CONCEPTS TO REMEMBER

Chemistry. Chemistry is the field of study that is concerned with the characteristics, composition, and transformations of matter (Section 1.1).

Matter. Matter, the substances of the physical universe, is anything that has mass and occupies space. Matter exists in three physical states: solid, liquid, and gas (Section 1.2).

Properties of matter. Properties, the distinguishing characteristics of a substance that are used in its identification and description, are of two types: physical and chemical. Physical properties are properties that can be observed without changing a substance into another substance. Chemical properties are properties that matter exhibits as it undergoes or resists changes in chemical composition. The failure of a substance to undergo change in the presence of another substance is considered a chemical property (Section 1.3).

Changes in matter. Changes that can occur in matter are classified into two types: physical and chemical. A physical change is a process that does not alter the basic nature (chemical composition) of the substance under consideration. No new substances are ever formed as a result of a physical change. A chemical change is a process that involves a change in the basic nature (chemical composition) of the substance. Such changes always involve conversion of the material or materials under consideration into one or more new substances that have properties and composition distinctly different from those of the original materials (Section 1.4).

Pure substances and mixtures. All specimens of matter are either pure substances or mixtures. A pure substance is a form of matter that has a definite and constant composition. A mixture is a physical combination of two or more pure substances in which the pure substances retain their identity (Section 1.5).

Types of mixtures. Mixtures can be classified as heterogeneous or homogeneous on the basis of the visual recognition of the components present. A heterogeneous mixture contains visibly different parts or phases, each of which has different properties. A homogeneous mixture contains only one phase, which has uniform properties throughout (Section 1.5).

Types of pure substances. A pure substance can be classified as either an element or a compound on the basis of whether it can be broken down into two or more simpler substances by chemical means. Elements cannot be broken down into simpler substances. Compounds yield two or more simpler substances when broken down. There are 117 pure substances that qualify as elements. There are millions of compounds (Section 1.6).

Chemical symbols. Chemical symbols are a shorthand notation for the names of the elements. Most consist of two letters; a few involve a single letter. The first letter of a chemical symbol is always capitalized, and the second letter is always lowercase (Section 1.8).

Atoms and molecules. An atom is the smallest particle of an element that can exist and still have the properties of the element. Free isolated atoms are rarely encountered in nature. Instead, atoms are almost always found together in aggregates or clusters. A molecule is a group of two or more atoms that functions as a unit because the atoms are tightly bound together (Section 1.9).

Types of molecules. Molecules are of two types: homoatomic and heteroatomic. Homoatomic molecules are molecules in which all atoms present are of the same kind. A pure substance containing homoatomic molecules is an element. Heteroatomic molecules are molecules in which two or more different kinds of atoms are present. Pure substances that contain heteroatomic molecules must be compounds (Section 1.9).

Chemical formulas. Chemical formulas are used to specify compound composition in a concise manner. They consist of the symbols of the elements present in the compound and numerical subscripts (located to the right of each symbol) that indicate the number of atoms of each element present in a molecule of the compound (Section 1.10).

EXERCISES *and* PROBLEMS

The members of each pair of problems in this section test similar material.

Chemistry: The Study of Matter (Section 1.1)

1.1 What are the two general characteristics that all types of matter possess?

1.2 What are the three aspects of matter that are of particular interest to chemists?

1.3 Classify each of the following as matter or energy (nonmatter).
a. Air b. Pizza c. Sound
d. Light e. Gold f. Virus

1.4 Classify each of the following as matter or energy (nonmatter).
a. Electricity b. Bacteria c. Silver
d. Cake e. Water f. Magnetism

Physical States of Matter (Section 1.2)

1.5 Give a characteristic that distinguishes
a. liquids from solids b. gases from liquids

1.6 Give a characteristic that is the same for
a. liquids and solids b. gases and liquids

1.7 Indicate whether each of the following substances does or does not take the shape of its container and also whether it has a definite volume.
a. Copper wire b. Oxygen gas
c. Granulated sugar d. Liquid water

1.8 Indicate whether each of the following substances does or does not take the shape of its container and also whether it has an indefinite volume.
a. Aluminum powder b. Carbon dioxide gas
c. Clean air d. Gasoline

Properties of Matter (Section 1.3)

1.9 The following are properties of the substance magnesium. Classify each property as physical or chemical.
a. Solid at room temperature
b. Ignites upon heating in air
c. Hydrogen gas is produced when it is dissolved in acids
d. Has a density of 1.738 g/cm^3 at 20°C

1.10 The following are properties of the substance magnesium. Clasify each property as physical or chemical.
a. Silvery-white in color
b. Does not react with cold water
c. Melts at 651°C
d. Finely divided form burns in oxygen with a dazzling white flame

1.11 Indicate whether each of the following statements describes a physical or a chemical property.
a. Silver salts discolor the skin by reacting with skin protein.
b. Hemoglobin molecules have a red color.
c. Beryllium metal vapor is extremely toxic to humans.
d. Aspirin tablets can be pulverized with a hammer.

