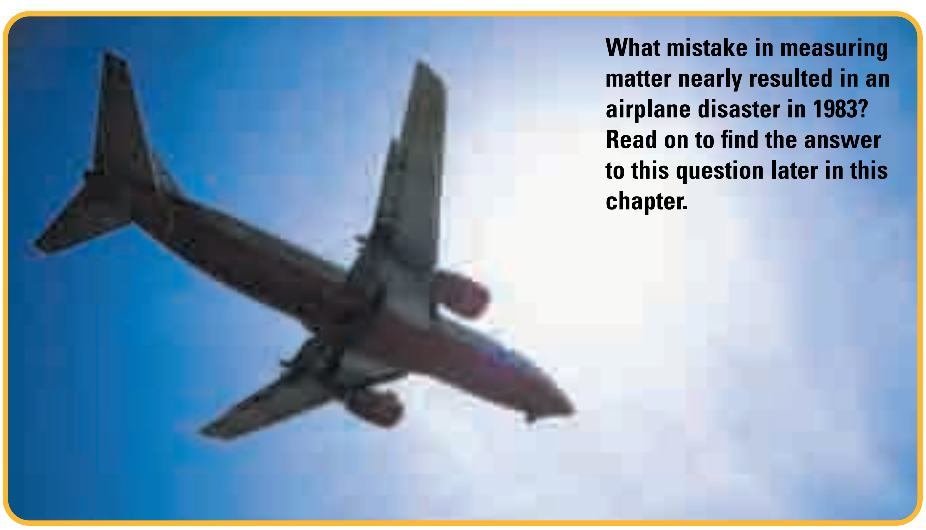
Imagine a chemical that
- is a key ingredient in most pesticides
- contributes to environmental hazards, such as acid rain, the greenhouse effect, and soil erosion
- helps to spread pollutants that are present in all contaminated rivers, lakes, and oceans
- is used in vast quantities by every industry on Earth
- can produce painful burns to exposed skin
- causes severe illness or death in either very low or very high concentrations in the body
- is legally discarded as waste by individuals, businesses, and industries
- has been studied extensively by scientists throughout the world

In 1996, a high school student wrote a report about this chemical, dihydrogen monoxide, for a science fair project. The information in the student's report was completely factual. As a result, 86% of those who read the report—43 out of 50 students—voted in favour of banning the chemical. What they did not realize was that "dihydrogen monoxide" is simply another name for water.

What if you did not know that water and dihydrogen monoxide are the same thing? What knowledge and skills can help you distinguish genuine environmental issues from pranks like this one? What other strategies can help you interpret all the facts, opinions, half-truths, and falsehoods that you encounter every day?

This chapter will reacquaint you with the science of chemistry. You will revisit important concepts and skills from previous grades. You will also prepare to extend your knowledge and skills in new directions.

Chapter Preview



What mistake in measuring matter nearly resulted in an airplane disaster in 1983? Read on to find the answer to this question later in this chapter.

1.1 The Study of Chemistry

Section Preview/ Specific Expectations

In this section, you will

- **identify** examples of chemistry and chemical processes in everyday use
- **communicate** ideas related to chemistry and its relationship to technology, society, and the environment, using appropriate scientific vocabulary
- **communicate** your understanding of the following terms: *chemistry, STSE*

Many people, when they hear the word "chemistry," think of scientists in white lab coats. They picture bubbling liquids, frothing and churning inside mazes of laboratory glassware.

Is this a fair portrayal of chemistry and chemists? Certainly, chemistry happens in laboratories. Laboratory chemists often do wear white lab coats, and they do use lots of glassware! Chemistry also happens everywhere around you, however. It happens in your home, your school, your community, and the environment. Chemistry is happening right now, inside every cell in your body. You are alive because of chemical changes and processes.

Chemistry is the study of matter and its composition. Chemistry is also the study of what happens when matter interacts with other matter. When you mix ingredients for a cake and put the batter in the oven, that is chemistry. When you pour soda water on a stain to remove it from your favourite T-shirt, that is chemistry. When a scientist puts a chunk of an ice-like solid into a beaker, causing white mist to ooze over the rim, that is chemistry, too. Figure 1.1 illustrates this interaction, as well as several other examples of chemistry in everyday life.

Figure 1.1

A Frozen (solid) carbon dioxide is also known as "dry ice." It changes to a gas at temperatures higher than –78°C. In this photograph, warm water has been used to speed up the process, and food colouring has been added.

B Dry ice is also used to create special effects for rock concerts, stage plays, and movies.

C Nitrogen gas becomes a liquid at –196°C. Liquid nitrogen is used to freeze delicate materials, such as food, instantly.

Chemistry: A Blend of Science and Technology

Like all scientists, chemists try to describe and explain the world. Chemists start by asking questions such as these:

- Why is natural gas such an effective fuel?
- How can we separate a mixture of crude oil and water?
- Which materials dissolve in water?
- What is rust and why does it form?

To answer these questions, chemists develop models, conduct experiments, and seek patterns. They observe various types of chemical reactions, and they perform calculations based on known data. They build continuously on the work and the discoveries of other scientists.

Long before humans developed a scientific understanding of the world, they invented chemical techniques and processes. These techniques and processes included smelting and shaping metals, growing crops, and making medicines. Early chemists invented technological instruments, such as glassware and distillation equipment.

Present-day chemical technologists continue to invent new equipment. They also invent new or better ways to provide products and services that people want. Chemical technologists ask questions such as the following:

- How can we redesign this motor to run on natural gas?
- How can we contain and clean up an oil spill?
- What methods can we use, or develop, to make water safe to drink?
- How can we prevent iron objects from rusting?


D


E


F

D Green plants use a chemical process, called photosynthesis, to convert water and carbon dioxide into the food substances they need to survive. All the foods that you eat depend on this process.

E Your body uses chemical processes to break down food and to release energy.

F Your home is full of products that are manufactured by chemical industries. The products that are shown here are often used for cleaning. Some of these products, such as bleach and drain cleaner, can be dangerous if handled improperly.

Chemistry, Technology, Society, and the Environment

Today we benefit in many ways from chemical understanding and technologies. Each benefit, however, has risks associated with it. The risks and benefits of chemical processes and technologies affect us either directly or indirectly. Many people—either on their own, in groups, or through their elected government officials—assess these risks and benefits. They ask questions such as the following:

- Is it dangerous to use natural gas to heat my home?
- Why is the cost of gasoline so high?
- Is my water really clean enough to drink and use safely?
- How does rust degrade machinery over time?

During your chemistry course this year, you will study the interactions among science, technology, society, and the environment. These interactions are abbreviated as **STSE**. Throughout the textbook—in examples, practice problems, activities, investigations, and features—STSE interactions are discussed. The issues that appear at the end of some units are especially rich sources for considering STSE interactions. In these simulations, you are encouraged to assess and make decisions about important issues that affect society and the environment.

STSE Issue: Are Phosphates Helpful or Harmful?

Phosphorus is an essential nutrient for life on Earth. Plants need phosphorus, along with other nutrients, in order to grow. Phosphorus is a component of bones and teeth. In addition, phosphorus is excreted as waste from the body. Thus, it is present in human sewage.

Since phosphorus promotes plant growth, phosphates are excellent fertilizers for crops. (*Phosphates* are chemicals containing phosphorus. You will learn more about phosphates later in this unit.) Phosphates are also used as food additives, and as components in some medicines. In addition, they are an important part of dishwasher and laundry detergents. For example, sodium tripolyphosphate (STPP) acts to soften water, and keep dirt suspended in the water. Before the 1970s, STPP was a major ingredient in most detergents.

Phosphates Causing Trouble

In the 1960s, residents around Lake Erie began to notice problems. Thick growths of algae carpeted the surface of the water. Large amounts of the algae washed onto beaches, making the beaches unfit for swimming. The water in the lake looked green, and had an unpleasant odour. As time passed, certain fish species in Lake Erie began to decrease.

In 1969, a joint Canadian and American task force pinpointed the source of the problem. Phosphates and other nutrients were entering the lake, causing algae to grow rapidly. The algae then began to die and rot, using up dissolved oxygen in the water. As a result, fish and other water species that needed high levels of oxygen were dying off.

