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3 SCIENTIFIC MEASUREMENT

SECTION 3.1 MEASUREMENTS AND THEIR UNCERTAINTY (pages 63–72)

This section describes the concepts of accuracy, precision, and error in measurements. It also explains the proper use of significant figures in measurements and calculations.

▶ Using and Expressing Measurements (page 63)

1. Why are numbers used in chemistry often expressed in scientific notation?

____

____

____

____

2. Circle the letter of each sentence that is true about numbers expressed in scientific notation.

a. A number expressed in scientific notation is written as the product of a coefficient and a power of 10.

b. The power of 10 is called the exponent.

c. The coefficient is always a number greater than or equal to one and less than ten.

d. For numbers less than one, the exponent is positive.

3. Circle the letter of the answer in which 503,000,000 is written correctly in scientific notation.

a. 5.03×10^{-7}

b. 503×10^{6}

c. 5.03×10^{8}

d. 503 million

▶ Accuracy, Precision, and Error (pages 64–65)

4. Is the following sentence true or false? To decide whether a measurement has good precision or poor precision, the measurement must be made more than once. ____________________

CHAPTER 3, Scientific Measurement *(continued)*

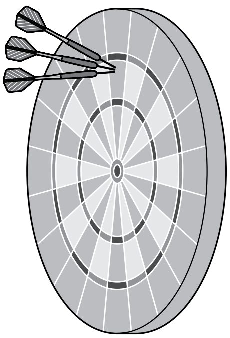
Label each of the three following sentences that describes accuracy with an *A*. Label each sentence that describes precision with a *P*.

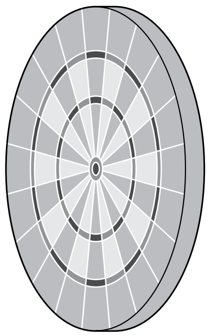
________ **5.** Four of five repetitions of a measurement were numerically identical, and the fifth varied from the others in value by less than 1%.

________ **6.** Eight measurements were spread over a wide range.

________ **7.** A single measurement is within 1% of the correct value.

8. On a dartboard, darts that are closest to the bull's-eye have been thrown with the greatest accuracy. On the second target, draw three darts to represent three tosses of lower precision, but higher accuracy than the darts on the first target.


First target


Second target

9. What is the meaning of "accepted value" with respect to an experimental measurement?

____

10. Complete the following sentence. For an experimental measurement, the experimental value minus the accepted value is called the ______________ .

11. Is the following sentence true or false? The value of an error must be positive. ______________

12. Relative error is also called ______________________ .

13. The accepted value of a length measurement is 200 cm, and the experimental value is 198 cm. Circle the letter of the value that shows the percent error of this measurement.

a. 2%

b. −2%

c. 1%

d. −1%

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▶ Significant Figures in Measurements (pages 66–67)

14. If a thermometer is calibrated to the nearest degree, to what part of a degree can you estimate the temperature it measures? ____________________

15. Circle the letter of the correct digit. In the measurement 43.52 cm, which digit is the most uncertain?

a. 4 **c.** 5

b. 3 **d.** 2

16. Circle the letter of the correct number of significant figures in the measurement 6.80 m.

a. 2 **c.** 4

b. 3 **d.** 5

17. List two situations in which measurements have an unlimited number of significant figures.

a. ____

b. ____

____

____

18. Circle the letter of each sentence that is true about significant figures.

a. Every nonzero digit in a reported measurement is assumed to be significant.

b. Zeros appearing between nonzero digits are never significant.

c. Leftmost zeros acting as placeholders in front of nonzero digits in numbers less than one are not significant.

d. All rightmost zeros to the right of the decimal point are always significant.

e. Zeros to the left of the decimal point that act as placeholders for the first nonzero digit to the left of the decimal point are not significant.

▶ Significant Figures in Calculations (pages 68–71)

19. Is the following sentence true or false? An answer is as precise as the most precise measurement from which it was calculated. ________________

Round the following measurements as indicated.

20. Round 65.145 meters to 4 significant figures. ________________

21. Round 100.1°C to 1 significant figure. ________________

CHAPTER 3, Scientific Measurement *(continued)*

22. Round 155 cm to two significant figures. ____________________

23. Round 0.000 718 kilograms to two significant figures. ____________________

24. Round 65.145 meters to three significant figures. ____________________

SECTION 3.2 THE INTERNATIONAL SYSTEM OF UNITS (pages 73–79)

This section defines units of measurement for length, volume, mass, temperature, and energy in the International System of Units (SI).