1.12 Indicate whether each of the following statements describes a physical or a chemical property.
a. Diamonds are very hard substances.
b. Gold metal does not react with nitric acid.
c. Lithium metal is light enough to float on water.
d. Mercury is a liquid at room temperature.

Changes in Matter (Section 1.4)

1.13 Classify each of the following changes as physical or chemical.
a. Crushing a dry leaf
b. Hammering a metal into a thin sheet
c. Burning your chemistry textbook
d. Slicing a ham

1.14 Classify each of the following changes as physical or chemical.
a. Evaporation of water from a lake
b. "Scabbing over" of a skin cut
c. Cutting a string into two pieces
d. Melting of some candle wax

1.15 Classify each of the following changes as physical or chemical.
a. A match burns
b. "Rubbing alcohol" evaporates
c. A copper object turns green over time
d. A pan of water boils

1.16 Classify each of the following changes as physical or chemical.
a. A newspaper page turns yellow over time
b. A rubber band breaks
c. A firecracker explodes
d. Dry ice "disappears" over time

1.17 Correctly complete each of the following sentences by placing the word *chemical* or *physical* in the blank.
a. The freezing over of a pond's surface is a _____ process.
b. The crushing of some ice to make ice chips is a _____ procedure.
c. The destruction of a newspaper through burning it is a _____ process.
d. Pulverizing a hard sugar cube using a mallet is a _____ procedure.

1.18 Correctly complete each of the following sentences by placing the word *chemical* or *physical* in the blank.
a. The reflection of light by a shiny metallic object is a _____ process.
b. The heating of a blue powdered material to produce a white glassy-type substance and a gas is a _____ procedure.
c. A burning candle produces light by _____ means.
d. The grating of a piece of cheese is a _____ technique.

Pure Substances and Mixtures (Section 1.5)

1.19 Classify each of the following statements as true or false.
a. All heterogeneous mixtures must contain three or more substances.
b. Pure substances cannot have a variable composition.
c. Substances maintain their identity in a heterogeneous mixture but not in a homogeneous mixture.
d. Pure substances are seldom encountered in the "everyday" world.

1.20 Classify each of the following statements as true or false.
a. All homogeneous mixtures must contain at least two substances.
b. Heterogeneous mixtures, but not homogeneous mixtures, can have a variable composition.
c. Pure substances cannot be separated into other kinds of matter by physical means.
d. The number of known pure substances is less than 100,000.

1.21 Assign each of the following descriptions of matter to one of the following categories: *heterogeneous mixture, homogeneous mixture,* or *pure substance.*
a. Two substances present, two phases present
b. Two substances present, one phase present
c. One substance present, two phases present
d. Three substances present, three phases present

1.22 Assign each of the following descriptions of matter to one of the following categories: *heterogeneous mixture, homogeneous mixture,* or *pure substance.*
a. Three substances present, one phase present
b. One substance present, three phases present
c. One substance present, one phase present
d. Two substances present, three phases present

1.23 Classify each of the following as a *heterogeneous mixture,* a *homogeneous mixture,* or a *pure substance.* Also indicate how many phases are present, assuming all components are present in the same container.
a. Water and dissolved salt
b. Water and sand
c. Water, ice, and oil
d. Carbonated water (soda water) and ice

1.24 Classify each of the following as a *heterogeneous mixture,* a *homogeneous mixture,* or a *pure substance*. Also indicate how many phases are present, assuming all components are present in the same container.
a. Water and dissolved sugar
b. Water and oil
c. Water, wax, and pieces of copper metal
d. Salt water and sugar water

Elements and Compounds (Section 1.6)

1.25 From the information given, classify each of the pure substances A through D as elements or compounds, or indicate that no such classification is possible because of insufficient information.
a. Analysis with an elaborate instrument indicates that substance A contains two elements.
b. Substance B decomposes upon heating.
c. Heating substance C to 1000°C causes no change in it.
d. Heating substance D to 500°C causes it to change from a solid to a liquid.