The phosphate pollution arrived in the lake from three main sources: wastewater containing detergents, sewage, and run-off from farms carrying phosphate fertilizers. The task force recommended reducing the amount of phosphate in detergents. They also suggested removing phosphorus at wastewater treatment plants before the treated water entered the lake.

Detergent manufacturers were upset by the proposed reduction in phosphates. Without this chemical, their detergents would be less effec-

Language LINK

Eutrophication is the process in which excess nutrients in a lake or river cause algae to grow rapidly. Look up this term in a reference book or on the Internet. Is eutrophication always caused by human action?

tive. Also, it would be expensive to develop other chemicals to do the same job. After pressure from the government, detergent companies reduced the amount of phosphate in their products by about 90%. Cities on Lake Erie spent millions of dollars adding phosphorus removal to their waste treatment. Today, Lake Erie has almost completely recovered.

The connection between technology (human-made chemical products) and the environment (Lake Erie) is an obvious STSE connection in this issue. What other connections do you see?

Canadians in Chemistry

John Charles Polanyi was born in Berlin, Germany, into a family of Hungarian origin. Polanyi was born on the eve of the Great Depression, shortly before the Nazi takeover. His father moved to England to become a chemistry professor at Manchester University. Polanyi was sent to Canada for safety during the darkest years of World War II.

John Polanyi went back to England to earn a doctorate in chemistry at Manchester University in 1952. He returned to Canada a few years later. Soon after, he took up a position at the University of Toronto. There Dr. Polanyi pursued the research that earned him a share of the Nobel Prize for chemistry in 1986. He pioneered the field of reaction dynamics, which addresses one of the most basic questions in chemistry: What happens when two substances interact to produce another substance? Polanyi's father had once investigated the same question.

Dr. Polanyi tried to provide some answers by studying the very faint light that is given off by molecules as they undergo chemical changes. This light is invisible to the unaided eye, because it is emitted in the infrared range of energy. It can be detected, however, with the right instruments. Dr. Polanyi's work led to the invention of the laser. As well, his research helped to explain what happens to energy during a chemical reaction.

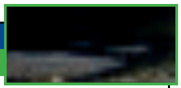
Dr. Polanyi believes that people must accept the responsibility that comes with scientific understanding and technological progress. He believes, as well, that a vital element of hope lies at the heart of modern science. To Dr. Polanyi, human rights are integral to scientific success. "Science must breathe the oxygen of freedom," he stated in 1999.

This is why Dr. Polanyi says that scientists must take part in the debate on technological, social, and political affairs. Dr. Polanyi points to the political role played by scientists such as Andrei Sakharov in the former Soviet Union, Linus Pauling in the United States, and Fang Lizhi in China.

Make Connections

1. Research the scientists whom Dr. Polanyi mentioned: Andrei Sakharov, Linus Pauling, and Fang Lizhi. What work distinguished them as scientists? What work distinguished them as members of society?
2. Throughout history, chemists have laboured to present the truth as they know it to their fellow scientists and to society. Some of them, such as Linus Pauling, have been scorned and ridiculed by the scientific community. Do further research to discover two other chemists who have struggled to communicate their ideas, and have succeeded.

COURSE CHALLENGE



At the end of this course, you will have a chance to use what you have learned to help you in the Course Challenge: Planet Unknown. In this challenge, you are a member of a science team sent to a new planet. It is your task to analyze the planet's resources. You will design and carry out hands-on investigations and analyze your results. Then you will prepare a presentation to persuade the Canadian government to invest in the establishment of a community on the planet. As you work through this book, keep a research portfolio of notes and ideas that may help you in the Course Challenge.

Section Wrap-up

During this chemistry course, your skills of scientific inquiry will be assessed using the same specific set of criteria (Table 1.1). You will notice that all review questions are coded according to this chart.

Table 1.1 Achievement Chart Criteria, Ontario Science Curriculum

Knowledge and Understanding (K/U)	Inquiry (I)	Communication (C)	Making Connections (MC)
• understanding of concepts, principles, laws, and theories • knowledge of facts and terms • transfer of concepts to new contexts • understanding of relationships between concepts	• application of the skills and strategies of scientific inquiry • application of technical skills and procedures • use of tools, equipment, and materials	• communication of information and ideas • use of scientific terminology, symbols, conventions, and standard (SI) units • communication for different audiences and purposes • use of various forms of communication • use of information technology for scientific purposes	• understanding of connections among science, technology, society, and the environment • analysis of social and economic issues involving science and technology • assessment of impacts of science and technology on the environment • proposing of courses of practical action in relation to science-and technology-based problems

Section Review

1 K/U Based on your current understanding of chemistry, list five ways in which chemistry and chemical processes affect your life.

2 I Earlier in this section, you learned that fertilizers containing phosphorus can cause algae to grow faster. Design an investigation on paper to determine the effect of phosphorus-containing detergents on algae growth.

3 C Design a graphic organizer that clearly shows the connections among science, technology, society, and the environment.

4 MC For each situation, identify which STSE interaction is most important.

(a) Research leads to the development of agricultural pesticides.

(b) The pesticides prevent insects and weeds from destroying crops.

(c) Rain soaks the excess pesticides on farm land into the ground. It ends up in groundwater systems.

(d) Wells obtain water from groundwater systems. Well-water in the area is polluted by the pesticides. It is no longer safe to drink.

Describing and Measuring Matter

1.2

As you can see in the photograph at the beginning of this chapter, water is the most striking feature of our planet. It is visible from space, giving Earth a vivid blue colour. You can observe water above, below, and at Earth's surface. Water is a component of every living thing, from the smallest bacterium to the largest mammal and the oldest tree. You drink it, cook with it, wash with it, skate on it, and swim in it. Legends and stories involving water have been a part of every culture in human history. No other kind of matter is as essential to life as water.

> As refreshing as it may be, water straight from the tap seems rather ordinary. Try this: Describe a glass of water to someone who has never seen or experienced water before. Be as detailed as possible. See how well you can distinguish water from other kinds of matter.

In addition to water, there are millions of different kinds of matter in the universe. The dust specks suspended in the air, the air itself, your chair, this textbook, your pen, your classmates, your teacher, and you—all these are examples of matter. In the language of science, **matter** is anything that has mass and volume (takes up space). In the rest of this chapter, you will examine some key concepts related to matter. You have encountered these concepts in previous studies. Before you continue, complete the Checkpoint activity to see what you recall and how well you recall it. As you proceed through this chapter, assess and modify your answers.

Describing Matter

You must observe matter carefully to describe it well. When describing water, for example, you may have used statements like these:
- Water is a liquid.
- It has no smell.
- Water is clear and colourless.
- It changes to ice when it freezes.
- Water freezes at 0°C.
- Sugar dissolves in water.
- Oil floats on water.

Characteristics that help you describe and identify matter are called **properties**. Figure 1.2 on the next page shows some properties of water and hydrogen peroxide. Examples of properties include physical state, colour, odour, texture, boiling temperature, density, and flammability (combustibility). Table 1.2 on the next page lists some common properties of matter. You will have direct experience with most of these properties during this chemistry course.

Section Preview/ Specific Expectations

In this section, you will
- **select** and **use** measuring instruments to collect and record data
- **express** the results of calculations to the appropriate number of decimal places and significant digits
- **select** and **use** appropriate SI units
- **communicate** your understanding of the following terms: *matter, properties, physical property, chemical property, significant digits, accuracy, precision*

CHECKPOINT

From memory, explain and define each of the following concepts. Use descriptions, examples, labelled sketches, graphic organizers, a computer FAQs file or Help file, or any combination of these. Return to your answers frequently during this chapter. Modify them as necessary.
- states of matter
- properties of matter
- physical properties
- chemical properties
- physical change
- chemical change
- mixture
- pure substance
- element
- compound

Figure 1.2 **Liquid water is clear, colourless, odourless, and transparent. Hydrogen peroxide (an antiseptic liquid that many people use to clean wounds) has the same properties. It differs from water, however, in other properties, such as boiling point, density, and reactivity with acids.**

Table 1.2 Common Properties of Matter

Physical Properties		Chemical Properties
Qualitative	**Quantitative**	
physical state	melting point	reactivity with water
colour	boiling point	reactivity with air
odour	density	reactivity with pure oxygen
crystal shape	solubility	reactivity with acids
malleability	electrical conductivity	reactivity with pure substances
ductility	thermal conductivity	combustibility (flammability)
hardness		toxicity
brittleness		decomposition

Properties may be physical or chemical. A **physical property** is a property that you can observe without changing one kind of matter into something new. For example, iron is a strong metal with a shiny surface. It is solid at room temperature, but it can be heated and formed into different shapes. These properties can all be observed without changing iron into something new.

