Chapter 2: Measurements

INTRODUCTION

Teaching Tip

A discussion can be initiated regarding how measurements are involved in our day-to-day life like buying a particular quantity of vegetables or consuming a particular quantity of medicine. This will help the students understand the significance of measurements.

2.1 Expressing Numbers

- **Learn to express numbers properly.**

Teaching Tip

A discussion can be initiated regarding the various ways in which a number can be expressed. This will help the students understand standard notations and scientific notations.

- Quantities have two parts: the number and the unit.
- **Standard notation** is the straightforward expression of a number.
- **Scientific notation** is an expression of a number using powers of 10. Small numbers can also be expressed in scientific notation but with negative exponents.
- A number is expressed in scientific notation by writing the first nonzero digit, then a decimal point, and then the rest of the digits.
    - The part of a number in scientific notation that is multiplied by a power of 10 is called the **coefficient.**
    - The raised number to the right of the 10 indicating the number of factors of 10 in the original number is the **exponent**.

Example 1
Test Yourself

Express these numbers in scientific notation.
1. 23,070
2. 0.0009706

Solution:
1. The number 23,070 is 2.307 times 10,000, or 2.307 times 10^4. In scientific notation, the number is 2.307×10^4.
2. The number 0.0009706 is 9.706 times 1/10,000, which is 9.706 times 10^{-4}. In scientific notation, the number is 9.706×10^{-4}.

IN-CLASS ACTIVITY
Students can be asked to explain standard notation and scientific notation with the help of examples.

Appropriate In-Class Use			
Discussion	**Team Activity**	**Class Time**	**Assign Ahead**
√	Not necessary	30 minutes	Not necessary

Exercises

1. Express these numbers in scientific notation.
a. 56.9
b. 563,100
c. 0.0804
d. 0.00000667

Solution:
a. The number 56.9 is 5.69 times 10, or 5.69 times 10^1. In scientific notation, the number is 5.69×10^1.
b. The number 563,100 is 5.631 times 100,000 or 5.631 times 10^5. In scientific notation, the number is 5.631×10^5.
c. The number 0.0804 is 8.04 times 1/100 or 8.04 times 10^{-2}. In scientific notation, the number is 8.04×10^{-2}.
d. The number 0.00000667 is 6.67 times 1/1,000,000 or 6.67 times 10^{-6}. In scientific notation, the number is 6.67×10^{-6}.

2. Express these numbers in scientific notation.
a. −890,000
b. 602,000,000,000
c. 0.0000004099
d. 0.000000000000011

Solution:
a. The number −890,000 is −8.9 times 100,000, or −8.9 times 10^5. In scientific notation, the number is -8.9×10^5.
b. The number 602,000,000,000 is 6.02 times 100,000,000,000, or 6.02 times 10^{11}. In scientific notation, the number is 6.02×10^{11}.
c. The number 0.0000004099 is 4.099 times 1/10,000,000, or 4.099 times 10^{-7}. In scientific notation, the number is 4.099×10^{-7}.
d. The number 0.000000000000011 is 1.1 times 1/100,000,000,000,000, or 1.1 times 10^{-14}. In scientific notation, the number is 1.1×10^{-14}.

3. Express these numbers in scientific notation.
a. 0.00656
b. 65,600
c. 4,567,000
d. 0.000005507

Solution:
a. The number 0.00656 is 6.56 times 1/1,000, or 6.56 times 10^{-3}. In scientific notation, the number is 6.56×10^{-3}.
b. The number 65,600 is 6.56 times 10,000, or 6.56 times 10^4. In scientific notation, the number is 6.56×10^4.
c. The number 4,567,000 is 4.567 times 1,000,000, or 4.567 times 10^6. In scientific notation, the number is 4.567×10^6.
d. The number 0.000005507 is 5.507 times 1/1,000,000, or 5.507 times 10^{-6}. In scientific notation, the number is 5.507×10^{-6}.

4. Express these numbers in scientific notation.
a. 65
b. −321.09
c. 0.000077099
d. 0.000000000218

Solution:
a. The number 65 is 6.5 times 10, or 6.5 times 10^1. In scientific notation, the number is 6.5×10^1.
b. The number −321.09 is −3.2109 times 100, or −3.2109 times 10^2. In scientific notation, the number is -3.2109×10^2.
c. The number 0.000077099 is 7.7099 times 1/100,000, or 7.7099 times 10^{-5}. In scientific notation, the number is 7.7099×10^{-5}.
d. The number 0.000000000218 is 2.18 times 1/10,000,000,000, or 2.18 times 10^{-10}. In scientific notation, the number is 2.18×10^{-10}.

5. Express these numbers in standard notation.
a. 1.381×10^5
b. 5.22×10^{-7}
c. 9.998×10^4

Solution:
a. In scientific notation, the number is 1.381×10^5, or 1.381 times 10^5, or 1.381 times 100,000. The standard notation is 138,100.
b. In scientific notation, the number is 5.22×10^{-7}, or 5.22 times 10^{-7}, or 5.22 times 1/10,000,000. The standard notation is 0.000000522.
c. In scientific notation, the number is 9.998×10^4, or 9.998 times 10^4, or 9.998 times 10,000. The standard notation is 99,980.

6. Express these numbers in standard notation.
a. 7.11×10^{-2}
b. 9.18×10^2
c. 3.09×10^{-10}

Solution:
a. In scientific notation, the number is 7.11×10^{-2}, or 7.11 times 10^{-2}, or 7.11 times 1/100. The standard notation is 0.0711.
b. In scientific notation, the number is 9.18×10^2, or 9.18 times 10^2, or 9.18 times 100. The standard notation is 918.
c. In scientific notation, the number is 3.09×10^{-10}, or 3.09 times 10^{-10}, or 3.09 times 1/10,000,000,000. The standard notation is 0.000000000309.

7. Express these numbers in standard notation.
a. 8.09×10^0
b. 3.088×10^{-5}
c. -4.239×10^2

Solution:
a. In scientific notation, the number is 8.09×10^0, or 8.09 times 10^0, or 8.09 times 1. The standard notation is 8.09.
b. In scientific notation, the number is 3.088×10^{-5}, or 3.088 times 10^{-5}, or 3.088 times 1/100,000. The standard notation is 0.00003088.
c. In scientific notation, the number is -4.239×10^2, or −4.239 times 10^2, or −4.239 times 100. The standard notation is −423.9.

8. Express these numbers in standard notation.
a. 2.87×10^{-8}
b. 1.78×10^{11}
c. 1.381×10^{-23}

Solution:
a. In scientific notation, the number is 2.87×10^{-8}, or 2.87 times 10^{-8}, or 2.87 times 1/100,000,000. The standard notation is 0.0000000287.
b. In scientific notation, the number is 1.78×10^{11}, or 1.78 times 10^{11}, or 1.78 times 100,000,000,000. The standard notation is 178,000,000,000.
c. In scientific notation, the number is 1.381×10^{-23}, or 1.381 times 10^{-23}, or 1.381 times 100,000,000,000,000,000,000,000. The standard notation is 0.00000000000000000000001381.

9. These numbers are not written in proper scientific notation. Rewrite them so that they are in proper scientific notation.
a. 72.44×10^3
b. $9{,}943 \times 10^{-5}$
c. $588{,}399 \times 10^2$

Solution:
a. The number 72.44×10^3 is 7.244 times 10,000, or 7.244 times 10^4. In scientific notation, the number is 7.244×10^4.
b. The number $9{,}943 \times 10^{-5}$ is 9.943 times 1/100, or 9.943 times 10^{-2}. In scientific notation, the number is 9.943×10^{-2}.
c. The number $588{,}399 \times 10^2$ is 5.88399 times 10,000,000, or 5.88399 times 10^7. In scientific notation, the number is 5.88399×10^7.

10. These numbers are not written in proper scientific notation. Rewrite them so that they are in proper scientific notation.
a. 0.000077×10^{-7}
b. 0.000111×10^8
c. $602{,}000 \times 10^{18}$

Solution:
a. The number 0.000077×10^{-7} is 7.7 times 1/1,000,000,000,000, or 7.7 times 10^{-12}. In scientific notation, the number is 7.7×10^{-12}.
b. The number 0.000111×10^8 is 1.11 times 10,000, or 1.11 times 10^4. In scientific notation, the number is 1.11×10^4.
c. The number $602{,}000 \times 10^{18}$ is 6.02 times 100,000,000,000,000,000,000,000, or 6.02 times 10^{23}. In scientific notation, the number is 6.02×10^{23}.

11. These numbers are not written in proper scientific notation. Rewrite them so that they are in proper scientific notation.
a. 345.1×10^2
b. 0.234×10^{-3}
c. $1{,}800 \times 10^{-2}$

Solution:
a. The number 345.1×10^2 is 3.451 times 10,000, or 3.451 times 10^4. In scientific notation, the number is 3.451×10^4.
b. The number 0.234×10^{-3} is 2.34 times 1/10,000, or 2.34 times 10^{-4}. In scientific notation, the number is 2.34×10^{-4}.
c. The number $1{,}800 \times 10^{-2}$ is 1.8 times 10, or 1.8 times 10^1. In scientific notation, the number is 1.8×10^1.

12. These numbers are not written in proper scientific notation. Rewrite them so that they are in proper scientific notation.
a. $8{,}099 \times 10^{-8}$
b. 34.5×10^0
c. 0.000332×10^4

Solution:
a. The number 8,099 × 10^{-8} is 8.099 times 1/100,000, or 8.099 times 10^{-5}. In scientific notation, the number is 8.099 × 10^{-5}.
b. The number 34.5 × 10^{0} is 3.45 times 10, or 3.45 times 10^{1}. In scientific notation, the number is 3.45 × 10^{1}.
c. The number 0.000332 × 10^{4} is 3.32 times 10^{0}. In scientific notation, the number is 3.32 × 10^{0}.

