Name ______________________ Class ______________ Date ____________

CHAPTER 1 Introduction to Science

SECTION 3

Organizing Data

KEY IDEAS

As you read this section, keep these questions in mind:

- What is scientific notation?
- How are precision and accuracy different?
- How do scientists use graphs to show data?

How Do Scientists Write Numbers?

When scientists conduct an experiment, they must carefully record the data. In most cases, the first step in recording data is writing down measurements. Scientists need to record their measurements carefully.

Sometimes, the value of a measurement is very large or very small. This results in long numbers with many zeros or decimal places. It is easy to make mistakes when writing and copying long numbers. Recall that you can use SI prefixes to reduce the number of zeros. Another way to reduce the number of zeros is to use scientific notation.

In **scientific notation**, you express a value as a number multiplied by a power of 10. A power of 10 is written as a small number above the 10 called an *exponent*. The exponent shows how many times 10 is multiplied by itself. For example, $10^2 = 10 \times 10$. Negative exponents show how many times to divide by 10. For example, $10^{-2} = 1 \div (10 \times 10)$. The table shows some other powers of 10.

Decimal Number	Equivalent Power of 10	Example
1,000,000	10^6	$5{,}000{,}000 = 5 \times 10^6$
1,000	10^3	$3{,}000 = 3 \times 10^3$
100	10^2	$150 = 1.5 \times 10^2$
10	10^1	$20 = 2 \times 10^1$
0.1	10^{-1}	$0.6 = 6 \times 10^{-1}$
0.001	10^{-3}	$0.009 = 9 \times 10^{-3}$
0.000001	10^{-6}	$0.000004 = 4 \times 10^{-6}$

To determine the power of ten for a number, count the number of zeroes in the number. For example, 800,000 m is written 8×10^5 m. If the number is less than one, count the number of decimal places. For example, 0.00004 cm is written as 4×10^{-5} cm. ☑

READING TOOLBOX

Apply Concepts After you read this section, create a table showing the heights of five of your friends. Then, use the data to make a bar graph.

Critical Thinking

1. Infer When may it be a good idea to use scientific notation or SI prefixes?

____

____

READING CHECK

2. Apply Concepts What exponent should you use to represent one hundred thousand?

____

MAKING CALCULATIONS USING SCIENTIFIC NOTATION

When you use scientific notation in calculations, follow the math rules for powers of 10. For example, when you multiply two values, you add the powers of 10. When you divide two values, you subtract the powers of 10.

Suppose you want to find out how long it takes for light to travel from Neptune to Earth. Light travels at a speed of about 3.0×10^8 m/s. The distance between Neptune and Earth is about 4.5×10^{12} m. To calculate the time it takes light to travel this distance, use the process below.

$$t = \frac{\text{distance from Earth to Neptune (m)}}{\text{speed of light (m/s)}}$$

$$t = \frac{4.5 \times 10^{12}\ \cancel{\text{m}}}{3.0 \times 10^{8}\ \cancel{\text{m}}/\text{s}}$$

$$t = \left(\frac{4.5}{3.0} \times \frac{10^{12}}{10^{8}}\right) \frac{\cancel{\text{m}}}{\cancel{\text{m}}/\text{s}}$$

$$t = (1.5 \times 10^{(12-8)})\ \text{s}$$

$$t = 1.5 \times 10^{4}\ \text{s}$$

Math Skills

3. Convert What is the distance between Neptune and Earth in kilometers? Give your answer in scientific notation.

____

PRECISION AND ACCURACY OF MEASUREMENTS

Imagine that you are measuring how far a long jumper jumped. If you use a tape measure that is marked every 0.1 m, you could report that the jump was 4.1 m. If you used a tape measure that was marked every 0.01 m, you could report a more exact value—4.11 m. The second measurement has greater **precision**, or exactness.

Scientists use **significant figures** to show the precision of a measurement. The distance of 4.1 m has two significant figures because the measured value has two digits. The distance of 4.11 m has three significant figures.

