In certain situations, the term *specific gravity* is used to describe the density of a liquid. **Specific gravity** is defined as the ratio of the density of a given liquid to the density of water at 4 °C. Because it is a ratio of densities, specific gravity has no units.

CHAPTER 2 REVIEW

Key Terms

measurement (p. 15)
scientific notation (2.1)
units (2.2)
English system (2.2)
metric system (2.2)
SI units (2.2)
volume (2.3)
mass (2.3)
significant figures (2.4)
rounding off (2.5)
conversion factor (2.6)
equivalence statement (2.6)
dimensional analysis (2.6)
Fahrenheit scale (2.7)
Celsius scale (2.7)
Kelvin (absolute) scale (2.7)
density (2.8)
specific gravity (2.8)

F directs you to the *Chemistry in Focus* feature in the chapter
VP indicates visual problems
OWL interactive versions of these problems are assignable in OWL.

Summary

1. A quantitative observation is called a measurement and always consists of a number and a unit.
2. We can conveniently express very large or very small numbers using scientific notation, which represents the number as a number between 1 and 10 multiplied by 10 raised to a power.
3. Units give a scale on which to represent the results of a measurement. The three systems discussed are the English, metric, and SI systems. The metric and SI systems use prefixes (Table 2.2) to change the size of the units.
4. The mass of an object represents the quantity of matter in that object.
5. All measurements have a degree of uncertainty, which is reflected in the number of significant figures used to express them. Various rules are used to round off to the correct number of significant figures in a calculated result.
6. We can convert from one system of units to another by a method called dimensional analysis, in which conversion factors are used.
7. Temperature can be measured on three different scales: Fahrenheit, Celsius, and Kelvin. We can readily convert among these scales.
8. Density is the amount of matter present in a given volume (mass per unit volume). That is,

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

Active Learning Questions

These questions are designed to be considered by groups of students in class. Often these questions work well for introducing a particular topic in class.

1. a. There are 365 days/year, 24 hours/day, 12 months/year, and 60 minutes/hour. How many minutes are there in one month?
   b. There are 24 hours/day, 60 minutes/hour, 7 days/week, and 4 weeks/month. How many minutes are there in one month?
   c. Why are these answers different? Which (if either) is more correct and why?

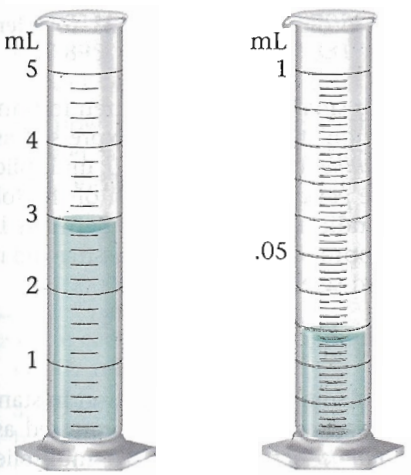
2. You go to a convenience store to buy candy and find the owner to be rather odd. He allows you to buy pieces only in multiples of four, and to buy four, you need \$0.23. He allows you only to use 3 pennies and 2 dimes. You have a bunch of pennies and dimes, and instead of counting them, you decide to weigh them. You have 636.3 g of pennies, and each penny weighs an average of 3.03 g. Each dime weighs an average of 2.29 g. Each piece of candy weighs an average of 10.23 g.
   a. How many pennies do you have?
   b. How many dimes do you need to buy as much candy as possible?
   c. How much would all of your dimes weigh?
   d. How many pieces of candy could you buy (based on the number of dimes from part b)?
   e. How much would this candy weigh?
   f. How many pieces of candy could you buy with twice as many dimes?

3. When a marble is dropped into a beaker of water, it sinks to the bottom. Which of the following is the best explanation?
   a. The surface area of the marble is not large enough for the marble to be held up by the surface tension of the water.
   b. The mass of the marble is greater than that of the water.

c. The marble weighs more than an equivalent volume of the water.
d. The force from dropping the marble breaks the surface tension of the water.
e. The marble has greater mass and volume than the water.

