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Chemistry in Our World

Studying chemistry has many practical benefits, from providing us with an understanding of the world around us to helping us make better informed consumer choices. Chemistry is also instrumental in addressing some of society's most pressing environmental concerns, from providing enough energy, food, and water for a growing world, to using resources more sustainably and responding to the challenges of climate change.

In your own life, the moment you start your day, you begin interacting with chemicals. Squeeze a strip of toothpaste onto your toothbrush and a mixture of chemicals (listed on the tube) helps you clean your teeth. As you dress, you cover your body with clothes made of chemicals, including cotton (a carbohydrate), wool (a protein), and/or synthetic fibers (polymers). Your foods are complex mixtures of chemicals—principally proteins, carbohydrates, and fats and oils. When you travel, you're likely to be carried along by energy derived from the hydrocarbons of petroleum. Your smartphone and other electronic devices run on chips of silicon. These and a variety of other chemicals form the sea of physical substances we're immersed in every day. Understanding them, how we use them, and how they affect us and the environment is what this book is about.

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CHAPTER OUTLINE

1.1 The Chemistry in Our Lives 4

How does chemistry affect our lives and benefit society at large?

- Energy
- Cleaning
- Clothing and Polymers
- Food
- Medicines

1.2 Benefits Versus Risks 8

What are the trade-offs between the benefits and risks in our use of everyday chemical substances?

- Three Common Chemicals with Known Benefits and Known Risks
- BPA—A Chemical with Known Benefits but Uncertain Risks

1.3 Resources and Sustainability 10

How can chemistry address environmental concerns?

- Our Limited Resources
- How Chemistry Improves Sustainability

1.4 The Science of Chemistry 12

What do chemists do? What is the scientific method?

- Collaborative Research
- The Scientific Method

1.5 Working with Scientific Units 15

What are scientific units? How do you convert from one set of units to another?

- SI Units and the Metric System
- SI Prefixes as Multipliers
- Converting Units Using Unit Cancellation

1.1 The Chemistry in Our Lives

LEARNING OBJECTIVES

1. **Define** chemistry.
2. **Describe** ways in which chemistry benefits both individuals and society as a whole.

Wherever we are in the world, **chemistry** is part of the picture. In essence, wherever there's matter, whether natural or made by humans, there's chemistry. To study chemistry is to engage in and to understand our material world—the kinds of things we can see, touch, feel, smell, and taste. Chemistry is much more as well. Understanding chemistry helps us turn the raw materials of our world—the components of our earth, water, and air—into useful products. It helps bring to reality the material objects that surround us and that we depend upon, whether as necessities or luxuries.

chemistry The study of matter—its composition, its properties, and the changes it undergoes.

We often start a typical day by turning on a light, showering, dressing, eating, and otherwise caring for ourselves and others. With this routine, we engage the world of chemistry in a multitude of ways. Since one of the goals of this book is to explore the chemistry of everyday things, we'll begin by looking at some of the chemistry involved in our use of energy, cleaning products, clothing, food, and medicine.

Energy

Our modern lives and prosperity depend on the widespread availability of reasonably priced energy. Whenever we turn on a light or plug a device into an electrical outlet,

Applications of chemical knowledge • Figure 1.1

The conversion of raw materials into valuable products often requires chemical knowledge.

a. Petroleum extraction and processing

Sarah Leen/National Geographic/GettyImages

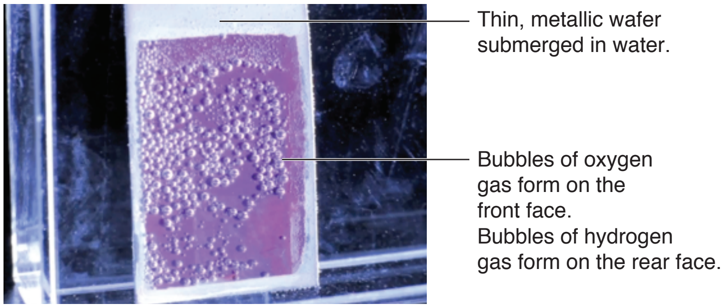
Fred Froese/Photodisc/Getty Images

Petroleum or crude oil—a natural resource—is pumped from the earth's crust and transported to a refinery.

At the refinery, a combination of chemical, physical, and engineering processes separate the components of the petroleum and converts them into:

- fuels for transportation, heating, and the production of electricity,
- feedstocks for the production of plastics, agricultural chemicals, and pharmaceuticals,
- asphalt for paving roads.

b. Energy from sunlight and water



Dan Nocera

Shining light on this "artificial leaf," developed by chemist Dr. Daniel Nocera of Harvard, converts water molecules into oxygen gas and hydrogen gas, a clean-burning fuel. Although still a prototype, this device points to a future in which sunlight and water, abundant natural resources, may be used to produce energy inexpensively and sustainably.

Ask Yourself

How does chemical expertise help turn petroleum (crude oil) into valuable products?

we're tapping into a vast energy network created by power companies. These utilities generate electricity through a variety of methods, but at present chiefly by burning fossil fuels—coal, natural gas, and oil. The energy produced by this combustion helps light our homes and streets, run our manufacturing plants, and keeps our homes, offices, and factories at comfortable temperatures and humidities.

Converting raw petroleum into useful fossil fuels takes chemical and engineering expertise. From the process we derive a host of valuable products (Figure 1.1). The fuels themselves—gasoline and diesel—help transport people and goods to where they need to go every day. Asphalt, another product of petroleum processing, helps pave our roads and highways.

In Chapter 4, we'll learn more about the **physical changes** that crude oil undergoes during its initial purification, a process called **distillation**. We'll also examine the **chemical changes** involved in the **combustion** of petroleum and other fossil fuels.

physical change A transformation of matter that occurs without any change in chemical composition.

chemical change A process that produces substances with new chemical compositions.

Cleaning

Chemistry brings us a variety of products to clean ourselves and the things around us (Figure 1.2a on the next page). Humans probably started using a crude form of soap about 4000 years ago. The active ingredients in soap are types of chemicals called **surfactants**. Chemists incorporate surfactants into various everyday cleansing products, including shampoos, shaving creams, laundry detergents, toothpastes, and even multipurpose contact lens solutions.

surfactant Shortened form of surface-active agent; a chemical that accumulates at a liquid's surface and changes the properties of that surface.

Clothing and Polymers

As we dress each morning, we cover our bodies with clothing made largely of **polymers**. Polymeric textiles include both natural fibers, principally cotton and wool, and synthetic fibers such as polyesters. Through the application of chemistry, synthetic fibers can be prepared with a wide range of properties. Whether the goal is imparting resistance to wrinkles or stains, or designing quick drying or antibacterial fabrics, the odds are that a textile chemist can find a technical solution to the problem at hand. We have workout clothes made from fabrics designed to wick away perspiration, backpacks made of lightweight but highly durable synthetic polymers, and fabrics with colorfast dyes (Figure 1.2b).

polymer A very large molecule formed by the repeated combination of much smaller molecules.

Even beyond the fabrics of clothing and containers, it's impossible to be far from a polymer at any moment. The plastics of our credit cards are polymers, as are cell phone and computer cases, plastic bottles, pens, and vinyl tabletops. Each of these comes from the work of chemistry.

Food

As we've seen, the hydrocarbons of our fuels—coal, natural gas, oil, and substances derived from them—supply the energy that sustains our society. Similarly, the **macronutrients** of our foods—their fats and oils, carbohydrates, and proteins—provide the energy that sustains our lives. These and the related **micronutrients**—the vitamins and minerals of our foods—come to our dining tables with the help of a variety of other natural and synthetic chemicals. These chemicals include fertilizers, herbicides, and pesticides used to grow food on a large scale, and the fuels needed to gather the food and transport it to local stores (Figure 1.2c). Throughout the entire process, food chemists address a variety of issues, including the safety, nutritional content, flavor, and appearance of what we eat.

macronutrients The major components of our foods that provide us with energy and the materials that form our bodies.

micronutrients Dietary substances needed in trace amounts for proper health.

Medicines

Medicines play a defining role in health care: They help cure the sick and enable those with chronic conditions to function normally (Figure 1.2d). Whether we might take a medication daily or only occasionally, we're likely to have first-hand knowledge of the many benefits a medicine can provide. Three classes of medicine that many of us may have benefited from are **analgesics** (pain reducers) and **antipyretics** (fever reducers), such as aspirin and ibuprofen, and **antibiotics** (antibacterial agents), which stem infection and have saved countless lives.

Chemistry InSight

Chemistry we see every day •

Figure 1.2

Chemical knowledge and innovation help bring to life a variety of everyday products, including our cleaning products, clothing, foods, and medicines.

a. Dry cleaning

The term *dry cleaning* is a little misleading; it refers to cleaning without water, but other liquids are used instead. Research chemists are constantly looking for dry-cleaning liquids that will remove dirt and stains from clothing without hurting the fabric, the workers, or the environment

Kim Steele/Photodisc/Getty Images

b. Dyeing and printing textiles

Dyes have a long history; in the Middle Ages, colorful clothing was expensive and hard to obtain except by royalty. Today, chemists have developed dyes used in printers that can produce textiles with an unlimited range of colors and designs that do not fade or wash away.