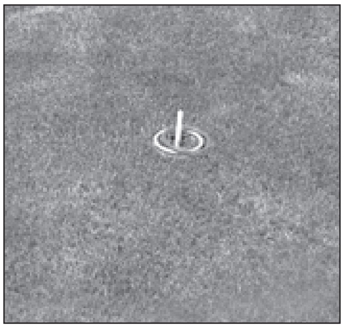
Suppose that the tape measure had a mistake in it. Instead of the marks being 0.01 m apart, they were actually 0.02 m apart. Your measurements would be far from their true value. In other words, they would not be very accurate. **Accuracy** describes how close a measurement is to the true value of the quantity being measured. The figures at the top of the next page give other examples of accuracy and precision.

Critical Thinking

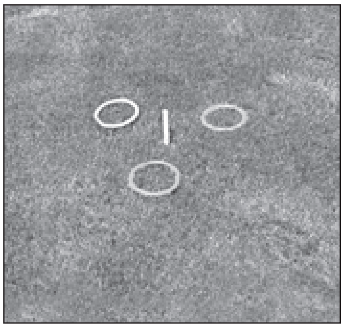
4. Apply Concepts A student has two rulers. One is marked in centimeters. The other is marked in millimeters. Which ruler should the student use to make the most precise measurements?

____

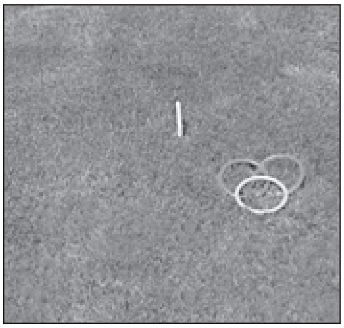
____



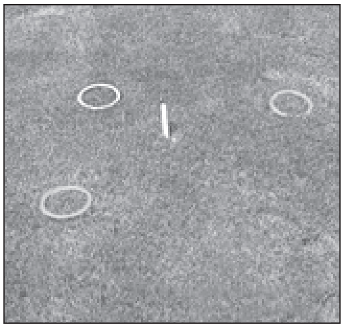
_________ precision,
_________ accuracy



_________ precision,
_________ accuracy



Good precision,
poor accuracy



_________ precision,
_________ accuracy

LOOKING CLOSER

5. Identify Fill in the blanks to describe the precision and accuracy shown in each picture.

SIGNIFICANT FIGURES IN CALCULATIONS

When you use measurements in calculations, you must give your answer with the correct number of significant figures. The answer can be only as precise as the least precise measurement used in the calculation. The least precise measurement is the one with the fewest significant figures. ☑

When you multiply or divide measurements, round the answer to the number of significant figures of the least precise measurement. For example, imagine that you need to calculate the area of a wall. The wall is 8.871 m long and 9.14 m high. To calculate the area, you multiply 8.871 m by 9.14 m. The result is 81.08094 m^2. The least precise value, 9.14 m, has three significant figures. The correctly rounded answer is therefore 81.1 m^2.

Whenever you add or subtract measurements, round the answer to the same number of decimal places as the least precise measurement. For example, if you add 6.3421 to 12.1, your answer should have only one decimal place. This is because the least precise value, 12.1, has one decimal place. Therefore, the correctly rounded answer is 18.4. ☑

READING CHECK

6. Describe A student takes several measurements. How can the student determine which measurement is the least precise?

____

____

____

READING CHECK

7. Identify A student adds two numbers together. How can the student determine the number of significant figures in the answer?

____

____

Math Skills

8. Identify Which measurement of the book is most precise?

____

MORE CALCULATIONS WITH SIGNIFICANT FIGURES

Suppose you want to find the volume of a book that is 24.8 cm long, 19 cm wide, and 6.2 cm high. The equation for finding volume is shown below.

$$volume = length \times width \times height$$

Substitute your book measurements into the equation.

$$volume = 24.8 \text{ cm} \times 19 \text{ cm} \times 6.2 \text{ cm}$$

If you use a calculator to solve the problem, you will get the answer shown below.

$$volume = 2{,}921.44 \text{ cm}^3$$

Is this the correct answer? Not yet. Remember, the answer can only be as precise as the least precise measurement. In this case, both the width and height were measured to two significant digits. Therefore, you must also round your answer to two significant digits. Rounding 2,921.44 cm^3 gives you the correct answer: 2,900 cm^3.

How Do Scientists Present Data?

