Chapter 2: Standards for Measurement

2.1 Scientific Notation

- A <u>measurement</u> (quantitative observation) consists of two parts:
  - Numerical value which gives magnitude, and
  - Unit which gives the scale used for the measurement.

- Scientific Notation is used to express very large or very small numbers.
  - Write the number as a product of a number between 1 and 10 multiplied by 10 raised to the appropriate power of 10.

$$93{,}000{,}000 = 9.3 \times 10{,}000{,}000 = 9.3 \times 10^7$$

- Any number can be written in scientific notation.

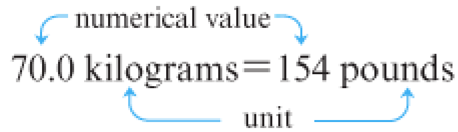
- The power of 10 depends on the number of places the decimal point is moved, and in which direction.
  - Move the decimal point so that it is positioned *after* the first *nonzero* digit in the number.
  - The *number of places* the decimal point is moved determines the *magnitude* of the power of 10.
  - The *direction* of the move determines the *sign*, whether the power of 10 is positive (move left) or negative (move right).

Correctly express 7,882 in scientific notation

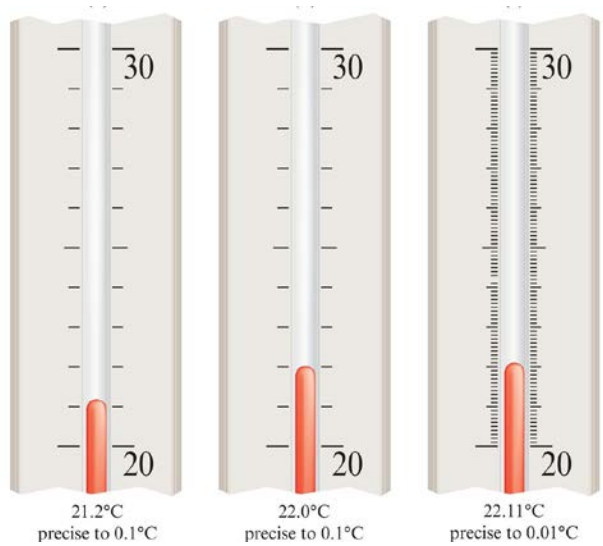
Correctly express 0.0000496 in scientific notation

2.2 Measurement and Uncertainty

- A measurement is a quantitative observation.



- No measurement is exact; it always has some degree of uncertainty. The precision of the measurement is limited by the instrument used.



- The last digit such a measurement is estimated and called the uncertain digit; the remaining digits of the measurement are certain digits.
  - o The last digit of a measurement read from a digital display is also the uncertain digit.

- When reading scales like those shown on the thermometers, we will learn rules for properly estimating the last, uncertain digit.

- The certain digits and the single uncertain digit of a measurement are known as the significant figures of the measurement.

2.3 Significant Figures

- We will calculate using measurements, and we must take care that the answers are not more precise than justified.
  - To do this, we need to count the significant figures in each measurement.

Rules for Counting Significant Figures

1. *Nonzero digits.* All nonzero digits are significant.

2. *Exact numbers.* Some numbers are exact and have an infinite number of significant figures. Exact numbers occur in simple counting operations; when you count 25 dollars. You have exactly 25 dollars. Defined numbers, such as 12 inches in 1 foot, 60 minutes in 1 hour, and 100 centimeters in 1 meter, are also considered to be exact numbers. Exact numbers have no uncertainty.

3. *Zeros.* A zero is *significant* when it is
   a. between nonzero digits:
      205 has three significant figures
      2.005 has four significant figures
      601.09 has five significant figures
   b. at the end of a number that includes a decimal point:
      0.500 has three significant figures
      25.160 has five significant figures
      3.00 has three significant figures
      20. has two significant figures

   A zero is *not significant* when it is:
   a. before the first nonzero digit. These zeros are used to locate a decimal point.
      0.0025 has two significant figures
      0.0108 has three significant figures
   b. at the end of a number without a decimal point:
      1000 has one significant figure
      590 has two significant figures

- Calculated results often need to be rounded off to the proper number of significant figures.

- Rules for rounding off and the OCC ⁝ line convention. *Differs from book!* Write a dashed line ⁝ after the last significant figure.

1. If first digit to drop < 5, last significant digit is not changed.
   5.6 4 rounded to two sig figs is 5.6

2. If first digit to drop > 5, last significant digit is increased by 1.
   3.8 61 rounded to two sig figs is 3.9

3. If first digit to drop = 5, there are two cases to consider:

3.1 If 5 is the only digit, or it is followed only by zeroes, the last digit retained is increased by 1 *if it is odd* (“add if odd”), else the last digit retained is unchanged.
   3.7 5 rounded to two sig figs is 3.8
   3.8 5 rounded to two sig figs is 3.8

3.2 If the 5 is followed by any nonzero digits, the last retained digit is increased by 1.
   3.8 501 rounded to two sig figs is 3.9

4. In a series of calculations, only round off the final result. This means that you should carry all of the digits that show on your calculator until you arrive at the final number and then round off, using the rules above.