ROSENFELD IMAGESLTD/SCIENCE PHOTO LIBRARY

c. Agricultural chemistry

Growing large quantities of food often requires adding chemical fertilizer, as well as herbicides and pesticides.

Andrew McLachlan/All CanadaPhotos/Getty Images

d. Developing modern medicine and medical equipment

Administering medication by intravenous therapy involves not only formulating the drug itself but also developing the plastics used in the container and in the valves that allow doctors to regulate the dosage.

TongRo/InMagine

WHAT A CHEMIST SEES

The Chemistry of Cars

When you step into a car, chances are you're not thinking about the polyurethane foam seats or the carbon black in the tires that improves durability, but these and a host of other chemicals are essential to the automobile being what it is today. Chemical know-how helps make cars more fuel efficient and less polluting. It's behind creating the materials that make up cars and the fuels, batteries, and lubricants that keep them running. For example, from petroleum we derive not only gasoline, motor oil, and lubricants, but also polymers—everything from rubber belts, tires, and wiper blades to plastic bumpers and fuel tanks.

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Polymer components are used throughout the car, often replacing traditional materials such as steel, thereby reducing weight and improving fuel efficiency.

In the case of a front-end impact, air bags inflate within fractions of a second due to the rapid production of nitrogen gas from a chemical reaction.

Polymers make up a host of components in the interior— from the polyurethane foam in the seats to the materials that make up the paneling, carpeting, and upholstery. Some of these polymers are eco-plastics, derived from the cellulose of plants.

The windshield is made of safety glass, in which a thin film of the plastic, polyvinyl butyral, is sandwiched between two layers of glass so as to minimize shattering on impact.

Halogen headlights employ a tungsten filament encased in bromine, a halogen gas, and argon or xenon, inert gases.

A lead–acid storage battery uses chemical reactions to create the electricity needed for ignition and lighting. In addition, hybrid cars use a large bank of nickel–metal hydride or lithium batteries to help power the engine.

A catalytic converter, present in the exhaust system, reduces pollution. Within it, metals such as rhodium and platinum help turn unburned fuel and carbon monoxide into less hazardous gases.

The car's finish, a mixture of pigments, binding agents, and sealants, is designed to protect against the elements for years of use.

Conventional and hybrid cars rely on the combustion of the hydrocarbons of gasoline, which produces carbon dioxide and water vapor exhaust along with other trace pollutants.

Ask Yourself

In which parts of the car would you find chemical changes?

Since all medicines are by nature chemical compounds, chemical expertise is essential in developing and manufacturing them. For example, **statins**, a class of drugs used to lower cholesterol, were first developed by a biochemist who isolated these active compounds from certain fungi.

Clearly, whatever common product or process of our everyday lives we might examine, chemistry almost certainly plays a part in its origin, development, and current operation. Consider, for example, one of our most widely used consumer products—cars. The common automobile presents an almost unending story of chemistry behind our use of an everyday object. (See *What a Chemist Sees.*)

CONCEPT CHECK

STOP

1. **How** do we rely on chemistry to help keep our homes warm in the winter and cool in the summer?
2. **What** is a type of chemical that occurs in our (a) clothes; (b) cleaning materials; (c) foods; and (d) medicines?

1.2 Benefits Versus Risks

LEARNING OBJECTIVES

1. **Identify** Paracelsus and state how he distinguished between a poison and a remedy.
2. **Explain** the relationship between the benefits and the risks of the chemicals we take into our bodies as food and as medicine.
3. **Describe** how a synthetic chemical like BPA can enter our bodies from commercial products.

The word **chemical** has a bad reputation. Labeling anything as a "chemical" often generates caution, suspicion, fear, or worse, even though all the material substances in our everyday world—including the food we eat, the water we drink, and the air we breathe—consist of chemicals. Occasionally you will see a statement on a box of cereal or other processed foods assuring you (incorrectly) that the product contains no chemicals. Articles in the media often associate the word **chemical** with other words that give it a sinister aspect—words like **pollutant**, **additive**, or **toxin**. But the reality is far more complex than the simplistic notion that if something is a chemical it must be dangerous.

The reality is that any substance we take into our bodies to provide a benefit also carries with it the risk of harm, even death. This holds true whether the substance we ingest is produced by nature or made by humans and whether we take it as a medicine, a sedative, a stimulant, or as part of our normal food and drink. The answer to the question of which dominates—the benefits it provides or the risks it carries—depends on a variety of factors, including our own sensitivity to the substance, how it enters our bodies, and how much of it we absorb. The importance of this last factor, the dosage, has been recognized for hundreds of years. In the 16th century, a Swiss physician and alchemist known today as Paracelsus recognized that any substance that enters our bodies can harm us as well as benefit us, and that the amount of harm is usually proportional to the quantity. He proclaimed:

> Poison is in everything, and no thing is without poison. The dosage makes it either a poison or a remedy.

Three Common Chemicals with Known Benefits and Known Risks

Today we sum up Paracelsus's statement more simply as, "The poison is in the dosage." Caffeine is a good example. Caffeine occurs naturally in coffee beans, and many of us start our day with a lift from the caffeine in a cup or two of coffee. The caffeine in several cups of coffee provides a jolt to the central nervous system that many of us find pleasant and beneficial. Yet, in large amounts caffeine can be lethal, as studies with mice have shown. If we responded to caffeine as mice do, we would stand a 50% chance of dying if we drank about 70 cups of coffee in one sitting. Of course, drinking that much coffee or at one time would generate other, very urgent problems. In any case, Paracelsus was right: In small amounts caffeine can provide a benefit to many of us; in large amounts it's clearly a risk.

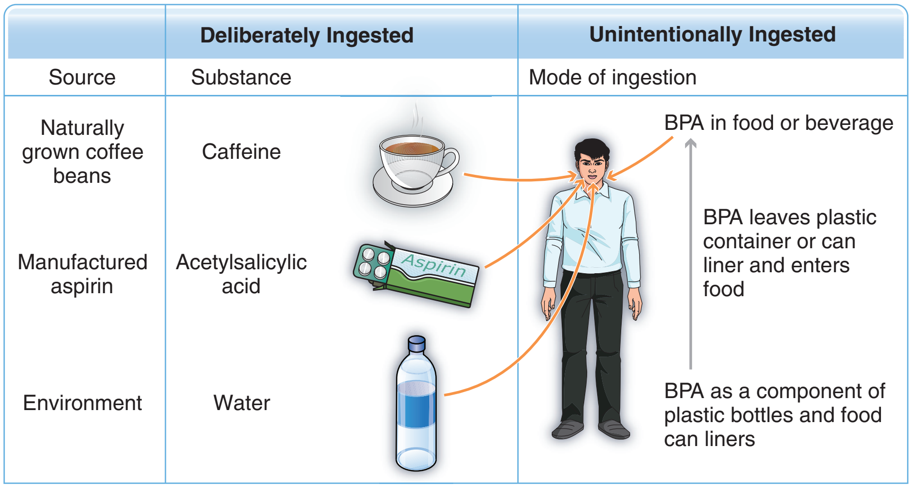
The risk–benefit balance can be more serious with aspirin. Known chemically as **acetylsalicylic acid**, aspirin has become one of our most widely used medications, with an annual worldwide production estimated at 45,000 tons and an annual consumption estimated at about 80 tablets per person. First synthesized in 1853, aspirin became accepted as an effective **analgesic** (pain reliever), **antipyretic** (fever reducer), and anti-inflammatory agent around the beginning of the 20th century. In addition to its capacity for reducing pain, fever, and inflammation, aspirin can inhibit the blood's ability to clot. This characteristic of aspirin provides a measure of protection against heart attacks resulting from internal blood clots. Small daily doses of aspirin are often prescribed to protect susceptible individuals from these kinds of heart attacks.

Aspirin's many benefits also come with associated risks. Its ability to reduce blood's clotting power, a benefit in small doses, becomes a risk with larger doses. Excessive use of aspirin can produce susceptibility to bruising and internal bleeding. Especially in children, large doses of aspirin can kill. The safety caps on bottles of aspirin and other medicines are designed to make it difficult for children to ingest their contents, perhaps mistaking the contents for candy.

Acetylsalicylic acid is a synthetic chemical; caffeine is a natural component of coffee beans. Thus chemicals produced by nature (caffeine) and chemicals manufactured by humans (acetylsalicylic acid) provide us with both risks and benefits. Still another chemical, one essential to our

Ingesting chemical substances • Figure 1.3

A variety of chemicals can enter our bodies through our intake of food and beverages.