13. Write these numbers in scientific notation by counting the number of places the decimal point is moved.
a. 123,456.78
b. 98,490
c. 0.000000445

Solution:
a. $1\underset{5}{2}\underset{4}{3},\underset{3}{4}\underset{2}{5}\underset{1}{6}.78 = 1.2345678 \times 10^{5}$

b. $9\underset{4}{8},\underset{3}{4}\underset{2}{9}\underset{1}{0} = 9.849 \times 10^{4}$

c. $0.\underset{1}{0}\underset{2}{0}\underset{3}{0}\underset{4}{0}\underset{5}{0}\underset{6}{0}\underset{7}{4}45 = 4.45 \times 10^{-7}$

14. Write these numbers in scientific notation by counting the number of places the decimal point is moved.
a. 0.000552
b. 1,987
c. 0.00000000887

Solution:
a. $0.\underset{1}{0}\underset{2}{0}\underset{3}{0}\underset{4}{5}52 = 5.52 \times 10^{-4}$

b. $1,\underset{3}{9}\underset{2}{8}\underset{1}{7} = 1.987 \times 10^{3}$

c. $0.\underset{1}{0}\underset{2}{0}\underset{3}{0}\underset{4}{0}\underset{5}{0}\underset{6}{0}\underset{7}{0}\underset{8}{0}\underset{9}{8}87 = 8.87 \times 10^{-9}$

15. Use your calculator to evaluate these expressions. Express the final answer in proper scientific notation.
a. 456 × (7.4 × 10^{8}) = ?
b. (3.02 × 10^{5}) ÷ (9.04 × 10^{15}) = ?
c. 0.0044 × 0.000833 = ?

Solution:
a. 456 × (7.4 × 10^{8}) = 3374.4 × 10^{8} = 3.3744 × 10^{11}
b. (3.02 × 10^{5}) ÷ (9.04 × 10^{15}) = 0.33407 × 10^{-10} = 3.3407 × 10^{-11}
c. 0.0044 × 0.000833 = 0.0000036652 × 10^{-10} = 3.6652 × 10^{-6}

16. Use your calculator to evaluate these expressions. Express the final answer in proper scientific notation.
a. 98,000 × 23,000 = ?
b. 98,000 ÷ 23,000 = ?
c. $(4.6 \times 10^{-5}) \times (2.09 \times 10^{3})$ = ?

Solution:
a. 98,000 × 23,000 = 2,254,000,000 = 2.254×10^{9}
b. 98,000 ÷ 23,000 = 4.2608 = 4.2608×10^{0}
c. $(4.6 \times 10^{-5}) \times (2.09 \times 10^{3}) = 9.614 \times 10^{-2}$

17. Use your calculator to evaluate these expressions. Express the final answer in proper scientific notation.
a. 45 × 132 ÷ 882 = ?
b. $[(6.37 \times 10^{4}) \times (8.44 \times 10^{-4})] \div (3.2209 \times 10^{15})$ = ?

Solution:
a. 45 × 132 ÷ 882 = 6.7346 = 6.7346×10^{0}
b. $[(6.37 \times 10^{4}) \times (8.44 \times 10^{-4})] \div (3.2209 \times 10^{15}) = 16.691 \times 10^{-15} = 1.6691 \times 10^{-14}$

18. Use your calculator to evaluate these expressions. Express the final answer in proper scientific notation.
a. $(9.09 \times 10^{8}) \div [(6.33 \times 10^{9}) \times (4.066 \times 10^{-7})]$ = ?
b. 9,345 × 34.866 ÷ 0.00665 = ?

Solution:
a. $(9.09 \times 10^{8}) \div [(6.33 \times 10^{9}) \times (4.066 \times 10^{-7})] = 0.35317 \times 10^{6} = 3.5317 \times 10^{5}$
b. 9,345 × 34.866 ÷ 0.00665 = 48,995,905.26 = 4.8995×10^{7}

2.2 Expressing Units

- **Learn the units that go with various quantities.**
- **Express units using their abbreviations.**
- **Make new units by combining numerical prefixes with units.**

Teaching Tip

Students can be asked to specify the amount of time they spend in the classroom. Students might indicate the time in terms of hours. Then the students can be asked to describe the amount of time in terms of different units such as minutes or seconds. This will help the students understand the significance of units.

- A number indicates “how much,” but the unit indicates “of what.”
- Chemistry uses the International System of Units, or SI for short. SI specifies certain units for various types of quantities, based on seven **fundamental units** for various quantities.
    - The meter (m) is the SI unit of length.
    - The SI unit of mass is the kilogram (kg).
    - The SI unit of time is the second (s).
    - A **derived unit** is a unit that is a product or a quotient of a fundamental unit.
    - SI also defines a series of **numerical prefixes** that refer to multiples or fractions of a fundamental unit to make a unit more conveniently sized for a specific quantity. Refer table 2.1.

Example 2
Test Yourself

1. Express the volume of an Olympic-sized swimming pool, 2,500,000 L, in more appropriate units.
2. A common garden snail moves about 6.1 m in 30 min. What is its velocity in meters per minute (m/min)?

Solution:
1. 2,500,000 L can be written as 2.5×10^6 L. Since 10^6 defines the mega- prefix, volume of the Olympic-sized swimming pool is about 2.5 ML.
2. If velocity is defined as a distance quantity divided by a time quantity, then velocity is 6.1 m/30 min. Dividing the numbers gives us 6.1/30 = 0.203, and dividing the units gives us meters/minute, or m/min. The velocity is 0.203 m/min.

IN-CLASS ACTIVITY

Students can be asked to specify various prefixes for SI units along with their multiplicative amounts.

Appropriate In-Class Use			
Discussion	**Team Activity**	**Class Time**	**Assign Ahead**
√	Not necessary	30 minutes	Not necessary

Exercises

1. Identify the unit in each quantity.
a. 2 boxes of crayons
b. 3.5 grams of gold

Solution:
a. boxes of crayons
b. grams of gold

2. Identify the unit in each quantity.
a. 32 oz of cheddar cheese
b. 0.045 cm^3 of water

Solution:
a. ounces of Cheddar cheese
b. cubic centimeters of water

3. Identify the unit in each quantity.
a. 9.58 s (the current world record in the 100 m dash)
b. 6.14 m (the current world record in the pole vault)

Solution:
a. seconds
b. meters

4. Identify the unit in each quantity.
a. two dozen eggs
b. 2.4 km/s (the escape velocity of the moon, which is the velocity you need at the surface to escape the moon's gravity)

Solution:
a. dozen eggs
b. kilometers per second

5. Indicate what multiplier each prefix represents.
a. k
b. m
c. M

Solution:
a. 1,000 ×
b. 1/1,000 ×
c. 1,000,000 ×

6. Indicate what multiplier each prefix represents.
a. c
b. G

c. μ

Solution:
a. 1/100 ×
b. 1,000,000,000 ×
c. 1/1,000,000 ×

7. Give the prefix that represents each multiplier.
a. 1/1,000th ×
b. 1,000 ×
c. 1,000,000,000 ×

Solution:
a. milli-
b. kilo-
c. giga-

8. Give the prefix that represents each multiplier.
a. 1/1,000,000,000th ×
b. 1/100th ×
c. 1,000,000 ×

Solution:
a. nano-
b. centi-
c. mega-

9. Complete the following table with the missing information.

Unit	Abbreviation
kilosecond	
	mL
	Mg
centimeter	

Solution:

Unit	Abbreviation
kilosecond	ks
milliliter	mL
megagram	Mg
centimeter	cm

10. Complete the following table with the missing information.

Unit	Abbreviation

kilometer per second	
	cm^3
	μL
nanosecond	

Solution:

Unit	Abbreviation
kilometer per second	km/s
centimeters cubed	cm^3
microliter	μL
nanosecond	ns

11. Express each quantity in a more appropriate unit. There may be more than one acceptable answer.
a. 3.44×10^{-6} s
b. 3,500 L
c. 0.045 m

Solution:
a. Since 10^{-6} defines the micro-prefix, 3.44×10^{-6} can be written as 3.44 μs.
b. 3,500 L can be written as 3.5×10^3 L. Since 10^3 defines the kilo- prefix, 3.5×10^3 L can be written as 3.5 kL.
c. 0.045 m can be written as 4.5×10^{-2} m. Since 10^{-2} defines the centi- prefix, 4.5×10^{-2} m can be written as 4.5 cm.

12. Express each quantity in a more appropriate unit. There may be more than one acceptable answer.
a. 0.000066 m/s (Hint: you need consider only the unit in the numerator.)
b. 4.66×10^6 s
c. 7,654 L

Solution:
a. 0.000066 m/s can be written as 66×10^{-6} m/s. Since 10^{-6} defines the micro- prefix, 66×10^{-6} m/s can be written as 66 μm/s.
b. Since 10^6 defines the mega- prefix, 4.66×10^6 s can be written as 4.66 Ms.
c. 7,654 L can be written as 7.654×10^3 L. Since 10^3 defines the kilo- prefix, 7.654×10^3 L can be written as 7.654 kL.

13. Express each quantity in a more appropriate unit. There may be more than one acceptable answer.
a. 43,600 mL
b. 0.0000044 m

c. 1,438 ms

Solution:
a. Since the milli- prefix is defined by 10^{-3}, 43,600 mL can be written as $43{,}600 \times 10^{-3}$ L or 43.6 L.
b. 0.0000044 m can be written as 4.4×10^{-6} m. Since 10^{-6} defines the micro- prefix, 4.4×10^{-6} m can be written as 4.4 μm.
c. Since the milli- prefix is defined by 10^{-3}, 1,438 ms can be written as $1{,}438 \times 10^{-3}$ s or 1.438 s.