▶ Units and Quantities (pages 74–79)

1. Complete the table showing selected SI base units of measurement.

Units of Measurement		
Quantity	SI base unit	Symbol
Length		
Mass		
Temperature		
Time		

2. All metric units of length are based on multiples of _______ .

3. The International System of Units (SI) is a revised version of the

____________________ .

4. Explain what is meant by a "derived unit."

____

____

____

5. Give at least one example of a derived unit.

____

____

____

6. Complete the following table showing some metric units of length. Remember that the meter is the SI base unit for length.

Metric Units of Length		
Unit	**Symbol**	**Factor Multiplying Base Unit**
Meter	m	1
Kilometer		
Centimeter		
Millimeter		
Nanometer		

Match each metric unit with the best estimate of its length or distance.

_______ **7.** Height of a stove top above the floor — **a.** 1 km

_______ **8.** Thickness of about 10 sheets of paper — **b.** 1 m

_______ **9.** Distance along a road spanning about 10 telephone poles — **c.** 1 cm

_______ **10.** Width of a key on a computer keyboard — **d.** 1 mm

11. The space occupied by any sample of matter is called its ________________ .

12. Circle the letter of each sentence that is true about units of volume.

a. The SI unit for volume is derived from the meter, the SI unit for length.

b. The liter (L) is a unit of volume.

c. The liter is an SI unit.

d. There are 1000 cm^3 in 1 L, and there are also 1000 mL in 1 L, so 1 cm^3 is equal to 1 mL.

Match each of the three descriptions of a volume to the appropriate metric unit of volume.

	Example	**Unit of Volume**
_______	**13.** Interior of an oven	**a.** 1 L
_______	**14.** A box of cookies	**b.** 1 m^3
_______	**15.** One-quarter teaspoon	**c.** 1 mL

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CHAPTER 3, Scientific Measurement *(continued)*

16. A volume of 1 L is also equal to

a. 1000 mL

b. 1 dm^3

c. 1000 cm

17. The volume of any solid, liquid, or gas will change with

_______________________ .

18. A kilogram was originally defined as the mass of ___________________________ .

19. Circle the letter of the unit of mass commonly used in chemistry that equals 1/1000 kilogram.

a. gram **b.** milligram **c.** milliliter

Match each unit of mass with the object whose mass would be closest to that unit.

	Mass	Unit of Mass
_______	**20.** A few grains of sand	**a.** 1 kg
_______	**21.** A liter bottle of soda	**b.** 1 g
_______	**22.** Five aspirin tablets	**c.** 1 mg

23. Circle the letter of the instrument shown that is used to measure mass.

a. scale

b. balance beam

c. platform balance

d. analytical balance

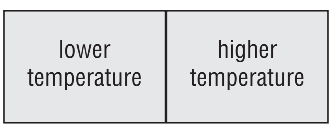
24. Is the following sentence true or false? The mass of an object changes with location. _______________________

25. When brought to the surface of the moon, will a mass have more or less weight than it did on the surface of Earth, or will it be the same weight? Explain.

____

____

26. Draw an arrow below the diagram, showing the direction of heat transfer between two objects.



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27. What properties explain the behavior of liquid-filled thermometers?

____

____

____

____

28. What are the two reference temperatures on the Celsius scale?

____

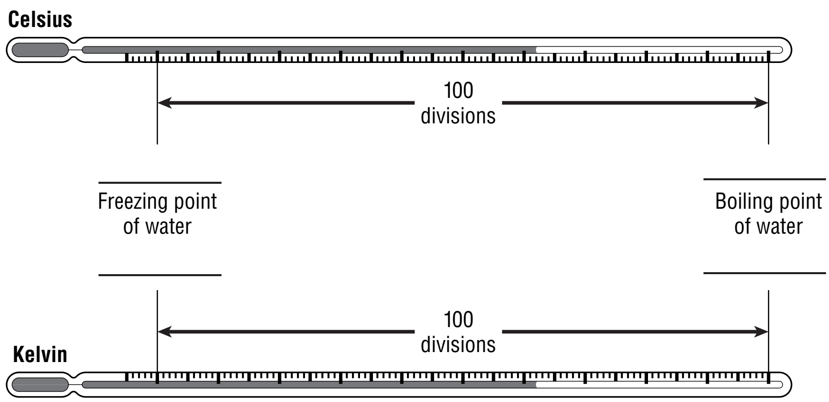
____

29. What is the zero point, 0 K, on the Kelvin scale called?

____

30. A change of temperature equal to one Kelvin is equal to a change of temperature of how many degrees Celsius? ______________________