Ask Yourself

1. What are some advantages of BPA as a plastics additive?
2. Why might there be concerns about using BPA?

health and life, provides an even more striking example of Paracelsus's proclamation: water, a chemical combination of hydrogen and oxygen.

We must drink water to live. The benefits of drinking water are clear, yet drinking too much water, too intensely, over too short a time, can kill. The damage, known as **water intoxication**, results from a severe disturbance of the electrolyte balance in the body. Deaths have resulted from excessive water drinking in hazing incidents, water-drinking contests and during intensive exercise. Clearly, water is essential to life. Yet Paracelsus was right. Drunk in unreasonably large volumes, even plain water can kill.

BPA—A Chemical with Known Benefits but Uncertain Risks

Today we face types of risk–benefit situations that were unknown to Paracelsus and his contemporaries. Paracelsus was concerned with substances—medicines, for example—that we knowingly take into our bodies to produce certain beneficial effects. We've seen that taking large amounts of some common substances, such as caffeine, aspirin, and even water, over short periods of time can be harmful. But by now we've progressed beyond Paracelsus's idea that "the poison is in the dosage." We recognize that even very small amounts of some substances taken into our bodies over long periods of time may pose risks. The synthetic chemical known as **BPA**, provides an illustration of the subtleties and uncertainties that can be associated with a modern risk analysis.

BPA An abbreviation for bisphenol-A, a chemical added to plastics and resins that improves and strengthens their physical properties.

Early in the 1960s, BPA became an important ingredient in the manufacture of plastics and resins. By 2009, over 3 million tons were being manufactured annually, with a substantial portion used in polycarbonate plastics and epoxy resins. The properties of these two materials make them useful in products designed to contain food and drink, such as water bottles, infant formula bottles, and liners for food cans. Among the benefits provided by the added BPA are an increase in the resistance of the plastic to breaking or shattering and an ability of the resin to remain in contact with food for long periods of time without changing the food's flavor or consistency.

However, the use of BPA has risks as well, principally the risk that it may pass from the container or liner into the stored food or drink and then into our bodies as we eat or drink the contaminated contents. Animal studies indicate that exposure to BPA may present a risk to fetuses and newborns. **Figure 1.3** summarizes the routes by which BPA and other common but potentially hazardous chemicals can enter our bodies. In later chapters, we'll look again at the risks and benefits of chemicals in everyday use when we examine what we mean when we say that a chemical—or anything else—is *safe*.

CONCEPT CHECK STOP

1. **What** is the modern version of Paracelsus's concept of a poison?
2. **What** are the benefits of moderate amounts of (a) caffeine and (b) aspirin? What is the risk in ingesting excessively large amounts of each of these substances over a very short period of time?
3. **What** commercial products contain BPA, and how does BPA enter our bodies from these products?

1.3 Resources and Sustainability

LEARNING OBJECTIVES

1. **Explain** how consumption of resources is growing despite limited availability.
2. **Distinguish** between renewable and nonrenewable resources.
3. **Describe** how chemistry can provide solutions for using resources more sustainably.

In today's world, a combination of advertising and media messages reinforces the notion that the accumulation of material products can contribute to the good life. Consumers living in the more highly developed countries—about a fifth of the world's population—consume well over half the planet's energy and materials and generate about three-quarters of all pollution and waste products. For the United States, consumer spending alone represents over two-thirds of the nation's economy.

The continuing growth of Earth's population, improvements in standards of living, and steadily increasing worldwide consumption all contribute to concerns about expanding environmental pollution and about the sustainability of the world's natural resources. Chemistry plays an important role here.

Our Limited Resources

We can separate all our natural resources into two categories: renewable and nonrenewable. **Renewable resources** include fresh water (restored by rain), trees, food crops, and other things that grow naturally or renew readily. **Nonrenewable resources** can't be restored readily. Prime examples include fossil fuels, principally natural gas, coal, and petroleum. As we consume these nonrenewable resources, their natural supplies within Earth's crust shrink steadily, become more difficult to extract, and can become unavailable to us within the foreseeable future. Beyond this, even our renewable resources are susceptible to abuse and overuse. If we consume them faster than they are restored, we risk their depletion and loss even in the short term. Let's now look at some of the chemistry involved in using our resources wisely.

renewable resources Natural resources that can be renewed or replenished readily by natural processes.

nonrenewable resources Natural resources that are not replenished readily by natural processes and become depleted as they are used.

How Chemistry Improves Sustainability

Given the continuing growth in our consumption and the limitations of our resources, our challenge lies in learning how to use these resources in a sustainable manner. How, for example, do we accommodate increasing worldwide energy needs while simultaneously reducing carbon dioxide emissions that contribute to global warming? One promising approach would be to reduce our reliance on fossil fuels (which generate carbon dioxide as they burn) while simultaneously increasing our efforts toward energy conservation and our use of biologically derived fuels (biofuels) and of solar, wind, geothermal, hydroelectric, nuclear, and other minimally polluting forms of energy.

Chemistry plays a vital role here because of its focus on matter and energy. To help us expand our use of solar energy, for example, chemists are developing new materials for use in solar panels, which convert the energy of sunlight into electricity. The challenge here is to make solar energy more competitive with fossil fuels by making solar power more efficient and less expensive.

Chemists and other scientists are also seeking a cost-effective way to use the energy of sunlight to convert water into its components of hydrogen and oxygen. The hydrogen produced can be used as an energy-rich fuel that generates only water as a by-product when it burns. Many technical hurdles must be overcome to make this idea commercially feasible, but if and when it does come about, chemists will share much of the credit for the success.

In the realm of consumer products—food, toiletries, cosmetics, clothing, electronics, appliances, and cars—people have a growing awareness of sustainability and the environment. Increasingly, many household products offered to us in stores carry statements that they contain "all natural ingredients" or that they are free of "toxic chemicals," or more simply "chemical free" (**Figure 1.4**). One of the important topics we'll address in later chapters is what we mean by the term *chemical*. We'll examine whether any substance can indeed be free of chemicals; whether any chemical can be considered safe or nontoxic; and whether natural products are inherently safe or harmless.

Consumer products • Figure 1.4

Chemists help formulate useful products that serve their purpose without harming either the consumer or the environment.

STEVE WINTER/NationalGeographic Creative

Baby laundry detergent Plant-derived cleaning agents designed to remove stains with no added dyes or fragrances

Dish detergent Made with fruit and vegetable oils to dissolve grease without hurting your hands or leaving residue in the sink

Laundry wash Ingredients derived from plant and vegetable sources produce low suds and toxicity levels

Bleach cleaner Based on oxygen instead of chlorine to avoid harmful environmental waste

Drain opener Uses a combination of enzymes and bacteria instead of harsh lye to dissolve organic wastes

Another growing trend lies in the area of **life-cycle assessment** of consumer goods. Its goal is to reduce the environmental impact of manufacturing and using a product by considering everything from the raw materials and energy required to make and transport the product through its use by consumers to its being discarded or recycled at the end of its useful life (Figure 1.5). Laundry detergents, for example, now commonly come in concentrated form, which reduces packaging and transportation costs. Household paints feature low-VOC (low volatile organic compound) versions, which emit fewer fumes. Life-cycle assessments such as these require the application of chemistry to the design, production, use, and disposal of environmentally friendly consumer products.

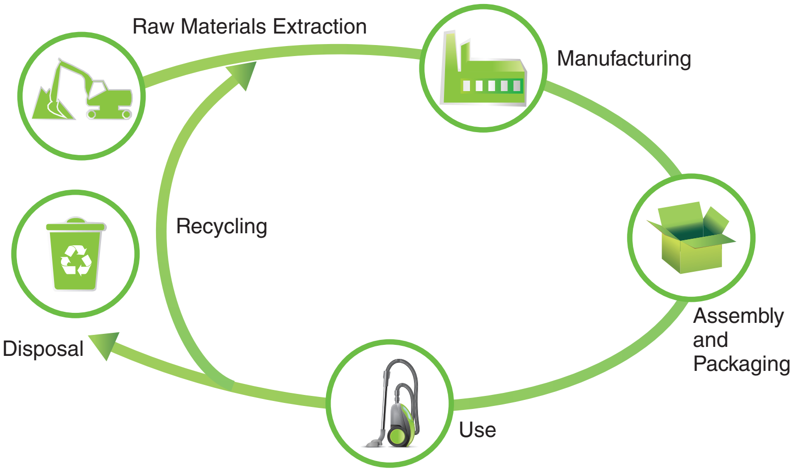
Related to the concept of life-cycle assessment is the growing practice of **green chemistry**, a general set of manufacturing principles aimed at reducing the use and generation of hazardous substances and shifting toward greater use of renewable resources. Not only can green chemistry help protect the environment, but it can be useful economically, as it's often more productive to avoid generating hazardous substances in the first place than to remove them from the environment once they are created. As we progress in our examination of chemistry in the world about us, we'll continue to explore chemistry's important role in addressing sustainability issues.

life-cycle assessment Considering a product's full environmental impact, from the process of obtaining its raw materials to the disposal or recycling of the exhausted product.

green chemistry Chemical practices that aim to conserve resources and reduce the generation of waste and toxic substances.