14. Express each quantity in a more appropriate unit. There may be more than one acceptable answer.
a. 0.000000345 m^3
b. 47,000,000 mm^3
c. 0.00665 L

Solution:
a. 0.000000345 m^3 can be written as 0.345×10^{-6} m^3. Since 10^{-2} defines the centi- prefix, $(10^{-2})^3$ is 10^{-6}. Hence, 0.345×10^{-6} m^3 can be written as 0.345 cm^3.
b. Since 10^{-3} is used to define the milli- prefix, 47,000,000 mm^3 can be written as $47{,}000{,}000 \times (10^{-3})^3$ m^3 or 0.047 m^3 or 4.7×10^{-2} m^3 or 4.7×10^4 cm^3.
c. 0.00665 L can be written as 6.65×10^{-3} L. Since 10^{-3} defines the milli- prefix, 6.65×10^{-3} L can be written as 6.65 mL.

15. Multiplicative prefixes are used for other units as well, such as computer memory. The basic unit of computer memory is the byte (b). What is the unit for one million bytes?

Solution: 1,000,000 or 10^6 is used to define the mega- prefix. Hence, the unit for one million bytes is 1 megabyte (Mb).

16. You may have heard the terms *microscale* or *nanoscale* to represent the sizes of small objects. What units of length do you think are useful at these scales? What fractions of the fundamental unit of length are these units?

Solution: micrometers and nanometers, respectively. They are 1/1,000,000th and 1/1,000,000,000th of a meter, respectively.

17. Acceleration is defined as a change in velocity per time. Propose a unit for acceleration in terms of the fundamental SI units.

Solution: meters/second^2

18. Density is defined as the mass of an object divided by its volume. Propose a unit of density in terms of the fundamental SI units.

Solution: g/m^3 is one possible unit.

2.3 Significant Figures

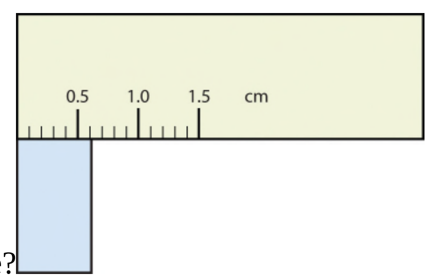
- **Apply the concept of significant figures to limit a measurement to the proper number of digits.**
- **Recognize the number of significant figures in a given quantity.**
- **Limit mathematical results to the proper number of significant figures.**

Teaching Tip

A ruler with millimeter markings can be given to the students and then they can be asked to measure the length of an object with accuracy upto the hundredth of a millimeter. This will help the students understand the concept of significant numbers.

- The concept of reporting the proper number of digits in a measurement or a calculation is called **significant figures**.
    - Significant figures (sometimes called significant digits) represent the limits of what values of a measurement or a calculation we are sure of.
    - The convention for a measurement is that the quantity reported should be all known values and the first estimated value.

Example 3
Test Yourself



What would be the reported width of this rectangle?

Solution: The rectangle width is between 0.5 and 1.0 cm. The rectangle's width is past the first tick mark but not the second; if each tick mark represents 0.1, then the rectangle is at least 0.6 cm. The next place we have to estimate because there are no markings to guide us. It appears to be about 3/10th the distance between the two tick marks, so we will estimate the next place to be 1. Thus, the measured width of the rectangle is 0.63 cm. The measurement is reported to two significant figures.

- The following conventions dictate which numbers in a reported measurement are significant and which are not significant:
    - Any nonzero digit is significant.
    - Any zeros between nonzero digits (i.e., embedded zeros) are significant.
    - Zeros at the end of a number without a decimal point (i.e., trailing zeros) are not significant; they serve only to put the significant digits in the correct positions. However, zeros at the end of any number with a decimal point are significant.
    - Zeros at the beginning of a decimal number (i.e., leading zeros) are not significant; again, they serve only to put the significant digits in the correct positions.

Example 4
Test Yourself

Give the number of significant figures in each measurement.
1. 0.000601 m
2. 65.080 kg

Solution:
1. By rule 4, the first four zeros are not significant, but by rule 2 the zero between six and one is; therefore, this number has three significant figures.
2. By rule 2, the zero after the decimal point is significant and by rule 3, zero at the end of the number with a decimal point is significant, so this measurement has five significant figures.

- Handling significant figures in case of addition and subtraction:
    - If the calculation is an addition or a subtraction, limit the reported answer to the rightmost column that all numbers have significant figures in common.
    - The final answer should be rounded up if the first dropped digit is 5 or greater and rounded down if the first dropped digit is less than 5.

Example 5
Test Yourself

Express the answer for 3.445 + 90.83 − 72.4 to the proper number of significant figures.

Solution: The answer obtained is 21.875. The first number stops its significant figure in the thousands place after the decimal, the second number stops its significant figure in the hundreds place after the decimal, and the third number stops its significant figure in the tenth place after the decimal. Hence, we limit our final answer to the tenth place after the decimal. The final answer is 21.9.

- Handling significant figures in case of multiplication and division:
  - If the operations being performed are multiplication or division, the rule is as follows: limit the answer to the number of significant figures that the data value with the *least* number of significant figures has.
  - The same rounding rules apply in multiplication and division as they do in addition and subtraction.

Example 6
Test Yourself

Express the final answer to the proper number of significant figures.
1. 22.4 × 8.314 = ?
2. 1.381 ÷ 6.02 = ?

Solution:
1. The answer obtained is 186.2336. The first number has three significant figures and the second number has four significant figures. Hence, we limit our answer to the three significant figures. The final answer is 186.
2. The answer obtained is 0.2294. The first number has four significant figures and the second number has three significant figures. Hence, we limit our answer to three significant figures. The final answer is 0.229.

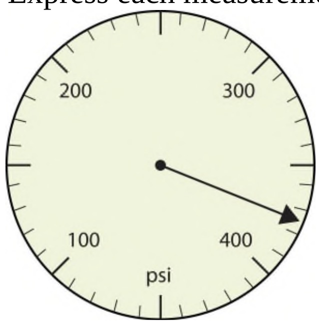
IN-CLASS ACTIVITY

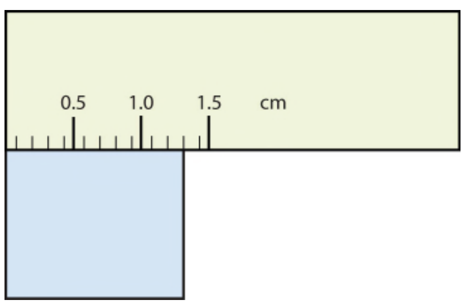
Students can be asked to specify the conventions that dictate which numbers in a reported measurement are significant.

Appropriate In-Class Use			
Discussion	**Team Activity**	**Class Time**	**Assign Ahead**
√	Not necessary	30 minutes	Not necessary

Exercises

1. Express each measurement to the correct number of significant figures.

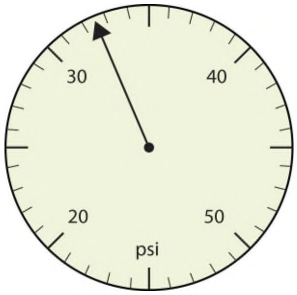
a. 



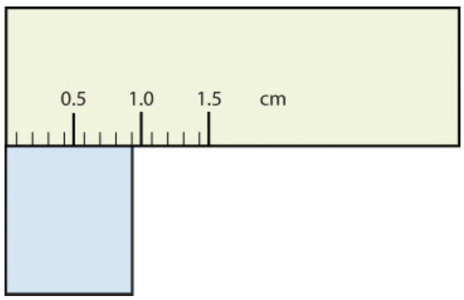
b.

Solution:
a. The arrow is between 300 and 400, so the measurement is at least 300. The arrow is between the seventh and eighth small tick marks, so it is at least 370. We will have to estimate the last place. It looks like about half of the way across the space, so let us estimate the units place as 5. Combining the digits, we have a measurement of 375 psi (psi stands for “pounds per square inch” and is a unit of pressure, like air in a tire). We say that the measurement is reported to three significant figures.
b. The rectangle width is between 1.0 and 1.5 cm. The rectangle’s width is on the third tick mark; if each tick mark represents 0.1, then the rectangle is at least 1.3 cm. The next place we have to estimate because there are no markings to guide us. It appears to be on the third tick mark, so we will estimate the next place to be 0. Thus, the measured width of the rectangle is 1.30 cm. The measurement is reported to two significant figures.

2. Express each measurement to the correct number of significant figures.



a.



b.

Solution:
a. The arrow is between 30 and 40, so the measurement is at least 30. The arrow is between the second and third small tick marks, so it is at least 32. We will have to estimate the last place. It looks like about half of the way across the space, so let us estimate the tenths place as 5. Combining the digits, we have a measurement of 32.5 psi (psi stands for "pounds per square inch" and is a unit of pressure, like air in a tire). We say that the measurement is reported to three significant figures.
b. The rectangle width is between 0.5 and 1.0 cm. The rectangle's width is on the fourth tick mark; if each tick mark represents 0.1, then the rectangle is at least 0.9 cm. The next place we have to estimate because there are no markings to guide us. It appears to be on the fourth tick mark, so we will estimate the next place to be 0. Thus, the measured width of the rectangle is 0.90 cm. The measurement is reported to two significant figures.

3. How many significant figures do these numbers have?
a. 23
b. 23.0
c. 0.00023
d. 0.0002302

Solution:
a. By rule 1, a nonzero digit is significant. Therefore, 23 has two significant figures.
b. By rule 3, zero at the end of any number with a decimal point is significant. Therefore, 23.0 has three significant figures.
c. By rule 4, zeros at the beginning of a decimal number (i.e., leading zeros) are not significant. Therefore, 0.00023 has two significant figures.

d. By rule 4, zeros at the beginning of a decimal number (i.e., leading zeros) are not significant. Therefore, 0.0002302 has four significant figures.

