Section 1
Tools and Models in Science

Key Concept Scientists use tools and models to increase their ability to investigate the natural world.

What You Will Learn

- Tools are used to make accurate measurements while collecting data.
- The International System of Units (SI) is a system of measurement used by most scientists.
- A model uses familiar things to describe unfamiliar things. Physical, conceptual, and mathematical models are commonly used in science.
- Models help scientific progress through their use in theories and laws.

Why It Matters

Understanding how scientists use tools and models can help you use them better in your own investigations.

To dig a hole, you need the correct tools. A *tool* is anything that helps you do a task. Scientists use many different tools to help them in their experiments.

Tools in Science

One way to collect data is to take measurements. To get the most accurate measurements, you must use the proper tools to gather data. For example, you can use a meterstick to measure length. You can use a thermometer to observe changes in temperature. Two other tools and their uses are shown in **Figure 1.**

Figure 1 Measurement Tools

You can use a stopwatch to measure time.

You can use a spring scale to measure force.

After you collect data, you need to evaluate and analyze the data. Calculators are handy tools to help you do calculations quickly. Or you might show your data in a graph or a figure. A computer that has the correct software can help you display your data. A pencil and graph paper are also tools you can use to display your data.

Standards Check Why is it important to use the proper tools for gathering data?

Making Measurements

Many years ago, different countries used different systems of measurement. In England, the standard for an inch used to be three grains of barley placed end to end. Other units were originally based on parts of the body, such as the foot.

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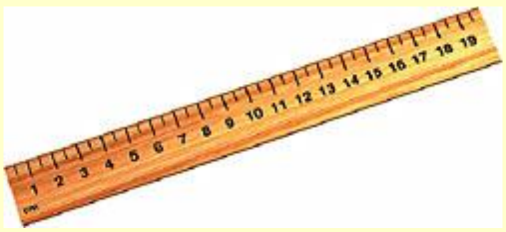
The International System of Units

In the late 1700s, the French Academy of Sciences set out to make a simple and reliable measurement system. Over the next 200 years, the metric system was formed. This system is now the International System of Units (SI). Because all SI units are expressed in multiples of 10, changing from one unit to another is easy. Prefixes are used to express SI units that are larger or smaller than basic units such as a meter and a gram. For example, *kilo-* means 1,000 times, and *milli-* indicates 1/1,000 times. **Table 1** shows common SI units.

Table 1 Common SI Units

	SI Units	**Conversions**
Length	**meter (m)**	
	kilometer (km)	1 km = 1,000 m
	decimeter (dm)	1 dm = 0.1 m
	centimeter (cm)	1 cm = 0.01 m
	millimeter (mm)	1 mm = 0.001 m
	micrometer (µm)	1 µm = 0.000001 m
	nanometer (nm)	1 nm = 0.000000001 m
Volume	**cubic meter (m^3)**	
	cubic centimeter (cm^3)	1 cm^3 = 0.000001 m^3
	liter (L)	1 L = 1 dm^3 = 0.001 m^3
	milliliter (mL)	1 mL = 0.001 L = 1 cm^3
Mass	**kilogram (kg)**	
	gram (g)	1 g = 0.001

		kg
	milligram (mg)	1 mg = 0.000001 kg
Temperature*	**kelvin (K)**	0ºC = 273 K
		100ºC = 373 K

*The Celsius (ºC) scale is a commonly used non-SI temperature scale.

Length

To describe the length of a large classroom , a scientist would use meters (m). A *meter* is the basic SI unit of length. Other SI units of length are larger or smaller than the meter by multiples of 10. For example, if you divide 1 m into 1,000 parts, each part equals 1 millimeter (mm). So, 1 mm is one-thousandth of a meter.

Mass

Mass is the amount of matter in an object. The *kilogram* (kg) is the basic SI unit for mass. The kilogram is used to describe the mass of large objects, such as a suitcase. One kilogram equals 1,000 g. So, the gram is more often used to describe the mass of small objects. Masses of very large objects, such as cars or airplanes, are often expressed in metric tons. A metric ton equals 1,000 kg.

Volume

Imagine that you need to move some lenses to a laser laboratory. How many lenses will fit into a crate? The answer depends on the volume of the crate and the volume of each lens. **Volume** is the amount of space that something occupies.