Explain each choice. That is, for choices you did not pick, explain why you feel they are wrong, and justify the choice you did pick.

4. Consider water in each graduated cylinder as shown:



You add both samples of water to a beaker. How would you write the number describing the total volume? What limits the precision of this number?

5. What is the numerical value of a conversion factor? Why must this be true?

6. For each of the following numbers, indicate which zeros are significant and explain. Do not merely cite the rule that applies, but explain the rule.

a. 10.020 b. 0.002050 c. 190 d. 270

7. Consider the addition of "15.4" to "28." What would a mathematician say the answer is? What would a scientist say? Justify the scientist's answer, not merely citing the rule, but explaining it.

8. Consider multiplying "26.2" by "16.43." What would a mathematician say the answer is? What would a scientist say? Justify the scientist's answer, not merely citing the rule, but explaining it.

9. In lab you report a measured volume of 128.7 mL of water. Using significant figures as a measure of the error, what range of answers does your reported volume imply? Explain.

10. Sketch two pieces of glassware: one that can measure volume to the thousandths place, and one that can measure volume only to the ones place.

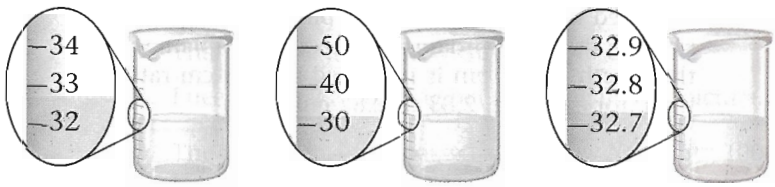
11. Oil floats on water but is "thicker" than water. Why do you think this fact is true?

12. Show how converting numbers to scientific notation can help you decide which digits are significant.

13. You are driving 65 mph and take your eyes off the road "just for a second." How many feet do you travel in this time?

14. You have a 1.0-cm^3 sample of lead and a 1.0-cm^3 sample of glass. You drop each in a separate beaker of water. How do the volumes of water that are displaced by the samples compare? Explain.

VP 15. The beakers shown below have different precisions.



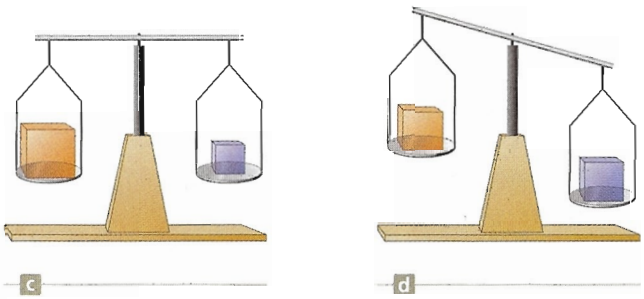
a. Label the amount of water in each of the three beakers to the correct number of significant figures.
b. Is it possible for each of the three beakers to contain the exact same amount of water? If no, why not? If yes, did you report the volumes as the same in part a? Explain.
c. Suppose you pour the water from these three beakers into one container. What should be the volume in the container reported to the correct number of significant figures?

16. True or False? For any mathematical operation performed on two measurements, the number of significant figures in the answer is the same as the least number of significant figures in either of the measurements. Explain your answer.

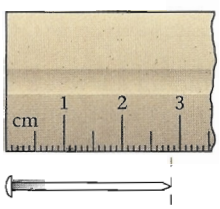
17. Complete the following and explain each in your own words: leading zeros are (never/sometimes/always) significant; captive zeros are (never/sometimes/always) significant; and trailing zeros are (never/sometimes/always) significant.

For any statement with an answer of "sometimes," give examples of when the zero is significant and when it is not, and explain.