31. Complete the diagram to show the reference temperatures in the Celsius and Kelvin scales.



32. One calorie is the quantity of heat that raises the temperature of ______________________ of pure water by ______________________ .

SECTION 3.3 CONVERSION PROBLEMS (pages 80–87)

This section explains how to construct conversion factors from equivalent measurements. It also describes how to apply the techniques of dimensional analysis to a variety of conversion problems.

▶ Conversion Factors (pages 80–81)

1. How are the two parts of a conversion factor related?

____

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2. Look at Figure 3.11. In a conversion factor, the smaller number is part of the quantity that has the ____________________ unit. The larger number is part of the quantity that has the ____________________ unit.

3. Is the following sentence true or false? The actual size of a measurement multiplied by a conversion factor remains the same, because the measurement being converted is multiplied by unity. ____________________

4. Write two conversion factors based on the relationship between hours and minutes.

____

5. The average lead for a mechanical pencil is 6.0 cm long when it is new. Circle the letter of the conversion factor you would use to find its length in inches.

a. $\frac{2.54\text{ cm}}{1\text{ in.}}$

b. $\frac{1\text{ in.}}{2.54\text{ cm}}$

c. $\frac{1\text{ in.}}{6.0\text{ cm}}$

d. $\frac{6.0\text{ cm}}{1\text{ in.}}$

6. A student is asked to calculate the volume, in milliliters, of 2 cups of oil. There are 225 mL per cup. The student calculates the volume as follows:

$$\text{Volume} = 2\text{ cups} \times \frac{1\text{ cup}}{25\text{ mL}} = 0.08\text{ cup}$$

List three errors the student made.

____

____

____

▶ Dimensional Analysis (pages 81–83)

7. What is dimensional analysis?

____

____

____

8. Reread Sample Problem 3.5. The correct conversion factor has the ____________ unit in the denominator and the ____________ unit in the numerator.

9. A container can hold 65 g of water. Circle the conversion factor needed to find the mass of water that 5 identical containers can hold.

 a. $\frac{5\ \text{containers}}{65\ \text{g water}}$

 b. $\frac{1\ \text{container}}{65\ \text{g water}}$

 c. $\frac{65\ \text{g water}}{1\ \text{container}}$

 d. $\frac{65\ \text{g water}}{5\ \text{containers}}$

▶ Converting Between Units (pages 84–85)

10. Converting between units is easily done using ______________________ .

11. Circle the letter of the conversion factor that you would use to convert tablespoons to milliliters.

 a. $\frac{4\ \text{fluid ounces}}{1\ \text{tablespoon}}$

 b. $\frac{1\ \text{tablespoon}}{4\ \text{fluid ounces}}$

 c. $\frac{1\ \text{tablespoon}}{15\ \text{mL}}$

 d. $\frac{15\ \text{mL}}{1\ \text{tablespoon}}$

12. Show the calculation you would use to convert the following:

 a. 0.25 m to centimeters ______________________________

 b. 9.8 g to kilograms ______________________________

 c. 35 ms to seconds ______________________________

 d. 4.2 dL to liters ______________________________

13. Complex conversions between units may require using ____________________ conversion factor.

14. How many conversion factors would you need to use to find the number of liters in a cubic decimeter? What are they?

____

____

Name ____________________ Date ______________ Class ______________

CHAPTER 3, Scientific Measurement *(continued)*

15. How would you calculate the number of nanometers in 8.1 cm?

____

16. What is the equivalent of 0.35 lb in grams?

____

17. A scientist has 0.46 mL of a solution. How would she convert this volume to microliters?

____

18. Describe the steps you would use to solve this problem. In a scale drawing of a dining room floor plan, 10 mm equals 2 meters. If the homeowners wanted to purchase flooring that costs $10.89 per square yard, how much would they spend on flooring for the dining room? The dimensions of the dining room on the floor plan are 40 mm × 32 mm.