Liquid volume is expressed in *liters* (L). Liters are based on the meter. A cubic meter (1 m^3) is equal to 1,000 L. So, 1,000 L will fit perfectly into a box that is 1 m on each side. A milliliter (mL) will fit perfectly into a box that is 1 cm on each side. So, 1 mL = 1 cm^3. Graduated cylinders are used to measure the volume of liquids. The volume of solid objects is usually expressed in cubic meters (m^3). The volume of smaller objects can be expressed in cubic centimeters (cm^3). To find the volume of a crate — or any other rectangular shape — multiply the length by the width by the height.

Density

If you measure the mass and the volume of an object, you have the information you need to find the density of the object. **Density** is the amount of matter in a given volume. You cannot measure density directly. But after you measure the mass and the volume, you can calculate density by dividing the mass by the volume, as shown in the following equation:

$$D = \frac{m}{V}$$

Standards Check What is the density of an object if its mass is 15 g and its volume is 3 cm^3?

Temperature

The **temperature** of a substance is a measurement of how hot (or cold) the substance is. Degrees Fahrenheit (ºF) and degrees Celsius (ºC) are used to describe temperature. However, the *kelvin* (K), the SI unit for temperature, is also used. Notice that the degree sign (º) is not used with the Kelvin scale. The thermometer in **Figure 2** shows how the Celsius and Fahrenheit scales compare.

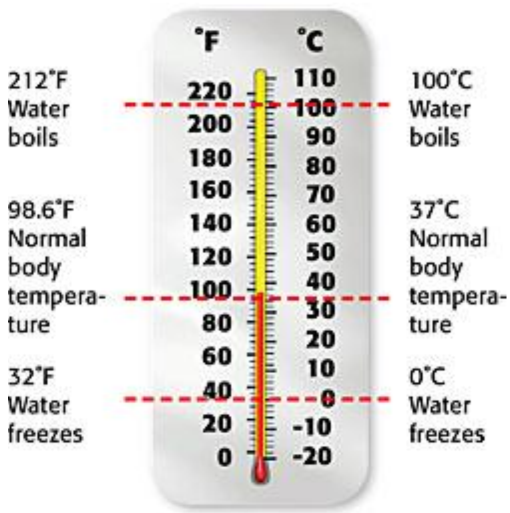


Figure 2 Some common temperature measurements are shown here in degrees Fahrenheit and degrees Celsius.

Models in Science

A **model** is a representation of an object or system. A model uses something familiar to help you understand something that is not familiar. For example, models of individual systems in the human body, such as the nervous system, can help you understand how the body works. Models can also be used to explain the past or to predict future events. There are three common kinds of scientific models. They are physical, conceptual (kuhn SEP choo uhl), and mathematical models. However, models have limitations because they are never exactly like the real thing.

Physical Models

Model airplanes, dolls, and drawings are examples of physical models. Other kinds of physical models can help you understand certain concepts. For example, look at the model space shuttle and the real space shuttle in **Figure 3.** Launching a model like the one on the right can help you understand how a real space shuttle blasts off into space.