1.26 From the information given, classify each of the pure substances A through D as elements or compounds, or indicate that no such classification is possible because of insufficient information.
a. Substance A cannot be broken down into simpler substances by chemical means.
b. Substance B cannot be broken down into simpler substances by physical means.
c. Substance C readily dissolves in water.
d. Substance D readily reacts with the element chlorine.

1.27 From the information given in the following equations, classify each of the pure substances A through G as elements or compounds, or indicate that no such classification is possible because of insufficient information.
a. $A + B \rightarrow C$ b. $D \rightarrow E + F + G$

1.28 From the information given in the following equations, classify each of the pure substances A through G as elements or compounds, or indicate that no such classification is possible because of insufficient information.
a. $A \rightarrow B + C$ b. $D + E \rightarrow F + G$

1.29 Indicate whether each of the following statements is true or false.
a. Both elements and compounds are pure substances.
b. A compound results from the physical combination of two or more elements.
c. In order for matter to be heterogeneous, at least two compounds must be present.
d. Compounds, but not elements, can have a variable composition.

1.30 Indicate whether each of the following statements is true or false.
a. Compounds can be separated into their constituent elements by chemical means.
b. Elements can be separated into their constituent compounds by physical means.
c. A compound must contain at least two elements.
d. A compound is a physical mixture of different elements.

Discovery and Abundance of the Elements (Section 1.7)

1.31 Indicate whether each of the following statements about elements is true or false.
a. Elements that do not occur in nature have been produced in a laboratory setting.
b. At present 108 elements are known.
c. Current chemical theory suggests there are more naturally occurring elements yet to be discovered.
d. More laboratory-produced elements exist than naturally occuring elements.

1.32 Indicate whether each of the following statements about elements is true or false.
a. The majority of the known elements have been discovered since 1990.
b. New naturally occuring elements have been identified within the past 10 years.
c. More than 25 laboratory-produced elements are known.
d. All laboratory-produced elements are unstable.

1.33 Indicate whether each of the following statements about elemental abundances is true or false.
a. Silicon is the second most abundant element in Earth's crust.
b. Hydrogen is the most abundant element in the universe but not in Earth's crust.
c. Oxygen and hydrogen are the two most abundant elements in the universe.
d. One element accounts for over one-half of the atoms in Earth's crust.

1.34 Indicate whether each of the following statements about elemental abundances is true or false.
a. Hydrogen is the most abundant element in both Earth's crust and the universe.
b. Oxygen and silicon are the two most abundant elements in the universe.
c. Helium is the second most abundant element in Earth's crust.
d. Two elements account for over three-fourths of the atoms in Earth's crust.

1.35 With the help of Figure 1.10 indicate whether the first listed element in each of the given pairs of elements is more abundant or less abundant in Earth's crust, in terms of atom percent, than the second listed element.
a. Silicon and aluminum b. Calcium and hydrogen
c. Iron and oxygen d. Sodium and potassium

1.36 With the help of Figure 1.10 indicate whether the first listed element in each of the given pairs of elements is more abundant or less abundant in Earth's crust, in terms of atom percent, than the second listed element.
a. Oxygen and hydrogen b. Iron and aluminum
c. Calcium and magnesium d. Copper and sodium

Names and Chemical Symbols of the Elements (Section 1.8)

1.37 Give the name of the element denoted by each of the following chemical symbols.
a. N b. Ni c. Pb d. Sn

1.38 Give the name of the element denoted by each of the following chemical symbols.
a. Li b. He c. F d. Zn

1.39 Give the chemical symbol for each of the following elements.
a. Aluminum b. Neon
c. Hydrogen d. Uranium

1.40 Give the chemical symbol for each of the following elements.
a. Mercury b. Chlorine
c. Gold d. Beryllium

1.41 Write the chemical symbol for each member of the following pairs of elements.
a. Sodium and sulfur b. Magnesium and manganese
c. Calcium and cadmium d. Arsenic and argon

1.42 Write the chemical symbol for each member of the following pairs of elements.
a. Copper and cobalt b. Potassium and phosphorus
c. Iron and iodine d. Silicon and silver

1.43 In which of the following sequences of elements do all the elements have two-letter symbols?
a. Magnesium, nitrogen, phosphorus
b. Bromine, iron, calcium
c. Aluminum, copper, chlorine
d. Boron, barium, beryllium

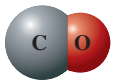
1.44 In which of the following sequences of elements do all the elements have symbols that start with a letter that is *not* the first letter of the element's English name?
a. Silver, gold, mercury
b. Copper, helium, neon
c. Cobalt, chromium, sodium
d. Potassium, iron, lead

Atoms and Molecules (Section 1.9)

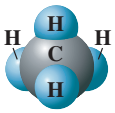
1.45 Classify the substances represented by the following models as *homoatomic* or *heteroatomic* molecules.
a. 