Measurements, calculations, and other results of experiments may lead to new questions that can be tested by different scientists. Therefore, scientists must present their data clearly. Otherwise, other scientists may not be able to understand or use the data easily. The best way to present data depends on the situation. ☑

READING CHECK

9. Explain Why should scientists present their data clearly?

____

____

Suppose you want to find the speed of a certain chemical reaction that makes a gas. You mix two chemicals in a flask attached to one end of a rubber hose. You place the other end of the hose in a graduated cylinder full of water. As the reaction proceeds, the gas travels through the hose and into the graduated cylinder. The gas bubbles push the water out of the graduated cylinder, as shown in the figure below.

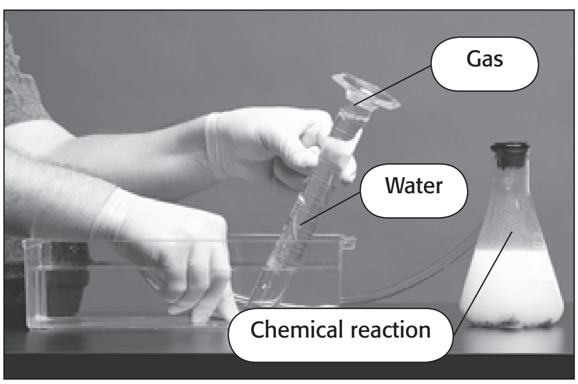
LOOKING CLOSER

10. Infer How could the person determine the volume of gas produced in the reaction?

____

____

____



You can measure the volume of the gas in the graduated cylinder and record your results in a data table.

USING LINE GRAPHS TO SHOW CHANGE

You can read the volume of gas in the cylinder every 20 s from the start of the reaction until there is no change in volume. Then, you can make a table like the one below to organize the data that you collect in the experiment.

Time (s)	Volume of Gas (mL)
0	0
20	6
40	25
60	58
80	100
100	140
120	152
140	156
160	156
180	156

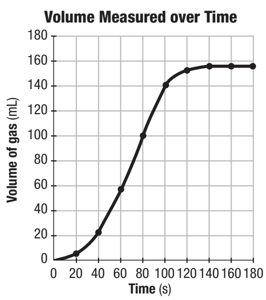
Math Skills

11. Calculate How many milliliters of gas were produced between 40 s and 100 s? Show your work.

____

____

The table of numbers is the best way to record your data accurately. However, a table can be difficult to read and interpret. You can help people more easily see how the volume changed by making a graph. There are many types of graphs that you could use. A *line graph* is a good choice for displaying data that change over time.



This graph makes it easier to see how the volume of gas changed over time.

LOOKING CLOSER

12. Read a Graph When did the reaction stop producing gas? Explain how you know.

____

____

____

____

____

The line graph above shows the same information as the data table. It shows two variables, time and volume. Time is the *independent variable*. In other words, it is the variable you could control in the experiment. The volume of gas is the *dependent variable* because it depends on the independent variable.

Line graphs clearly show changes during an experiment. The graph shows that gas was produced slowly during the first 20 s. From 40 s to 100 s, the gas was produced at a rate of about 40 mL every 20 s. The reaction then slowed down and stopped after about 140 s.

USING BAR GRAPHS TO SHOW THE VALUE OF ITEMS

Suppose a scientist measured the melting temperatures of some metals. The scientist could show her data in a table, like the one below. However, a list of numbers in a table does not easily show the relationship between the values. Suppose you want to know which metal has the highest melting temperature. To find out, you must read through all of the entries in the temperature column.

LOOKING CLOSER

13. Compare Which has the higher melting temperature, gold or silver?

____

Element	**Melting temperature (K)**
Aluminum	933
Gold	1,337
Iron	1,808
Lead	601
Silver	1,235

To more easily compare the data, you could show the data in a graph. A *bar graph* shows the values of several different items. Bar graphs can be useful when you want to compare data for several individual items or events. By comparing the sizes of the bars in the graph, you can determine which value is largest or smallest. The graph below is a bar graph of the melting temperatures in the table. ☑

READING CHECK

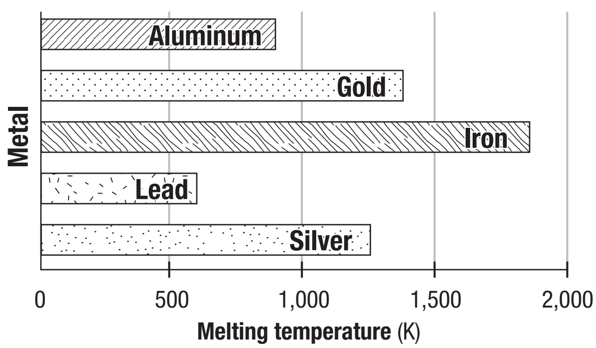
14. Identify When should you use a bar graph to display your data?