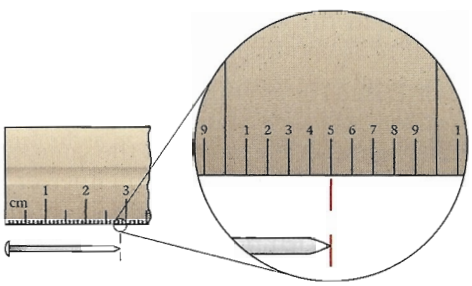
VP 18. For each of the following figures, a through d, decide which block is more dense: the orange block, the blue block, or it cannot be determined. Explain your answers.



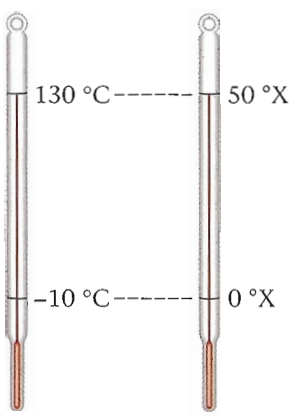
VP 19. For the pin shown below, why is the third digit determined for the length of the pin uncertain? Considering that the third digit is uncertain, explain why the length of the pin is indicated as 2.85 cm rather than, for example, 2.83 or 2.87 cm.



VP 20. Why can the length of the pin shown below not be recorded as 2.850 cm?



VP 21. Use the figure below to answer the following questions.



a. Derive the relationship between °C and °X.
b. If the temperature outside is 22.0 °C, what is the temperature in units of °X?
c. Convert 58.0 °X to units of °C, K, and °F.

Questions and Problems

2.1 Scientific Notation

QUESTIONS

1. A _____ represents a quantitative observation.
2. Although your textbook lists the rules for converting an ordinary number to scientific notation, oftentimes students remember such rules better if they put them into their own words. Pretend you are helping your 12-year-old niece with her math homework, and write a paragraph explaining to her how to convert the ordinary number 2421 to scientific notation.
3. When a large or small number is written in standard scientific notation, the number is expressed as the product of a *number* between 1 and 10, multiplied by the appropriate *power* of 10. For each of the following numbers, indicate what number between 1 and 10 would be appropriate when expressing the numbers in standard scientific notation.

   a. 9651 c. 93,241
   b. 0.003521 d. 0.000001002

4. When a large or small number is written in standard scientific notation, the number is expressed as the product of a *number* between 1 and 10, multiplied by the appropriate *power* of 10. For each of the following numbers, indicate what power of 10 would be appropriate when expressing the numbers in standard scientific notation.

   a. 82,350
   b. 0.009375
   c. 251
   d. 0.00000000000000000000000000000009109

PROBLEMS

5. Will the power of 10 have a *positive* or a *negative* exponent when each of the following numbers is rewritten in standard scientific notation?

   a. 42,751 c. 0.002045
   b. 1253 d. 0.1089

6. Will the power of 10 have a *positive, negative,* or *zero* exponent when each of the following numbers is rewritten in standard scientific notation?

   a. 0.9091 c. 9091
   b. 9.091 d. 0.00000009091

7. Express each of the following numbers in *standard* scientific notation.

   a. 0.5012
   b. 5,012,000
   c. 0.000005012
   d. 5.012
   e. 5012
   f. 0.005012

8. Rewrite each of the following as an "ordinary" decimal number.

   a. 2.789×10^{3}
   b. 2.789×10^{-3}
   c. 9.3×10^{7}
   d. 4.289×10^{1}
   e. 9.999×10^{4}
   f. 9.999×10^{-5}

9. By how many places must the decimal point be moved, and in which direction, to convert each of the following to "ordinary" decimal numbers?

   a. 4.311×10^{6}
   b. 7.895×10^{-5}
   c. 8.712×10^{1}
   d. 4.995×10^{0}
   e. 2.331×10^{18}
   f. 1.997×10^{-16}

10. By how many places must the decimal point be moved, and in which direction, to convert each of the following to standard scientific notation?

    a. 5993
    b. −72.14
    c. 0.00008291
    d. 62.357
    e. 0.01014
    f. 324.9