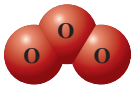
b. 

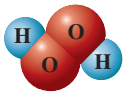
c. 

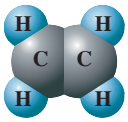
d. 

1.46 Classify the substances represented by the following models as *homoatomic* or *heteroatomic* molecules.

a. 

b. 

c. 

d. 

1.47 Classify the substances represented by the models in Problem 1.45 as to the number of atoms present per molecule, that is, as *diatomic, triatomic, tetraatomic,* etc.

1.48 Classify the substances represented by the models in Problem 1.46 as to the number of atoms present per molecule, that is, as *diatomic, triatomic, tetraatomic,* etc.

1.49 Classify the substances represented by the models in Problem 1.45 as to type of pure substance, that is, as *element* or *compound*.

1.50 Classify the substances represented by the models in Problem 1.46 as to type of pure substance, that is, as *element* or *compound*.

1.51 Indicate whether each of the following statements is true or false. If a statement is false, change it to make it true. (Such a rewriting should involve more than merely converting the statement to the negative of itself.)

a. The atom is the limit of chemical subdivision for both elements and compounds.
b. Triatomic molecules must contain at least two kinds of atoms.
c. A molecule of a compound must be heteroatomic.
d. Only heteroatomic molecules may contain three or more atoms.

1.52 Indicate whether each of the following statements is true or false. If a statement is false, change it to make it true. (Such a rewriting should involve more than merely converting the statement to the negative of itself.)

a. A molecule of an element may be homoatomic or heteroatomic, depending on which element is involved.
b. The limit of chemical subdivision for a compound is a molecule.
c. Heteroatomic molecules do not maintain the properties of their constituent elements.
d. Only one kind of atom may be present in a homoatomic molecule.

1.53 Draw a diagram of each of the following molecules using circular symbols of your choice to represent atoms.

a. A diatomic molecule of a compound
b. A molecule that is triatomic and homoatomic
c. A molecule that is tetraatomic and contains three kinds of atoms
d. A molecule that is triatomic, is symmetrical, and contains two elements

1.54 Draw a diagram of each of the following molecules using circular symbols of your choice to represent atoms.

a. A triatomic molecule of an element
b. A molecule that is diatomic and heteroatomic
c. A molecule that is triatomic and contains three elements
d. A molecule that is triatomic, is not symmetrical, and contains two kinds of atoms

Chemical Formulas (Section 1.10)

1.55 Write chemical formulas for the substances represented by the molecular models given in Problem 1.45.

1.56 Write chemical formulas for the substances represented by the molecular models given in Problem 1.46.

1.57 On the basis of its chemical formula, classify each of the following substances as an element or a compound.

a. $LiClO_3$ b. CO c. Co d. S_8

1.58 On the basis of its chemical formula, classify each of the following substances as an element or a compound.

a. $CoCl_2$ b. $COCl_2$ c. SN d. Sn

1.59 List the element(s) present in each of the substances whose chemical formulas were given in Problem 1.57.

1.60 List the element(s) present in each of the substances whose chemical formulas were given in Problem 1.58.

1.61 Write chemical formulas for compounds in which the combining ratios of atoms are as follows:

a. Table sugar: carbon:hydrogen:oxygen, 12:22:11
b. Caffeine: carbon:hydrogen:nitrogen:oxygen, 8:10:4:2

1.62 Write chemical formulas for compounds in which the combining ratios of atoms are as follows:

a. Vitamin C: carbon:hydrogen:oxygen, 6:8:6
b. Nicotine: carbon:hydrogen:nitrogen, 10:14:2

1.63 Write a chemical formula for each of the following substances based on the information given about a molecule of the substance.

a. A molecule of hydrogen cyanide is triatomic and contains the elements hydrogen, carbon, and nitrogen.
b. A molecule of sulfuric acid is heptaatomic and contains two atoms of hydrogen, one atom of sulfur, and the element oxygen.

1.64 Write a chemical formula for each of the following substances based on the information given about a molecule of the substance.

a. A molecule of nitrous oxide contains twice as many atoms of nitrogen as of oxygen and is triatomic.
b. A molecule of nitric acid is pentaatomic and contains three atoms of oxygen and the elements hydrogen and nitrogen.

