



Complete Solutions

CHAPTER

1

What Is Chemistry?

- 1.1** See solution in textbook.
- 1.2** Milk is a heterogeneous mixture. If you could use a microscopic spoon to take samples from different locations in a container of milk, the spoon would pick up fat globules from some locations and watery liquid from other locations.
- 1.3** Fog is a heterogeneous mixture. A microscopic spoon used to take samples would pick up water in some spots and air in others.
- 1.4** See solution in textbook.
- 1.5** (d) and (e) are compounds. (a) is an elemental substance, (b) is a heterogeneous mixture, and (c) is a homogeneous mixture.
- 1.6** True. All compounds are pure substances, but a pure substance can also be an elemental substance. Example: O₂, N₂, and Fe are pure substances but are not compounds (they are elemental substances).
- 1.7** See solution in textbook.
- 1.8** (c) This change in state is an example of freezing (also called solidification), when a liquid changes to a solid.
- 1.9** False. It is ethanol in the gas state but still ethanol. Changes in state do not cause chemical change.
- 1.10** Heat the metal until it just begins to melt. Then measure the temperature of the liquid to see if it is the same as the melting point of gold. Melting point is a characteristic property of pure substances and therefore can be used to determine the identity of a substance.
- 1.11** See solution in textbook.
- 1.12** Methane and oxygen are the reactants; water and carbon dioxide are the products.
- 1.13** (b) Both products contain hydrogen, H, an element not present in either reactant.
- 1.14** See solution in textbook.
- 1.15** A law summarizes experimental data and states an experimentally proved relationship between natural phenomena.
- 1.16** If the theory is used to predict the results of proposed experiments and then the data from those experiments agree with the prediction, this is good evidence the theory is correct.

- 1.17** Science is the experimental investigation and explanation of natural phenomena. Technology is the application of scientific knowledge. Here, the discovery of electromagnetic induction is an example of science and the use of magnets to produce electricity is an example of technology.
- 1.18** Chemistry is the study of matter and the transformations it undergoes.
- 1.19** Numerous answers possible. Example: insecticides were developed in chemical laboratories to help control agricultural pests (positive result), but they pollute lakes and streams (negative result).
- 1.20** Numerous answers possible. One is that the chemical industry may be reluctant to fund basic research because of the possibility there will be no immediate financial profit from the work.
- 1.21** Numerous answers possible.
- 1.22** Matter is anything that has mass and occupies space.
- 1.23** Yes, because every compound is a pure substance and a mixture is defined as two or more pure substances intermingled. Example: salt water is a mixture of the two compounds NaCl and H₂O.
- 1.24** A solution is a *homogeneous* mixture—its composition is uniform throughout, but not every mixture is a solution. A *heterogeneous* mixture is not uniform throughout and its components can be told apart.
- 1.25** It is a heterogeneous mixture. A microscopic spoon would be able to extract either flour or sugar, depending on where in the mixture the spoon was placed. No amount of mechanical grinding of two solids can ever produce a solution (which, remember, is just another name for a homogeneous mixture).
- 1.26** (a) It is a heterogeneous mixture, as in Problem 1.25.
(b) It is a solution. Once the mixture becomes liquid (molten), the composition is uniform throughout because the Cu and Zn atoms mix completely.
(c) It is a solution. When the liquid freezes, all the Cu and Zn atoms are still completely intermingled and the composition is the same throughout the solid.
- 1.27** Air (assuming it is free of all the pollution particles!) is a solution because the atoms and molecules of which it is composed are evenly dispersed throughout, resulting in a uniform composition throughout.
- 1.28** An element is a pure substance and one of the basic building blocks of matter. There are 118 known elements today, but several more are predicted to exist.
- 1.29** Na comes from *natrium*, the Latin word meaning “sodium,” and Fe comes from *ferrum*, the Latin word meaning “iron.” With only 26 letters in the English alphabet and 118 known elements, there are not enough letters for each element to have a one-letter symbol. Some names and symbols of atoms may be also influenced by other foreign languages (e.g., Ag from Greek *argentum*), names of scientists (e.g., Rf for Ernest *Rutherford*) or a country (e.g., Po for *Pologne–Poland* in French).
- 1.30** The smallest possible piece of an element is an atom. There are a few elemental substances whose smallest unit is a diatomic (two-atom) molecule. You should memorize all the diatomic elemental substances. They are hydrogen, H₂, nitrogen, N₂, oxygen, O₂, fluorine, F₂, chlorine, Cl₂, bromine, Br₂, and iodine, I₂.
- 1.31** Lead, Pb; molybdenum, Mo; tungsten, W; chromium, Cr; mercury, Hg.
- 1.32** Sulfur, S; chlorine, Cl; phosphorus, P; magnesium, Mg; manganese, Mn.
- 1.33** Ti, titanium; Zn, zinc; Sn, tin; He, helium; Xe, xenon; Li, lithium.
- 1.34** U, uranium; Pu, plutonium; Cs, cesium; Ba, barium; F, fluorine; Si, silicon.