A **chemical property** is a property that you can observe when one kind of matter is converted into a different kind of matter. For example, a chemical property of iron is that it reacts with oxygen to form a different kind of matter: rust. Rust and iron have completely different physical and chemical properties.

Figure 1.3 shows another example of a chemical property. Glucose test paper changes colour in the presence of glucose. Thus, a chemical property of glucose test paper is that it changes colour in response to glucose. Similarly, a chemical property of glucose is that it changes the colour of glucose test paper.

Recall that some properties of matter, such as colour, and flammability, are *qualitative*. You can describe them in words, but you cannot measure them or express them numerically. Other properties, such as density and boiling point, can be measured and expressed numerically. Such properties are *quantitative*. In Investigation 1-A you will use both qualitative and quantitative properties to examine a familiar item.

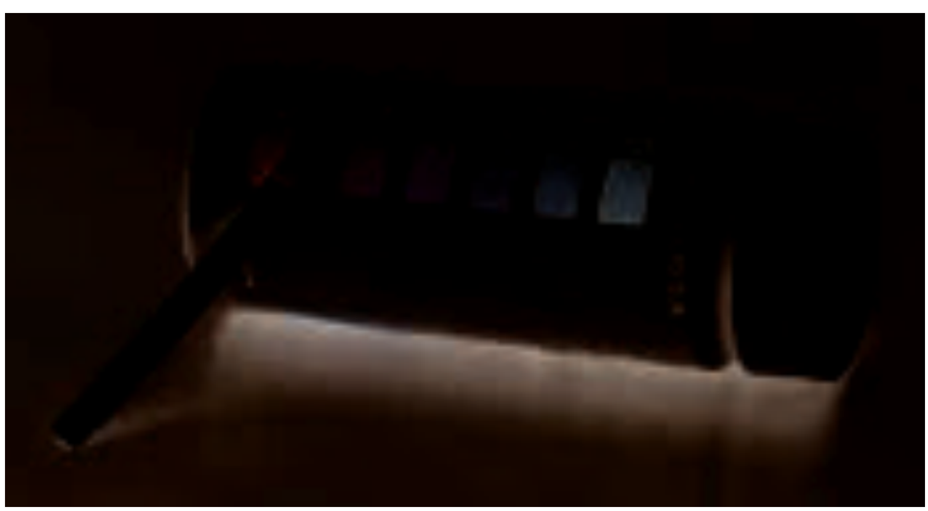


Figure 1.3 **People with diabetes rely on a chemical property to help them monitor the amount of glucose (a simple sugar) in their blood.**

Investigation 1-A

SKILL FOCUS

Initiating and Planning

Performing and recording

Analyzing and interpreting

Observing Aluminum Foil

Problem

Safety Precautions

Materials

Procedure

CAUTION

Analysis

Conclusion

Applications

Using Measurements to Describe Matter

In the investigation, you measured the size and mass of a piece of aluminum foil. You have probably performed these types of measurement many times before. Measurements are so much a part of your daily life that you can easily take them for granted. The clothes you wear come in different sizes. Much of the food you eat is sold by the gram, kilogram, millilitre, or litre. When you follow a recipe, you measure amounts. The dimensions of paper and coins are made to exact specifications. The value of money is itself a measurement.

Measurements such as clothing size, amounts of food, and currency are not standard, however. Clothing sizes in Europe are different from those in North America. European chefs tend to measure liquids and powdered solids by mass, rather than by volume. Currencies, of course, differ widely from country to country.

To communicate effectively, scientists rely on a standard system of measurement. As you have learned in previous studies, this system is called the *International System of Units* (Le système international d'unités, *SI*). It allows scientists anywhere in the world to describe matter in the same quantitative language. There are seven base SI units, and many more units that are derived from them. The metre (m), the kilogram (kg), and the second (s) are three of the base SI units. You will learn about two more base units, the mole (mol) and the kelvin (K), later in this book.

When you describe matter, you use terms such as mass, volume, and temperature. When you measure matter, you use units such as grams, cubic centimetres, and degrees Celsius. Table 1.3 lists some quantities and units that you will use often in this course. You are familiar with all of them except, perhaps, for the mole and the kelvin. The mole is one of the most important units for describing amounts of matter. You will be introduced to the mole in Unit 2. The kelvin is used to measure temperature. You will learn more about the kelvin scale in Unit 5. Consult Appendix E if you would like to review other SI quantities and units.

Table 1.3 Important SI Quantities and Their Units

Quantity	Definition	SI units or their derived equivalents	Equipment use to measure the quantity
mass	the amount of matter in an object	kilogram (kg) gram (g) milligram (mg)	balance
length	the distance between two points	metre (m) centimetre (cm) millimetre (mm)	ruler
temperature	the hotness or coldness of a substance	kelvin (K) degrees Celsius (°C)	thermometer
volume	the amount of space that an object occupies	cubic metre (m^3) cubic centimetre (cm^3) litre (L) millilitre (mL)	beaker, graduated cylinder, or pipette; may also be calculated
mole	the amount of a substance	mole (mol)	calculated not measured
density	the mass per unit of volume of a substance	kilograms per cubic metre (kg/m^3) grams per cubic centimetre (g/cm^3)	calculated or measured
energy	the capacity to do work (to move matter)	joule (J)	calculated not measured

Measurement and Uncertainty

Before you look more closely at matter, you need to know how much you can depend on measurements. How can you recognize when a measurement is trustworthy? How can you tell if it is only an approximation? For example, there are five Great Lakes. Are you sure there are five? Is there any uncertainty associated with the value "five" in this case? What about the number of millilitres in 1 L, or the number of seconds in 1 min? Numbers such as these—numbers that you can count or numbers that are true by definition—are called *exact numbers*. You are certain that there are five Great Lakes (or nine books on the shelf, or ten students in the classroom) because you can count them. Likewise, you are certain that there are 1000 mL in 1 L, and 60 s in 1 min. These relationships are true by definition.

Now consider the numbers you used and the calculations you did in Investigation 1-A. They are listed in Figure 1.4.

CHECKPOINT

Give five examples of exact numbers that you have personally experienced today or over the past few days.

- The area of the aluminum square measured 100 cm^2 (10 cm × 10 cm).

> Did you verify these dimensions? Are you certain that each side measured exactly 10 cm? Could it have been 9.9 cm or 10.1 cm?

- The mass of the aluminum square, as measured by an electronic balance, may have been about 0.33 g.

> If you used an electronic balance, are you certain that the digital read-out was accurate? Did the last digit fluctuate at all? If you used a triple-beam balance, are you certain that you read the correct value? Could it have been 0.34 g or 0.32 g?

- The density of aluminum is 2.70 g/cm^3 at a given temperature.

> What reference did you use to find the density? Did you consult more than one reference? Suppose that the density was actually 2.699 g/cm^3. Would this make a difference in your calculations? Would this make a difference in the certainty of your answer?

- The thickness of the aluminum square, calculated using a calculator, may have been about 0.001 222 cm.