11. Write each of the following numbers in *standard* scientific notation.

    a. 97,820
    b. 42.14×10^{3}
    c. 0.08214×10^{-3}
    d. 0.0003914
    e. 927.1
    f. $4.781 \times 10^{2} \times 10^{-3}$

12. Write each of the following numbers as "ordinary" decimal numbers.

    a. 6.244×10^{3}
    b. 9.117×10^{-2}
    c. 8.299×10^{1}
    d. 1.771×10^{-4}
    e. 5.451×10^{2}
    f. 2.934×10^{-5}

13. Write each of the following numbers in *standard* scientific notation.

    a. 1/1033
    b. $1/10^{5}$
    c. $1/10^{-7}$
    d. 1/0.0002
    e. 1/3,093,000
    f. $1/10^{-4}$
    g. $1/10^{9}$
    h. 1/0.000015

14. Write each of the following numbers in *standard* scientific notation.

    a. 1/0.00032
    b. $10^{3}/10^{-3}$
    c. $10^{3}/10^{3}$
    d. 1/55,000
    e. $(10^{5})(10^{4})(10^{-4})/(10^{-2})$
    f. $43.2/(4.32 \times 10^{-5})$
    g. $(4.32 \times 10^{-5})/432$
    h. $1/(10^{5})(10^{-6})$

2.2 Units

QUESTIONS

15. What are the fundamental units of mass, length, and temperature in the metric system?

16. Give several examples of how *prefixes* are used in the metric system to indicate quantities that are multiples or divisions of the fundamental units of the metric system.

2.3 Measurements of Length, Volume, and Mass

QUESTIONS

Students often have trouble relating measurements in the metric system to the English system they have grown up with. Give the approximate English system equivalents for each of the following metric system descriptions in Exercises 17–20.

17. My new kitchen floor will require 25 square meters of linoleum.

18. My recipe for chili requires a 125-g can of tomato paste.

19. The gas tank in my new car holds 48 liters.

20. I need some 2.5-cm-long nails to hang up this picture.

21. The road sign I just passed says "New York City 100 km," which is about _____ mi.

22. Which contains more soda, a 2-liter bottle or a 2-quart bottle?

23. The tablecloth on my dining room table is 2 m long, which is _____ cm or about _____ in.

24. Who is taller, a man who is 1.62 m tall or a woman who is 5 ft 6 in. tall?

25. The fundamental SI unit of length is the meter. However, we often deal with larger or smaller lengths or distances for which multiples or fractions of the fundamental unit are more useful. For each of the following situations, suggest what fraction or multiple of the meter might be the most appropriate measurement.

    a. the distance between Chicago and Saint Louis
    b. the size of your bedroom
    c. the dimensions of this textbook
    d. the thickness of a hair

26. Which metric unit of length or distance is most comparable in scale to each of the following English system units for making measurements?

    a. an inch
    b. a yard
    c. a mile

27. The unit of volume in the metric system is the liter, which consists of 1000 milliliters. How many liters or milliliters is each of the following common English system measurements approximately equivalent to?

    a. a gallon of gasoline
    b. a pint of milk
    c. a cup of water

28. Which metric system unit is most appropriate for measuring the distance between two cities?

    a. meters
    b. millimeters
    c. centimeters
    d. kilometers

2.4 Uncertainty in Measurement

QUESTIONS

29. If you were to measure the width of this page using a ruler, and you used the ruler to the limits of precision permitted by the scale on the ruler, the last digit you would write down for the measurement would be *uncertain* no matter how careful you were. Explain.

30. What does it mean to say that every measurement we make with a measuring device contains some measure of *uncertainty?*

31. For the pin shown in Figure 2.5, why is the third figure determined for the length of the pin uncertain? Considering that the third figure is uncertain, explain why the length of the pin is indicated as 2.85 cm rather than, for example, 2.83 or 2.87 cm.

