

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

9. Paracelsus, a sixteenth-century alchemist and healer, adopted as his slogan: "The patients are your textbook, the sickbed is your study." Is this view consistent with using the scientific method?
10. What is wrong with the following statement?
"The results of the experiment do not agree with the theory. Something must be wrong with the experiment."
11. Why is it incorrect to say that the results of a measurement were accurate but not precise?
12. What data would you need to estimate the money you would spend on gasoline to drive your car from New York to Chicago? Provide estimates of values and a sample calculation.
13. 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.
14. You have a 1.0-cm³ sample of lead and a 1.0-cm³ sample of glass. You drop each in separate beakers of water. How do the volumes of water displaced by each sample compare? Explain.
15. Sketch a magnified view (showing atoms/molecules) of each of the following and explain:
 - a. a heterogeneous mixture of two different compounds
 - b. a homogeneous mixture of an element and a compound

A blue question or exercise number indicates that the answer to that question or exercise appears at the back of this book and a solution appears in the *Solutions Guide*.

Questions

16. Define and explain the differences between the following terms.
 - a. law and theory
 - b. theory and experiment
 - c. qualitative and quantitative
 - d. hypothesis and theory
17. Is the scientific method suitable for solving problems only in the sciences? Explain.
18. Which of the following statements (hypotheses) could be tested by quantitative measurement?
 - a. Ty Cobb was a better hitter than Pete Rose.
 - b. Ivory soap is 99.99% pure.
 - c. Roloids consumes 47 times its weight in excess stomach acid.
19. Explain why the uncertainty of a measurement depends on the precision of the measuring device. Give an example to illustrate.

20. A student performed an analysis of a sample for its calcium content and got the following results:

14.92% 14.91% 14.88% 14.91%

The actual amount of calcium in the sample is 15.7%. What conclusion can you draw about the accuracy and precision of these results?

21. Distinguish between physical changes and chemical changes.
22. Why is the separation of mixtures into pure or relatively pure substances so important when performing a chemical analysis?

Exercises

In this section similar exercises are paired.

Significant Figures and Unit Conversions

23. Which of the following are exact numbers?
 - a. The elevation of Breckenridge, Colorado, is 9600 ft.
 - b. There are 12 eggs in a dozen.
 - c. One yard is equal to 0.9144 m.
 - d. The announced attendance at a football game was 52,800.
 - e. In 1983, 1759 Ph.D.s in chemistry were awarded in the United States.
 - f. The budget deficit of the U.S. government in fiscal year 1990 was \$269 billion.
24. Which of the following are exact numbers?
 - a. There are 100 cm in 1 m.
 - b. One meter equals 1.094 yard.
 - c. We can use the equation

$$^{\circ}\text{F} = \frac{9}{5}^{\circ}\text{C} + 32$$

to convert from Celsius to Fahrenheit temperature. Are numbers $\frac{9}{5}$ and 32 exact or inexact?

- d. $\pi = 3.1415927$.
25. How many significant figures are in each of the following?
 - a. 12
 - b. 1098
 - c. 2001
 - d. 2.001×10^3
 - e. 0.0000101
 - f. 1.01×10^{-5}
 - g. 1000.
 - h. 22.04030
26. How many significant figures are in each of the following?
 - a. 100
 - b. 1.0×10^2
 - c. 1.00×10^3
 - d. 100.
 - e. 0.0048
 - f. 0.00480

g. 4.80×10^{-3} h. 4.800×10^{-3}

27. Round off each of the following numbers to three significant figures, and write the answer in standard exponential notation.

- a. 312.54
b. 0.00031254
c. 31,254,000
d. 0.31254
e. 31.254×10^{-3}

28. Use exponential notation to express the number 480 to
a. one significant figure
b. two significant figures
c. three significant figures
d. four significant figures

29. Perform the following mathematical operations, and express each result to the correct number of significant figures.

- a. $97.381 + 4.2502 + 0.99195$
b. $171.5 + 72.915 - 8.23$
c. $1.00914 + 0.87104 + 1.2012$
d. $21.901 - 13.21 - 4.0215$

30. Perform the following mathematical operations, and express each result to the correct number of significant figures.

- a. $\frac{0.102 \times 0.0821 \times 273}{1.01}$
b. $0.14 \times 6.022 \times 10^{23}$
c. $4.0 \times 10^4 \times 5.021 \times 10^{-3} \times 7.34993 \times 10^2$
d. $\frac{2.00 \times 10^6}{3.00 \times 10^{-7}}$

31. Perform the following mathematical operations, and express each result to the correct number of significant figures.

- a. $4.184 \times 100.62 \times (25.27 - 24.16)$
b. $\frac{8.925 - 8.904}{8.925} \times 100$

(This type of calculation is done many times in calculating a percentage error. Assume that this example is such a calculation; thus 100 can be considered to be an exact number.)