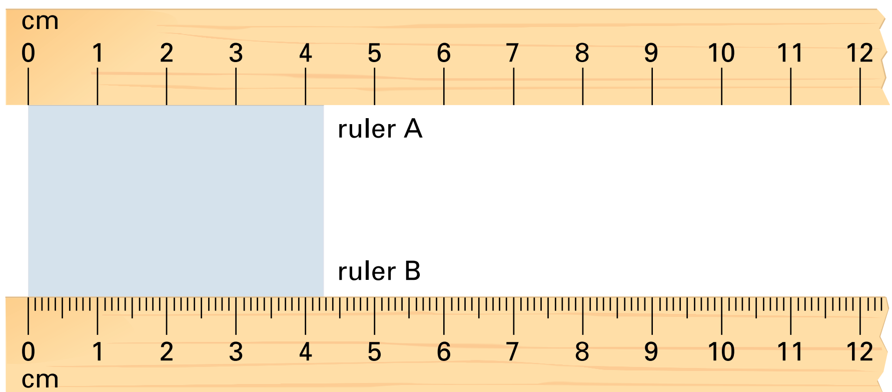
> Are you certain that this value is fair, given the other values that you worked with? Is it fair to have such a precise value, with so many digits, when there are so few digits (just two: the 1 and the 0) in your dimensions of the aluminum square?

Figure 1.4 Numbers and calculations from Investigation 1-A

During the investigations in this textbook, you will use equipment such as rulers, balances, graduated cylinders, and thermometers to measure matter. You will calculate values with a calculator or with specially programmed software. How exact can your measurements and calculations be? How exact *should* they be?

Two main factors affect your ability to record and communicate measurements and calculations. One factor is the instruments you use. The other factor is your ability to read and interpret what the instruments tell you. Examine Figures 1.5 and 1.6. They will help you understand which digits you can know with certainty, and which digits are uncertain.

What is the length measured by ruler A? Is it 4.2 cm, or is it 4.3 cm? You cannot be certain. The 2 of 4.2 is an estimate. The 3 of 4.3 is also an estimate. In both cases, therefore, you are uncertain about the last (farthest right) digit.



What is the length measured by ruler B? Is it 4.27 cm or 4.28 cm? Again, you cannot be certain. Ruler B lets you make more precise measurements than ruler A. Despite ruler B's higher precision, however, you must still estimate the last digit. The 7 of 4.27 is an estimate. The 8 of 4.28 is also an estimate.

Figure 1.5 **These two rulers measure the same length of the blue square. Ruler A is calibrated into divisions of 1 cm. Ruler B is calibrated into divisions of 0.1 cm. Which ruler can help you make more precise measurements?**

Figure 1.6 **These two thermometers measure the same temperature. Thermometer A is calibrated into divisions of 0.1˚C. Thermometer B is calibrated into divisions of 1˚C. Which thermometer lets you make more precise measurements? Which digits in each thermometer reading are you certain about? Which digits are you uncertain about?**

Significant Digits, Certainty, and Measurements

All measurements involve uncertainty. One source of this uncertainty is the measuring device itself. Another source is your ability to perceive and interpret a reading. In fact, you cannot measure anything with complete certainty. The last (farthest right) digit in any measurement is always an estimate.

The digits that you record when you measure something are called **significant digits**. Significant digits include the digits that you are certain about *and* a final, uncertain digit that you estimate. For example, 4.28 g has three significant digits. The first two digits, the 4 and the 2, are certain. The last digit, the 8, is an estimate. Therefore, it is uncertain. The value 4.3 has two significant digits. The 4 is certain, and the 3 is uncertain.

How Can You Tell Which Digits Are Significant?

You can identify the number of significant digits in any value. Table 1.4 lists some rules to help you do this.

Table 1.4 Rules for Determining Significant Digits

Rules	Examples
1. All non-zero numbers are significant.	7.886 has four significant digits. 19.4 has three significant digits. 527.266 992 has nine significant digits.
2. All zeros that are located between two non-zero numbers are significant.	408 has three significant digits. 25 074 has five significant digits.
3. Zeros that are located to the left of a value are *not* significant.	0.0907 has three significant digits. They are the 9, the third 0 to the right, and the 7. The function of the 0.0 at the begining is only to locate the decimal. 0.000 000 000 06 has one significant digit.
4. Zeros that are located to the right of a value may or may not be significant.	22 700 may have three significant digits, *or* it may have five significant digits. See the box below to find out why.

Explaining Three Significant Digits

The Great Lakes contain 22 700 km^3 of water. Is there exactly that amount of water in the Great Lakes? No, 22 700 km^3 is an approximate value. The actual volume could be anywhere from 22 651 km^3 to 22 749 km^3. You can use scientific notation to rewrite 22 700 km^3 as 2.27×10^4 km. This shows that only three digits are significant. (See Appendix E at the back of the book, if you would like to review scientific notation.)

Explaining Five Significant Digits

What if you were able to measure the volume of water in the Great Lakes? You could verify the value of 22 700 km^3. Then all five digits (including the zeros) would be significant. Here again, scientific notation lets you show clearly the five significant digits: 2.2700×10^4 km^3.

Practice Problems

1. Write the following quantities in your notebook. Beside each quantity, record the number of significant digits.
   - **(a)** 24.7 kg
   - **(b)** 247.7 mL
   - **(c)** 247.701 mg
   - **(d)** 0.247 01 L
   - **(e)** 8.930×10^5 km
   - **(f)** 2.5 g
   - **(g)** 0.0003 mL
   - **(h)** 923.2 g
2. Consider the quantity 2400 g.
   - **(a)** Assume that you measured this quantity. How many significant digits does it have?
   - **(b)** Now assume that you have no knowledge of how it was obtained. How many significant digits does it have?

Accuracy and Precision

In everyday speech, you might use the terms "accuracy" and "precision" to mean the same thing. In science, however, these terms are related to certainty. Each, then, has a specific meaning.

Accuracy refers to how close a given quantity is to an accepted or expected value. (See Figure 1.7.) **Precision** may refer to the exactness of a measurement. For example, ruler B in Figure 1.5 lets you measure length with greater precision than ruler A. Precision may also refer to the closeness of a series of data points. Data that are very close to one another are said to be precise. Examine Figure 1.8. Notice that a set of data can be precise but not accurate.

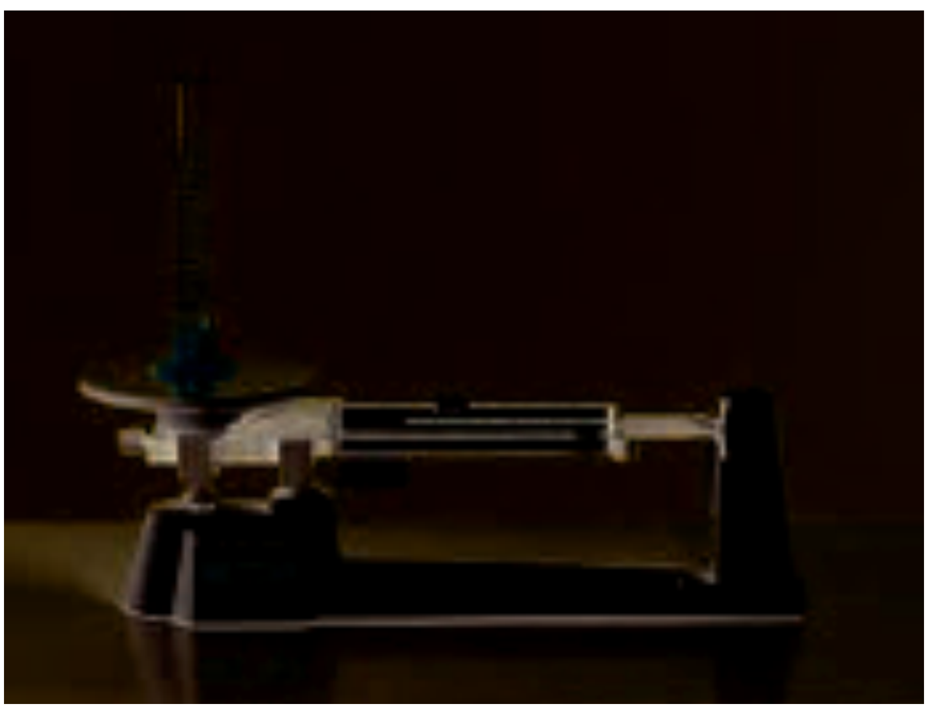


Figure 1.7 **Under standard conditions of temperature and pressure, 5 mL of water has a mass of 5 g. Why does the reading on this balance show a different value?**