4. How many significant figures do these numbers have?
a. 5.44×10^8
b. 1.008×10^{-5}
c. 43.09
d. 0.0000001381

Solution:
a. 5.44×10^8 can be written as 544,000,000. By rule 3, zeros at the end of a number without a decimal point (i.e., trailing zeros) are not significant. Therefore, 544,000,000 has three significant figures.
b. 1.008×10^{-5} can be written as 0.00001008. By rule 4, zeros at the beginning of a decimal number (i.e, leading zeros) are not significant. Therefore, 0.00001008 has four significant figures.
c. By rule 2, the zero between 3 and 9 is significant. Hence, the number 43.09 has four significant figures.
d. By rule 4, zeros at the beginning of a decimal number (i.e, leading zeros) are not significant. Therefore, 0.0000001381 has four significant figures.

5. How many significant figures do these numbers have?
a. 765,890
b. 765,890.0
c. 1.2000×10^5
d. 0.0005060

Solution:
a. By rule 3, zeros at the end of a number without a decimal point (i.e., trailing zeros) are not significant. Therefore, 765,890 has five significant figures.
b. By rule 3, zero at the end of any number with a decimal point is significant. Therefore, 765,890.0 has seven significant figures.
c. By rule 3, zero at the end of any number with a decimal point is significant. Therefore, 1.2000×10^5 has five significant figures.
d. By rule 3, zero at the end of any number with a decimal point is significant. Therefore, 0.0005060 has four significant figures.

6. How many significant figures do these numbers have?
a. 0.009
b. 0.0000009
c. 65,444
d. 65,040

Solution:
a. By rule 4, zeros at the beginning of a decimal number (i.e, leading zeros) are not significant. Therefore, 0.009 has one significant figure.
b. By rule 4, zeros at the beginning of a decimal number (i.e, leading zeros) are not significant. Therefore, 0.0000009 has one significant figure.

c. By rule 1, a nonzero digit is significant. Therefore, 65,444 has five significant figures.
d. By rule 3, zeros at the end of a number without a decimal point (i.e., trailing zeros) are not significant. Therefore, 65,040 has four significant figures.

7. Compute and express each answer with the proper number of significant figures, rounding as necessary.
a. 56.0 + 3.44 = ?
b. 0.00665 + 1.004 = ?
c. 45.99 − 32.8 = ?
d. 45.99 − 32.8 + 75.02 = ?

Solution:
a. 56.0 + 3.44 = 59.44. The first number stops its significant figure in the tenths place after the decimal, and the second number stops its significant figure in the hundredths place after the decimal. Hence, we limit our final answer to the tenths place after the decimal. The final answer is 59.4.
b. 0.00665 + 1.004 = 1.01065. The first number stops its significant figure in the ten thousandths place after the decimal, and the second number stops its significant figure in the thousandths place after the decimal. Hence, we limit our final answer to the thousandths place after the decimal. The final answer is 1.011.
c. 45.99 − 32.8 = 13.19. The first number stops its significant figure in the hundredths place after the decimal, and the second number stops its significant figure in the tenths place after the decimal. Hence, we limit our final answer to the tenths place after the decimal. The final answer is 13.2.
d. 45.99 − 32.8 + 75.02 = 88.21. The first number stops its significant figure in the hundredths place after the decimal, the second number stops its significant figure in the tenths place after the decimal, and the third number stops its significant figure in the hundredths place after the decimal. Hence, we limit our final answer to the tenths place after the decimal. The final answer is 88.2.

8. Compute and express each answer with the proper number of significant figures, rounding as necessary.
a. 1.005 + 17.88 = ?
b. 56,700 − 324 = ?
c. 405,007 − 123.3 = ?
d. 55.5 + 66.66 − 77.777 = ?

Solution:
a. 1.005 + 17.88 = 18.885. The first number stops its significant figure in the thousandths place after the decimal, the second number stops its significant figure in the hundredths place after the decimal. Hence, we limit our final answer to the hundredths place after the decimal. The final answer is 18.89.
b. 56,700 − 324 = 56,376. The first number has three significant figures, and the second number has three significant figures. Hence, we limit our answer to three significant figures. The final answer is 56,400.
c. 405,007 − 123.3 = 404,883.7. The first number has no decimals, and the second number stops its significant number in the tenths place after the decimal. Hence, the final answer is limited to six significant figures. The final answer is 404,884.

d. $55.5 + 66.66 - 77.777 = 44.383$. The first number stops its significant figure in the tenths place after the decimal, the second number stops its significant figure in the hundredths place after the decimal, and the third number stops its significant figure in the thousandths place after the decimal. Hence, we limit our final answer to the tenths place after the decimal. The final answer is 44.4.

9. Compute and express each answer with the proper number of significant figures, rounding as necessary.
a. $56.7 \times 66.99 = ?$
b. $1.000 \div 77 = ?$
c. $1.000 \div 77.0 = ?$
d. $6.022 \times 1.89 = ?$

Solution:
a. $56.7 \times 66.99 = 3{,}798.33$. The first number has three significant figures; the second number has 4 significant figures. Hence, the final answer is limited to three significant figures. The final answer is 3,800 or 3.80×10^3.
b. $1.000 \div 77 = 0.01298$. The first number has four significant figures; the second number has two significant figures. Hence, the final answer is limited to two significant figures. The final answer is 0.013.
c. $1.000 \div 77.0 = 0.01298$. The first number has four significant figures; the second number has three significant figures. Hence, the final answer is limited to three significant figures. The final answer is 0.0130.
d. $6.022 \times 1.89 = 11.38158$. The first number has four significant figures; the second number has three significant figures. Hence, the final answer is limited to three significant figures. The final answer is 11.4.

10. Compute and express each answer with the proper number of significant figures, rounding as necessary.
a. $0.000440 \times 17.22 = ?$
b. $203{,}000 \div 0.044 = ?$
c. $67 \times 85.0 \times 0.0028 = ?$
d. $999{,}999 \div 3{,}310 = ?$

Solution:
a. $0.000440 \times 17.22 = 7.5768 \times 10^{-3}$. The first number has three significant figures; the second number has four significant figures. Hence, the final answer is limited to three significant figures. The final answer is 7.58×10^{-3} or 0.00758.
b. $203{,}000 \div 0.044 = 4{,}613{,}636.364$. The first number has three significant figures; the second number has two significant figures. Hence, the final answer is limited to two significant figures. The final answer is 4,600,000.
c. $67 \times 85.0 \times 0.0028 = 15.946$. The first number has two significant figures, the second number has three significant figures, and the third number has two significant figures. Hence, the final answer is limited to two significant figures. The final answer is 16.
d. $999{,}999 \div 3{,}310 = 302.1145$. The first number has six significant figures; the second number has three significant figures. Hence, the final answer is limited to three significant figures. The final answer is 302.

11.
a. Write the number 87,449 in scientific notation with four significant figures.
b. Write the number 0.000066600 in scientific notation with five significant figures.

Solution:
a. Scientific notation of 87,449 is 8.7449×10^4. With respect to four significant figures, 8.7449×10^4 can be written as 8.745×10^4.
b. Scientific notation of 0.000066600 is 6.6600×10^{-5}. With respect to five significant figures, 6.6600×10^{-5} stays the same.

12.
a. Write the number 306,000,000 in scientific notation to the proper number of significant figures.
b. Write the number 0.0000558 in scientific notation with two significant figures.

Solution:
a. Scientific notation of 306,000,000 is 3.06×10^8.
b. Scientific notation of 0.0000558 is 5.58×10^{-5}. With respect to two significant figures, 5.58×10^{-5} can be written as 5.6×10^{-5}.

13. Perform each calculation and limit each answer to three significant figures.
a. $67{,}883 \times 0.004321 = ?$
b. $(9.67 \times 10^3) \times 0.0055087 = ?$

Solution:
a. $67{,}883 \times 0.004321 = 293.322$. With respect to three significant figures, 293.322 can be written as 293.
b. $(9.67 \times 10^3) \times 0.0055087 = 53.2691$. With respect to three significant figures, 53.2691 can be written as 53.3.

14. Perform each calculation and limit each answer to four significant figures.
a. $18{,}900 \times 76.33 \div 0.00336 = ?$
b. $0.77604 \div 76{,}003 \times 8.888 = ?$

Solution:
a. $18{,}900 \times 76.33 \div 0.00336 = 429{,}356{,}250$. With respect to four significant figures, 429,356,250 can be written as 429,400,000 or 4.294×10^8.
b. $0.77604 \div 76{,}003 \times 8.888 = 0.0000907522$. With respect to four significant figures, 0.0000907522 can be written as 0.00009075 or 9.075×10^{-5}.

2.4 Converting Units

- **Convert from one unit to another unit of the same type.**

Teaching Tip

Students can be asked to describe multiple prefixes along with their multiplicative units as studied in section 2.2. This will help the students in converting the units.

- The rules of algebra say that you can change (i.e., multiply or divide or add or subtract) the equality (as long as you don't divide by zero) and the new expression will still be an equality. For example, 1 yd = 3 ft, if we divide both sides by 2, we get $\frac{1}{2}\text{ yd} = \frac{3}{2}\text{ ft}$.
- The quantities in the numerator and denominator cancel, both the number *and* the unit: $\frac{\cancel{1\text{ yd}}}{\cancel{1\text{ yd}}} = \frac{3\text{ ft}}{1\text{ yd}}$
- A **conversion factor** is a fraction that can be used to convert a quantity from one unit to another.