- 1.35** An elemental substance contains only one type of atom, while a compound contains two or more different types of atoms. Here, both S_8 and S_6 are elemental substances, while SO_2 is a compound.
- 1.36** The chemical formula tells how many of each type of atom are present in the smallest possible piece of a pure substance.
- 1.37** Numerous answers possible. Example: the elements hydrogen and oxygen, both gases at room temperature, combine to form the compound water, a liquid at room temperature.
- 1.38** F_2 , P_4 , Ar, and Al are elemental substances because each contains atoms of only one element; $BrCl_3$, C_2H_2 , HCl, and Al_2O_3 are compounds because each contains atoms of more than one element.
- 1.39** Chlorine, Cl_2 , sulfur, S_8 , and neon, Ne, are elemental substances (atoms of only one element); octane, C_8H_{18} , is a compound (atoms of more than one element).
- 1.40** The chemical formula for hydrogen peroxide is H_2O_2 .
- 1.41** The chemical formula for nonane is C_9H_{20} .
- 1.42** The chemical formula for glucose is $C_6H_{12}O_6$.
- 1.43** (a) Knowing the chemical formula N_2 , you can say that the smallest possible piece of nitrogen gas contains two nitrogen atoms.
(b) Nitrogen gas, N_2 , is not a compound. It is an elemental substance because it contains only one type of atom, N.
- 1.44** The three most common states of matter are solid, liquid, and gas.
- 1.45** Sublimation is the process whereby matter changes directly from the solid state to the gas state.
- 1.46** Condensation (gas state to liquid state) is the opposite of evaporation (liquid state to gas state).
- 1.47** The propane would be a gas, and the hexane would be a liquid.
- 1.48** The melting point is $-114.3\text{ }^\circ\text{C}$ because melting point and freezing point are the same temperature.
- 1.49** Sublimation is occurring. The compound the mothballs are made of is going directly from the solid state to the gas state.
- 1.50** The melting point is $0\text{ }^\circ\text{C}$ or $32\text{ }^\circ\text{F}$, and the boiling point is $100\text{ }^\circ\text{C}$ or $212\text{ }^\circ\text{F}$.
- 1.51** O_2 and O_3 are completely different substances and therefore have completely different physical and chemical properties. When determining chemical and physical properties, the *number* of atoms in a molecule is as important as *which* atoms are present.
- 1.52** Because H_2O and H_2O_2 are different compounds, they have different properties.
- 1.53** (a) Sugar has undergone a chemical change because its chemical composition has been changed. New compounds, CO_2 and H_2O , have been formed.
(b) Condensation: $H_2O(g)$ condenses into $H_2O(l)$.
(c) The fog cannot be due to the condensation of $CO_2(g)$ as the temperature of the window is well above the condensation point of CO_2 of $-78\text{ }^\circ\text{C}$.
- 1.54** The chemical change is the reaction between the wax and oxygen, resulting in the formation of new compounds: CO_2 and H_2O . The physical change takes place when solid wax melts into liquid wax.
- 1.55** Gasoline (C_8H_{18}) reacts with oxygen (O_2) in a car's engine, forming new compounds: $CO_2(g)$ and $H_2O(g)$. When water vapor condenses at the end of the exhaust pipe, it becomes $H_2O(l)$ and drips out.
- 1.56** This is a description of a chemical property because it tells you how white phosphorus behaves when combined with another substance—it forms a new compound, P_4O_{10} .

- 1.57 This is a chemical change because the pure substance Ag is transformed into the different pure substance Ag_2S .
- 1.58 A chemical transformation has taken place because a new compound has been formed. Any compound formed in a chemical transformation usually has properties very different from the properties of the substances from which it was made, and that is certainly the case here.
- 1.59 A law is a statement that summarizes experimental data. A theory is a statement that proposes an explanation of why a law is true.
- 1.60 The scientific method requires that experiments be run to test a theory. A theory becomes unchallengeable when no experimental data, new or otherwise, yield results that are different from those predicted by the theory.
- 1.61 Numerous answers possible. For instance, you may have noticed that some plants thrive in full sun. So, formulate a *prediction* or *hypothesis*, such as “the longer the exposure to sunlight, the faster the plant grows,” then conduct a series of experiments, in which you measure the growth of several plants of the same kind when allowed different number of hours in the sun. Ensure that all other experimental conditions are the same (e.g., type of soil, temperature, moisture). Collect *data* for each exposure time and analyze them. Formulate a *theory* based on the collected data by attempting to explain the results. Then repeat the cycle by selecting a different plant type. If new experiments provide results that do not support your theory, you need to revise or replace the theory. If new data obtained with many more different plant types support your theory, you can attempt to formulate a *law*.
- 1.62 Numerous answers possible. Four factors that might account for the “failure” of the scientific method are human error, faulty experimental equipment, biased scientists who do not accurately report results, and incomplete data.
- 1.63 C, Na, and Hg are elemental substances; NaHCO_3 and CO_2 are compounds.
- 1.64 $\text{C}(s)$, $\text{N}_2(g)$, and $\text{N}_2(l)$, are elemental substances; $\text{H}_2\text{O}(l)$ and $\text{HNO}_3(l)$ are compounds.
- 1.65 (a) Science. (b) Science. (c) Technology. (d) Science. (e) Technology.
- 1.66 Sulfuric acid is the compound. Ozone is an elemental substance, and stainless steel and coffee are mixtures.
- 1.67 This process is a chemical reaction because a new substance is formed.
- 1.68 (a) Mixture. (b) Mixture. (c) Compound. (d) Compound. (e) Elemental substance.
- 1.69 Evaporation.
- 1.70 (a) Sodium. (b) Iron. (c) Cobalt. (d) Tin. (e) Manganese.
- 1.71 (a) Gold. (b) Mercury. (c) Potassium. (d) Phosphorus. (e) Silver.
- 1.72 This is a chemical change because iron, Fe, is transformed into Fe_2O_3 , iron oxide, aka rust.
- 1.73 This is the definition of a scientific law.
- 1.74 The salt and sugar can form homogeneous mixtures with water. Because their particles can never intermingle completely with water, sand and gold form heterogeneous mixtures with water.
- 1.75 The sugar dissolved in water is a liquid that is a mixture, and the melted sugar is a liquid that is a pure substance.
- 1.76 Numerous answers possible. One is alcohol and water.
- 1.77 Numerous answers possible. One is ammonia gas dissolved in water.