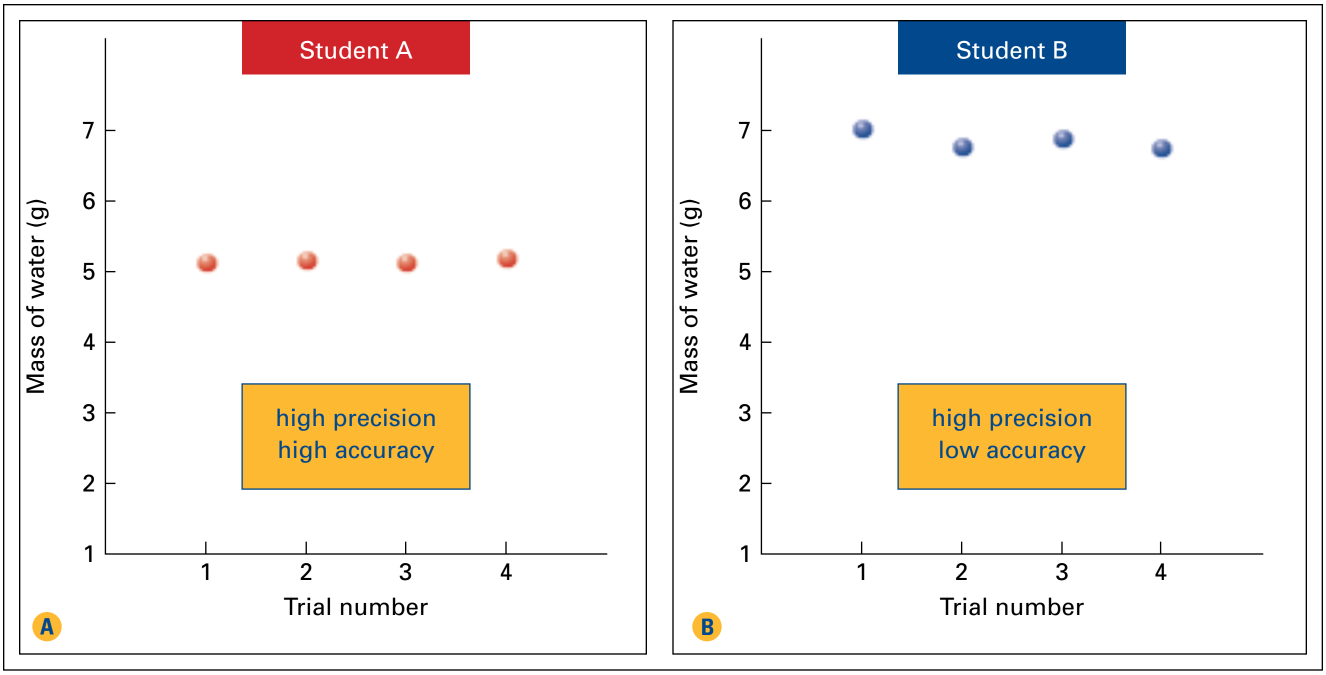


Figure 1.8 Compare student A's results with results obtained by student B.

Two students conducted four trials each to measure the volumes and masses of 5 mL of water. The graphs in Figure 1.8 show their results. The expected value for the mass of water is 5 g. Student A's results show high precision and high accuracy. Student B's results show high precision but low accuracy.

In the following Express Lab, you will see how the equipment you use affects the precision of your measurements.

ExpressLab Significant Digits

You know that the precision of a measuring device affects the number of significant digits that you should report. In this activity, each group will use different glassware and a different balance to collect data.

Materials

glassware for measuring volume: for example, graduated cylinders, Erlenmeyer flasks, pipettes or beakers

balance

water

Procedure

1. Obtain the glassware and balance assigned to your group.
2. Determine the mass and volume of a quantity of water. (The quantity you use is up to you to decide.)
3. From the data you collect, calculate the density of water.
4. Enter your values for mass, volume, and density in the class table.

Analysis

1. Examine each group's data and calculated value for density. Note how the number of significant digits in each value for density compares with the number of significant digits in the measured quantities.
2. Propose a rule or guideline for properly handling significant digits when you multiply and divide measured quantities.

Calculating with Significant Digits

In this course, you will often take measurements and use them to calculate other quantities. You must be careful to keep track of which digits in your calculations and results are significant. Why? Your results should not imply more certainty than your measured quantities justify. This is especially important when you use a calculator. Calculators usually report results with far more figures—greater certainty—than your data warrant. Always remember that calculators do not make decisions about certainty. You do.

There are three rules for reporting significant digits in calculated answers. These rules are summarized in Table 1.5. Reflect on how they apply to your previous experiences. Then examine the Sample Problems that follow.

Table 1.5 Rules for Reporting Significant Digits in Calculations

Rule 1: Multiplying and Dividing The value with the fewest number of significant digits, going into the calculation, determines the number of significant digits that you should report in your answer.
Rule 2: Adding and Subtracting The value with the fewest number of decimal places, going into the calculation, determines the number of decimal places that you should report in your answer.
Rule 3: Rounding To get the appropriate number of significant digits (rule 1) or decimal places (rule 2), you may need to round your answer. If your answer ends in a number that is greater than 5, increase the preceding digit by 1. For example, 2.346 can be rounded to 2.35. If your answer ends with a number that is less than 5, leave the preceding number unchanged. For example, 5.73 can be rounded to 5.7. If your answer ends with 5, increase the preceding number by 1 if it is odd. Leave the preceding number unchanged if it is even. For example, 18.35 can be rounded to 18.4, but 18.25 is rounded to 18.2.

Sample Problem

Reporting Volume Using Significant Digits

Problem

A student measured a regularly shaped sample of iron and found it to be 6.78 cm long, 3.906 cm wide, and 11 cm tall. Determine its volume to the correct number of significant digits.

What Is Required?

You need to calculate the volume of the iron sample. Then you need to write this volume using the correct number of significant digits.

Continued ...

Continued ...
FROM PAGE 20

What Is Given?

You know the three dimensions of the iron sample.

Length = 6.78 cm (three significant digits)

Width = 3.906 cm (four significant digits)

Height = 11 cm (two significant digits)

Plan Your Strategy

To calculate the volume, use the formula

$$\text{Volume} = \text{Length} \times \text{Width} \times \text{Height}$$
$$V = l \times w \times h$$

Find the value with the smallest number of significant digits. Your answer can have only this number of significant digits.

Act on Your Strategy

$$\begin{aligned} V &= l \times w \times h \\ &= 6.78 \text{ cm} \times 3.906 \text{ cm} \times 11 \text{ cm} \\ &= 291.309\ 48 \text{ cm}^3 \end{aligned}$$

The value 11 cm has the smallest number of significant digits: two. Thus, your answer can have only two significant digits. In order to have only two significant digits, you need to put your answer into scientific notation.

$$V = 2.9 \times 10^2 \text{ cm}^3$$

Therefore, the volume is 2.9×10^2 cm^3, to two significant digits.

Check Your Solution

- Your answer is in cm^3. This is a unit of volume.
- Your answer has two significant digits. The least number of significant digits in the question is also two.

Sample Problem

Reporting Mass Using Significant Digits

Problem

Suppose that you measure the masses of four objects as 12.5 g, 145.67 g, 79.0 g, and 38.438 g. What is the total mass of the objects?

What Is Required?

You need to calculate the total mass of the objects.

What Is Given?

You know the mass of each object.

Continued ...

Continued ...
FROM PAGE 21

Plan Your Strategy

- Add the masses together, aligning them at the decimal point.
- Underline the estimated (farthest right) digit in each value. This is a technique you can use to help you keep track of the number of estimated digits in your final answer.
- In the question, two values have the fewest decimal places: 12.5 and 79.0. You need to round your answer so that it has only one decimal place.

PROBLEM TIP

Notice that adding the values results in an answer that has three decimal places. Using the underlining technique mentioned in "Plan Your Strategy" helps you count them quickly.

Act on Your Strategy

$$\begin{array}{r} 12.\underline{5} \\ 145.6\underline{7} \\ 79.\underline{0} \\ +\ 38.43\underline{8} \\ \hline 275.\underline{608} \end{array}$$

Total mass = 275.608 g

Therefore, the total mass of the objects is 275.6 g.

Check Your Solution

- Your answer is in grams. This is a unit of mass.
- Your answer has one decimal place. This is the same as the values in the question with the fewest decimal places.