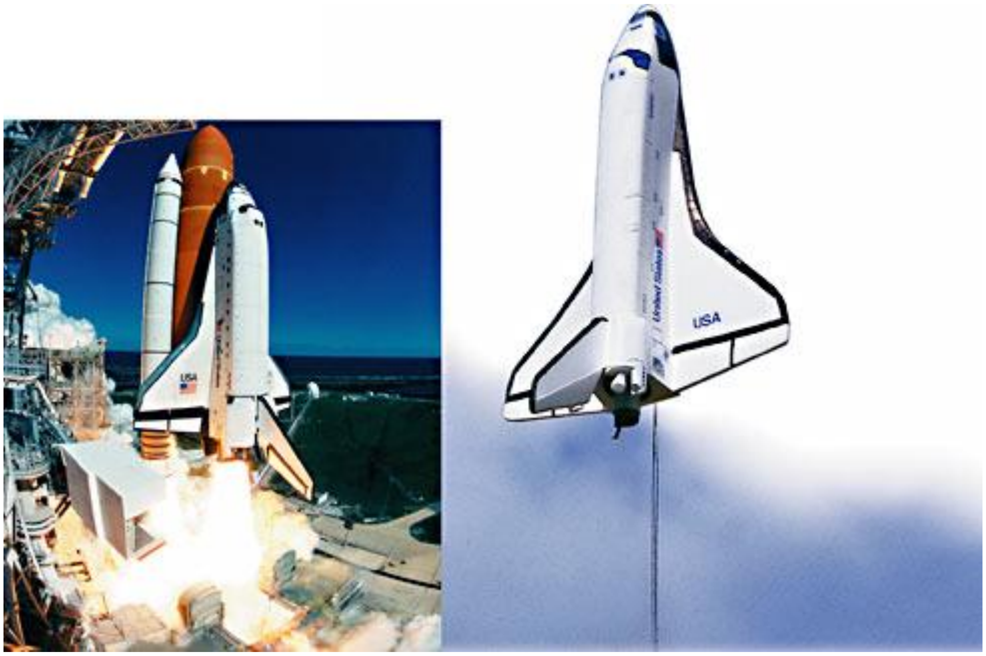


Figure 3 Using a model of a space shuttle can help you understand how a real space shuttle works.

Conceptual Models

The second kind of model is a conceptual model. A conceptual model tries to put many ideas together to explain or summarize something. After a conceptual model is formed, data are sometimes found that do not fit the model. The model may then be revised to fit the new data. For example, the big bang theory is a conceptual model that explains why the universe seems to be expanding. This model is described in **Figure 4.** Although the big bang theory is widely accepted by astronomers, some data do not fit the model. So, conceptual models may not take certain data into account. Or the models may include certain ideas but not others.

Figure 4 The big bang theory says that 12 billion to 15 billion years ago, an event called the big bang sent matter in all directions. This matter eventually formed the galaxies and planets.

Mathematical Models

Every day, people try to predict the weather. One way to predict the weather is to use mathematical models. A mathematical model is made up of mathematical equations and data. Some mathematical models are simple. These models allow you to calculate things such as force and acceleration. But other mathematical models, like those that predict the weather, are so complex that only computers can handle them. Some of these very complex models have many variables. Using the wrong value for even a single variable could cause the model to make highly inaccurate predictions.

Standards Check Why is having accurate data important when working with a mathematical model?

Models: The Right Size

Models are often used to represent things that are very small or very large. The solar system is too large to view all at once. So, a model can help you picture the thing in your mind. Sometimes, models are used to learn about things you cannot see, such as sound waves. Look at **Figure 5.** A coiled spring toy is often used as a model of sound waves because the spring toy behaves similarly to the way sound waves do.

Figure 5 The compressed coils on the spring toy can be used to model the way air particles are crowded together in a sound wave.

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The Limits of Models

Models are an important tool for scientists. Mathematical models can help scientists analyze complex systems quickly and efficiently. For example, scientists can use models to study how certain drugs might fight diseases without scientists having to test the drugs on animals or people.

But it is important for a scientist to remember the limitations of the models that he or she uses. A model is not exactly the same as the real object or system. To make sense of the information gathered, a scientist must know the ways in which a model does not act exactly as the real thing does.

Using Models for Scientific Progress

Models can represent scientific ideas and objects. Models can also be tools to help you summarize and learn new information. When scientists need to communicate information that would be difficult to explain, they often create a model. **Figure 6** shows a model of a protein molecule. Molecules are too small to be seen with your eyes. And some molecules are made of a large number of atoms. So, a drawing of a molecule that tries to show the location of every single atom would be very confusing to look at. But by using a model, you can see the shape of the molecule from any side.