Life-cycle assessment • Figure 1.5

Each step in the production, packaging, transportation, use, and disposal of a product has some effect on the environment. Sometimes a single step can be so damaging that the entire product needs to be redesigned for overall safety.



CONCEPT CHECK STOP

1. **What** factors account for high levels of consumption of energy and goods on a worldwide basis?
2. **What** are three nonrenewable resources and three renewable resources?
3. **How** does chemistry provide solutions for sustainable energy? Give two examples.

1.4 The Science of Chemistry

LEARNING OBJECTIVES

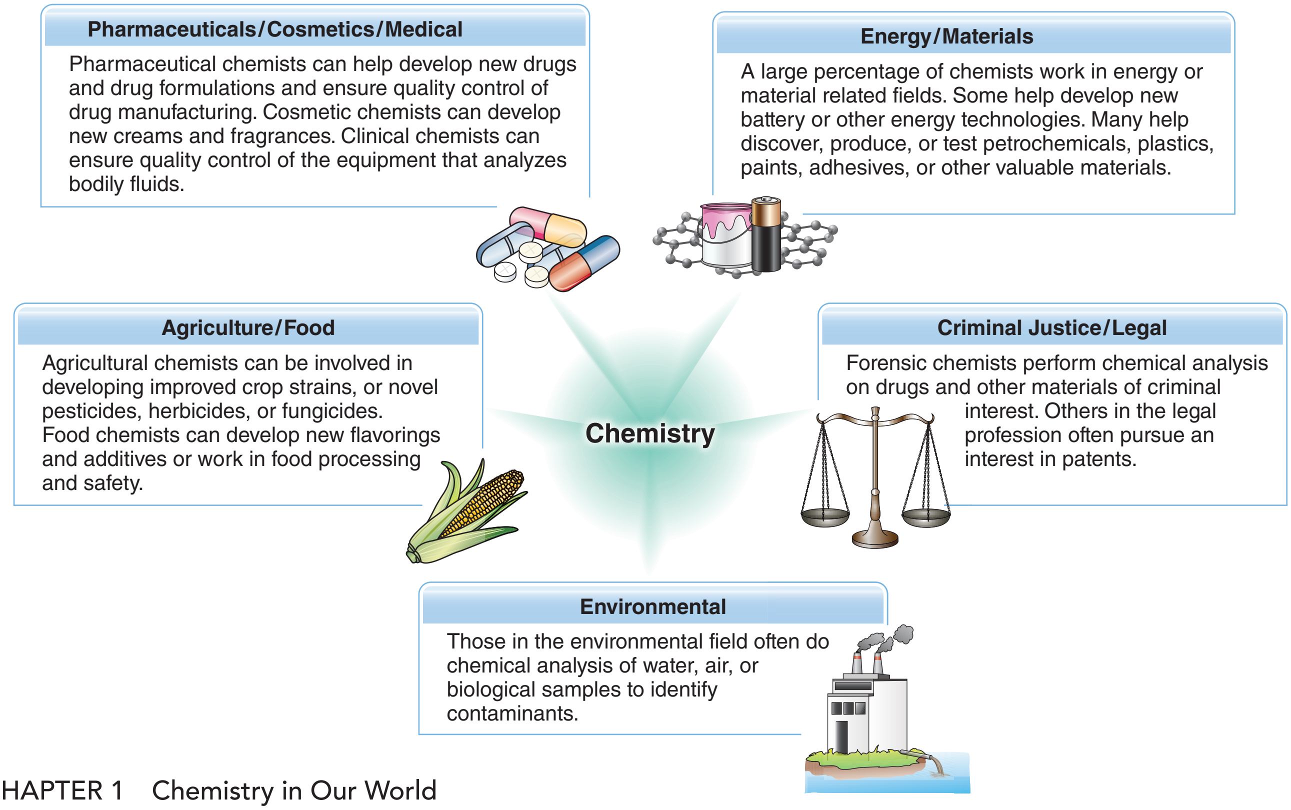
1. **List** the types of jobs chemists perform and the fields in which they work.
2. **Describe** chemistry's role as a central science and the value of collaborative research.
3. **Explain** the general tenets of the scientific method.

The work chemists do is about as varied as the ways their activities affect our everyday lives. Most chemists work in the private or commercial sector; the remainder are in academic or governmental positions. They can spend their time in offices, in laboratories, in manufacturing plants, out in the field, or in any combination of these. They can work alone, in small groups, or in large teams. Their ability to work with others and to communicate can be as important as their technical and scientific skills. Chemists perform a variety of functions including:

- analyzing substances to determine their chemical compositions and properties,
- synthesizing new compounds,
- understanding and controlling chemical processes, and

Representative fields in which chemists work • Figure 1.6

Because chemistry touches on so many aspects of our lives, chemists work in a wide variety of fields, some of which are described here.



Pharmaceuticals/Cosmetics/Medical

Pharmaceutical chemists can help develop new drugs and drug formulations and ensure quality control of drug manufacturing. Cosmetic chemists can develop new creams and fragrances. Clinical chemists can ensure quality control of the equipment that analyzes bodily fluids.

Energy/Materials

A large percentage of chemists work in energy or material related fields. Some help develop new battery or other energy technologies. Many help discover, produce, or test petrochemicals, plastics, paints, adhesives, or other valuable materials.

Agriculture/Food

Agricultural chemists can be involved in developing improved crop strains, or novel pesticides, herbicides, or fungicides. Food chemists can develop new flavorings and additives or work in food processing and safety.

Criminal Justice/Legal

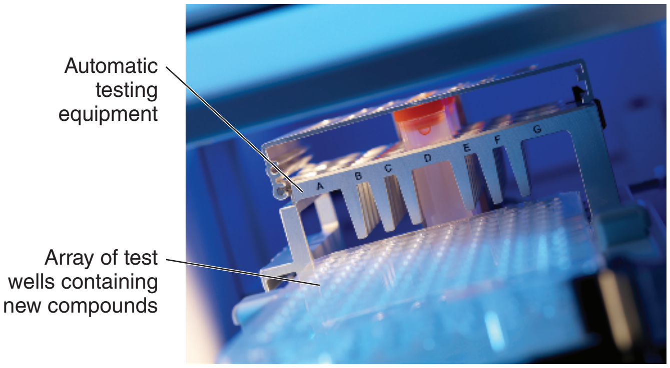
Forensic chemists perform chemical analysis on drugs and other materials of criminal interest. Others in the legal profession often pursue an interest in patents.

Environmental

Those in the environmental field often do chemical analysis of water, air, or biological samples to identify contaminants.

Research and development • Figure 1.7

High-throughput screening technology is used in drug discovery for the rapid evaluation of millions of compounds.



Andrew Brookes, National PhysicalLaboratory/Science Source

- formulating many types of new products, including medicines, cosmetics, foods, cleaning products, agricultural chemicals, and paints.

Figure 1.6 gives us a sense of what they do and how they do it.

Collaborative Research

Because chemistry deals with matter, its transformations, and its interactions with the world around us, chemistry is often called the central science. Much of the creative and productive work done in chemistry results from collaboration with scientists in other fields.

For example, chemists can gain insights from biology and medicine to develop strategies for finding new drugs. Using tools from computer science and robotics, chemists can screen millions of compounds to identify potential drug candidates—a process called **high-throughput screening**. Collaborative teams across the chemical, biological, computer science and engineering fields use this and related tools to aid in drug discovery. This is an example of a broader class of activities called **research and development** (Figure 1.7).

In addition, many scientists perform **basic research**, with the objective of adding to our fundamental knowledge of the universe. A chemist working in collaboration with astronomers, for example, could help identify the composition of other planets or distant stars (Figure 1.8). Although the goal of basic research is to increase our understanding of the world we live in, the insights it provides can help spawn the development of new and useful products and technologies, with important benefits to society. For example, medical imaging devices, such as magnetic resonance imaging (MRI) scanners, were developed

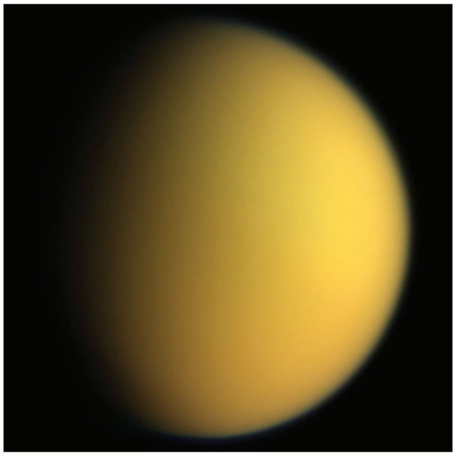
research and development Gathering knowledge with the goal of creating new products or improving existing ones.

basic research Fundamental research that increases our understanding of the world.