- c. $(9.04 - 8.23 + 21.954 + 81.0) \div 3.1416$
d. $\frac{9.2 \times 100.65}{8.321 + 4.026}$

- e. $0.1654 + 2.07 - 2.114$
f. $8.27(4.987 - 4.962)$
g. $\frac{9.5 + 4.1 + 2.8 + 3.175}{4}$

(Assume that this operation is taking the average of four numbers. Thus 4 in the denominator is exact.)

- h. $\frac{9.025 - 9.024}{9.025} \times 100$ (100 is exact)

32. Perform the following mathematical operations, and express the result to the correct number of significant figures.

- a. $6.022 \times 10^{23} \times 1.05 \times 10^2$
b. $\frac{6.6262 \times 10^{-34} \times 2.998 \times 10^8}{2.54 \times 10^{-9}}$

- c. $1.285 \times 10^{-2} + 1.24 \times 10^{-3} + 1.879 \times 10^{-1}$
d. $1.285 \times 10^{-2} - 1.24 \times 10^{-3}$

e. $\frac{(1.00866 - 1.00728)}{6.02205 \times 10^{23}}$

f. $\frac{9.875 \times 10^2 - 9.795 \times 10^2}{9.875 \times 10^2} \times 100$ (100 is exact)

g. $\frac{9.42 \times 10^2 + 8.234 \times 10^2 + 1.625 \times 10^3}{3}$ (3 is exact)

33. Perform each of the following conversions.

- a. 8.43 cm to millimeters
b. 2.41×10^2 cm to meters
c. 294.5 nm to centimeters
d. 1.445×10^4 m to kilometers
e. 235.3 m to millimeters
f. 903.3 nm to micrometers

34. a. How many kilograms are in one teragram?
b. How many nanometers are in 6.50×10^2 terameters?
c. How many kilograms are in 25 femtograms?
d. How many liters are in 8.0 cubic decimeters?
e. How many microliters are in one milliliter?
f. How many picograms are in one microgram?

35. Many atomic dimensions are expressed in angstroms. ($1 \text{ \AA} = 1 \times 10^{-8} \text{ cm}$). What is the angstrom equal to in terms of the SI units nanometer (nm) and picometer (pm)?

36. Two atoms in a molecule are 134 pm apart. What is the distance in nanometers and angstroms?

37. Perform the following unit conversions.

- a. Congratulations! You and your spouse are the proud parents of a new baby, born while you are studying in a country that uses the metric system. The nurse has informed you that the baby weighs 3.91 kg and measures 51.4 cm. Convert your baby's weight to pounds and ounces and her length to inches (rounded to the nearest quarter inch).
b. The circumference of the earth is 25,000 mi at the equator. What is the circumference in kilometers? in meters?
c. A rectangular solid measures 1.0 m by 5.6 cm by 2.1 dm. Express its volume in cubic meters, liters, cubic inches, and cubic feet.

38. Perform the following unit conversions.

- a. 908 oz to kilograms
b. 12.8 L to gallons
c. 125 mL to quarts
d. 2.89 gal to milliliters
e. 4.48 lb to grams
f. 550 mL to quarts

39. Use the following exact conversion factors to perform the stated calculations:

$$5\frac{1}{2} \text{ yards} = 1 \text{ rod}$$

$$40 \text{ rods} = 1 \text{ furlong}$$

$$8 \text{ furlongs} = 1 \text{ mile}$$

- a. The Kentucky Derby race is 1.25 miles. How long is the race in rods, furlongs, meters, and kilometers?
- b. A marathon race is 26 miles, 385 yards. What is this distance in rods, furlongs, meters, and kilometers?
40. Although the preferred SI unit of area is the square meter, land is often measured in the metric system in hectares (ha). One hectare is equal to $10,000 \text{ m}^2$. In the English system, land is often measured in acres ($1 \text{ acre} = 160 \text{ rod}^2$). Use the exact conversions and those given in Exercise 39 to calculate the following.
- a. $1 \text{ ha} = \underline{\hspace{2cm}} \text{ km}^2$.
- b. The area of a 5.5-acre plot of land in hectares, square meters, and square kilometers.
- c. A lot with dimensions 120 ft by 75 ft is to be sold for \$6500. What is the price per acre? What is the price per hectare?

