Scientific Notation

• Large and small numbers can be difficult to use. For example:

The mass of one iron atom is:

\[ 0.0000000000000000000000911 \text{ g} \]

The number of water molecules in one cup is:

\[ 7,910,000,000,000,000,000,000,000 \text{ molecules} \]

Scientific notation is a system in which an ordinary decimal number is expressed as a product of a number between 1 and 9 multiplied by 10 raised to a power.

In scientific notation:

Mass of an iron atom = \( 9.11 \times 10^{-23} \text{ g} \)

# of water molecules in one cup = \( 7.91 \times 10^{24} \text{ molecules} \)
Writing numbers in scientific notation

\[ 7070 = 7.07 \times 10^3 \]

Must be between 1 and 9

\[ 0.0004601 = 4.601 \times 10^{-4} \]

Express the following numbers in scientific notation:

a) 16,020,000 mg  
b) 0.00001206 m  
c) 24 km

Express the following numbers in decimal notation:

a) \(4.38 \times 10^4\)  
b) \(8.770 \times 10^{-15}\)  
c) \(6.23 \times 10^8\)

**Significant figures**

- A method for handling uncertainty in measurement
• Two kinds of numbers are associated with physical quantities:

  **Exact numbers**
  and
  **Measured numbers**

**Exact numbers** - we know the exact value
- no approximation involved

**Measured numbers** - we can never know the exact value

Exact number examples:

  1 dozen eggs = 12 eggs **exactly**
  
  A square has 4 sides (not 3.7 or 4.1)

• **All** measured numbers carry with them a degree of uncertainty. **The degree of uncertainty depends on the measuring device used.**
Thermometer A marked off in 1 degree increments - can estimate temp as 29.2°C or 29.3°C

Thermometer B divided into 0.1 degree increments - the temp can be estimated as 29.18°C or 29.19°C

(Thermometer B is more precise)

Significant Figures are the digits in any measurement that are known with certainty plus one digit that is uncertain.
Guidelines for Determining the Number of Significant Figures

1. All nonzero digits are significant
   45.1
   49
   1.279

2. Confined zeros (or zeros between nonzero digits) **ALWAYS** count as significant
   2.075
   70.7
   940005.008

3. Trailing zeros are significant **if** there is a decimal point in the number
   62.00
   78.00012000
   0.02000

4. Leading zeros (zeros to the left of the first nonzero number) are **NOT** significant. These zeros merely "place" the decimal point.
   0.0145
   0.00034
   0.000002279
5. In cases where there is no decimal point, assume trailing zeros are NOT significant. (These types of numbers should be avoided by using scientific notation).

   93,000,000
   60
   4000
   6310

How many significant figures are in the following numbers?

<table>
<thead>
<tr>
<th>Number</th>
<th>Significant Figures</th>
</tr>
</thead>
<tbody>
<tr>
<td>426</td>
<td>3</td>
</tr>
<tr>
<td>406.00</td>
<td>4</td>
</tr>
<tr>
<td>4600</td>
<td>4</td>
</tr>
<tr>
<td>515.0</td>
<td>3</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>200</td>
<td>2</td>
</tr>
<tr>
<td>200.00</td>
<td>3</td>
</tr>
<tr>
<td>907,000,000</td>
<td>7</td>
</tr>
<tr>
<td>6.022 x 10^{23}</td>
<td>3</td>
</tr>
<tr>
<td>6.022 x 10^{-5}</td>
<td>3</td>
</tr>
</tbody>
</table>
Calculations with Significant Figures

**Rounding off** is the process of deleting insignificant digits from a calculated number.

→ If the digit to be dropped is less than 5, that digit and all digits that follow it are simply dropped

62.314 rounded to 3 sf becomes 62.3
504.902 rounded to 4 sf becomes ______
9,017.000427 rounded to 8 sf = ______

→ If the digit to be dropped is 5 or greater, the last retained digit is increased by **one**

62.782 rounded to 2 sf becomes 63
726.679 rounded to 5 sf becomes ______
4.056639 x 10^{17} rounded to 4 sf = ______

**Calculated quantities cannot be any more precise than the least precise piece of information that goes into the calculations**
Multiplying and Dividing: There can be no more total sig. figs. in the answer than there are in the quantity having the fewest sig. figs.

Adding and Subtracting: There can be no more decimal places in the answer than in the quantity with the least number of decimal places.

\[ 65.6 \times 0.0024 = 983.24 \text{ g} = 1270 \text{ cm}^3 \]

\[ 46.014 \text{ g} - 27.8 \text{ g} + 1.4762 \text{ cm} = 1.578 \text{ cm} + 1.4762 \text{ cm} = 1.52 \text{ cm} \]

Calculations involving multiplication/division and addition/subtraction:

\[(1.023 \times 0.895) + 0.16 = \]

\[(4.1792 - 4.024) \times 57.884 = \]
Metric and SI Units

• The metric system is much easier to use than the English system. There are fewer units to learn and it is much easier to interconvert in the metric system.

• System used for scientific measurements (based on the metric system) is called the SI System (System International). The SI System is used throughout the world.