Basic research • Figure 1.8

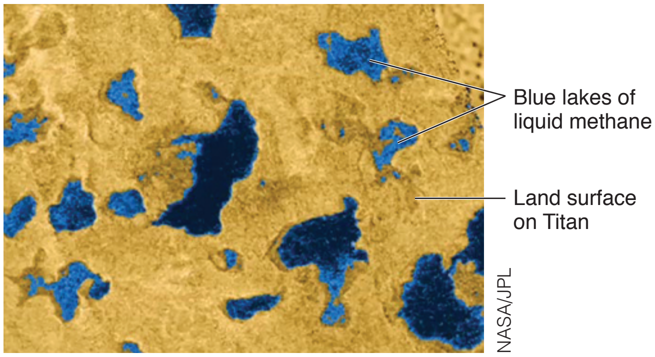
Scientists involved in basic research explore fundamental questions with no specific application in mind. Planetary scientists, for example, may seek to understand the chemical composition of other planets and their moons. As they do, they often use tools of *spectroscopy,* analyzing the light reflected from these celestial objects to determine their compositions.

a. Saturn's moon Titan is the only moon in the solar system with a dense atmosphere.



NASA

b. Chemists and astronomers have studied images of Titan (shown here in false color) and concluded that the dark-blue areas are lakes of liquid methane. This result has led to theories of a weather system on Titan based on methane instead of water, making Titan unique in the solar system.



NASA/JPL

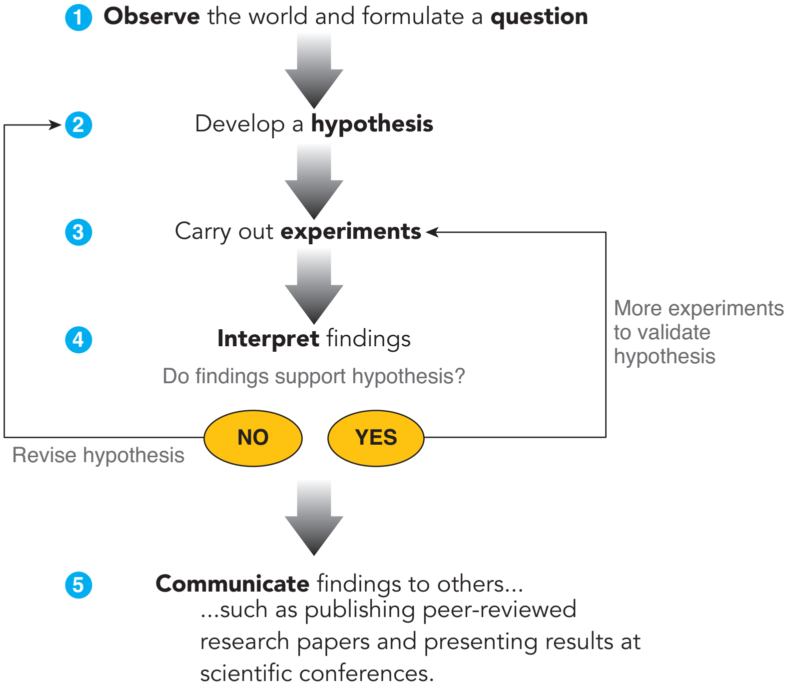
PROCESS DIAGRAM

Common steps in the scientific method • Figure 1.9

In practice, scientists often follow various procedures in carrying out research, such as trying several different hypotheses or experiments before proposing a theory.


Thomas Koehler/Photothek via Getty Images

All of science is ultimately based on observation, asking questions, and experiment.



Think Critically

1. Can a theory be proven to be correct? If *yes*, explain how. If *no*, explain why not.
2. In which steps of the scientific method is observation especially important?

from fundamental discoveries in the fields of physics and chemistry. The field of molecular biology and the development of a host of products to diagnose and treat medical conditions were built on the discovery of the structure of **DNA** (deoxyribonucleic acid) and an understanding of how it functions. The development of new drugs against diseases such as Alzheimer's, cancer, and others will likely benefit from fundamental insights into how protein molecules behave within the body. Funding for basic research is typically supported by government agencies.

The Scientific Method

Science, from the Latin *scire*, "to know," is a way of knowing and understanding the universe we live in. As scientists, chemists operate by a general set of principles known as the **scientific method**. This can take many forms, but it generally involves asking questions about the universe by means of experiments and tests; interpreting the resulting observations and findings; and communicating those results and interpretations to other scientists. The scientific method relies not only on evidence and observations gathered by a single scientist or group of scientists, but also on the validation of results and interpretations by a community of scientists who may accept or challenge them by suggesting alternative experiments or explanations.

scientific method The process by which science operates, involving the development of explanations for observations of the universe.

hypothesis A tentative explanation for a relatively small set of observations.

The scientific method involves the development of a tentative explanation called a **hypothesis**. Scientists perform experiments to test hypotheses. Over time, one or more substantiated, related hypotheses may mature into a **theory**. It is important to note, though, that even a widely accepted theory may have to be modified, revised, or even abandoned as the result of even a single new observation. A scientific theory gains footing not because it is proven per se, but rather because a large set of confirmed observations support it and none can disprove it. **Figure 1.9** describes the common steps in the scientific method.

theory A generally accepted principle based on a large set of confirmed observations.

CONCEPT CHECK

1. **What** is an example of chemical research in each of the five fields shown in Figure 1.6?
2. **Why** is high-throughput screening an example of how chemistry is a central science?
3. **What** are five general steps in the scientific method?

1.5 Working with Scientific Units

LEARNING OBJECTIVES

1. **List** the standard scientific units for distance, mass, and time.
2. **Explain** the use of prefixes in conjunction with scientific units.
3. **Convert** measurements from one unit to another using unit cancellation.

In our everyday lives, we regularly encounter and use units of measure: A speed limit may be so many **miles** per **hour**, referring to units of length and time; computer hard drives are rated in giga or terabytes, referring to units of data storage capacity; soft drinks commonly come in 2-**liter** bottles, referring to volume; and pretzels are often sold in 1-**pound** bags, referring to weight.

Long ago, probably well before the beginning of recorded history, humans started devising units of measure for use in agriculture, trade, and various other activities. Later, as commerce between societies and nations grew, people recognized the need for establishing common units of measurement.

SI Units and the Metric System

In the late 1700s, around the time of the French Revolution, the standardized system of units now used by most of the world—the metric system—was developed. A modern variant of the metric system, known as the International System in English and as the *Système International d'Unités* in French, is now the principal system of units used in science and in international trade and commerce. It is commonly referred to as the SI System, an abbreviation of its French title. Contained within this SI system are a set of **SI base units** for various measured quantities, such as length, mass, and time. The term **mass** is an inherent measure of the amount of matter in a substance. Mass and weight are often used interchangeably in everyday use but actually have different meanings, as we'll discuss in the next chapter.

SI base units Fundamental units of the SI system, such as the meter, kilogram, and second.

A meter extends slightly beyond 3 feet (a yard). For much greater lengths, perhaps the distance between two cities, we use a much larger unit, such as the **kilometer (km)**, which equals 1000 meters (m). Los Angeles, for example, is about 3900 km from New York. If, on the other hand, we were to describe something extremely small, say the width of a period on this page, a smaller unit makes more sense. A period on this page has a diameter of about 2 **millimeters (mm)**, or 2 one-thousandths of a meter.

Time standard • Figure 1.10

The cesium atomic clock at the National Institute of Standards and Technology sets the time standard for the United States. Atoms of the element cesium are suspended in a magnetic field within the vertical tube. A laser system counts the natural vibrations of each atom. Over 9 billion vibrations define a time interval of 1 second.

© 05 Geoffrey Wheeler Photography

One of the great advantages of the SI or the metric system itself is that we can scale a reference unit either larger or smaller by using **SI prefixes** that refer to powers of ten. As we just saw, the prefix **kilo**- effectively multiplies a unit by 1000, while **milli**- divides it by 1000. In comparison, consider the older, English units of length: the inch, foot, yard, and mile. While these may be more familiar to most of us, the fact that 12 inches make a foot, 3 feet make a yard, and 5280 feet make a mile makes such conversions of English units to larger or smaller scales both more difficult and more cumbersome than in the metric system.

SI prefixes Prefixes that scale an SI unit either larger or smaller by some factor of ten.

reference standards Precise quantities upon which SI base units are defined.

The **kilogram (kg)**, the SI base unit of mass, is equivalent to 2.2 pounds (lb). From our everyday experience, this is what a liter of water weighs and is very nearly the weight of a quart of milk. A kilogram, as the name implies, equals 1000 grams (g). A gram, in turn, is just about the weight of a simple, large paper clip. A level teaspoon of sugar weighs roughly 5 g.