41. Precious metals and gems are measured in troy weights in the English system:

24 grains = 1 pennyweight (exact)

20 pennyweight = 1 troy ounce (exact)

12 troy ounces = 1 troy pound (exact)

1 grain = 0.0648 gram

1 carat = 0.200 gram

- a. The most common English unit of mass is the pound avoirdupois. What is one troy pound in kilograms and in pounds?
- b. What is the mass of a troy ounce of gold in grams and in carats?
- c. The density of gold is 19.3 g/cm^3 . What is the volume of a troy pound of gold?
42. Apothecaries (druggists) use the following set of measures in the English system:

20 grains ap = 1 scruple (exact)

3 scruples = 1 dram ap (exact)

8 dram ap = 1 oz ap (exact)

1 dram ap = 3.888 g

- a. Is an apothecary grain the same as a troy grain? (See Exercise 41.)
- b. $1 \text{ oz ap} = \underline{\hspace{2cm}} \text{ oz troy}$
- c. An aspirin tablet contains $5.00 \times 10^2 \text{ mg}$ of active ingredient. How many grains ap of active ingredient does it contain? How many scruples?
- d. What is the mass of 1 scruple in grams?

43. In the United Kingdom, British Rail runs two types of modern high-speed passenger trains, the Intercity-125 and the Intercity-225. The Intercity-125 has a top speed of 125 mi/h, whereas the newer Intercity-225 has a top speed of 225 km/h. Which train is faster?

44. The world record for the hundred meter dash is 9.79 s. What is the corresponding average speed in units of m/s, km/h, ft/s,

and mi/h? At this speed, how long would it take to run 1.00×10^2 yards?

45. You're planning to buy a new car. One model that you're considering gets 32 miles to a gallon of gasoline in highway travel. The one that your spouse likes gets 14 kilometers to the liter. Which car has the better gas mileage?
46. You pass a road sign saying "New York 112 km." If you drive at a constant speed of 65 mi/h, how long should it take you to reach New York? If your car gets 28 miles to the gallon, how many liters of gasoline are necessary to travel 112 km?

Temperature

47. A person has a temperature of 102.5°F . What is this temperature on the Celsius scale? on the Kelvin scale?
48. If the temperature in a room is 74°F , what is this temperature on the Celsius scale? on the Kelvin scale?
49. Many chemical quantities are specified as being measured at 25°C . What is this temperature on the Fahrenheit scale? on the Kelvin scale?
50. Helium boils at about 4 K. What is this temperature in $^\circ\text{F}$? in $^\circ\text{C}$?
51. A thermometer gives a reading of $20.6^\circ\text{C} \pm 0.1^\circ\text{C}$. What is the temperature in $^\circ\text{F}$? What is the uncertainty?
52. A thermometer gives a reading of $96.1^\circ\text{F} \pm 0.2^\circ\text{F}$. What is the temperature in $^\circ\text{C}$? What is the uncertainty?

Density

53. The density of aluminum is 2.70 g/cm^3 . Express this value in units of kilograms per cubic meter and pounds per cubic foot.
54. A material will float on the surface of a liquid if the material has a density less than that of the liquid. Given that the density of water is approximately 1.0 g/mL , will a block of material having a volume of $1.2 \times 10^4 \text{ in}^3$ and weighing 350 lb float or sink when placed in a reservoir of water?
55. A star is estimated to have a mass of $2 \times 10^{36} \text{ kg}$. Assuming it to be a sphere of average radius $7.0 \times 10^5 \text{ km}$, calculate the average density of the star in units of grams per cubic centimeter.
56. A rectangular block has dimensions $2.9 \text{ cm} \times 3.5 \text{ cm} \times 10.0 \text{ cm}$. The mass of the block is 615.0 g. What are the volume and density of the block?
57. Diamonds are measured in carats, and $1 \text{ carat} = 0.200 \text{ g}$. The density of diamond is 3.51 g/cm^3 . What is the volume of a 5.0-carat diamond?
58. The volume of a diamond is found to be 2.8 mL. What is the mass of the diamond in carats? (See Exercise 57.)
59. A sample containing 33.42 g of metal pellets is poured into a graduated cylinder initially containing 12.7 mL of water, causing the water level in the cylinder to rise to 21.6 mL. Calculate the density of the metal.