1.65 Write chemical formulas for the following compounds by using the given "verbally transmitted" information.

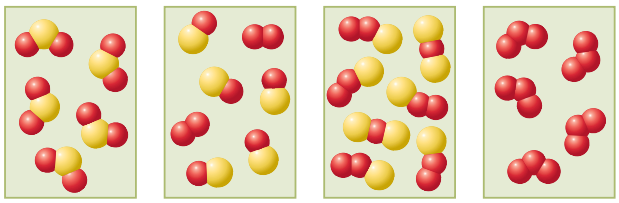
a. BA (pause) CL2
b. H (pause) N (pause) O3
c. NA3 (pause) P (pause) O4
d. MG (pause) OH taken twice

1.66 Write chemical formulas for the following compounds by using the given "verbally transmitted" information.

a. NA (pause) BR
b. H2 (pause) S (pause) O4
c. ZN (pause) CL2
d. FE (pause) CN taken three times

ADDITIONAL PROBLEMS

1.67 In the following diagrams, the different colored spheres represent atoms of different elements.

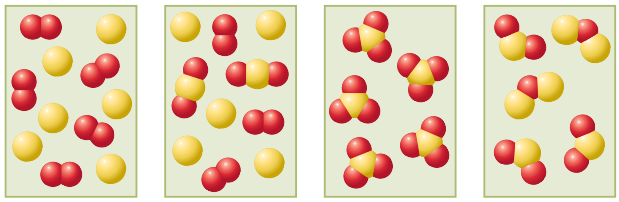


I II III IV

Select the diagram or diagrams that represent each of the listed situations. (Note that there may be more than one correct answer for a given situation and that answers may be used more than once or not at all.)

a. Which diagram(s) represent(s) a compound whose molecules are triatomic?
b. Which diagram(s) represent(s) a mixture of two compounds?
c. Which diagram(s) represent(s) a mixture that contains two different types of diatomic molecules?
d. Which diagram(s) represent(s) a pure substance?

1.68 In the following diagrams, different colored spheres represent atoms of different elements.



I II III IV

Select the diagram or diagrams that represent each of the listed situations. (Note that there may be more than one correct answer for a given situation and that answers may be used more than once or not at all.)

a. Which diagram(s) represent(s) a compound whose molecules are tetraatomic?
b. Which diagram(s) represent(s) a mixture of two substances?
c. Which diagram(s) represent(s) a mixture of two elements?
d. Which diagram(s) represent(s) a pure substance?

1.69 Assign each of the following descriptions of matter to one of the following categories: *element, compound,* or *mixture*.

a. One substance present, one phase present, substance cannot be decomposed by chemical means
b. One substance present, three elements present
c. Two substances present, two phases present
d. Two elements present, composition is definite and constant

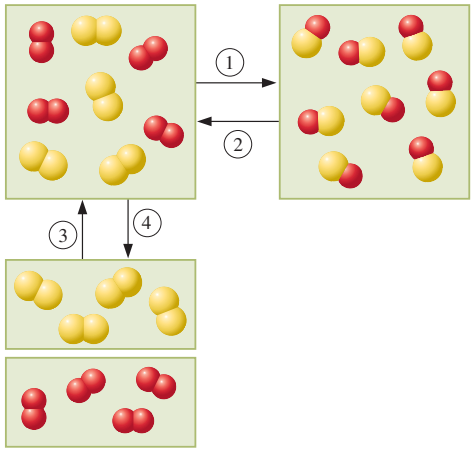
1.70 Indicate whether each of the following samples of matter is a *heterogeneous mixture,* a *homogeneous mixture,* a *compound,* or an *element.*

a. A colorless gas, only part of which reacts with hot iron
b. A "cloudy" liquid that separates into two layers upon standing for two hours
c. A green solid, all of which melts at the same temperature to produce a liquid that decomposes upon further heating
d. A colorless gas that cannot be separated into simpler substances using physical means and that reacts with copper to produce both a copper-nitrogen compound and a copper-oxygen compound

1.71 Assign each of the following descriptions of matter to one of the following categories: *element, compound,* or *mixture*.

a. One substance present, one phase present, one kind of homoatomic molecule present
b. Two substances present, two phases present, all molecules are heteroatomic
c. One phase present, two kinds of homoatomic molecules present
d. One phase present, all molecules are triatomic, all molecules are heteroatomic, all molecules are identical

1.72 In the following diagram, the different colored spheres represent atoms of different elements. Four changes, denoted by the four numbered arrows, are shown.