Round off these numbers to the numbers of significant figures indicated:

42.246 (four)

88.015 (three)

0.08965 (three)

0.08965 (two)

225.3 (three)

14. 50 (three)

2.4 Significant Figures in Calculations

- When calculating with measured values, we have to express the result with the appropriate number of significant figures.

- Significant Figures in Mathematical Operations
  1. When multiplying or dividing, the number of significant figures in the result is the same as that in the measurement with the smallest number of significant figures.

     1.342 cm × 5.5 cm = 7.3 81 cm^2 = 7.4 cm^2

  2. When adding or subtracting, the limiting term is the one with the smallest number of decimal places.

     23.446 g + 7.83 g = 31.27 6 g = 31.28 g

  3. We will look at counting sig figs when taking log or antilogs later.

2.5 The Metric System

- The Fundamental (Base) SI Units cannot be simplified:

TABLE 2.2 | International System's Standard Units of Measurement

Quantity	Name of unit	Abbreviation
Length	meter	m
Mass	kilogram	kg
Temperature	kelvin	K
Time	second	s
Amount of substance	mole	mol
Electric current	ampere	A
Luminous intensity	candela	cd

- Prefixes are used to change the size of the unit.

TABLE 2.1 | Common Prefixes and Numerical Values for SI Units

Prefix	Symbol	Numerical value	Power of 10 equivalent
giga	G	1,000,000,000	10^{9}
mega	M	1,000,000	10^{6}
kilo	k	1,000	10^{3}
hecto	h	100	10^{2}
deka	da	10	10^{1}
—	—	1	10^{0}
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro	μ	0.000001	10^{-6}
nano	n	0.000000001	10^{-9}
pico	p	0.000000000001	10^{-12}
femto	f	0.000000000000001	10^{-15}

Measurements of Length, Volume, and Mass

- Measurements may be expressed in several ways depending on convenience and custom.
- The *meter* is the SI base unit of length.

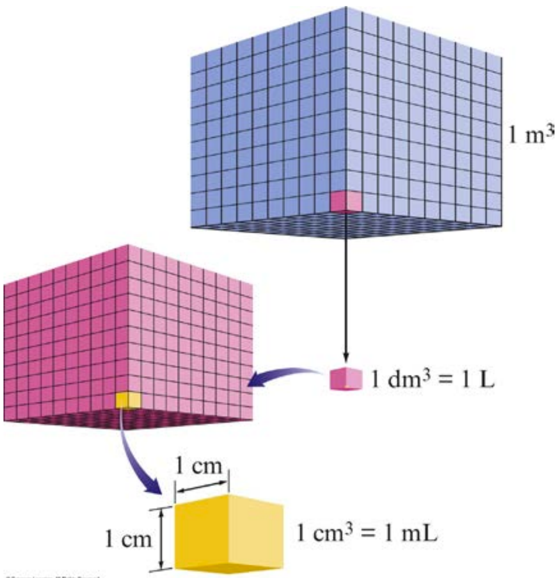
TABLE 2.3 | Metric Units of Length

Unit	Abbreviation	Meter equivalent	Exponential equivalent
kilometer	km	1000 m	10^{3} m
meter	m	1 m	10^{0} m
decimeter	dm	0.1 m	10^{-1} m
centimeter	cm	0.01 m	10^{-2} m
millimeter	mm	0.001 m	10^{-3} m
micrometer	μm	0.000001 m	10^{-6} m
nanometer	nm	0.000000001 m	10^{-9} m
angstrom	Å	0.0000000001 m	10^{-10} m

- Volume measures of the amount of three-dimensional space occupied by a substance.

- Volume is expressed in *derived* SI units defined by base units; these equivalence are exact by definition

  - 1 L = 1 dm^3
  - 1 mL = 1 cm^3



- Mass measures the amount of matter present in an object.

  - The SI base unit of mass is the kilogram (kg)
    - 1 kg = 2.2046 pounds (lbs)
    - 1 lb = 453.59 g

TABLE 2.5 | Metric Units of Mass

Unit	Abbreviation	Gram equivalent	Exponential equivalent
kilogram	kg	1000 g	10^3 g
gram	g	1 g	10^0 g
decigram	dg	0.1 g	10^{-1} g
centigram	cg	0.01 g	10^{-2} g
milligram	mg	0.001 g	10^{-3} g
microgram	μg	0.000001 g	10^{-6} g

2.6 Dimensional Analysis: A Problem-Solving Method

- Numeric problems will fall into one of two types:
  - Performing conversions
  - Applying formulas

- Specific problem-solving techniques will be presented.
  - Learn them!
  - Use them!

- Unit conversions
  - Identify one or more equivalences that relate the initial and final units, especially one that includes the initial units.
  - Convert the equivalence to a conversion factor (fraction) that allows the initial units to be cancelled. Repeat until the final units are obtained.
  - Multiply the initial quantity by the conversion factor(s) to give the result with the desired units.
  - Determine the appropriate number of sig figs for the result.
  - Check that your answer makes sense!