32. Why can the length of the pin shown in Figure 2.5 not be recorded as 2.850 cm?

2.5 Significant Figures

QUESTIONS

33. Indicate the number of significant figures in each of the following:

    a. 250. b. 250 c. 2.5×10^2 d. 250.0

34. Indicate the number of significant figures implied in each of the following statements:

    a. One inch is equivalent to 2.54 cm.
    b. My chemistry instructor gave us 24 homework problems to solve this week!
    c. My monthly car payment is $249.75.
    d. It's about 2500 mi from California to Hawaii.

Rounding Off Numbers

QUESTIONS

35. When we round off a number, if the number to the right of the digit to be rounded is greater than 5, then we should _____ .

36. In a multiple-step calculation, is it better to round off the numbers to the correct number of significant figures in each step of the calculation or to round off only the final answer? Explain.

37. Round off each of the following numbers to three significant digits, and express the result in standard scientific notation.

    a. 254,931 c. 47.85×10^3
    b. 0.00025615 d. 0.08214×10^5

38. Round off each of the following numbers to three significant digits, and express the result in standard scientific notation.

    a. 0.004175×10^{-3}
    b. 38,652
    c. 0.00000000000000000000000000000009109
    d. 5.455×10^6

39. Round off each of the following numbers to the indicated number of significant digits and write the answer in standard scientific notation.

    a. 4341×10^2 to three significant digits
    b. 93.441×10^3 to three significant digits
    c. 0.99155×10^2 to four significant digits
    d. 9.3265 to four significant digits

40. Round off each of the following numbers to the indicated number of significant digits and write the answer in standard scientific notation.

    a. 0.0008751 to two significant digits
    b. 93,745 to four significant digits
    c. 0.89724 to three significant digits
    d. 9.995×10^2 to three significant digits

Determining Significant Figures in Calculations

QUESTIONS

41. Consider the calculation indicated below:

$$\frac{2.21 \times 0.072333 \times 0.15}{4.995}$$

    Explain why the answer to this calculation should be reported to only two significant digits.

42. Suppose a group of objects were to be weighed separately on a scale and then the individual masses *added together* to determine the total mass of the group of objects. What would determine how many significant digits should appear in the reported total mass? Give an example of such a calculation.

43. When the calculation $(2.31)(4.9795 \times 10^3)/(1.9971 \times 10^4)$ is performed, how many significant digits should be reported for the answer? You should *not* need to perform the calculation.

44. Try this with your calculator: Enter 2 ÷ 3 and press the = sign. What does your calculator say is the answer? What would be wrong with that answer if the 2 and 3 were experimentally determined numbers?

45. When the sum 4.9965 + 2.11 + 3.887 is calculated, to how many decimal places should the answer be reported? You should *not* need to perform the calculation.

46. How many digits after the decimal point should be reported when the calculation (10,434 − 9.3344) is performed?

PROBLEMS

Note: See the Appendix for help in doing mathematical operations with numbers that contain exponents.

47. Evaluate each of the following mathematical expressions, and express the answer to the correct number of significant digits.

    a. 44.2124 + 0.81 + 7.335
    b. 9.7789 + 3.3315 − 2.21
    c. 0.8891 + 0.225 + 4.14
    d. (7.223 + 9.14 + 3.7795)/3.1

48. Evaluate each of the following mathematical expressions, and express the answer to the correct number of significant digits.

a. $(4.771 + 2.3)/3.1$
b. $5.02 \times 10^2 + 4.1 \times 10^2$
c. $1.091 \times 10^3 + 2.21 \times 10^2 + 1.14 \times 10^1$
d. $(2.7991 \times 10^{-6})/(4.22 \times 10^6)$

49. *Without actually performing the calculations indicated,* tell to how many significant digits the answer to the calculation should be expressed.

a. $(0.196)(0.08215)(295)/(1.1)$
b. $(4.215 + 3.991 + 2.442)/(0.22)$
c. $(7.881)(4.224)(0.00033)/(2.997)$
d. $(6.219 + 2.03)/(3.1159)$

50. *Without actually performing the calculations indicated,* tell to how many significant digits the answer to the calculation should be expressed.