Example 7
Test Yourself

1. Convert 67.08 μL to liters.
2. Convert 56.8 m to kilometers.

Solution:

1. Conversion factor: $\frac{10^{-6}\text{L}}{1\ \mu\text{L}}$

On multiplying 67.08 μL with the conversion factor,

$\frac{10^{-6}\text{L}}{1\ \mu\text{L}} \times 67.08\ \mu\text{L} = 6.708 \times 10^{-5}\text{ L}$

2. Conversion factor: $\frac{10^{-3}\text{km}}{1\text{ m}}$

On multiplying 56.8 m with the conversion factor,

$\frac{10^{-3}\text{km}}{1\text{ m}} \times 56.8\text{ m} = 5.68 \times 10^{-2}\text{ km}$

Example 8

Test Yourself

How many cubic millimeters are present in 0.0923 m^3?

Solution: Conversion factor: $\frac{1{,}000\ \text{mm}}{1\ \text{m}}$

Multiply 0.0923 m^3 with the conversion factor three times, since the exponent is 3,

$$0.0923\ \text{m}^3 \times \frac{1{,}000\ \text{mm}}{1\ \text{m}} \times \frac{1{,}000\ \text{mm}}{1\ \text{m}} \times \frac{1{,}000\ \text{mm}}{1\ \text{m}} = 9.23 \times 10^7\ \text{mm}^3$$

Example 9
Test Yourself

Convert 0.203 m/min to meters/second.

Solution: Conversion factor: $\frac{1\ \text{min}}{60\ \text{s}}$

On multiplying 0.203 m/min with the conversion factor,

$$0.203 \frac{\text{m}}{\text{min}} \times \frac{1\ \text{min}}{60\ \text{s}} = 0.00338\ \text{m/s or } 3.38 \times 10^{-3}\ \text{m/s}$$

- Sometimes there will be a need to convert from one unit with one numerical prefix to another unit with a different numerical prefix. It can be done n following two ways:
    - Memorizing the conversion factors
    - First convert the quantity to the base unit, the unit with no numerical prefix, using the definition of the original prefix. Then convert the quantity in the base unit to the desired unit using the definition of the second prefix.

Example 10
Test Yourself

How many milliliters are in 607.8 kL?

Solution:

$$607.8\ \text{kL} \times \frac{1{,}000\ \text{L}}{1\ \text{kL}} \times \frac{1{,}000\ \text{mL}}{1\ \text{L}} = 6.078 \times 10^8\ \text{mL}$$

- An **exact number** is a number from a defined relationship, not a measured one. For example, the prefix *kilo-* means 1,000—*exactly* 1,000, no more or no less. Thus, in constructing the conversion factor

Example 11
Test Yourself

What is the volume of a block in cubic meters whose dimensions are 2.1 cm × 34.0 cm × 118 cm?

Solution:

$$2.1\text{ cm} \times 34.0\text{ cm} \times 118\text{ cm} \times \frac{1\text{ m}}{100\text{ cm}} \times \frac{1\text{ m}}{100\text{ cm}} \times \frac{1\text{ m}}{100\text{ cm}} = 8.4252 \times 10^{-3}\text{ m}^3$$

Considering significant figures, 8.4252×10^{-3} m^3 can be written as 8.4×10^{-3} m^3 or 0.0084 m^3.

IN-CLASS ACTIVITY

Students can be asked to convert a particular length in different units.

Appropriate In-Class Use			
Discussion	**Team Activity**	**Class Time**	**Assign Ahead**
√	Not necessary	30 minutes	Not necessary

Exercises

1. Write the two conversion factors that exist between the two given units.
a. milliliters and liters
b. microseconds and seconds
c. kilometers and meters

Solution:

a. $\frac{1{,}000\text{ mL}}{1\text{ L}}$ and $\frac{1\text{ L}}{1{,}000\text{ mL}}$

b. $\frac{1{,}000{,}000\ \mu\text{s}}{1\text{ s}}$ and $\frac{1\text{ s}}{1{,}000{,}000\ \mu\text{s}}$

c. $\frac{1{,}000\text{ m}}{1\text{ km}}$ and $\frac{1\text{ km}}{1{,}000\text{ m}}$

2. Write the two conversion factors that exist between the two given units.

a. kilograms and grams
b. milliseconds and seconds
c. centimeters and meters

Solution:

a. $\frac{1{,}000\text{ g}}{1\text{ kg}}$ and $\frac{1\text{ kg}}{1{,}000\text{ g}}$

b. $\frac{1{,}000\text{ ms}}{1\text{ s}}$ and $\frac{1\text{ s}}{1{,}000\text{ ms}}$

c. $\frac{100\text{ cm}}{1\text{ m}}$ and $\frac{1\text{ m}}{100\text{ cm}}$

3. Perform the following conversions.
a. 5.4 km to meters
b. 0.665 m to millimeters
c. 0.665 m to kilometers

Solution:

a. $5.4\text{ km} \times \frac{1{,}000\text{ m}}{1\text{ km}} = 5{,}400\text{ m}$

b. $0.665\text{ m} \times \frac{1{,}000\text{ mm}}{1\text{ m}} = 665\text{ mm}$

c. $0.665\text{ m} \times \frac{1\text{ km}}{1{,}000\text{ m}} = 6.65 \times 10^{-4}\text{ km}$

4. Perform the following conversions.
a. 90.6 mL to liters
b. 0.00066 ML to liters
c. 750 L to kiloliters

Solution:

a. $90.6\text{ mL} \times \frac{1\text{ L}}{1{,}000\text{ mL}} = 0.0906\text{ L}$

b. $0.00066\text{ ML} \times \frac{1{,}000{,}000\text{ L}}{1\text{ ML}} = 660\text{ L}$

c. $750\text{ L} \times \frac{1\text{ kL}}{1{,}000\text{ L}} = 0.75\text{ kL}$

5. Perform the following conversions.
a. 17.8 μg to grams
b. 7.22×10^{2} kg to grams
c. 0.00118 g to nanograms

Solution:

a. $17.8\ \mu g \times \frac{1\ g}{1,000,000\ \mu g} = 1.78 \times 10^{-5}$ g

b. 7.22×10^{2} kg $\times \frac{1,000\ g}{1\ kg} = 7.22 \times 10^{5}$ g

c. $0.00118\ g \times \frac{1,000,000,000\ ng}{1\ g} = 1.18 \times 10^{6}$ ng

6. Perform the following conversions.
a. 833 ns to seconds
b. 5.809 s to milliseconds
c. 2.77×10^{6} s to megaseconds

Solution:

a. $833\ ns \times \frac{1\ s}{1,000,000,000\ ns} = 8.33 \times 10^{-7}$ s

b. $5.809\ s \times \frac{1,000\ ms}{1\ s} = 5.809 \times 10^{3}$ ms

c. $2.77 \times 10^{6}\ s \times \frac{1\ Ms}{1,000,000\ s} = 2.77$ Ms

7. Perform the following conversions.
a. 9.44 m^2 to square centimeters
b. 3.44×10^{8} mm^3 to cubic meters

Solution:

a. $9.44\ m^2 \times \frac{100\ cm}{1\ m} \times \frac{100\ cm}{1\ m} = 94,400\ cm^2$

b. $3.44 \times 10^{8}\ mm^3 \times \frac{1\ m}{1,000\ mm} \times \frac{1\ m}{1,000\ mm} \times \frac{1\ m}{1,000\ mm} = 0.344\ m^3$

8. Perform the following conversions.
a. 0.00444 cm^3 to cubic meters
b. 8.11×10^{2} m^2 to square nanometers

Solution:

a. $0.00444\ cm^3 \times \frac{1\ m}{100\ cm} \times \frac{1\ m}{100\ cm} \times \frac{1\ m}{100\ cm} = 4.44 \times 10^{-9}\ m^3$

b. $8.11 \times 10^{2}\ m^2 \times \frac{1,000,000,000\ nm}{1\ m} \times \frac{1,000,000,000\ nm}{1\ m} = 8.11 \times 10^{20}\ nm^2$

9. Why would it be inappropriate to convert square centimeters to cubic meters?

Solution: One is a unit of area, and the other is a unit of volume.

10. Why would it be inappropriate to convert from cubic meters to cubic seconds?

Solution: One is a unit of volume, and the other is a unit of time cubed.

11. Perform the following conversions.
a. 45.0 m/min to meters/second
b. 0.000444 m/s to micrometers/second
c. 60.0 km/h to kilometers/second

Solution:

a. $45.0\ \frac{\text{m}}{\text{min}} \times \frac{1\ \text{min}}{60\ \text{s}} = 0.75\ \text{m/s}$

b. $0.000444\ \frac{\text{m}}{\text{s}} \times \frac{1{,}000{,}000\ \mu\text{m}}{1\ \text{m}} = 444\ \mu\text{m/s}$

c. $60.0\ \frac{\text{km}}{\text{h}} \times \frac{1\ \text{h}}{60\ \text{min}} \times \frac{1\ \text{min}}{60\ \text{s}} = 0.0166\ \text{km/s or } 1.666 \times 10^{-2}\ \text{km/s}$

12. Perform the following conversions.
a. 3.4×10^2 cm/s to centimeters/minute
b. 26.6 mm/s to millimeters/hour
c. 13.7 kg/L to kilograms/milliliters

Solution:

a. $3.4 \times 10^2 \frac{\text{cm}}{\text{s}} \times \frac{60\ \text{s}}{1\ \text{min}} =\ 20{,}400\ \text{cm/min or } 2.04 \times 10^4\ \text{cm/min}$

b. $26.6\ \frac{\text{mm}}{\text{s}} \times \frac{60\ \text{s}}{1\ \text{min}} \times \frac{60\ \text{min}}{1\ \text{h}} = 95{,}760\ \text{mm/h}$

c. $13.7\ \frac{\text{kg}}{\text{L}} \times \frac{1\ \text{L}}{1{,}000\ \text{mL}} = 0.0137\ \text{kg/mL}$

13. Perform the following conversions.
a. 0.674 kL to milliliters
b. 2.81×10^{12} mm to kilometers
c. 94.5 kg to milligrams

