

## 1.1: What is Chemistry?

### Learning Objectives

1. Define chemistry in relation to other sciences.
2. Identify the general steps in the scientific method.

Chemistry is the study of matter—what it consists of, what its properties are, and how it changes. Being able to describe the ingredients in a cake and how they change when the cake is baked is called chemistry. Matter is anything that has mass and takes up space—that is, anything that is physically real. Some things are easily identified as matter—this book, for example. Others are not so obvious. Because we move so easily through air, we sometimes forget that it, too, is matter.

Chemistry is one branch of science. Science is the process by which we learn about the natural universe by observing, testing, and then generating models that explain our observations. Because the physical universe is so vast, there are many different branches of science (Figure 1.1.1). Thus, chemistry is the study of matter, biology is the study of living things, and geology is the study of rocks and the earth. Mathematics is the language of science, and we will use it to communicate some of the ideas of chemistry.

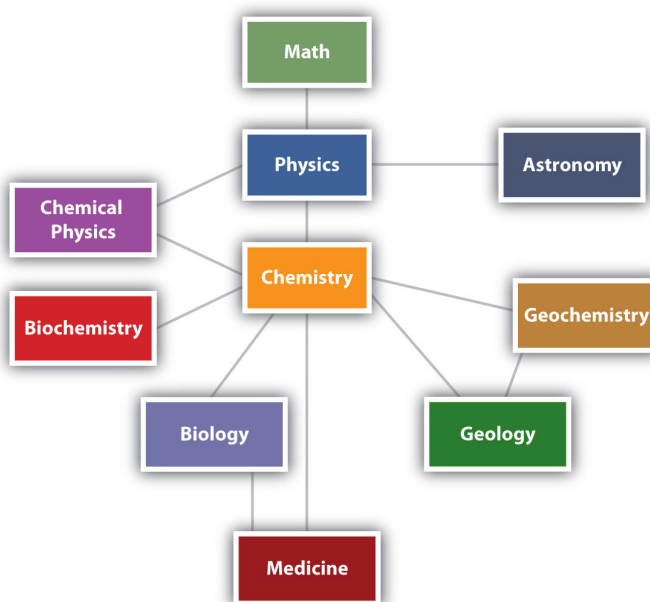


Figure 1.1.1: The Relationships between Some of the Major Branches of Science. Chemistry lies more or less in the middle, which emphasizes its importance to many branches of science.

Although we divide science into different fields, there is much overlap among them. For example, some biologists and chemists work in both fields so much that their work is called biochemistry. Similarly, geology and chemistry overlap in the field called geochemistry. Figure 1.1.1 shows how many of the individual fields of science are related.

*There are many other fields of science in addition to the ones listed here.*

### Alchemy

As our understanding of the universe has changed over time, so has the practice of science. Chemistry in its modern form, based on principles that we consider valid today, was developed in the 1600s and 1700s. Before that, the study of matter was known as *alchemy* and was practiced mainly in China, Arabia, Egypt, and Europe.

Alchemy was a somewhat mystical and secretive approach to learning how to manipulate matter. Practitioners, called alchemists, thought that all matter was composed of different proportions of the four basic elements—fire, water, earth, and air—and believed that if you changed the relative proportions of these elements in a substance, you could change the substance. The long-standing attempts to “transmute” common metals into gold represented one goal of alchemy. Alchemy’s other major goal was to synthesize the philosopher’s stone, a material that could impart long life—even immortality. Alchemists used

[illegible]

Esprits acides.	Terre absorbante.	♂ Cuivre.	♂ Soufre minéral. [Principe.
Acide du sel marin.	<sup>SN</sup> Substances métalliques.	♂ Fer.	♂ Principe huileux ou Soufre
Acide nitreux.	♂ Mercure.	♂ Plomb.	♂ Esprit de vinaigre.
Acide vitriolique.	♂ Règle d'Antimoine.	♂ Etain.	♂ Eau.
Sel alcali fixe.	♂ Or.	♂ Zinc.	♂ Sel. [dents
Sel alcali volatil.	♂ Argent.	♂ Pierre Calaminaire.	♂ Esprit de vin et Esprits ar-

In spite of this secrecy, in its time alchemy was respected as a serious, scholarly endeavor. Isaac Newton, the great mathematician and physicist, was also an alchemist.