We blink, and a second of time passes. But have you ever stopped to wonder how we know exactly how long a second lasts? We could say that a second is 1/60th of a minute, but that's a *relative* answer, based on the length of a minute. It prompts us in turn to define just what a minute is. What we need is an *absolute* definition of a specific unit of time.

A solution does exist to the problem of absolute definitions of specific SI units. It's a solution based on **reference standards**, or definitions established through international bodies. The exact definition for the second is beyond the scope of our studies here, but it's based on properties of a substance called cesium. In the United States, the National Institute of Standards and Technology maintains what's known as a **cesium atomic clock**, a technical device that keeps exceedingly precise time (Figure 1.10). It's predicted to be accurate to within one second as it runs continuously over the next 60 million years! (A **meter**, in turn, is defined as the distance light travels in a vacuum during a well defined, minute fraction of a second.)

In the science of chemistry, as in our daily lives, we're often concerned with the volume of a substance, usually a liquid. In the U.S., for example, we usually buy milk by the quart and gasoline by the gallon. In science and international commerce, commonly used units of volume include the **liter (L)**, which runs just slightly larger than a quart, and the **milliliter (ml)**, which is one-thousandth of a liter. We'll have more to say about SI and other units as we proceed with our examination of chemistry.

SI Prefixes as Multipliers

As we saw earlier with the prefixes kilo- and milli-, the SI or metric system allows us to use prefixes to express larger or smaller variants of a unit easily and conveniently. Other useful prefixes include **giga**-, meaning one billion, **mega**-, one million, **centi**-, one-hundredth, and **micro**-, one-millionth. A microsecond, for example, is one-millionth of a second. Figure 1.11 shows some examples of the use of both SI and English units in everyday life.

Chemistry InSight

Units of measurement in everyday life • Figure 1.11

The SI or metric system uses prefixes, some of which are shown in **Figure a**. Almost all countries have adopted the metric system exclusively, but a few, such as the United States, commonly use both metric and English units.

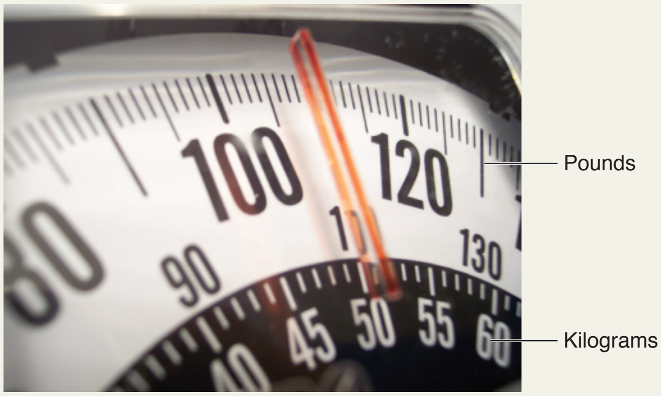
a. SI Prefixes

giga-	Billion	1,000,000,000
mega-	Million	1,000,000
kilo-	Thousand	1,000
hecto-	Hundred	100
deca-	Ten	10
(none)	One	1
deci-	Tenth	0.1
centi-	Hundredth	0.01
milli-	Thousandth	0.001
micro-	Millionth	0.000 001
nano-	Billionth	0.000 000 001

b. Volume Bottled drink labels often show volumes in both English units (fluid ounces, fl oz) and metric units (milliliters, mL).

GIPhotoStock/Photo Researchers

c. Weight This scale measures weight in both pounds and kilograms.



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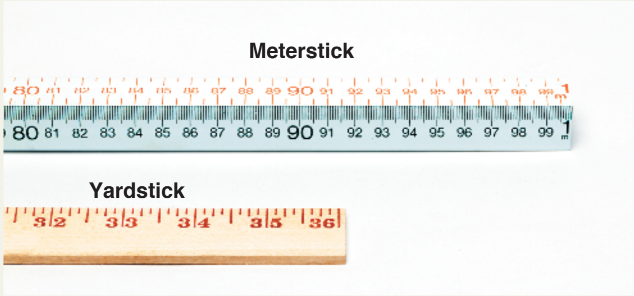
d. Distance A meter runs slightly longer than a yard.



Tim O. Walker

DID YOU KNOW?

Forensic Chemists are Unlikely to Set Foot in a Crime Scene as a Routine Part of their Work

The enormous popularity of crime scene investigation TV shows (**Figure a**) has shed a spotlight on forensic science, a multidisciplinary field that includes chemists, biologists, medical professionals, and others. In these programs, a single character may collect evidence at the crime scene, perform laboratory analysis, and interrogate suspects. But in the real world these various activities are carried out by separate individuals, each with specialized training. Forensic chemists, for example, routinely carry out their work in crime laboratories without any interaction in other aspects of a case, except occasionally testifying in court regarding their scientific findings.

Unlike the quick lab results presented on these shows, real forensic work can be quite detailed, complex, and time consuming. Take, for instance, the case of cocaine residues on money. It's widely reported that most U.S. paper currency is contaminated by minute amounts of cocaine, on the order of nanograms (billionths of a gram) per bill. The most reasonable explanation for this is that some bills become contaminated directly by drug traffickers or later by users who roll them up to inhale the drug. As these contaminated bills continue in general circulation, they cycle through banks, contaminating money-counting machines. The rollers on these machines, in turn, cross contaminate large numbers of "innocent" bills with minute particles of the drug.

With 90% of U.S. bills contaminated, as recent studies have suggested, would drug-detector dogs (**Figure b**) alert police to the presence of drugs on anyone carrying this currency? Defendants in drug-money confiscation cases have argued this very point: that a sniffer dog's alert should not constitute probable cause for authorities to search their property or premises. Controlled lab tests have shown that drug dogs respond to the presence of **methyl benzoate**, a volatile contaminant in cocaine, rather than to the cocaine itself. Furthermore, the minimum amount of methyl benzoate needed to trigger an alert is on the order of micrograms, or one-thousand times the level of nanograms. It follows that only currency carrying sufficient quantities of this signature odor—in other words, currency that was recently tainted by illicit cocaine—should trigger an alert, and makes it highly unlikely that "innocent" money would do the same.

a. Dramatic effects of dimly lit laboratories and procedures that produce rapid results are often the purview of TV forensic science (© CBS Corporation).

CBS via Getty Images

b. A drug-detector dog and handler during a training session. The dog is trained to discriminate between target odors (such as those from illicit drugs) and distractor scents (such as those from food or other animals.)

Mia Foster/PhotoEdit

Think Critically

1. Why would it be important for a crime lab chemist carrying out routine analyses to be ignorant of the other investigative aspects of a case?
2. The term *false positive* refers to an erroneous indication of a positive result. For example, evidence suggests that eating poppy seed bagels or pastries just prior to a drug test can lead to false positives for the presence of opiates. For which "diagnostic test" mentioned in this passage would it be helpful to understand false-positive rates?
3. Just as the smell of perfume or cologne on someone dissipates over time, the faint odor of methyl benzoate on cocaine dissipates with time. Why would it be useful to understand the rate at which it dissipates?

The *Did You Know?* feature shows how scientific principles and scientific units are brought to bear in solving real-world problems.

Converting Units Using Unit Cancellation

Applications occasionally require us to convert from one unit to another. A useful technique known as **unit cancellation** can help us considerably in problems of this sort. In track and field events, for example, a 100-yard dash is slightly shorter than a similar event called the 100-meter dash or sprint. Suppose, for example, we know that a certain athlete can run 100 yards in 12.0 seconds. Now we ask: "Assuming she ran at the same speed, how long would it take her to run 100 meters? We can solve this problem by converting the English unit of yards to the metric unit of meters, while keeping the unit of seconds unchanged. Here's how:

unit cancellation
A method of converting from one unit to another by multiplying by one or more equivalences.

- First, we want to know the time it takes her to run the course, so we'll set up a fraction with the unit of time, the second, in the numerator (the top part of the fraction).

$$\frac{12.0 \text{ seconds}}{100 \text{ yards}}$$

- In Appendix A, you can see that 1 meter is equivalent to 1.094 yard. That is, a piece of string that is 1 meter long is exactly the same length as another piece of string that is 1.094 yards long. So we can write:

$$1 \text{ meter} = 1.094 \text{ yard}$$

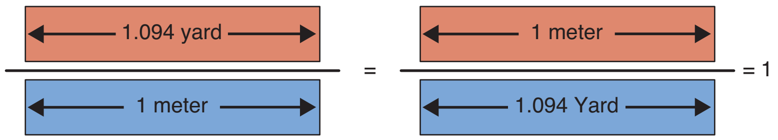
- Then, since 1 meter and 1.094 yard are identical, we know that each of the following fractions is equal to 1:

$$\frac{1 \text{ meter}}{1.094 \text{ yard}} = 1$$

and

$$\frac{1.094 \text{ yard}}{1 \text{ meter}} = 1$$

The following diagram shows this equivalence graphically:



- Now we multiply the fraction that represents the runner's speed,

$$\frac{12.0 \text{ seconds}}{100 \text{ yards}}$$

by a fraction representing 1, in such a way that the unit *yards* that appears in the denominator (bottom part of the fraction) is canceled out by the same unit, *yards*, that appears in the numerator of the fraction containing both yards and meters:

$$\frac{12.0 \text{ seconds}}{100 \cancel{\text{ yards}}} \times \frac{1.094 \cancel{\text{ yard}}}{1 \text{ meter}} = \frac{(12.0 \times 1.094) \text{ seconds}}{(100 \times 1) \text{ meters}}$$

$$= \frac{13.13 \text{ seconds}}{100 \text{ meters}}$$

If the athlete ran at the same speed in the 100-meter sprint as she did in the 100-yard dash, it would take her 13.13 seconds to run the 100 meters.