____

____

____

19. Name three common measurements that are expressed as a ratio of two units.

____

20. What technique can be used to convert complex units?

____

21. A normal concentration of glucose, or sugar, in the blood is 95 mg/dL. How many grams of sugar would be present per liter of blood? Show the conversion factors you use.

____

22. Replace each question mark in the table with the conversion factors needed to obtain the given units of density.

Mass	Volume	Density
g	$mm^3 \times$?	g/m^3
kg × ?	$cm^3 \times$?	g/m^3

23. A man can run a mile in 4 minutes. Calculate his average speed in kilometers per hour. Show your work. (1 mile = 1.61 km)

____

____

Name ____________________ Date ______________ Class ______________

24. A baseball player's batting average is .254 (254 hits per 1000 at bats). If she is at bat an average of 3 times per game, how many hits will she make in 52 games? Show your work.

____

____

SECTION 3.4 DENSITY (pages 89–93)

This section defines density. It explains that density is a characteristic property that depends on the composition of a substance, not on the size of the sample.

▶ Determining Density (page 89–90)

1. Is the mass of one pound of lead greater than, less than, or equal to the mass of one pound of feathers? ______________

2. Which material has a greater density, lead or feathers? ______________

3. How is density defined?

____

4. The mass of a sample is measured in grams, and its volume is measured in cubic centimeters. In what units would its density be reported?

____

5. Look at Table 3.6 on page 90. Circle the letter of the material that will sink in liquid water at 4°C.

a. aluminum

b. corn oil

c. ice

d. gasoline

▶ Density and Temperature (pages 91–92)

6. The density of a substance generally decreases as its temperature increases. Are there any exceptions to this statement? Explain.

____

____

____

Name ____________________ Date ______________ Class ______________

GUIDED PRACTICE PROBLEMS

GUIDED PRACTICE PROBLEM 3 (page 69)

3. Round 87.073 meters to three significant figures. Write your answer in scientific notation.

Step 1. To round to three significant figures, round to the nearest tenth. 87.073 rounds to _______

Step 2. Write the number in scientific notation. ____________________ meters

GUIDED PRACTICE PROBLEM 34 (page 85)

34. The radius of a potassium atom is 0.227 nm.
Express this radius in centimeters.
Complete the following steps to solve the problem.

Step 1. Use the conversion factors for nanometers and centimeters. $0.227\text{ nm} \times \frac{\square}{1 \times 10^9\text{ nm}} \times \square$

Step 2. Simplify. $= \frac{0.227 \times 10^2}{10^9}$ $\square$

Step 3. Divide. $= \square$ cm

EXTRA PRACTICE (similar to Practice Problem 36, page 86)

36. Gold has a density of about 20 g/cm^3. Estimate this density in kg/m^3.

Name ______________________ Date ________________ Class ________________

GUIDED PRACTICE PROBLEM 46 (page 91)

46. A student finds a shiny piece of metal that she thinks is aluminum. In the lab, she determines that the metal has a volume of 245 cm^3 and a mass of 612 g. Calculate the density. Is the metal aluminum?

Analyze

Step 1. List the known values.

Volume = 245 cm^3

Mass = _______ g

Step 2. List the unknown.

____

Calculate

Step 3. Use the following relationship to find the density. Remember to round your answer to three significant figures.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$= \frac{612\ \text{g}}{\_\_\_\_\_\ \text{cm}^3}$$

$$= \_\_\_\_\_\ \text{g/cm}^3$$

Step 4. To determine whether the piece of metal is aluminum, compare the density of the metal to the density of aluminum given in Table 3.7 on page 90. Is the metal aluminum? ______________________

Evaluate

Step 5. Underline the correct word(s) that complete(s) this statement. Because the mass of the metal is about two and one-half times the volume, a density of about 2.5 g/cm^3 is reasonable. Because a density of 2.50 g/cm^3 is nearly 10% less than 2.7 g/cm^3, the density of aluminum, the metal (is, is not) aluminum.

EXTRA PRACTICE (similar to Practice Problem 48a, page 92)

48a. Use dimensional analysis to convert 4.68 g of boron to cubic centimeters of boron. The density of boron is 2.34 g/cm^3.