60. The density of pure silver is 10.5 g/cm^3 at 20°C . If 5.25 g of pure silver pellets is added to a graduated cylinder containing 11.2 mL of water, to what volume level will the water in the cylinder rise?
61. In each of the following pairs, which has the greater mass? (See Table 1.5.)
- 1.0 kg of feathers or 1.0 kg of lead
 - 1.0 mL of mercury or 1.0 mL of water
 - 19.3 mL of water or 1.00 mL of gold
 - 75 mL of copper or 1.0 L of benzene
62. In each of the following pairs, which has the greater volume?
- 1.0 kg of feathers or 1.0 kg of lead
 - 100 g of gold or 100 g of water
 - 1.0 L of copper or 1.0 L of mercury

Classification and Separation of Matter

63. What are some of the differences between a solid, a liquid, and a gas?
64. What is the difference between homogeneous and heterogeneous matter? Classify each of the following as homogeneous or heterogeneous.
- soil
 - the atmosphere
 - a carbonated soft drink
 - gasoline
 - gold
 - a solution of ethanol and water
65. Classify each of the following as a mixture or a pure substance.
- water
 - blood
 - the oceans
 - iron
 - brass
 - uranium
 - wine
 - leather
 - table salt (NaCl)
- Of the pure substances, which are elements and which are compounds?
66. The properties of a mixture are typically averages of the properties of its components. The properties of a compound may differ dramatically from the properties of the elements that combine to produce the compound. For each process described below, state whether the material being discussed is most likely a mixture or a compound, and state whether the process is a chemical change or a physical change.
- An orange liquid is distilled, resulting in the collection of a yellow liquid and a red solid.
 - A colorless, crystalline solid is decomposed, yielding a pale yellow-green gas and a soft, shiny metal.
 - A cup of tea becomes sweeter as sugar is added to it.

Additional Exercises

67. A children's pain relief elixir contains $80. \text{ mg}$ acetaminophen per 0.50 teaspoon. The dosage recommended for a child who weighs between 24 and 35 lb is 1.5 teaspoons. What is the range of acetaminophen dosages, expressed in mg acetaminophen/ kg body weight, for children who weigh between 24 and 35 lb ?
68. A mole of helium gas contains 6.02×10^{23} helium atoms. How many helium atoms are there in a millimole of helium? in a kilomole?
69. In Shakespeare's *Richard III*, the First Murderer says:
- "Take that, and that! [Stabs Clarence]
If that is not enough, I'll drown you in a malmsey butt within!"
- Given that $1 \text{ butt} = 126 \text{ gal}$, in how many liters of malmsey (a foul brew similar to mead) was the unfortunate Clarence about to be drowned?
70. You are in Paris and want to buy some peaches for lunch. The sign in the fruit stand indicates that peaches are 11.5 francs per kilogram. Given that there are approximately 5 francs to the dollar, calculate what a pound of peaches will cost in dollars.
71. The contents of one $40. \text{ lb}$ bag of topsoil will cover $10.$ square feet of ground to a depth of 1.0 inch. How many bags are needed to cover a plot which measures $200.$ by $300.$ m to a depth of 4.0 cm ?
72. Science fiction often uses nautical analogies to describe space travel. If the starship *U.S.S. Enterprise* is traveling at warp factor 1.71 , what is its speed in knots? (Warp $1.71 = 5.00$ times the speed of light; speed of light $= 3.00 \times 10^8 \text{ m/s}$; $1 \text{ knot} = 2000 \text{ yd/h}$, exactly.)
73. Convert the following Celsius temperatures to Kelvin and to Fahrenheit degrees.
- the boiling-point temperature of ethyl alcohol, 78.1°C
 - a cold wintery day, -25°C
 - the lowest possible temperature, -273°C
 - the melting-point temperature of sodium chloride, 801°C
74. In the opening scenes of the movie *Raiders of the Lost Ark*, Indiana Jones tries to remove a gold idol from a booby-trapped pedestal. He replaces the idol with a bag of sand of approximately equal volume. (Density of gold $= 19.32 \text{ g/cm}^3$; density of sand $\approx 2 \text{ g/cm}^3$.)
- Did he have a reasonable chance of not activating the mass-sensitive booby trap?
 - In a later scene he and an unscrupulous guide play catch with the idol. Assume that the volume of the idol is about 1.0 L . If it were solid gold, what mass would the idol have? Is playing catch with it plausible?
75. Mercury poisoning is a debilitating disease that is often fatal. In the human body, mercury reacts with essential enzymes leading to irreversible inactivity of these enzymes. If the