Select the change, by listing the arrow number, that represents each of the listed situations. (Note that there may be more than one correct answer for a given situation and that answers may be used more than once or not at all.)

a. Which change(s) is a (are) physical change(s)?
b. Which change(s) is a (are) chemical change(s)?
c. Which change(s) is a (are) change(s) in which a compound is decomposed into its constituent elements?
d. Which change(s) is a (are) change(s) in which two elements combine to form a compound?

1.73 Certain words can be viewed whimsically as sequential combinations of symbols of elements. For example, the given name Stephen is made up of the following sequence of chemical symbols: S-Te-P-He-N. Analyze each of the following given names in a similar manner.

a. Barbara
b. Eugene
c. Heather
d. Allan

1.74 In each of the following pairs of chemical formulas, indicate whether the first chemical formula listed denotes *more total atoms, the same number of total atoms,* or *fewer total atoms* than the second chemical formula listed.

a. HN_3 and NH_3
b. $CaSO_4$ and $Mg(OH)_2$
c. $NaClO_3$ and $Be(CN)_2$
d. $Be_3(PO_4)_2$ and $Mg(C_2H_3O_2)_2$

1.75 On the basis of the given information, determine the numerical value of the subscript x in each of the following chemical formulas.
a. BaS_2O_x: formula unit contains 6 atoms
b. $Al_2(SO_x)_3$; formula unit contains 17 atoms
c. SO_xCl_x; formula unit contains 5 atoms
d. $C_xH_{2x}Cl_x$; formula unit contains 8 atoms

1.76 A mixture contains the following five pure substances: N_2, N_2H_4, NH_3, CH_4, and CH_3Cl.
a. How many different kinds of molecules that contain four or fewer atoms are present in the mixture?
b. How many different kinds of atoms are present in the mixture?
c. How many total atoms are present in a mixture sample containing five molecules of each component?
d. How many total hydrogen atoms are present in a mixture sample containing four molecules of each component?

Multiple-Choice Practice Test

1.77 Which of the following is a property of *both* liquids and solids?
a. Definite shape
b. Definite volume
c. Indefinite shape
d. Indefinite volume

1.78 In which of the following pairs of properties are both of the properties *physical* properties?
a. Freezes at 10°C, red in color
b. Decomposes at 75°C, reacts with oxygen
c. Good conductor of electricity, flammable
d. Has a low density, nonflammable

1.79 Which of the following is *always* a characteristic of a *chemical change*?
a. Heat is absorbed.
b. Light is emitted.
c. One or more new substances are produced.
d. A change of state occurs.

1.80 Which of the following statements is *incorrect*?
a. Some, but not all, pure substances contain homoatomic molecules.
b. Some, but not all, pure substances contain heteroatomic molecules.
c. Some, but not all, compounds are pure substances.
d. Some, but not all, compounds contain three or more elements.

1.81 A pure substance A is found to change upon heating into two new pure substances B and C. Substance B, but not substance C, undergoes reaction with oxygen. Based on this information we definitely know that
a. A is a compound and C is an element.
b. Both A and B are compounds.
c. B is a compound and C is an element.
d. A is a compound.

1.82 In which of the following listings of elements do each of the elements have a two-letter chemical symbol?
a. Tin, nitrogen, zinc
b. Potassium, fluorine, carbon
c. Lead, hydrogen, iodine
d. Magnesium, silicon, chlorine

1.83 Which of the following statements concerning elemental abundances is *incorrect*?
a. One element accounts for over one-half of all atoms present in Earth's crust.
b. Two elements account for over three-fourths of all atoms present in Earth's crust.
c. Elemental abundances in Earth's crust closely parallel elemental abundances in the universe as a whole.
d. Hydrogen is the most abundant type of atom in the universe as a whole.

1.84 Which of the following pairings of terms is *incorrect*?
a. Element—a single type of atom
b. Pure substance—variable composition
c. Heterogeneous mixture—two or more regions with different properties
d. Compound—two or more elements present

1.85 Which of the following classifications of matter could *not* contain molecules that are both heteroatomic and diatomic?
a. Heterogeneous mixture
b. Homogeneous mixture
c. Compound
d. Element

1.86 In which of the following pairs of chemical formulas do the two members of the pair contain the same number of atoms per molecule?
a. NaSCN and H_2CO_3
b. $CoCl_2$ and $COCl_2$
c. H_3N and HN_3
d. $Mg(OH)_2$ and SO_3