In carrying out unit cancellations, be sure that the fractions representing 1—also known as equivalences—cancel all units except for those needed in the answer. In our example, the equivalence (1.094 yard/1 meter) canceled "yards", which was not needed in the answer, and replaced it with "meters". **Figure 1.12** on the next page, provides another example involving speed.

In Words, Math and Pictures

Unit conversions • Figure 1.12

A variety of chemistry and everyday problems require us to convert from one set of units to another. We can use the principles of unit cancellation just described to work through the following conversion.

3DDock/Shutterstock

If a commercial airplane's top speed is 600 miles per hour, how fast is this in meters per second?

Solution:

We'll need the following equivalences to answer this question:

1 mile = 5280 feet.
1 meter = 3.28 feet.

Step 1: Start with the initial value, expressed as a fraction:

$$\frac{600\text{ miles}}{1\text{ hour}}$$

Step 2: Think ahead to the units you'll need for the final answer:

$$\frac{600\text{ miles}}{1\text{ hour}} \Rightarrow \frac{\text{meters}}{\text{second}}$$

Step 3: Multiply the original fraction by a series of equivalences, canceling *units* (but not numbers) along the way, until you arrive at the desired units.

$$\frac{600\text{ miles}}{1\ \cancel{\text{hour}}} \times \frac{1\ \cancel{\text{hour}}}{60\text{ minutes}}$$

Notice we cancel the units but not the numbers. Continue on, one step at a time…

$$\frac{600\text{ miles}}{1\ \cancel{\text{hour}}} \times \frac{1\ \cancel{\text{hour}}}{60\ \cancel{\text{minutes}}} \times \frac{1\ \cancel{\text{minute}}}{60\text{ seconds}}$$

$$\frac{600\ \cancel{\text{miles}}}{1\ \cancel{\text{hour}}} \times \frac{1\ \cancel{\text{hour}}}{60\ \cancel{\text{minutes}}} \times \frac{1\ \cancel{\text{minute}}}{60\text{ seconds}} \times \frac{5280\text{ feet}}{1\ \cancel{\text{mile}}}$$

$$\frac{600\ \cancel{\text{miles}}}{1\ \cancel{\text{hour}}} \times \frac{1\ \cancel{\text{hour}}}{60\ \cancel{\text{minutes}}} \times \frac{1\ \cancel{\text{minute}}}{60\text{ seconds}} \times \frac{5280\ \cancel{\text{feet}}}{1\ \cancel{\text{mile}}} \times \frac{1\text{ meter}}{3.28\ \cancel{\text{feet}}}$$

… until you're left with the desired units, meters per second. Now use the numbers to arrive at the answer:

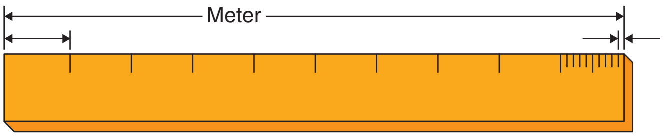
$$\frac{(600 \times 1 \times 1 \times 5280 \times 1)\ \textbf{meters}}{(1 \times 60 \times 60 \times 1 \times 3.28)\ \textbf{seconds}} = \frac{(600 \times 5280)\ \textbf{meters}}{(60 \times 60 \times 3.28)\ \textbf{seconds}} = 268\text{ meters per second}$$

Ask Yourself

Calculate the answer to the same question, but this time, in Step 3, work with the *miles* first and then the *hours*. Do you arrive at the same answer?

KNOW BEFORE YOU GO

1. Identify the missing units in the figure.



Solve the following unit conversion problems.

2. If pears sell for 2.80 euros (€) per kilogram (kg) in a market in France, what would be the equivalent price in U.S. dollars ($) per pound (lb)? For the purposes of this question, assume a currency exchange rate of 0.70 euros to the U.S. dollar. Also, 1 kg = 2.2 lb.

3. Your car gets 40 miles per gallon on the highway. What is the equivalent value expressed in kilometers (km) per liter (l)? Use the following equivalences to find your answer:

   1 mile = 1.6 km and 1 gallon = 3.8 l.

4. A pain reliever label states that adults can take up to 500 milligrams of the active ingredient every 4 hours. If the medicine comes in liquid form and each 15 ml supplies 500 mg of the active ingredient, how many milliliters can an adult receive over an 8-hour period?

CONCEPT CHECK

1. **What** *two* SI base units would you use to express an object's speed?
2. **How** are prefixes used in conjunction with scientific units?
3. **How** many millimeters are in a kilometer?

Summary

1

The Chemistry in Our Lives 4

- ***How does chemistry affect our lives and benefit society at large?***
  Chemistry is the study of matter, its composition, properties, and the changes it undergoes. Chemistry affects our everyday lives and society in multiple ways. Through combustion, fossil fuels provide most of the energy we need for transportation and for generating electricity. The cleaning power of soaps and detergents comes from chemicals called surface-active agents, or **surfactants**. Our clothing consists mostly of **polymers**, very large molecules formed by the repeated combination of much smaller ones. The energy content of our food is provided by its fats, carbohydrates, and proteins, known collectively as **macronutrients**. Our food also supplies us with **micronutrients**, the vitamins and minerals our bodies need to utilize the macronutrients effectively and to keep us in good health. All medicines are chemical compounds, such as the solution being administered to the patient shown here, and chemical expertise is essential in developing them.

Figure 1.2 • Chemistry We See Every Day

TongRo/InMagine

2

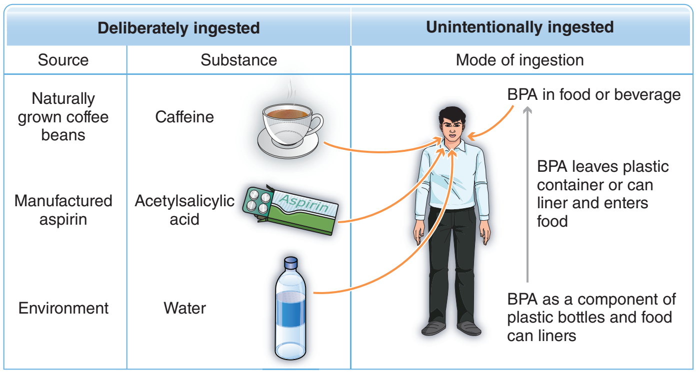
Benefits Versus Risks 8

- ***What are the trade-offs between the benefits and risks in our use of everyday chemical substances?***
  Any substance we take into our bodies that can benefit us in any way also carries with it the potential for harming us. The risk of harm depends on several factors, including the amount of the substance we ingest. Sufficiently high dosages

of the caffeine in coffee, of acetylsalicylic acid (the active ingredient in aspirin) and even pure water can be harmful and even toxic if taken over a short time span.

- **BPA**, an abbreviation for bisphenol-A, is an ingredient of plastics and resins that provides shatter resistance to beverage bottles made of plastic and prevents resin liners of food cans from affecting the flavor or consistency of the contained food. BPA appears to be able to leak from the plastic and resin of the bottles and can and enter our bodies as we consume their contents, as shown in the diagram. Concern about the potential harm this ingested BPA might cause to adults and children is leading to the abandonment of BPA as a component of food and beverage containers.