- 1.78 The copper and zinc must be melted, mixed to form a homogeneous liquid solution, and then cooled to form brass, a solid solution.
- 1.79 Numerous answers possible. One is oxygen gas dissolved in nitrogen gas, which is a homogeneous mixture because one substance *dissolved* in another forms a *solution*, which is another name for homogeneous mixture.
- 1.80 Sublimation.
- 1.81 A chemical change; a change in color generally indicates that a new substance is formed.
- 1.82 A chemical change; all combustion (explosive combustion in this case) requires oxygen, and there the explosive powder in the dynamite reacted with oxygen from the air.
- 1.83 You could use a magnet to separate the iron filings from the sand.
- 1.84 You could first add water to the mixture, dissolving the salt. Once all the salt was dissolved, you would filter the liquid–sand mixture. The sand would remain on the filter paper, and evaporating the filtered water would leave you with the salt.
- 1.85 This separation cannot be done physically because pure water is a compound and the components of a compound can be separated only by *chemical* means.
- 1.86 N_2 is the only elemental substance in this list.
- 1.87 This is a scientific theory because it offers an explanation (“because they all have a single electron . . .”) for some experimentally observed behavior (that these metals react with water).
- 1.88 The substances to the left of the arrow, $C_6H_{12}O_6$ and O_2 , are the reactants; those to the right of the arrow, CO_2 and H_2O , are products. The equation represents a chemical change because new substances are formed.
- 1.89 The 14-karat gold is the homogeneous mixture made by melting gold and other metals together and then letting the solution solidify.
- 1.90 Fog is the heterogeneous mixture because it is made of numerous components and its composition varies from one place to another in a sample.
- 1.91 True.
- 1.92 Ozone, O_3 , is the elemental substance in this list.
- 1.93 Bronze, which is a solid solution of copper metal and tin metal.
- 1.94 True.
- 1.95 $NaCl$ is the only compound in the list, being made of two types of atoms. Ozone and liquid nitrogen are elemental substances, 18-karat gold is a homogeneous mixture of gold and other metals, and iced tea is a heterogeneous mixture of a tea solution and solid H_2O .
- 1.96 Sample (a) would be considered heterogeneous because the gold and silver atoms are distributed unevenly on an atomic scale.
- 1.97 The hydrogen peroxide (H_2O_2) in beaker (a) is undergoing a chemical change because it is converted into water (H_2O) and oxygen (O_2), both different substances. The water in beaker (b) is undergoing a physical change because it is still water after the change.
- 1.98 Albert must go through more cycles of the scientific method to turn his hypothesis into a theory. He must do even more experiments and collect more data. If his hypothesis holds up after further cycles of the scientific method, he can elevate it to a theory.

- 1.99** A degree Celsius, °C, is larger than a degree Fahrenheit, °F. It is about twice as large because a change of 100 °C represents the same temperature change as a difference of 180 °F. Note that on the Celsius scale the melting point of ice is 0 °C and the boiling point of water is 100 °C (a change of 100 °C). However, on the Fahrenheit scale, the melting point of ice is 32 °F and the boiling point of water is 212 °F (a change of 180 °F).
- 1.100** A 10 °C change would be more noticeable because it represents a greater change in temperature. Recall that a degree Celsius is about twice as large as a degree Fahrenheit.
- 1.101** No. There is also a change in the substances, making this a chemical change.
- 1.102** The melting point is also $-114.3\text{ }^{\circ}\text{C}$ because the melting point of the solid substance is the same as the freezing point of the liquid.

Answers to Concept Questions:

- 1.** (c), **2.** (d), **3.** (a), **4.** (b), **5.** (b), **6.** (b), **7.** (c), **8.** (c), **9.** (c), **10.** (c)