____

____

____

Melting Points of Some Common Metals



This bar graph shows the relative melting points of different metals. It is easier to read than the data table.

Compare the table of melting temperatures to the bar graph. The bar graph contains the same data as the table. However, the differences in melting temperature between the metals are easier to see in the bar graph. You can easily tell that iron has the highest melting temperature. You can also see that the melting temperature of aluminum is about half the melting temperature of iron.

USING PIE GRAPHS TO SHOW THE PARTS OF A WHOLE

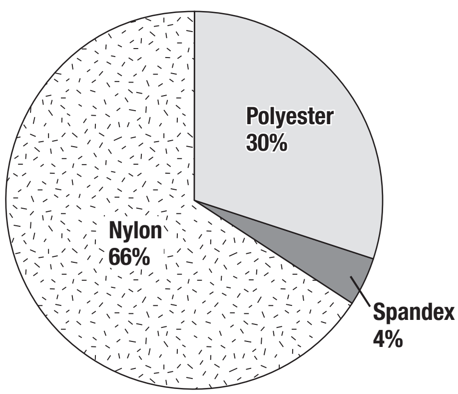
Sometimes, you need to use a graph to show the amounts of different parts of a whole. For example, suppose a clothing company is making a new kind of winter coat. The new coat is made from three different materials. Each material gives the coat different properties. The company wants to show how much of each material is in the new coat.

The company could make a data table that shows the different materials in the coat. The table may look like the one below. From the table, you can see that the coat is made from three different materials: nylon, polyester, and spandex. You can also see how much of each material is in the coat.

Type of Fabric	Percentage of Fabric in the Coat
Nylon	66
Polyester	30
Spandex	4

The company could also use a pie graph to show the materials in the coat. In a *pie graph*, the different parts of a whole are shown as "slices" of a pie. The size of each slice shows how much of the whole is made up of that part. For example, the pie graph below shows the composition of the winter coat. In this case, the "pie" represents the coat. Each slice represents a different material in the coat. ☑

Materials in a Winter Coat



The graph shows the same information as the data table. However, the graph makes it easier to see that most of the coat is nylon. Only a small fraction of the coat is spandex.

Talk About It

Brainstorm Think of some other examples that you have seen of people displaying data. What kind of data were being displayed? How were they displayed? Share your list with a small group.

LOOKING CLOSER

15. Identify Which material makes up the smallest fraction of the coat?

____

READING CHECK

16. Describe What do the different slices in a pie graph represent?

____

____

Name ______________________ Class ______________ Date ______________

Section 3 Review

SECTION VOCABULARY

accuracy a description of how close a measurement is to the true value of the quantity measured

precision the exactness of a measurement

scientific notation a method of expressing a quantity as a number multiplied by 10 to the appropriate power

significant figure a prescribed decimal place that determines the amount of rounding off to be done based on the precision of the measurement

1. **Evaluate** A student measures her height with a meter stick and finds that she is about 1.5 m tall. How can she measure her height with greater accuracy and precision?

____

____

____

____

2. **Compare** Fill in the blank spaces in the table below.

Example of Data to Be Displayed	Best Type of Graph to Use
changes in the mass of a rock over time	
the fractions of different gases in the atmosphere	
the maximum speed of several different cars	
how the height of a rocket changes with time	
the relative amounts of different minerals in a rock	

3. **Apply Concepts** A student measures the length, width, and height of a fish tank. She finds that the fish tank is 105 cm long, 75 cm wide, and 80.5 cm high. What is the volume of the fish tank? Show your work. Use scientific notation and show the correct number of significant figures in your answer.