Solution:

a. $0.674\ \text{kL} \times \frac{1{,}000\ \text{L}}{1\ \text{kL}} \times \frac{1{,}000\ \text{mL}}{1\ \text{L}} = 674{,}000\ \text{mL}$

b. $2.81 \times 10^{12}\ \text{mm} \times \frac{1\ \text{m}}{1{,}000\ \text{mm}} \times \frac{1\ \text{km}}{1{,}000\ \text{m}} = 2.81 \times 10^6\ \text{km}$

c. $94.5\ \text{kg} \times \frac{1{,}000\ \text{g}}{1\ \text{kg}} \times \frac{1{,}000\ \text{mg}}{1\ \text{g}} = 9.45 \times 10^7\ \text{mg}$

14. Perform the following conversions.
a. 6.79×10^{-6} kg to micrograms

b. 1.22 mL to kiloliters
c. 9.508×10^{-9} ks to milliseconds

Solution:

a. $6.79 \times 10^{-6} \text{ kg} \times \frac{1{,}000 \text{ g}}{1 \text{ kg}} \times \frac{1{,}000{,}000 \ \mu\text{g}}{1 \text{ g}} = 6{,}790 \ \mu\text{g}$ or $6.79 \times 10^{3} \ \mu\text{g}$

b. $1.22 \text{ mL} \times \frac{1 \text{ L}}{1{,}000 \text{ mL}} \times \frac{1 \text{ kL}}{1{,}000 \text{ L}} = 1.22 \times 10^{-6} \text{ kL}$

c. $9.508 \times 10^{-9} \text{ ks} \times \frac{1{,}000 \text{ s}}{1 \text{ ks}} \times \frac{1{,}000 \text{ ms}}{1 \text{ s}} = 9.508 \times 10^{-3} \text{ ms}$

15. Perform the following conversions.
a. 6.77×10^{14} ms to kiloseconds
b. 34,550,000 cm to kilometers

Solution:

a. $6.77 \times 10^{14} \text{ ms} \times \frac{1 \text{ s}}{1{,}000 \text{ ms}} \times \frac{1 \text{ ks}}{1{,}000 \text{ s}} = 6.77 \times 10^{8} \text{ ks}$

b. $34{,}550{,}000 \text{ cm} \times \frac{1 \text{ m}}{100 \text{ cm}} \times \frac{1 \text{ km}}{1000 \text{ m}} = 345.5 \text{ km}$

16. Perform the following conversions.
a. 4.701×10^{15} mL to kiloliters
b. 8.022×10^{-11} ks to microseconds

Solution:

a. $4.701 \times 10^{15} \text{ mL} \times \frac{1 \text{ L}}{1{,}000 \text{ mL}} \times \frac{1 \text{ kL}}{1{,}000 \text{ L}} = 4.701 \times 10^{9} \text{ kL}$

b. $8.022 \times 10^{-11} \text{ ks} \times \frac{1{,}000 \text{ s}}{1 \text{ ks}} \times \frac{1{,}000{,}0000 \ \mu\text{s}}{1 \text{ s}} = 8.022 \times 10^{-2} \ \mu\text{s}$

17. Perform the following conversions. Note that you will have to convert units in both the numerator and the denominator.
a. 88 ft/s to miles/hour (Hint: use 5,280 ft = 1 mi.)
b. 0.00667 km/h to meters/second

Solution:

a. $88 \ \frac{\text{ft}}{\text{s}} \times \frac{1 \text{ mi}}{5{,}280 \text{ ft}} \times \frac{60 \text{ s}}{1 \text{ min}} \times \frac{60 \text{ min}}{1 \text{ h}} = 60 \text{ mi/h}$ or 6.0×10^{1} mi/h

b. $0.00667 \ \frac{\text{km}}{\text{h}} \times \frac{1{,}000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{60 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ s}} = 0.00185 \text{ m/s}$

18. Perform the following conversions. Note that you will have to convert units in both the numerator and the denominator.
a. 3.88×10^{2} mm/s to kilometers/hour

b. 1.004 kg/L to grams/milliliter

Solution:

a. $3.88 \times 10^2 \ \frac{\text{mm}}{\text{s}} \times \frac{1\ \text{m}}{1{,}000\ \text{mm}} \times \frac{1\ \text{km}}{1{,}000\ \text{m}} \times \frac{60\ \text{s}}{1\ \text{min}} \times \frac{60\ \text{min}}{1\ \text{h}}$ = 1.3968 km/h

b. $1.004 \frac{\text{kg}}{\text{L}} \times \frac{1{,}000\ \text{g}}{1\ \text{kg}} \times \frac{1\ \text{L}}{1{,}000\ \text{mL}}$ = 1.004 g/mL

19. What is the area in square millimeters of a rectangle whose sides are 2.44 cm × 6.077 cm? Express the answer to the proper number of significant figures.

Solution: Area in square millimeters = 2.44 cm × 6.077 cm × $\frac{10\ \text{mm}}{1\ \text{cm}} \times \frac{10\ \text{mm}}{1\ \text{cm}}$ =

1,482.788 mm^2

Considering significant numbers, 1,482.788 mm^2 can be written as 1,480 mm^2 or $1.48 \times 10^3\ \text{mm}^2$.

20. What is the volume in cubic centimeters of a cube with sides of 0.774 m? Express the answer to the proper number of significant figures.

Solution: Volume = 0.774 m × 0.774 m × 0.774 m

Volume in cm^3 = 0.463684824 $\text{m}^3 \times \frac{100\ \text{cm}}{1\ \text{m}} \times \frac{100\ \text{cm}}{1\ \text{m}} \times \frac{100\ \text{cm}}{1\ \text{m}}$ = 463,684.824 cm^3

Considering significant numbers, 463,684.824 cm^3 can be written as 464,000 cm^3 or $4.64 \times 10^5\ \text{cm}^3$.

21. The formula for the area of a triangle is ½ × base × height. What is the area of a triangle in square centimeters if its base is 1.007 m and its height is 0.665 m? Express the answer to the proper number of significant figures.

Solution: Area = ½ × 1.007 m × 0.665 m = 0.3348275 m^2

Area = 0.3348275 $\text{m}^2 \times \frac{100\ \text{cm}}{1\ \text{m}} \times \frac{100\ \text{cm}}{1\ \text{m}}$ = 3,348.275 cm^2

Considering significant numbers, 3,348.275 cm^2 can be written as 3,350 cm^2 or $3.35 \times 10^3\ \text{cm}^2$.

22. The formula for the area of a triangle is ½ × base × height. What is the area of a triangle in square meters if its base is 166 mm and its height is 930.0 mm? Express the answer to the proper number of significant figures.

Solution: Area = ½ × 166 mm × 930.0 mm = 77,190 mm^2

Area = 77,190 $\text{mm}^2 \times \frac{1\ \text{m}}{1{,}000\ \text{mm}} \times \frac{1\ \text{m}}{1{,}000\ \text{mm}}$ = 0.07719 m^2

Considering significant numbers, 0.07719 m^2 can be written as 0.0772 m^2 or 7.72×10^{-2} m^2.

2.5 Other Units: Temperature and Density

- **Learn about the various temperature scales that are commonly used in chemistry.**
- **Define density and use it as a conversion factor.**

Teaching Tip

A discussion can be initiated about the absolute zero temperature. This will help the students understand the significance of the Kelvin temperature scale.

- **Temperature** is a measure of the average amount of energy of motion, or *kinetic energy*, a system contains.
- Temperatures are expressed using scales using units called **degrees**.
  - In the United States, the commonly used temperature scale is the *Fahrenheit scale.* On this scale, the freezing point of liquid water is 32°F, and the boiling point of water is 212°False
  - The Celsius scale (°C) is a temperature scale where 0°C is the freezing point of water and 100°C is the boiling point of water

$$^{\circ}\mathrm{C} = \left(^{\circ}\mathrm{F} - 32\right) \times \frac{5}{9}$$

$$^{\circ}\mathrm{F} = \left(^{\circ}\mathrm{C} \times \frac{9}{5}\right) + 32$$

Example 12
Test Yourself

1. Convert 0°F to degrees Celsius.
2. Convert 212°C to degrees Fahrenheit.

Solution:

1. Using the formula, $^{\circ}\mathrm{C} = \left(^{\circ}\mathrm{F} - 32\right) \times \frac{5}{9}$

$$^{\circ}\text{C} = (0-32) \times \frac{5}{9} = -17.8^{\circ}\text{C}$$

2. Using the formula, $^{\circ}\text{F} = \left(^{\circ}\text{C}\times\frac{9}{5}\right) + 32$

$$^{\circ}\text{F} = \left(212\times\frac{9}{5}\right) + 32 = 413.6^{\circ}\text{F}$$

Considering significant numbers, 413.6°F can be written as 414°F.

- The fundamental unit of temperature in SI is the kelvin (K).
  - The Kelvin temperature scale uses degrees that are the same size as the Celsius degree, but the numerical scale is shifted up by 273.15 units.

    K = °C + 273.15

    °C = K − 273.15
  - The Kelvin scale does not use the word *degrees.*
  - The Kelvin temperature scale is set so that 0 K is **absolute zero**, and temperature is counted upward from there.

Example 13
Test Yourself

What is 98.6°F on the Kelvin scale?

Solution: Using the formula, $^{\circ}\text{C} = (^{\circ}\text{F}-32)\times\frac{5}{9}$

$$^{\circ}\text{C} = (98.6-32) \times \frac{5}{9} = 37^{\circ}\text{C}$$

K = 37°C + 273.15 = 310.15 K
Considering significant numbers, 310.15 K can be written as 310.2 K.