Figure 1.3 • Ingesting chemical substances



Deliberately ingested		Unintentionally ingested
Source	Substance	Mode of ingestion
Naturally grown coffee beans	Caffeine	BPA in food or beverage
Manufactured aspirin	Acetylsalicylic acid	BPA leaves plastic container or can liner and enters food
Environment	Water	BPA as a component of plastic bottles and food can liners

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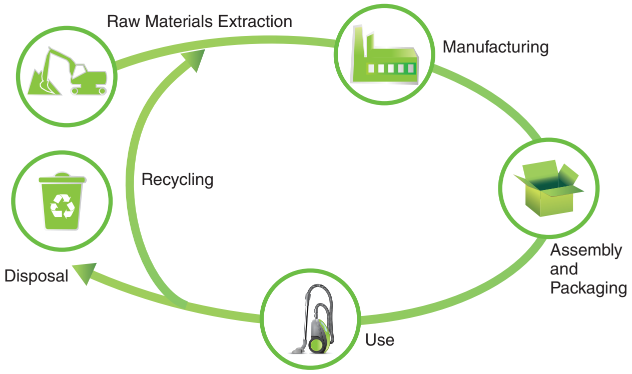
3 Resources and Sustainability 10

- ***How can chemistry address environmental concerns?***
  With its focus on matter and energy, chemistry provides approaches to using resources more sustainably. Chemists are working to make solar energy, biofuels, and hydrogen fuels more cost-competitive with traditional fossil fuels. As shown in the diagram, **life-cycle assessment** aims to reduce the environmental impact of a product by considering everything from the raw materials used to produce it through to its disposal or recycling. Chemists address these issues in developing more environmentally friendly consumer products.

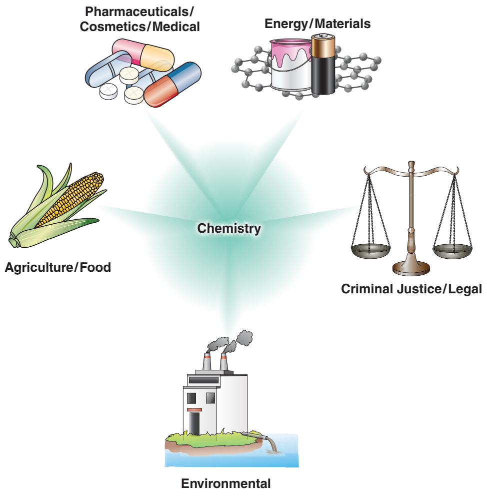
Life-cycle assessment • Figure 1.5



4 The Science of Chemistry 12

- ***What do chemists do?***
  Chemists work in a variety of fields, including those shown below. Chemists perform a variety of functions, including synthesizing new compounds, analyzing samples to determine chemical composition, formulating new products, and understanding and controlling chemical processes.

Figure 1.6 • Representative fields in which chemists work

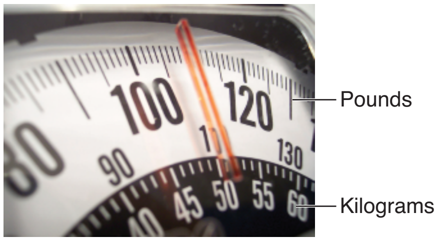


- ***What is the scientific method?***
  The **scientific method** is a set of general guidelines under which scientists carry out their work. This generally involves asking questions about the universe by means of experiments and tests; objectively interpreting the resulting observations and findings; and communicating those results and interpretations to other scientists.

5 Working with Scientific Units 15

- ***What are scientific units?***
  The SI system, a modern variant of the metric system, is the principal set of units currently used in science and in international trade and commerce. The **SI base unit** of length is the meter; for mass, the kilogram (as shown here);

Figure 1.11 • Units of measurement in everyday life


© travelpixpro/iStockphoto

and for time, the second. A commonly used unit of volume is the liter. One advantage of the SI or metric system is the use of multiplier prefixes to scale a unit either larger or smaller by some factor of ten.

- ***How do you convert from one set of units to another?*** **Unit cancellation** is useful for converting units of one system to those of another. In this method, an initial value is multiplied by one or more equivalences, so that units appearing in both a numerator and a denominator (including the unit to be converted) cancel each other, with the newly desired unit(s) remaining uncanceled in the result.

Key Terms

- basic research 13
- BPA 9
- chemical change 5
- chemistry 4
- green chemistry 11
- hypothesis 14
- life-cycle assessment 11
- macronutrients 5
- micronutrients 5
- nonrenewable resources 10
- physical change 5
- polymer 5
- reference standards 16
- renewable resources 10
- research and development 13
- scientific method 14
- SI base units 15
- SI prefixes 16
- surfactant 5
- theory 15
- unit cancellation 19

What is happening in this picture?

In the photo, chlorine levels in a pool are being tested. Chlorine is a disinfectant widely used to help keep swimming pools sanitary and to treat municipal drinking water.
However, consider the warning label for chlorine found on storage tanks of this chemical.

Tim O. Walker

Think Critically Based on your understanding of themes presented in this chapter, how do you reconcile these two contradictory perspectives of chlorine?

Exercises

Review

1. What are three fossil fuels that provide society with energy? Name or describe three sources of energy that we might use to replace fossil fuels as our major source of energy.

2. a. Name one common, commercial fuel that is derived from petroleum.

b. Name one common fuel that is not derived from petroleum.

3. a. What common household product is most likely to contain chemicals known as surfactants?

b. What function do these chemicals perform as you use this household product?

4. What common household product, often found in a medicine cabinet, contains an ingredient that serves as an analgesic and can also provide some protection against heart attacks? What is the chemical name of this ingredient? What function does this ingredient perform that allows it to reduce the risk of a heart attack?

5. Name or describe a substance or an object that you use every day that is composed entirely or largely of polymers.

6. Name the mathematical procedure used repeatedly in the process of unit cancellation.

7. Name one unit of the metric system and one unit of the English system used for measuring:

a. length;

b. volume;

c. weight.

8. Identify the missing unit prefixes in the following chart.

	Million	1,000,000
	Thousand	1,000
hecto-	Hundred	100
deca-	Ten	10
(none)	One	1
deci-	Tenth	0.1
	Hundredth	0.01
	Thousandth	0.001
	Millionth	0.000 001

9. Describe who Paracelsus was and how he contributed to our understanding of what a poison or a toxin is.

10. a. What is BPA. and what is it used for?

b. How can BPA enter our bodies?

11. a. Identify a renewable resource and explain how it is renewed.

b. Identify a nonrenewable resource and explain why it is classified as nonrenewable.

Think

12. Burning a fossil fuel produces heat. Explain how burning a fossil fuel can help keep us cool rather than warm.

13. a. Identify the SI base units of mass, length, and time, respectively.

b. Why are reference standards necessary in defining these units?

14. Which of the two systems—English and metric—do you think is more useful to us as individuals and as a society? Explain your reasoning.

15. What word would you use as the term for a single unit of mass that consists of exactly 1000 mg?

16. a. How does basic research differ from applied research and development?

b. What arguments can be made for why funding for basic research is a worthy investment for society?

17. Describe the difference between

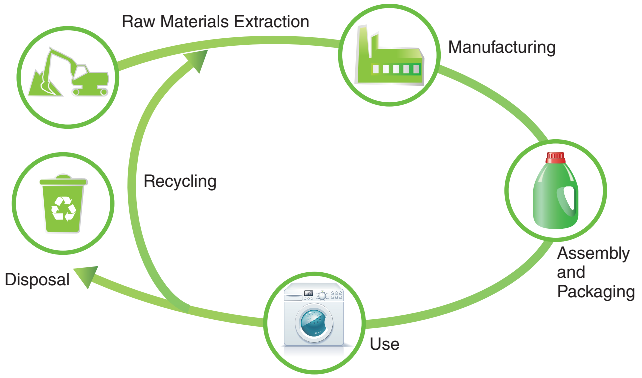
a. a hypothesis and a theory and

b. an observation and an experiment.

18. a. Describe the difference between the macronutrients and the micronutrients of our food. Give an example of each.

b. Would a sample of "vitamin-fortified" bottled water that also contains small amounts of sugars supply macronutrients, micronutrients, or both?

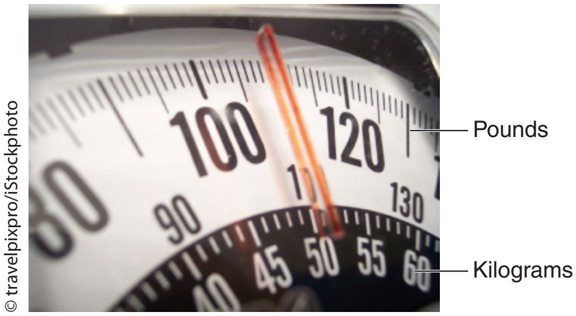
19. Consider the life-cycle assessment of a common consumer product such as laundry detergent. For each of the stages shown in the diagram, how could the expertise of a chemist be helpful in reducing the environmental impact of the product?



Calculate

20. Based on this image, the number of pounds in 1 kilogram is closest to:

a. 0.5 b. 1.0 c. 1.8 d. 2.2 e. 2.9



© travelpixpro/iStockphoto

21. Calculate the number of

a. millimeters in a mile

b. milliseconds in a year

c. micrograms in a ton (2000 lb)

22. Calculate the number of kilograms in a gram.

23. If New York is approximately 4100 km from San Francisco, how far is this in centimeters?

24. Light travels at about 30 billion (30,000,000,000) centimeters per second. A light-year is defined as the distance that light travels in a vacuum in 1 year. What is the length of a light-year in

a. meters?

b. miles?