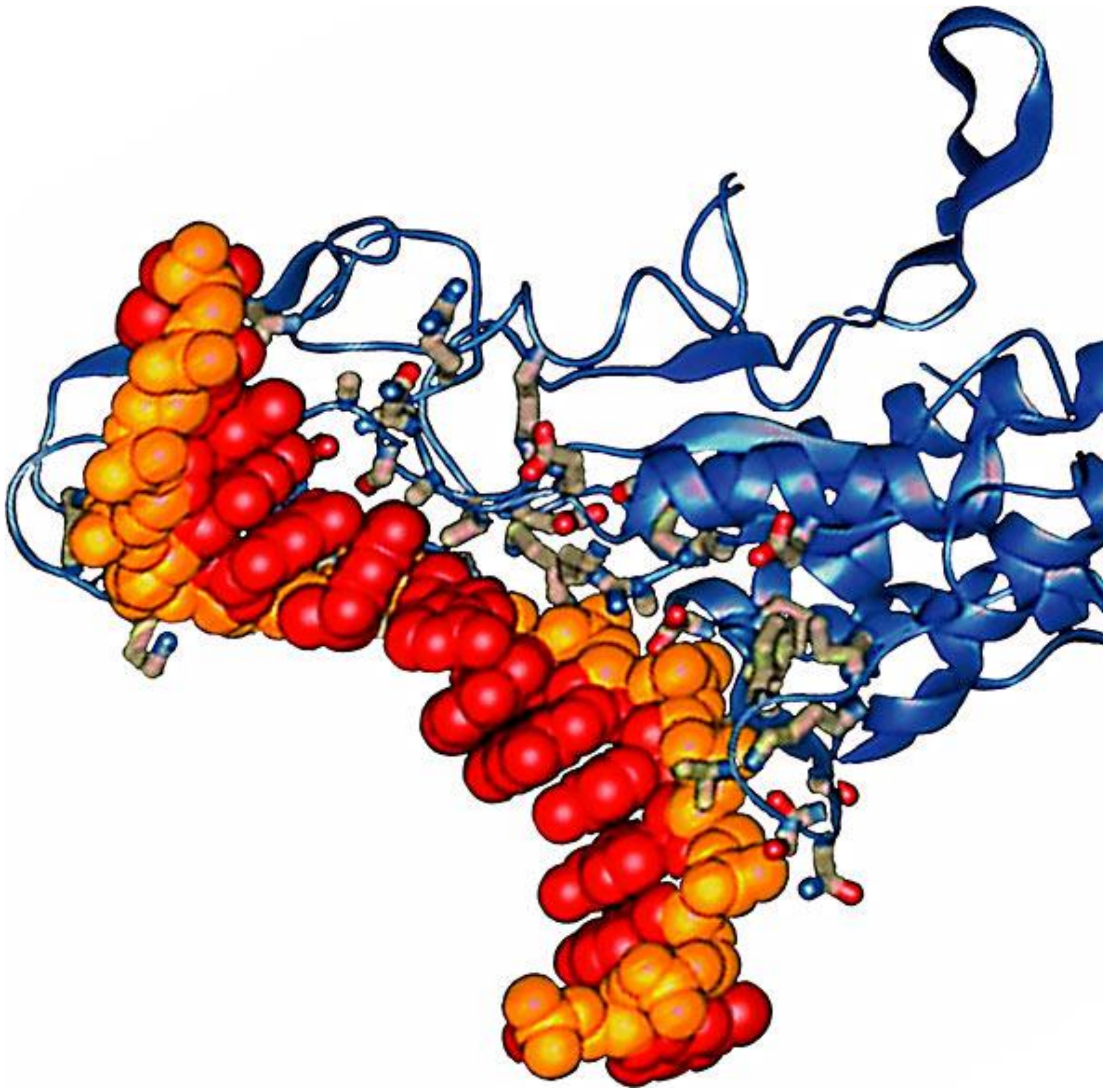

Figure 6 This image was generated by a computer. It is a model of a protein molecule.

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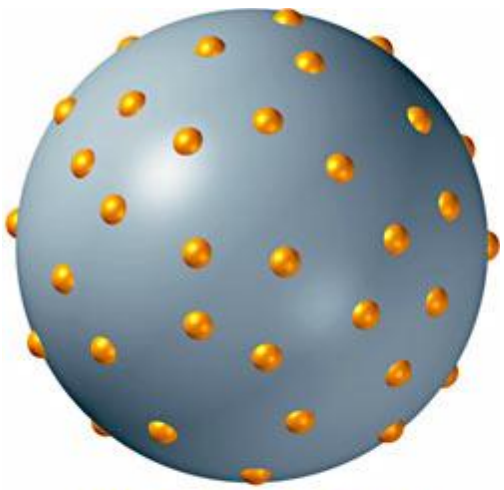
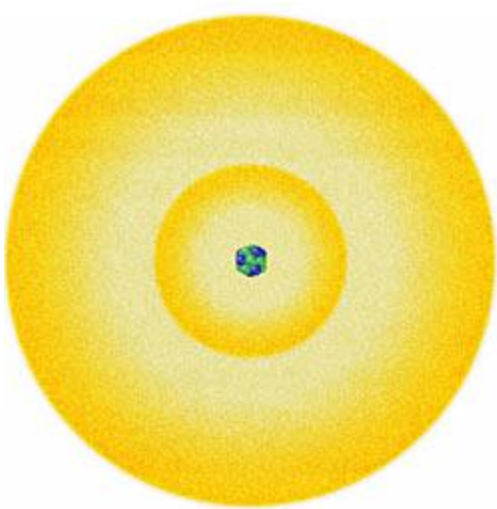
Scientific Theories