- Density is a physical property that is defined as a substance's mass divided by its volume:

  $$\text{density} = \frac{\text{mass}}{\text{volume}} \text{ or } d = \frac{m}{V}$$
- Density can act as conversion factor for switching between units of mass and volume.

Example 14
Test Yourself

What is the mass of 25.0 cm^3 of iron?

Solution: From the Table 2.2 in the text, density of iron is 7.87 g/cm^3.
To calculate the mass of iron:

$$25.0\ \text{cm}^3 \times \frac{7.87\ \text{g}}{1\ \text{cm}^3} = 196.75\ \text{g}$$

Considering significant numbers 196.75 g can be written as 197 g.

Example 15
Test Yourself

What is the volume of 3.78 g of gold?

Solution: From the Table 2.2 in the text, density of gold is 19.3 g/cm^3.
To calculate the volume of gold:

$$3.78\ \text{g} \times \frac{1\ \text{cm}^3}{19.3\ \text{g}} = 0.196\ \text{cm}^3$$

IN-CLASS ACTIVITY

Students can be asked to compare the Kelvin temperature scale and the Celsius temperature scale.

Appropriate In-Class Use			
Discussion	**Team Activity**	**Class Time**	**Assign Ahead**
√	Not necessary	30 minutes	Not necessary

Exercises

1. Perform the following conversions.
a. 255°F to degrees Celsius
b. −255°F to degrees Celsius
c. 50.0°C to degrees Fahrenheit
d. −50.0°C to degrees Fahrenheit

Solution:

a. Using the formula, $^\circ\text{C} = \left(^\circ\text{F} - 32\right) \times \frac{5}{9}$

$$^\circ\text{C} = \left(255 - 32\right) \times \frac{5}{9} = 124^\circ\text{C}$$

b. Using the formula, $^{\circ}\mathrm{C} = \left(^{\circ}\mathrm{F} - 32\right) \times \frac{5}{9}$

$^{\circ}\mathrm{C} = \left(-255 - 32\right) \times \frac{5}{9} = -159^{\circ}\mathrm{C}$

c. Using the formula, $^{\circ}\mathrm{F} = \left(^{\circ}\mathrm{C} \times \frac{9}{5}\right) + 32$

$^{\circ}\mathrm{F} = \left(50 \times \frac{9}{5}\right) + 32 = 122^{\circ}\mathrm{F}$

d. Using the formula, $^{\circ}\mathrm{F} = \left(^{\circ}\mathrm{C} \times \frac{9}{5}\right) + 32$

$^{\circ}\mathrm{F} = \left(-50 \times \frac{9}{5}\right) + 32 = -58^{\circ}\mathrm{F}$

2. Perform the following conversions.
a. 1,065°C to degrees Fahrenheit
b. −222°C to degrees Fahrenheit
c. 400.0°F to degrees Celsius
d. 200.0°F to degrees Celsius

Solution:

a. Using the formula, $^{\circ}\mathrm{F} = \left(^{\circ}\mathrm{C} \times \frac{9}{5}\right) + 32$

$^{\circ}\mathrm{F} = \left(1{,}065 \times \frac{9}{5}\right) + 32 = 1{,}949^{\circ}\mathrm{F}$

b. Using the formula, $^{\circ}\mathrm{F} = \left(^{\circ}\mathrm{C} \times \frac{9}{5}\right) + 32$

$^{\circ}\mathrm{F} = \left(-222 \times \frac{9}{5}\right) + 32 = -368^{\circ}\mathrm{F}$

c. Using the formula, $^{\circ}\mathrm{C} = \left(^{\circ}\mathrm{F} - 32\right) \times \frac{5}{9}$

$^{\circ}\mathrm{C} = \left(400.0 - 32\right) \times \frac{5}{9} = 204^{\circ}\mathrm{C}$

d. Using the formula, $^{\circ}\mathrm{C} = \left(^{\circ}\mathrm{F} - 32\right) \times \frac{5}{9}$

$^{\circ}\mathrm{C} = \left(200.0 - 32\right) \times \frac{5}{9} = 93^{\circ}\mathrm{C}$

3. Perform the following conversions.
a. 100.0°C to kelvins
b. −100.0°C to kelvins
c. 100 K to degrees Celsius
d. 300 K to degrees Celsius

Solution:
a. K = 100.0 + 273.15 = 373 K
b. K = −100.0 + 273.15 = 173 K
c. °C = 100 − 273.15 = −173°C
d. °C = 300 − 273.15 = 27°C

4. Perform the following conversions.
a. 1,000.0 K to degrees Celsius
b. 50.0 K to degrees Celsius
c. 37.0°C to kelvins
d. −37.0°C to kelvins

Solution:
a. °C = 1,000.0 − 273.15 = 727°C
b. °C = 50.0 − 273.15 = −223°C
c. K = 37.0 + 273.15 = 310 K
d. K = −37.0 + 273.15 = 236 K

5. Convert 0 K to degrees Celsius. What is the significance of the temperature in degrees Celsius?

Solution: −273°C. This is the lowest possible temperature in degrees Celsius.

6. Convert 0 K to degrees Fahrenheit. What is the significance of the temperature in degrees Fahrenheit?

Solution: 0 K = −273.15°C
Using the formula, $^{\circ}\mathrm{F} = \left(^{\circ}\mathrm{C} \times \frac{9}{5}\right) + 32$

$$^{\circ}\mathrm{F} = \left(-273.15 \times \frac{9}{5}\right) + 32 = -459\ ^{\circ}\mathrm{F}$$

7. The hottest temperature ever recorded on the surface of the earth was 136°F in Libya in 1922. What is the temperature in degrees Celsius and in kelvins?

Solution: Using the formula, $^{\circ}\mathrm{C} = \left(^{\circ}\mathrm{F} - 32\right) \times \frac{5}{9}$

$$^{\circ}\mathrm{C} = \left(136 - 32\right) \times \frac{5}{9} = 57.8^{\circ}\mathrm{C}$$

K = 57.8 + 273.15 = 331 K

8. The coldest temperature ever recorded on the surface of the earth was −128.6°F in Vostok, Antarctica, in 1983. What is the temperature in degrees Celsius and in kelvins?

Solution: Using the formula, $^{\circ}\mathrm{C} = \left(^{\circ}\mathrm{F} - 32\right) \times \frac{5}{9}$

$$^{\circ}\text{C} = (-128.6 - 32) \times \frac{5}{9} = -\,89^{\circ}\text{C}$$

K = − 89 + 273.15 = 184 K

9. Give at least three possible units for density.

Solution: g/mL, g/L, and kg/L (answers will vary)

10. What are the units when density is inverted? Give three examples.

Solution: L/g, mL/g, and L/kg (answers will vary)

11. A sample of iron has a volume of 48.2 cm^3. What is its mass?

Solution: Using the Table 2.2 in the text, density of iron is 7.87 g/cm^3.
To calculate the mass of the iron sample:

$$48.2\ \text{cm}^3 \times \frac{7.87\ \text{g}}{1\ \text{cm}^3} = 379\ \text{g}$$

12. A sample of air has a volume of 1,015 mL. What is its mass?

Solution: Using the Table 2.2 in the text, density of air is 0.0012 g/cm^3.
1 mL = 1 cm^3
To calculate the mass of the sample of air:

$$1{,}015\ \text{mL} \times \frac{1\ \text{cm}^3}{1\ \text{mL}} \times \frac{0.0012\ \text{g}}{1\ \text{cm}^3} = 1.2\ \text{g}$$

13. The volume of hydrogen used by the *Hindenburg*, the German airship that exploded in New Jersey in 1937, was 2.000×10^8 L. If hydrogen gas has a density of 0.0899 g/L, what mass of hydrogen was used by the airship?

Solution: To calculate the mass of hydrogen used by the airship:

$$2.000 \times 10^8\,\text{L} \times \frac{0.0899\ \text{g}}{1\ \text{L}} = 1.80\ \times 10^7\,\text{g}$$

14. The volume of an Olympic-sized swimming pool is 2.50×10^9 cm^3. If the pool is filled with alcohol (d = 0.789 g/cm^3), what mass of alcohol is in the pool?

Solution: To calculate the mass of alcohol in the swimming pool:

$$2.50 \times 10^9\,\text{cm}^3 \times \frac{0.789\ \text{g}}{1\ \text{cm}^3} = 1.97 \times 10^9\,\text{g}$$

15. A typical engagement ring has 0.77 cm^3 of gold. What mass of gold is present?

Solution: Using the Table 2.2 in the text, density of gold is 19.3 g/cm^3.
To calculate the mass of gold present in the ring:

$$0.77\ \text{cm}^3 \times \frac{19.3\ \text{g}}{1\ \text{cm}^3} = 15\ \text{g}$$

16. A typical mercury thermometer has 0.039 mL of mercury in it. What mass of mercury is in the thermometer?

Solution: Using the Table 2.2 in the text, density of mercury is 13.6 g/cm^3.
1 cm^3 = 1 mL
To calculate the mass of mercury in the thermometer:

$$0.039\ \text{mL} \times \frac{1\ \text{cm}^3}{1\ \text{mL}} \times \frac{13.6\ \text{g}}{1\ \text{cm}^3} = 0.53\ \text{g}$$

17. What is the volume of 100.0 g of lead if lead has a density of 11.34 g/cm^3?

Solution: Density = 11.34 g/cm^3
To calculate the volume of lead:

$$100.0\ \text{g} \times \frac{1\ \text{cm}^3}{11.34\ \text{g}} = 8.818\ \text{cm}^3$$

18. What is the volume of 255.0 g of uranium if uranium has a density of 19.05 g/cm^3?

Solution: Density = 19.05 g/cm^3
To calculate the volume of uranium:

$$255.0\ \text{g} \times \frac{1\ \text{cm}^3}{19.05\ \text{g}} = 13.39\ \text{cm}^3$$

19. What is the volume in liters of 222 g of neon if neon has a density of 0.900 g/L?

Solution: Density = 0.900 g/L
To calculate the volume of neon:

$$222\ \text{g} \times \frac{1\ \text{L}}{0.900\ \text{g}} = 247\ \text{L}$$

20. What is the volume in liters of 20.5 g of sulfur hexafluoride if sulfur hexafluoride has a density of 6.164 g/L?

Solution: Density = 6.164 g/L
To calculate the volume of sulfur hexafluoride:

$$20.5\ \text{g} \times \frac{1\ \text{L}}{6.164\ \text{g}} = 3.33\ \text{L}$$

21. Which has the greater volume, 100.0 g of iron (d = 7.87 g/cm^3) or 75.0 g of gold (d = 19.3 g/cm^3)?

Solution: For iron, density = 7.87 g/cm^3.