A golfer putted a golf ball 6.8 ft across a green. How many inches is this?

An iron sample has a mass of 4.50 lb. What is the mass of this sample in grams?

How many meters are in 5 yards?

How many milliliters are in a cube with sides measuring 13.1 inches each?

2.7 Percent

- The composition of mixtures and compounds is often given as a percent:
    - Air is 78 % nitrogen by volume.
    - Table salt is 60.7 % chlorine by mass.
- Percent composition can be calculated if the quantities of the part and the whole are known (if the whole is not given, add up all the parts!):

$$\text{percent of part} = \left(\frac{\text{part}}{\text{whole}}\right) \times 100\ \%$$

- A given percentage can be used to create a conversion factor.

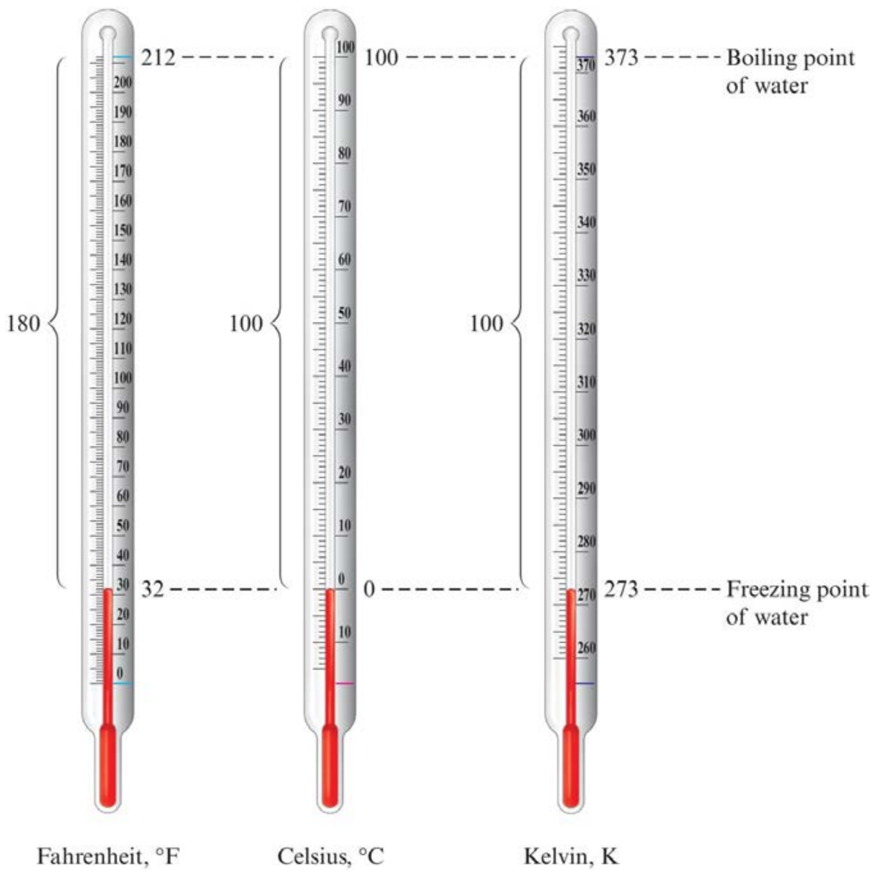
An alloy of bronze can be manufactured by melting 50.0 g of copper with 6.82 g of tin. What is the percent of copper by mass in this alloy?

A chocolate bar contains 0.047 % caffeine by mass. How many mg of caffeine will you consume if you eat a 1.5 oz chocolate bar?

2.8 Measurement of Temperature

- *Hint*: Use a formula!

- The three major temperature scales:



- Converting between scales

$$T_K = T_{°C} + 273.15 \qquad T_{°C} = T_K - 273.15$$

$$T_{°C} = \frac{(T_{°F} - 32)}{1.8} \qquad T_{°F} = 1.8(T_{°C}) + 32$$

The normal body temperature for a dog is approximately 102°F. What is this equivalent to on the Kelvin temperature scale?

At what temperature does °C = °F?

2.9 Density

- Density expresses the mass of a substance per unit volume.

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \qquad\qquad d = \frac{m}{V}$$

  - Common units are: $\frac{g}{cm^3}$ (solids) $\frac{g}{mL}$ (liquids) $\frac{g}{L}$ (gases)

- Density is <u>frequently</u> used as a conversion factor.

A certain mineral has a mass of 17.8 g and a volume of 2.35 cm^3. What is the density of this mineral?

What is the mass of a 49.6 mL sample of a liquid, which has a density of 0.85 g/mL?

If an object has a mass of 243.8 g and occupies a volume of 0.125 L, what is the density of this object in g/cm^3?

Copper has a density of 8.96 g/cm^3. If 75.0 g of copper is added to 50.0 mL of water in a graduated cylinder, to what volume reading will the water level in the cylinder rise?