Astronomy is the study of stars and planets, which are part of the natural universe. Astronomy is therefore a field of science.

a, b and c only

How do scientists work? Generally, they follow a process called the scientific method. The scientific method is an organized procedure for learning answers to questions and making explanations for observations. To find the answer to a question (for example, “Why do birds fly toward Earth’s equator during the cold months?”), a scientist goes through the following steps, which are also illustrated in Figure 1.1.2:

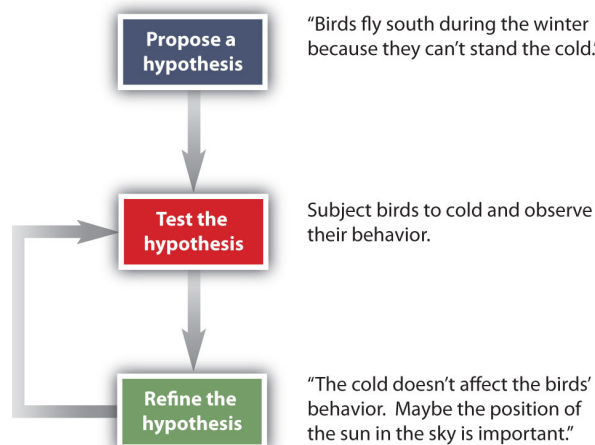


Figure 1.1.2: The General Steps of the Scientific Method. After an observation is made or a question is identified, a hypothesis is made and experiments are designed to test the hypothesis.

The steps may not be as clear-cut in real life as described here, but most scientific work follows this general outline.

1. **Propose a hypothesis.** A scientist generates a testable idea, or hypothesis, to try to answer a question or explain an observation about how the natural universe works. Some people use the word *theory* in place of hypothesis, but the word hypothesis is the proper word in science. For scientific applications, the word theory is a general statement that describes a large set of observations and data. A theory represents the highest level of scientific understanding.
2. **Test the hypothesis.** A scientist evaluates the hypothesis by devising and carrying out experiments to test it. If the hypothesis passes the test, it may be a proper answer to the question. If the hypothesis does not pass the test, it may not be a good answer.
3. **Refine the hypothesis if necessary.** Depending on the results of experiments, a scientist may want to modify the hypothesis and then test it again. Sometimes the results show the original hypothesis to be completely wrong, in which case a scientist will have to devise a new hypothesis.

Not all scientific investigations are simple enough to be separated into these three discrete steps. But these steps represent the general method by which scientists learn about our natural universe.

#### Exercise

Define science and chemistry.

#### Answer

Science is a process by which we learn about the natural universe by observing, testing, and then generating models that explain our observations. Chemistry is the study of matter.

#### Exercise

Name the steps of the scientific method.

#### Answer

After identifying the problem or making an observation, propose a hypothesis, test the hypothesis, and refine the hypothesis, if necessary

## Key Takeaways

- Chemistry is the study of matter and how it behaves.
  - The scientific method is the general process by which we learn about the natural universe.
1. Based on what you know, which fields are branches of science?
    - a. meteorology (the study of weather)
    - b. astrophysics (the physics of planets and stars)
    - c. economics (the study of money and monetary systems)
    - d. astrology (the prediction of human events based on planetary and star positions)
    - e. political science (the study of politics)
  2. Based on what you know, which fields are a branches of science?
    - a. history (the study of past events)
    - b. ornithology (the study of birds)
    - c. paleontology (the study of fossils)
    - d. zoology (the study of animals)
    - e. phrenology (using the shape of the head to determine personal characteristics)
  3. Which of the following are examples of matter?
    - a. a baby
    - b. an idea
    - c. the Empire State Building
    - d. an emotion
    - e. the air
    - f. Alpha Centauri, the closest known star (excluding the sun) to our solar system
  4. Which of the following are examples of matter?
    - a. your textbook
    - b. brain cells
    - c. love
    - d. a can of soda
    - e. breakfast cereal
  5. Suggest a name for the science that studies the physics of rocks and the earth.
  6. Suggest a name for the study of the physics of living organisms.
  7. Engineering is the practical application of scientific principles and discoveries to develop things that make our lives easier. Is medicine science or engineering? Justify your answer.
  8. Based on the definition of engineering in Exercise 7, would building a bridge over a river or road be considered science or engineering? Justify your answer.
  9. When someone says, “I have a theory that excess salt causes high blood pressure,” does that person really have a theory? If it is not a theory, what is it?
  10. When a person says, “My hypothesis is that excess calcium in the diet causes kidney stones,” what does the person need to do to determine if the hypothesis is correct?
  11. Some people argue that many scientists accept many scientific principles on faith. Using what you know about the scientific method, how might you argue against that assertion?
  12. Most students take multiple English classes in school. Does the study of English use the scientific method?

## Answers

1.
  - a. science
  - b. science

- c. not science
- d. not science
- e. not science

2.

- a. not science
- b. science
- c. science
- d. science
- e. not science

3.

- a. matter
- b. not matter
- c. matter
- d. not matter
- e. matter
- f. matter

4.

- a. matter
- b. matter
- c. not matter
- d. matter
- e. matter

5. geophysics

6. biophysics

7. Medicine is probably closer to a field of engineering than a field of science, but this may be arguable. Ask your doctor.

8. Engineering

- 9. In scientific terms, this person has a hypothesis.
- 10. Conduct experiments to determine if kidney stones contain calcium.
- 11. Science is based on reproducible facts, not blind belief.
- 12. No.

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