To calculate the volume of iron:

$$100.0\ \text{g} \times \frac{1\ \text{cm}^3}{7.87\ \text{g}} = 12.7\ \text{cm}^3$$

For gold, density = 19.3 g/cm^3.
To calculate the volume of gold:

$$75.0\ \text{g} \times \frac{1\ \text{cm}^3}{19.3\ \text{g}} = 3.89\ \text{cm}^3$$

The 100 g of iron has the greater volume.

22. Which has the greater volume, 100.0 g of hydrogen gas (d = 0.0000899 g/cm^3) or 25.0 g of argon gas (d = 0.00178 g/cm^3)?

Solution: For hydrogen, density = 0.0000899 g/cm^3.
To calculate the volume of hydrogen gas:

$$100.0\ \text{g} \times \frac{1\ \text{cm}^3}{0.0000899\ \text{g}} = 1.11 \times 10^6\ \text{cm}^3$$

For argon, density = 0.00178 g/cm^3.
To calculate the volume of argon gas:

$$25.0\ \text{g} \times \frac{1\ \text{cm}^3}{0.00178\ \text{g}} = 1.40 \times 10^4\ \text{cm}^3$$

The hydrogen gas has the larger volume.

2.6 Additional Exercises

1. Evaluate 0.00000000552 × 0.0000000006188 and express the answer in scientific notation. You may have to rewrite the original numbers in scientific notation first.

Solution:
$0.00000000552 = 5.52 \times 10^{-9}$
$0.0000000006188 = 6.188 \times 10^{-10}$
$5.52 \times 10^{-9} \times 6.188 \times 10^{-10} = 3.42 \times 10^{-18}$

2. Evaluate 333,999,500,000 ÷ 0.00000000003396 and express the answer in scientific notation. You may need to rewrite the original numbers in scientific notation first.

Solution:
$333{,}999{,}500{,}000 = 3.339995 \times 10^{11}$
$0.00000000003396 = 3.396 \times 10^{-11}$
$3.339995 \times 10^{11} \div 3.396 \times 10^{-11} = 9.835 \times 10^{21}$

3. Express the number 6.022×10^{23} in standard notation.

Solution: 602,200,000,000,000,000,000,000

4. Express the number 6.626×10^{-34} in standard notation.

Solution: 0.0000000000000000000000000000000006626

5. When powers of 10 are multiplied together, the powers are added together. For example, $10^2 \times 10^3 = 10^{2+3} = 10^5$. With this in mind, can you evaluate $(4.506 \times 10^4) \times (1.003 \times 10^2)$ without entering scientific notation into your calculator?

Solution: $(4.506 \times 10^4) \times (1.003 \times 10^2) = (4.506 \times 1.003) \times 10^{2\,+\,4} = 4.520 \times 10^6$

6. When powers of 10 are divided into each other, the bottom exponent is subtracted from the top exponent. For example, $10^5/10^3 = 10^{5-3} = 10^2$. With this in mind, can you evaluate $(8.552 \times 10^6) \div (3.129 \times 10^3)$ without entering scientific notation into your calculator?

Solution:$(8.552 \times 10^6) \div (3.129 \times 10^3) = (8.552 \div 3.129) \times 10^{6\,-\,3} = 2.733 \times 10^3$

7. Consider the quantity two dozen eggs. Is the number in this quantity “two” or “two dozen”? Justify your choice.

Solution: The quantity is two; dozen is the unit.

8. Consider the quantity two dozen eggs. Is the unit in this quantity “eggs” or “dozen eggs”? Justify your choice.

Solution: The unit is dozen eggs.

9. Fill in the blank: 1 km = _______________ μm.

Solution: $1\text{ km} \times \dfrac{1{,}000\text{ m}}{1\text{ km}} \times \dfrac{1{,}000{,}000\ \mu\text{m}}{1\text{ m}} = 1{,}000{,}000{,}000\ \mu\text{m}$

10. Fill in the blank: 1 Ms = _______________ ns.

Solution: $1\text{ Ms} \times \dfrac{1{,}000{,}000\text{ s}}{1\text{ Ms}} \times \dfrac{1{,}000{,}000{,}000\text{ ns}}{1\text{ s}} = 10^{15}\text{ ns}$

11. Fill in the blank: 1 cL = _______________ ML.

Solution: $1\text{ cL} \times \dfrac{1\text{ L}}{100\text{ cL}} \times \dfrac{1\text{ ML}}{1{,}000{,}000\text{ L}} = \dfrac{1}{100{,}000{,}000}\text{ ML}$

12. Fill in the blank: 1 mg = _______________ kg.

Solution: $1\text{ mg} \times \dfrac{1\text{ g}}{1{,}000\text{ mg}} \times \dfrac{1\text{ kg}}{1{,}000\text{ g}} = \dfrac{1}{1{,}000{,}000}\text{ kg}$

13. Express 67.3 km/h in meters/second.

Solution: $67.3\ \frac{\text{km}}{\text{h}} \times \frac{1{,}000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{h}}{60\ \text{min}} \times \frac{1\ \text{min}}{60\ \text{s}} = 18.7\ \text{m/s}$

14. Express 0.00444 m/s in kilometers/hour.

Solution: $0.00444\ \frac{\text{m}}{\text{s}} \times \frac{1\ \text{km}}{1{,}000\ \text{m}} \times \frac{60\ \text{min}}{1\ \text{h}} \times \frac{60\ \text{s}}{1\ \text{min}} = 0.0160\ \text{km/h}$

15. Using the idea that 1.602 km = 1.000 mi, convert a speed of 60.0 mi/h into kilometers/hour.

Solution: $60.0\ \frac{\text{mi}}{\text{h}} \times \frac{1.602\ \text{km}}{1\ \text{mi}} = 96.1\ \text{km/h}$

16. Using the idea that 1.602 km = 1.000 mi, convert a speed of 60.0 km/h into miles/hour.

Solution: $60.0\ \frac{\text{km}}{\text{h}} \times \frac{1\ \text{mi}}{1.602\ \text{km}} = 37.5\ \text{mi/h}$

17. Convert 52.09 km/h into meters/second.

Solution: $52.09\ \frac{\text{km}}{\text{h}} \times \frac{1{,}000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{h}}{60\ \text{h}} \times \frac{1\ \text{min}}{60\ \text{s}} = 14.47\ \text{m/s}$

18. Convert 2.155 m/s into kilometers/hour.

Solution: $2.155\ \frac{\text{m}}{\text{s}} \times \frac{1\ \text{km}}{1{,}000\ \text{m}} \times \frac{60\ \text{s}}{1\ \text{min}} \times \frac{60\ \text{min}}{1\ \text{h}} = 7.758\ \text{km/h}$

19. Use the formulas for converting degrees Fahrenheit into degrees Celsius to determine the relative size of the Fahrenheit degree over the Celsius degree.

Solution: One Fahrenheit degree is 9/5ths the size of a Celsius degree.

20. Use the formulas for converting degrees Celsius into kelvins to determine the relative size of the Celsius degree over kelvins.

Solution: Celsius degrees and kelvins are the same size.

21. What is the mass of 12.67 L of mercury?

Solution: Using the Table 2.2 in the text, density of mercury is 13.6 g/cm^3.

$1\ \text{cm}^3 = 1\ \text{mL}$
To calculate the mass of mercury:

$$12.67\ \text{L} \times \frac{10^3\ \text{mL}}{1\ \text{L}} \times \frac{1\ \text{cm}^3}{1\ \text{mL}} \times \frac{13.6\ \text{g}}{1\ \text{cm}^3} = 1.72 \times 10^5\ \text{g}$$

22. What is the mass of $0.663\ \text{m}^3$ of air?

Solution: Using the Table 2.2 in the text, density of air is $0.0012\ \text{g/cm}^3$.
To calculate the mass of air:

$$0.663\ \text{m}^3 \times 0.0012\,\frac{\text{g}}{\text{cm}^3} \times \frac{1000\ \text{cm}}{1\ \text{m}} \times \frac{1000\ \text{cm}}{1\ \text{m}} \times \frac{1000\ \text{cm}}{1\ \text{m}} = 796\ \text{g}$$

23. What is the volume of 2.884 kg of gold?

Solution: Using the Table 2.2 in the text, density of gold is $19.3\ \text{g/cm}^3$.
To calculate the volume of gold:

$$2.884\ \text{kg} \times \frac{1{,}000\ \text{g}}{1\ \text{kg}} \times \frac{1\ \text{cm}^3}{19.3\ \text{g}} = 149.4\ \text{cm}^3 \text{ or mL}$$

24. What is the volume of 40.99 kg of cork? Assume a density of $0.22\ \text{g/cm}^3$.

Solution: Density = $0.22\ \text{g/cm}^3$
To calculate the volume of cork:

$$40.99\ \text{kg} \times \frac{1{,}000\ \text{g}}{1\ \text{kg}} \times \frac{1\ \text{cm}^3}{0.22\ \text{g}} = 1.9 \times 10^5\ \text{cm}^3 \text{ or mL}$$