<table>
<thead>
<tr>
<th>TABLE 2.1</th>
<th>Important SI Standard Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quantity</strong></td>
<td><strong>Unit</strong></td>
</tr>
<tr>
<td>length</td>
<td>meter</td>
</tr>
<tr>
<td>mass</td>
<td>kilogram</td>
</tr>
<tr>
<td>time</td>
<td>second</td>
</tr>
<tr>
<td>temperature*</td>
<td>kelvin</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 2.2</th>
<th>SI Prefix Multipliers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prefix</strong></td>
<td><strong>Symbol</strong></td>
</tr>
<tr>
<td>tera-</td>
<td>T</td>
</tr>
<tr>
<td>giga-</td>
<td>G</td>
</tr>
<tr>
<td>mega-</td>
<td>M</td>
</tr>
<tr>
<td>kilo-</td>
<td>k</td>
</tr>
<tr>
<td>deci-</td>
<td>d</td>
</tr>
<tr>
<td>centi-</td>
<td>c</td>
</tr>
<tr>
<td>milli-</td>
<td>m</td>
</tr>
<tr>
<td>micro-</td>
<td>μ</td>
</tr>
<tr>
<td>nano-</td>
<td>n</td>
</tr>
<tr>
<td>pico-</td>
<td>p</td>
</tr>
<tr>
<td>femto-</td>
<td>f</td>
</tr>
</tbody>
</table>

* Temperature is not an SI base unit.
Ex: kilo means a thousand so:

- 1 kilometer = 1000 meters
- 1 kilogram = 1000 grams
- 1 kiloliter = 1000 liters

5.62 Gm (gigameters) = 5.62 \times 10^9 \text{ meters}
(5620000000 \text{ meters})

12.5 ml (milliliters) = 12.5 \times 10^{-3} \text{ liters}
(1.25 \times 10^{-2} \text{ liters in scientific notation})

5 \mu\text{s (microseconds)} = 5 \times 10^{-6} \text{ seconds}
(0.000005 \text{ seconds})

3.9 \text{ ng (nanograms)} = \text{__________________________g}

Units of Volume

Volume is a measure of the amount of space occupied by an object. Volume is 3-dimensional so the units are ft^3, cm^3, in^3... etc.

Liter is also a volume unit
A liter is the basic unit of measurement in the metric system. A liter is a volume equal to a perfect cube that is 10 cm on each side.

\[ 1 \text{ L} = 10 \text{ cm} \times 10 \text{ cm} \times 10 \text{ cm} = 1000 \text{ cm}^3 \]

(symbol for Liter is capital "L")

**Converting from One Unit to Another**

We often need to convert from one unit to another: inches → feet, lbs → kg, miles → km

To do this, use Conversion Factors!

- Conversion factors are derived from equal quantities of two different units

Ex. 1 foot = 12 inches

conversion factors:

\[ \frac{1 \text{ foot}}{12 \text{ inches}} \quad \text{or} \quad \frac{12 \text{ inches}}{1 \text{ foot}} \]
How many inches are in 2.30 feet?

?? inches = \(2.30 \text{ ft} \times \frac{12 \text{ in}}{1 \text{ ft}}\) (choose conversion factor that allows cancellation of unwanted unit)

= 27.6 inches

**Metric-to-Metric Conversion Factors**

You will need to know the metric conversions in Table 2.2 that are enclosed in the box.

Ex. 0.01 meters = 1 cm or 100 cm = 1 meter

Conversion factors:

\[
\begin{align*}
0.01 \text{ m} & \quad \text{or} \quad 1 \text{ cm} & \quad 100 \text{ cm} & \quad \text{or} \quad 1 \text{ m} \\
1 \text{ cm} & \quad \text{or} \quad 0.01 \text{ m} & \quad 1 \text{ m} & \quad \text{or} \quad 100 \text{ cm}
\end{align*}
\]

English-to-English and Metric-to-English conversion factors will be provided on the Constants and Conversion Sheet.
• How many meters are in $9.87 \times 10^{-3}$ km?

• How many inches are in 0.13 miles?

• A trip takes 2.5 days. How many seconds did the trip take?

• A certain species of snail can travel 14.0 feet in 1.00 day. How many kilometers can the snail travel in 1.00 year?

• The tallest person in the NBA is 7 ft 7 in. What is his height in cm and m?
• How many cans of Diet Coke would you have to drink to consume 1.00 gallon?
  (1 can Diet Coke = 12.0 fluid ounces)

• To get a daily dose of the antibiotic tetracycline a patient needs 25.0 mg per kg of body weight. How many mg of tetracycline should a 154 lb patient take daily?

• A car travels at 50.0 miles per hour. How fast is this in meters per second?

• A bedroom has a volume of 135 m$^3$. What is this volume in km$^3$?
Density

• Density is the ratio of the mass of an object to the volume occupied by that object

\[
\text{Density} = \frac{\text{mass}}{\text{volume}}
\]

Most frequently encountered units are:

Solids \ g/cm^3
Liquids \ g/mL
Gases \ g/L

Rounded to 2 sig. figs
the density of water
at room temp = 1.0 g/mL

(You need to know this)

• A solid 75.0 cm^3 block of table salt has a mass of 163 g. What is its density?
Density

• The density of solid gold is 19.3 g/cm$^3$
  $\quad$ (19.3 g = 1 cm$^3$ of gold)

Density can be used as a conversion factor:

\[
\frac{19.3 \text{ g}}{1 \text{ cm}^3} \quad \text{or} \quad \frac{1 \text{ cm}^3}{19.3 \text{ g}}
\]

• What is the mass of 25.6 cm$^3$ of gold?

• What is the volume (in cm$^3$) of 342 g of gold?

• The density of ethyl alcohol is 0.790 g/mL.
  What is the mass of 875 mL of ethyl alcohol?