Models are often used to help illustrate and explain scientific theories. In science, a **theory** is an explanation for many hypotheses and observations. Usually, these hypotheses have been supported by repeated tests. A theory not only explains an observation you've made but also can predict what might happen in the future.

Scientists use models to help guide their search for new information. This information can help support a theory or can show that the theory is wrong. Keep in mind that models can be changed or replaced. These changes happen when scientists make new observations. Because of these new observations, scientists may have to change their theories. **Figure 7** compares an old model with a current model.



1897 atomic model



Current atomic model

Figure 7 These models show how the theory about an atom's structure has changed over time.

Standards Check Why is having accurate data important during the development and testing of a theory?

Scientific Laws

What happens when a model correctly predicts the results of many different experiments? A scientific law can be constructed. In science, a **law** is a summary of many experimental results and observations. A law tells you how things work. Laws are not the same as theories. Laws tell you only what happens, not why it happens. Look at **Figure 8.** A chemical change took place when the flask was turned over. A light blue solid and a dark blue solution formed. Notice that the mass did not change, which demonstrates the *law of conservation of mass*. This law says that during a chemical change, the total mass of the materials formed is the same as the total mass of the starting materials. However, the law doesn't explain why. It tells you only what will happen during every chemical change.

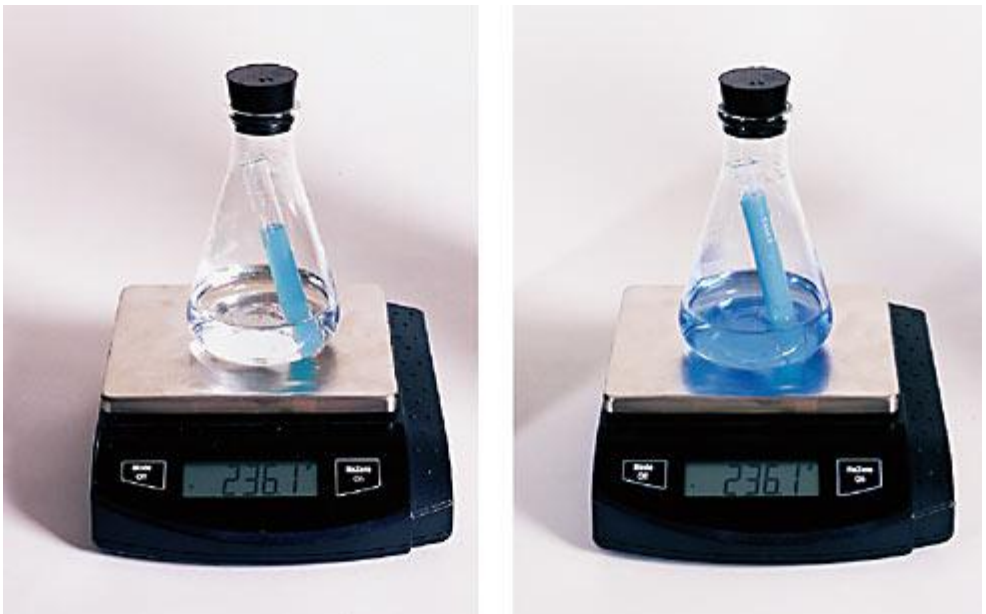


Figure 8 The total mass before the chemical change is always the same as the total mass after the change.

Section Summary

- Tools are used to make observations, take measurements, and analyze data.
- The International System of Units (SI) is the standard system of measurement.
- Length, mass, volume, density, and temperature are common measurements.
- A model uses familiar things to describe

unfamiliar things.

- Physical, conceptual, and mathematical models are commonly used in science.
- A scientific theory is an explanation for many hypotheses and observations.