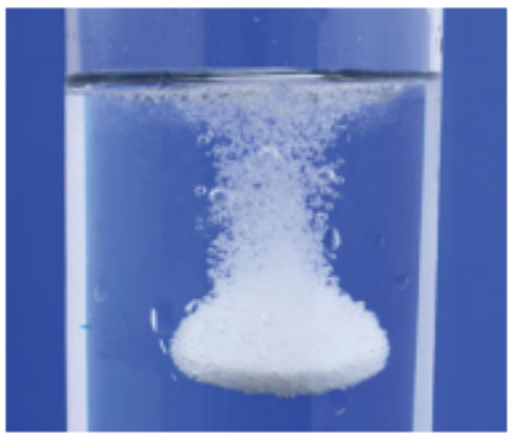
$$2\,Al(OH)_3(s) + 3\,H_2SO_4(aq) \longrightarrow Al_2(SO_4)_3(aq) + 6\,H_2O(l)$$

Which is the limiting reactant when 0.500 mol $Al(OH)_3$ and 0.500 mol H_2SO_4 are allowed to react? How many moles of $Al_2(SO_4)_3$ can form under these conditions? How many moles of the excess reactant remain after the completion of the reaction?

3.77 The fizz produced when an Alka-Seltzer® tablet is dissolved in water is due to the reaction between sodium bicarbonate ($NaHCO_3$) and citric acid ($H_3C_6H_5O_7$):

$$3\,NaHCO_3(aq) + H_3C_6H_5O_7(aq) \longrightarrow 3\,CO_2(g) + 3\,H_2O(l) + Na_3C_6H_5O_7(aq)$$

In a certain experiment 1.00 g of sodium bicarbonate and 1.00 g of citric acid are allowed to react. **(a)** Which is the limiting reactant? **(b)** How many grams of carbon dioxide form? **(c)** How many grams of the excess reactant remain after the limiting reactant is completely consumed?



3.78 One of the steps in the commercial process for converting ammonia to nitric acid is the conversion of NH_3 to NO:

$$4\,NH_3(g) + 5\,O_2(g) \longrightarrow 4\,NO(g) + 6\,H_2O(g)$$

In a certain experiment, 2.00 g of NH_3 reacts with 2.50 g of O_2 **(a)** Which is the limiting reactant? **(b)** How many grams of NO and of H_2O form? **(c)** How many grams of the excess reactant remain after the limiting reactant is completely consumed? **(d)** Show that your calculations in parts (b) and (c) are consistent with the law of conservation of mass.

3.79 Solutions of sodium carbonate and silver nitrate react to form solid silver carbonate and a solution of sodium nitrate. A solution containing 3.50 g of sodium carbonate is mixed with one containing 5.00 g of silver nitrate. How many grams of sodium carbonate, silver nitrate, silver carbonate, and sodium nitrate are present after the reaction is complete?

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.

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?

3.82 When ethane (C_2H_6) reacts with chlorine (Cl_2), the main product is C_2H_5Cl, but other products containing Cl, such as $C_2H_4Cl_2$, are also obtained in small quantities. The formation of these other products reduces the yield of C_2H_5Cl. **(a)** Calculate the theoretical yield of C_2H_5Cl when 125 g of C_2H_6 reacts with 255 g of Cl_2, assuming that C_2H_6 and Cl_2 react only to form C_2H_2Cl and HCl. **(b)** Calculate the percent yield of C_2H_5Cl if the reaction produces 206 g of C_2H_5Cl.

3.83 Hydrogen sulfide is an impurity in natural gas that must be removed. One common removal method is called the Claus process, which relies on the reaction:

$$8\,H_2S(g) + 4\,O_2(g) \longrightarrow S_8(l) + 8\,H_2O(g)$$

Under optimal conditions the Claus process gives 98% yield of S_8 from H_2S. If you started with 30.0 grams of H_2S and 50.0 grams of O_2, how many grams of S_8 would be produced, assuming 98% yield?

3.84 When hydrogen sulfide gas is bubbled into a solution of sodium hydroxide, the reaction forms sodium sulfide and water. How many grams of sodium sulfide are formed if 1.25 g of hydrogen sulfide is bubbled into a solution containing 2.00 g of sodium hydroxide, assuming that the sodium sulfide is made in 92.0% yield?

ADDITIONAL EXERCISES

3.85 Write the balanced chemical equations for **(a)** the complete combustion of acetic acid (CH_3COOH), the main active ingredient in vinegar; **(b)** the decomposition of solid calcium hydroxide into solid calcium(II) oxide (lime) and water vapor; **(c)** the combination reaction between nickel metal and chlorine gas.

3.86 If 1.5 mol C_2H_5OH, 1.5 mol C_3H_8, and 1.5 mol $CH_3CH_2COCH_3$ are completely combusted in oxygen, which produces the largest number of moles of H_2O? Which produces the least? Explain.

3.87 The effectiveness of nitrogen fertilizers depends on both their ability to deliver nitrogen to plants and the amount of nitrogen they can deliver. Four common nitrogen-containing fertilizers are ammonia, ammonium nitrate, ammonium sulfate, and urea [$(NH_2)_2CO$]. Rank these fertilizers in terms of the mass percentage nitrogen they contain.

3.88 **(a)** The molecular formula of acetylsalicylic acid (aspirin), one of the most common pain relievers, is $C_9H_8O_4$. How many moles of $C_9H_8O_4$ are in a 0.500-g tablet of aspirin? **(b)** How many molecules of $C_9H_8O_4$ are in this tablet? **(c)** How many carbon atoms are in the tablet?

3.89 Very small crystals composed of 1000 to 100,000 atoms, called quantum dots, are being investigated for use in electronic devices.

(a) A quantum dot was made of solid silicon in the shape of a sphere, with a diameter of 4 nm. Calculate the mass of the quantum dot, using the density of silicon (2.3 g/cm^3).

(b) How many silicon atoms are in the quantum dot?

(c) The density of germanium is 5.325 g/cm^3. If you made a 4-nm quantum dot of germanium, how many Ge atoms would it contain? Assume the dot is spherical.

3.90 **(a)** One molecule of the antibiotic penicillin G has a mass of 5.342×10^{-21} g. What is the molar mass of penicillin G? **(b)** Hemoglobin, the oxygen-carrying protein in red blood cells, has four iron atoms per molecule and contains 0.340% iron by mass. Calculate the molar mass of hemoglobin.