Practice Problems

3. Do the following calculations. Express each answer using the correct number of significant digits.

(a) 55.671 g + 45.78 g

(b) 1.9 mm + 0.62 mm

(c) 87.9478 L − 86.25 L

(d) 0.350 mL + 1.70 mL + 1.019 mL

(e) 5.841 g × 6.03 g

(f) $\dfrac{0.6 \text{ kg}}{15 \text{ L}}$

(g) $\dfrac{17.51 \text{ g}}{2.2 \text{ cm}^3}$

Chemistry, Calculations, and Communication

Mathematical calculations are an important part of chemistry. You will need your calculation skills to help you investigate many of the topics in this textbook. You will also need calculation skills to communicate your measurements and results clearly when you do activities and investigations. Chemistry, however, is more than measurements and calculations. Chemistry also involves finding and interpreting patterns. This is the focus of the next section.

Chemistry Bulletin

Science | Technology | Society | Environment

Air Canada Flight 143

Air Canada Flight 143 was en route from Montréal to Edmonton on July 23, 1983. The airplane was one of Air Canada's first Boeing 767s, and its systems were almost completely computerized.

While on the ground in Montréal, Captain Robert Pearson found that the airplane's fuel processor was malfunctioning. As well, all three fuel gauges were not operating. Pearson believed, however, that it was safe to fly the airplane using manual fuel measurements.

Partway into the flight, as the airplane passed over Red Lake, Ontario, one of two fuel pumps in the left wing failed. Soon the other fuel pump failed and the left engine flamed out. Pearson decided to head to the closest major airport, in Winnipeg. He began the airplane's descent. At 8400 m, and more than 160 km from the Winnipeg Airport, the right engine also failed. The airplane had run out of fuel.

In Montréal, the ground crew had determined that the airplane had 7682 L of fuel in its fuel tank. Captain Pearson had calculated that the mass of fuel needed for the trip from Montréal to Edmonton was 22 300 kg. Since fuel is measured in litres, Pearson asked a mechanic how to convert litres into kilograms. He was told to multiply the amount in litres by 1.77.

By multiplying 7682 L by 1.77, Pearson calculated that the airplane had 13 597 kg of fuel on board. He subtracted this value from the total amount of fuel for the trip, 22 300 kg, and found that 8703 kg more fuel was needed.

To convert kilograms back into litres, Pearson divided the mass, 8703 kg, by 1.77. The result was 4916 L. The crew added 4916 L of fuel to the airplane's tanks.

This conversion number, 1.77, had been used in the past because the density of jet fuel is 1.77 *pounds* per litre. Unfortunately, the number that should have been used to convert litres into kilograms was 0.803. The crew should have added 20 088 L of fuel, not 4916 L.

First officer Maurice Quintal calculated their rate of descent. He determined that they would never make Winnipeg. Pearson turned north and headed toward Gimli, an abandoned Air Force base. Gimli's left runway was being used for drag-car and go-kart races. Surrounding the runway were families and campers. It was into this situation that Pearson and Quintal landed the airplane.

Tires blew upon impact. The airplane skidded down the runway as racers and spectators scrambled to get out of the way. Flight 143 finally came to rest 1200 m later, a mere 30 m from the dazed onlookers.

Miraculously no one was seriously injured. As news spread around the world, the airplane became known as "The Gimli Glider."

Making Connections

1. You read that the airplane should have received 20 088 L of fuel. Show how this amount was calculated.
2. Use print or electronic resources to find out what caused the loss of the *Mars Climate Orbiter* spacecraft in September 1999. How is this incident related to the "Gimli Glider" story? Could a similar incident happen again? Why or why not?

Section Wrap-up

In this section, you learned how to judge the accuracy and precision of your measurement. You learned how to recognize significant digits. You also learned how to give answers to calculations using the correct number of significant digits.

In the next section, you will learn about the properties and classification of matter.

Section Review

1. K/U Explain the difference between accuracy and precision in your own words.

2. C What SI or SI-derived unit of measurement would you use to describe:
   - **(a)** the mass of a person
   - **(b)** the mass of a mouse
   - **(c)** the volume of a glass of juice
   - **(d)** the length of your desk
   - **(e)** the length of your classroom

3. K/U Record the number of significant digits in each of the following values:
   - **(a)** 3.545
   - **(b)** 308
   - **(c)** 0.000876

4. K/U Complete the following calculations and give your answer to the correct number of significant digits.
   - **(a)** 5.672 g + 92.21 g
   - **(b)** 32.34 km × 93.1 km
   - **(c)** 66.0 mL × 0.031 mL
   - **(d)** 11.2 g ÷ 92 mL

5. I What lab equipment would you use in each situation? Why?
   - **(a)** You need 2.00 mL of hydrogen peroxide for a chemical reaction.
   - **(b)** You want approximately 1 L of water to wash your equipment.
   - **(c)** You are measuring 250 mL of water to heat on a hot plate.
   - **(d)** You need 10.2 mL of alcohol to make up a solution.

6. I Review the graphs in Figure 1.8. Draw two more graphs to show
   - **(a)** data that have high accuracy but low precision
   - **(b)** data that have low accuracy and low precision

Classifying Matter and Its Changes

1.3

Matter is constantly changing. Plants grow by converting matter from the soil and air into matter they can use. Water falls from the sky, evaporates, and condenses again to form liquid water in a never-ending cycle. You can probably suggest many more examples of matter changing.

Matter changes in response to changes in energy. Adding energy to matter or removing energy from matter results in a change. Figure 1.9 shows a familiar example of a change involving matter and energy.

Section Preview/ Specific Expectations

In this section, you will

- **identify** chemical substances and chemical changes in everyday life
- **demonstrate** an understanding of the need to use chemicals safely in everyday life
- **communicate** your understanding of the following terms: *physical changes, chemical changes, mixture, pure substance, element, compound*

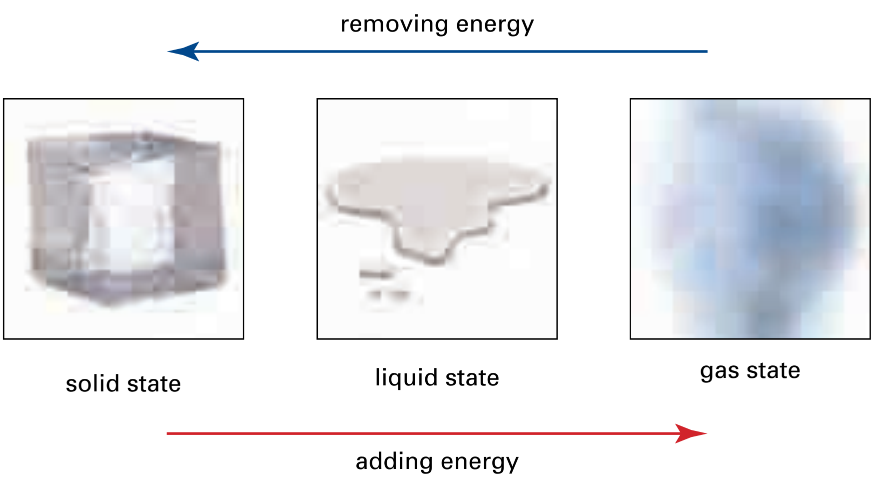


Figure 1.9 **Like all matter, water can change its state when energy is added or removed.**

Physical and Chemical Changes in Matter

A change of state alters the appearance of matter. The composition of matter remains the same, however, regardless of its state. For example, ice, liquid water, and water vapour are all the same kind of matter: water. Melting and boiling other kinds of matter have the same result. The appearance and some other physical properties change, but the matter retains its identity—its composition. Changes that affect the physical appearance of matter, but *not* its composition, are **physical changes**.

Figure 1.10 shows a different kind of change involving water. Electrical energy is passed through water, causing it to decompose. Two completely different kinds of matter result from this process: hydrogen gas and oxygen gas. These gases have physical and chemical properties that are different from the properties of water and from each other's properties. Therefore, decomposing water is a change that affects the composition of water. Changes that alter the composition of matter are called **chemical changes**. Iron rusting, wood burning, and bread baking are three examples of chemical changes.