a. $\dfrac{(9.7871)(2)}{(0.00182)(43.21)}$
b. $(67.41 + 0.32 + 1.98)/(18.225)$
c. $(2.001 \times 10^{-3})(4.7 \times 10^{-6})(68.224 \times 10^{-2})$
d. $(72.15)(63.9)[1.98 + 4.8981]$

51. How many significant digits should be used to report the answer to each of the following calculations? Do not perform the calculations.

a. $(2.7518 + 9.01 + 3.3349)/(2.1)$
b. $(2.7751 \times 1.95)/(.98)$
c. $12.0078/3.014$
d. $(0.997 + 4.011 + 3.876)/(1.86 \times 10^{-3})$

52. Evaluate each of the following and write the answer to the appropriate number of significant figures.

a. $(2.0944 + 0.0003233 + 12.22)/(7.001)$
b. $(1.42 \times 10^2 + 1.021 \times 10^3)/(3.1 \times 10^{-1})$
c. $(9.762 \times 10^{-3})/(1.43 \times 10^2 + 4.51 \times 10^1)$
d. $(6.1982 \times 10^{-4})^2$

2.6 Problem Solving and Dimensional Analysis

QUESTIONS

53. A _____ represents a ratio based on an equivalence statement between two measurements.

54. How many significant figures are understood for the numbers in the following definition: 1 mi = 5280 ft?

55. Given that 1 mi = 1760 yd, determine what conversion factor is appropriate to convert 1849 yd to miles; to convert 2.781 mi to yards.

56. Given that 1 in. = 2.54 cm exactly, indicate what conversion factor is appropriate to convert 12.3 in. to centimeters; to convert 63.52 cm to inches.

For Exercises 57 and 58, apples cost \$0.79 per pound.

57. What conversion factor is appropriate to express the cost of 5.3 lb of apples?

58. What conversion factor could be used to determine how many pounds of apples could be bought for \$2.00?

PROBLEMS

Note: Appropriate equivalence statements for various units are found inside the back cover of this book.

59. Perform each of the following conversions, being sure to set up the appropriate conversion factor in each case.

a. 12.5 in. to centimeters
b. 12.5 cm to inches
c. 2513 ft to miles
d. 4.53 ft to meters
e. 6.52 min to seconds
f. 52.3 cm to meters
g. 4.21 m to yards
h. 8.02 oz to pounds

60. Perform each of the following conversions, being sure to set up the appropriate conversion factor in each case.

a. 4.21 ft to inches
b. 37.3 in. to feet
c. 45.2 cm to millimeters
d. 761.2 mm to centimeters
e. 1.25 L to quarts
f. 4.21 qt to pints
g. 6.21 kg to pounds
h. 1.75 lb to ounces

61. Perform each of the following conversions, being sure to set up the appropriate conversion factor in each case.

a. 1.75 mi to kilometers
b. 2.63 gal to quarts
c. 4.675 calories to joules
d. 756.2 mm Hg to atmospheres
e. 36.3 atomic mass units to kilograms
f. 46.2 in. to centimeters
g. 2.75 qt to fluid ounces
h. 3.51 yd to meters

62. Perform each of the following conversions, being sure to set up the appropriate conversion factor in each case.

a. 104.971 kilopascals to atmospheres
b. 6.25 pt to quarts
c. 18.0 oz to kilograms
d. 4.213 joules to calories
e. 1.632 mi to feet
f. 4.52 qt to pints
g. 9.25 oz to grams
h. 56.2 fluid ounces to quarts

63. 12.01 g of carbon contains 6.02×10^{23} carbon atoms. What is the mass in grams of 1.89×10^{25} carbon atoms?

64. Los Angeles and Honolulu are 2558 mi apart. What is this distance in kilometers?

65. The United States has high-speed trains running between Boston and New York capable of speeds up to 160 mi/h. Are these trains faster or slower than the fastest trains in the United Kingdom, which reach speeds of 225 km/h?

66. The radius of an atom is on the order of 10^{-10} m. What is this radius in centimeters? in inches? in nanometers?