You learned about physical and chemical properties earlier in this chapter. A physical change results in a change of physical properties only. A chemical change results in a change of both physical and chemical properties.

Figure 1.10 **An electrical current is used to decompose water. This process is known as electrolysis.**

mind STRETCH

Before adopting the metric system, Canadians measured temperature in units called Fahrenheit degrees (°F). Based on the Fahrenheit scale, water boils at 212°F and freezes at 32°F. A few countries, including the United States, still use the Fahrenheit scale. Without checking any reference materials, design a method for converting Fahrenheit temperatures to Celsius temperatures, and back again. Show your work, and explain your reasoning.

Practice Problems

4. Classify each situation as either a physical change or a chemical change. Explain your reasoning.
   - **(a)** A rose bush grows from a seed that you have planted and nourished.
   - **(b)** A green coating forms on a copper statue when the statue is exposed to air.
   - **(c)** Your sweat evaporates to help balance your body temperature.
   - **(d)** Frost forms on the inside of a freezer.
   - **(e)** Salt is added to clear chicken broth.
   - **(f)** Your body breaks down the food you eat to provide energy for your body's cells.
   - **(g)** Juice crystals dissolve in water.
   - **(h)** An ice-cream cone melts on a hot day.

Figure 1.11 **To see the components of soil, add some soil to a glass of water. What property is responsible for separating the components?**

Classifying Matter

All matter can be classified into two groups: mixtures and pure substances. A **mixture** is a physical combination of two or more kinds of matter. For example, soil is a mixture of sand, clay, silt, and decomposed leaves and animal bodies. If you look at soil under a magnifying glass, you can see these different components. Figure 1.11 shows another way to see the components of soil.

The components in a mixture can occur in different proportions (relative quantities). Each individual component retains its identity. Mixtures in which the different components are clearly visible are called *heterogeneous mixtures*. The prefix "hetero-" comes from the Greek word *heteros*, meaning "different."

Mixtures in which the components are blended together so well that the mixture looks like just one substance are called *homogeneous mixtures*. The prefix "homo- " comes from the Greek word *homos*, meaning "the same." Saltwater, clean air, and grape juice are common examples. Homogeneous mixtures are also called solutions. You will investigate solutions in Unit 3.

A **pure substance** has a definite composition, which stays the same in response to physical changes. A lump of copper is a pure substance. Water (with nothing dissolved in it) is also a pure substance. Diamond, carbon dioxide, gold, oxygen, and aluminum are pure substances, too.

Pure substances are further classified into elements and compounds. An **element** is a pure substance that cannot be separated chemically into any simpler substances. Copper, zinc, hydrogen, oxygen, and carbon are examples of elements.

A **compound** is a pure substance that results when two or more elements combine chemically to form a different substance. Compounds can be broken down into elements using chemical processes. For example, carbon dioxide is a compound. It can be separated into the elements carbon and oxygen. The Concept Organizer on the next page outlines the classification of matter at a glance. The ThoughtLab reinforces your understanding of properties, mixtures, and separation of substances.

Word LINK

The word "pure" can be used to mean different things. In ordinary conversation, you might say that orange juice is "pure" if no other materials have been added to it. How is this meaning of pure different from the scientific meaning in the term "pure substance?"

Concept Organizer — The Classification System for Matter.

Matter
- anything that has mass and volume
- found in three physical states: solid, liquid, gas

Mixtures
- physical combinations of matter in which each component retains its identity

Heterogenous Mixtures (Mechanical Mixtures)
- all components are visible

Homogeneous Mixtures (Solutions)
- components are blended so that it looks like a single substance.

Physical Changes

Pure Substances
- matter that has a definite composition

Elements
- matter that cannot be decomposed into simpler substances

Chemical Changes

Compounds
- matter in which two or more elements are chemically combined

ThoughtLab — Mixtures, Pure Substances, and Changes

You frequently use your knowledge of properties to make and separate mixtures and substances. You probably do this most often in the kitchen. Even the act of sorting clean laundry, however, depends on your ability to recognize and make use of physical properties. This activity is a "thought experiment." You will use your understanding of properties to mix and separate a variety of chemicals, all on paper. Afterward, your teacher may ask you to test your ideas, either in the laboratory or at home in the kitchen.

Procedure

1. Consider the following chemicals: table salt, water, baking soda, sugar, iron filings, sand, vegetable oil, milk, and vinegar. Identify each chemical as a mixture or a pure substance.
2. Which of these chemicals can you mix together *without* producing a chemical change? In your notebook, record as many of these physical combinations as you can.
3. Which of these chemicals can you mix together to produce a chemical change? Record as many of these chemical combinations as you can.
4. Record a mixture that is made with four of the chemicals. Then suggest one or more techniques that you can use to separate the four chemicals from one another. Write notes and sketch labelled diagrams to show your techniques. Identify the properties that your techniques depend on.

Analysis

1. In step 2, what properties of the chemicals did you use to determine your combinations?
2. In step 3, what properties did you use to determine your combinations?

Application

3. Exchange your four-chemical mixture with a partner. Do not include your notes and diagrams. Challenge your partner to suggest techniques to separate the four chemicals. Then assess each other's techniques. What modifications, if any, would you make to your original techniques?

Section Wrap-up

Notice that the classification system for matter, shown in the Concept Organizer, is based mainly on the changes that matter undergoes:

- physical changes to separate mixtures into elements or compounds
- chemical changes to convert compounds or elements into different compounds or elements

To explain how and why these chemical changes occur, you must look "deeper" into matter. You must look at its composition. This is what you will do in the next chapter. You will see how examining the composition of matter leads to a different classification system: the periodic table. You will also see how the periodic table allows chemists to make predictions about the properties and behaviour of matter.

Section Review

1 C Copy Figure 1.9 into your notebook. Add the following labels in the appropriate places: evaporation, condensation, melting, freezing, solidifying. **Note:** Some labels may apply to the same places on the diagram.

2 C You may recall that sublimation is a change of state in which a solid changes directly into a gas. The reverse is also true. Add the label "sublimation" to your diagram for question 1. Include arrows to show the addition or removal of energy.

3 K/U List three mixtures that you use frequently.

(a) Explain how you know that each is a mixture.

(b) Classify each mixture as either heterogeneous or homogenous.

4 K/U List three pure substances that you use frequently.

(a) Explain how you know that each is a pure substance.

(b) Try to classify each substance as an element or compound. Explain your reasoning.

5 I You are given a mixture of wood chips, sand, coffee grounds, and water. Design a process to clean the water.

6 MC The water going down your drain and toilet is cleaned and recycled. You will learn about water purification processes in Chapter 9.

(a) Propose a possible series of steps that you could use to clean the waste water from your home.

(b) Will this cleaned water be drinkable? Explain your answer.

(c) What further steps may be needed to clean this water?

CHAPTER 1 Review

Reflecting on Chapter 1

Summarize this chapter in the format of your choice. Here are a few ideas to use as guidelines:

- List possible interactions among science, technology, society, and the environment (STSE).
- Give examples of physical and chemical properties.
- Make a table of common SI units.
- Think about measurement and uncertainty. When is a number exact?
- Make up a list of values. Challenge your friends to identify the number of significant digits in each.
- Review the rules for significant digits when adding, subtracting, multiplying, and dividing numbers.
- Explain the difference between accuracy and precision.
- Give examples of physical and chemical changes.
- Into what categories can matter be classified?

Reviewing Key Terms

For each of the following terms, write a sentence that shows your understanding of its meaning.

accuracy	chemical changes
chemical property	chemistry
compound	element
matter	mixture
physical changes	physical property
precision	properties
pure substance	significant digits
STSE	

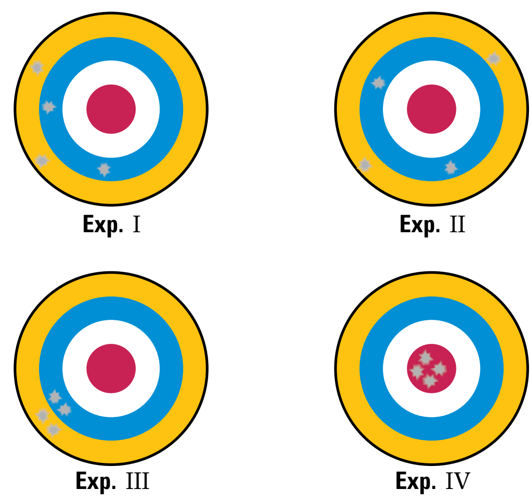
Knowledge/Understanding

1. Identify each property as either physical or chemical.
   (a) Hydrogen gas is extremely flammable.
   (b) The boiling point of ethanol is 78.5°C.
   (c) Chlorine gas is pale green in colour.
   (d) Sodium metal reacts violently with water.

2. How can you tell the difference between a physical change and a chemical change?

3. Name the property that each change depends on. Then classify the property as either chemical or physical.
   (a) You separate a mixture of gravel and road salt by adding water to it.
   (b) You add baking soda to vinegar, and the mixture bubbles and froths.
   (c) You use a magnet to locate iron nails that were dropped in a barn filled knee-deep with straw.
   (d) Carbon dioxide gas freezes at a temperature of −78°C.
   (e) You recover salt from a solution of saltwater by heating the solution until all the water has evaporated.
   (f) The temperature of a compost pile rises as the activity of the bacteria inside the pile increases.

4. Use the terms "accuracy" and "precision" to describe the results on the dart boards shown below. Assume that the darts represent data and the bulls-eye represents the expected value.



5. Examine the containers on the next page.
   (a) What volume of liquid does each container contain? Be as accurate and precise as possible in your answers.
   (b) Assume that the liquid in all three containers is water. If the flask and the graduated cylinder are emptied into the beaker, what is the total volume of water in the beaker? Report your answer to the correct number of significant digits.
   (c) Which container is the best choice for measuring volume in a laboratory? Explain why.

6. Make each conversion below.
   (a) 10 kg to grams (g)
   (b) 22.3 cm to metres (m)
   (c) 52 mL to centimetres cubed (cm^3)
   (d) 1.0 L to centimetres cubed (cm^3)
7. Identify the number of significant digits in each value.
   (a) 0.002 cm
   (b) 3107 km
   (c) 5 g
   (d) 8.6×10^{10} m^3
   (e) 4.0003 mL
   (f) 5.432×10^2 km^2
   (g) 91 511 L
8. (a) Explain why the value 5700 km could have two, three, or four significant digits.
   (b) Write 5700 km with two significant digits.
   (c) Write 5700 km with four significant digits.
9. Complete each calculation. Express your answer to the correct number of significant digits.
   (a) 4.02 mL + 3.76 mL + 0.95 mL
   (b) $(2.7 \times 10^2$ m$) \times (4.23 \times 10^2$ m$)$
   (c) 5 092 kg ÷ 23 L
   (d) 2 – 0.3 + 6 – 7
   (e) $(6.853 \times 10^3$ L$) + (5.40 \times 10^3$ L$)$
   (f) (572.3 g + 794.1 g) ÷ (24 mL + 52 mL)
10. Round each value to the given number of significant digits.
    (a) 62 091 to three significant digits
    (b) 27 to one significant digit
    (c) 583 to one significant digit
    (d) 17.25 to three significant digits
11. A plumber installs a pipe that has a diameter of 10 cm and a length of 2.4 m. Calculate the volume of water (in cm^3) that the pipe will hold. Express your answer to the correct number of significant digits. **Note:** The formula for the volume of a cylinder is $V = \pi r^2 h$, where r is the radius and h is the height or length.
12. During an investigation, a student monitors the temperature of water in a beaker. The data from the investigation are shown in the table below.
    (a) What was the average temperature of the water? Express your answer to the appropriate number of significant digits.
    (b) The thermometer that the student used has a scale marked at 1˚ intervals. Which digits in the table below are estimated?

Time (min)	Temperature (˚C)
0.0	25
1	24.3
2	24
3	23.7
4	23.6

13. Identify each change as either physical or chemical.
    (a) Over time, an iron swing set becomes covered with rust.
    (b) Juice crystals "disappear" when they are stirred into a glass of water.
    (c) Litmus paper turns pink when exposed to acid.
    (d) Butter melts when you spread it on hot toast.

Inquiry

14. Your teacher asks the class to measure the mass of a sample of aluminum. You measure the mass three times, and obtain the following data: 6.74, 6.70, and 6.71 g. The actual value is 6.70 g. Here are the results of three other students:

    Student A 6.50, 6.49, and 6.52 g

    Student B 6.57, 6.82, and 6.71 g

    Student C 6.61, 6.70, and 6.87 g

    (a) Graph the four sets of data. (Call yourself "student D.")

(b) Which results are most precise?
(c) Which results are most accurate?
(d) Which results have the highest accuracy *and* precision?

15. (a) Design an investigation to discover some of the physical and chemical properties of hydrogen peroxide, H_2O_2.
(b) List the materials you need to carry out your investigation.
(c) What specific physical and/or chemical properties does your investigation test for?
(d) What variables are held constant during your investigation? What variables are changed? What variables are measured?
(e) If you have time, obtain some hydrogen peroxide from a drugstore. Perform your investigation, and record your observations.

Communication

16. Choose one of the common chemicals listed below. In your notebook, draw a concept web that shows some of the physical properties, chemical properties, and uses of this chemical.
- table salt (sodium chloride)
- water
- baking soda (sodium hydrogen carbonate)
- sugar (sucrose)

17. In your notebook, draw a flowchart or concept web that illustrates the connections between the following words:
- mixture
- pure substance
- homogeneous
- heterogeneous
- solution
- matter
- water
- cereal
- aluminum
- apple juice

18. Is salad dressing a homogenous mixture or a heterogeneous mixture? Use diagrams to explain.

Making Connections

19. Locate 3 cleaning products in your home. For each product, record the following information:
- the chemical(s) most responsible for its cleaning action
- any safety symbols or warnings on the packaging or container
- any hazards associated with the chemical(s) that the product contains
- suggestions for using the product safely

Back in class, share and analyze the chemicals that everyone found.
(a) Prepare a database that includes all the different chemicals, the products in which they are found, their hazards, and instructions for their safe use. Add to the database throughout the year. Make sure that you have an updated copy at all times.
(b) Identify the cleaning products that depend mainly on chemical changes for their cleaning action. How can you tell?

20. At the beginning of this chapter, you saw how water, a very safe chemical compound, can be misrepresented to appear dangerous. Issues about toxic and polluting chemicals are sometimes reported in newspapers or on television. List some questions you might ask to help you determine whether or not an issue was being misrepresented.

21. Describe the most important STSE connections for each situation.
(a) Car exhaust releases gases such as sulfur dioxide, $SO_{2(g)}$, and nitrogen oxide, $NO_{(g)}$. These gases lead to smog in cities. As well, they are a cause of acid rain.
(b) In the past, people used dyes from plants and animals to colour fabrics. These natural dyes produced a limited range of colours, and they faded quickly. Today long-lasting artificial dyes are available in almost every possible colour. These dyes were invented by chemists. They are made in large quantities for the fabric and clothing industries.

Answers to Practice Problems and Short Answers to Section Review Questions

Practice Problems: **1.(a)** 3 **(b)** 4 **(c)** 6 **(d)** 5 **(e)** 4 **(f)** 2 **(g)** 1 **(h)** 4 **2.(a)** 4 **(b)** 2 **3.(a)** 101.45 g **(b)** 2.5 mm **(c)** 1.70 L **(d)** 3.07 mL **(e)** 35.2 g^2 **(f)** 4×10^{-2} kg/L **(g)** 8.0 g/cm^3 **4.(a)** chemical **(b)** chemical **(c)** physical **(d)** physical **(e)** physical **(f)** chemical **(g)** physical **(h)** physical
Section Review: 1.2: **2.(a)** kg **(b)** g **(c)** mL **(d)** cm **(e)** m **3.(a)** 4 **(b)** 3 **(c)** 3 **4.(a)** 97.88 g **(b)** 3.01×10^3 km^2 **(c)** 2.0 mL^2 **(d)** 0.12 g/mL **5.(a)** pipette **(b)** Erlenmeyer flask or large beaker **(c)** 250 mL beaker **(d)** graduated cylinder