Chapter 1

An Introduction to Chemistry

By Mark Bishop
The science that deals with the structure and behavior of matter
Chapter Map

Measurement and units

Base units

International system (SI) of measurement

Metric prefixes

Derived units

Length

Volume

Mass

Temperature

Accuracy

Precision

Relationship between mass and weight
• A **value** is a quantitative description that includes both a unit and a number.

• For **100 meters**, the **meter** is a unit by which distance is measured, and the **100** is the number of units contained in the measured distance.

• **Units** are quantities defined by standards that people agree to use to compare one event or object to another.
<table>
<thead>
<tr>
<th>Type</th>
<th>Base Unit</th>
<th>Abb.</th>
<th>Defined in terms of</th>
</tr>
</thead>
<tbody>
<tr>
<td>length</td>
<td>meter</td>
<td>m</td>
<td>the fixed numerical value of the speed of light in vacuum $c$ to be 299,792,458 when expressed in the unit $m , s^{-1}$, where the second is defined as below.</td>
</tr>
<tr>
<td>mass</td>
<td>kilogram</td>
<td>kg</td>
<td>the fixed numerical value of the Planck constant, $h$, to be $6.62607015 \times 10^{-34}$ when expressed in the unit $J , s$, which is equal to $kg , m^2 , s^{-1}$, where the meter and the second are defined in terms of $c$ and $\Delta v_{Cs}$.</td>
</tr>
<tr>
<td>time</td>
<td>second</td>
<td>s</td>
<td>the fixed numerical value of the cesium frequency, $\Delta v_{Cs}$, which is the unperturbed ground-state hyperfine transition frequency of the cesium-133 atom, to be 9,192,631,770 when expressed in the unit $Hz$, which is equal to $s^{-1}$.</td>
</tr>
<tr>
<td>temperature</td>
<td>kelvin</td>
<td>K</td>
<td>the fixed numerical value of the Boltzmann constant, $k$, to be $1.380 , 649 \times 10^{-23}$ when expressed in the unit $J , K^{-1}$, which is equal to $kg , m^2 , s^{-2} , K^{-1}$, where the kilogram, meter and second are defined in terms of $h$, $c$ and $\Delta v_{Cs}$.</td>
</tr>
</tbody>
</table>
Derived Unit

1 cubic meter = 1000 liters

1 \text{ L} = 10^{-3} \text{ m}^3

10^3 \text{ L} = 1 \text{ m}^3
### Some Base Units and Their Abbreviations for the International System of Measurement

<table>
<thead>
<tr>
<th>Type</th>
<th>Base Unit</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>meter</td>
<td>m</td>
</tr>
<tr>
<td>Mass</td>
<td>gram</td>
<td>g</td>
</tr>
<tr>
<td>Volume</td>
<td>liter</td>
<td>L or l</td>
</tr>
<tr>
<td>Energy</td>
<td>joule</td>
<td>J</td>
</tr>
<tr>
<td>Prefix</td>
<td>Abbreviation</td>
<td>Number</td>
</tr>
<tr>
<td>--------</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>giga</td>
<td>G</td>
<td>$10^9$ or 1,000,000,000</td>
</tr>
<tr>
<td>mega</td>
<td>M</td>
<td>$10^6$ or 1,000,000</td>
</tr>
<tr>
<td>kilo</td>
<td>k</td>
<td>$10^3$ or 1000</td>
</tr>
<tr>
<td>centi</td>
<td>c</td>
<td>$10^{-2}$ or 0.01</td>
</tr>
<tr>
<td>milli</td>
<td>m</td>
<td>$10^{-3}$ or 0.001</td>
</tr>
<tr>
<td>micro</td>
<td>$\mu$</td>
<td>$10^{-6}$ or 0.000001</td>
</tr>
<tr>
<td>nano</td>
<td>n</td>
<td>$10^{-9}$ or 0.00000001</td>
</tr>
<tr>
<td>pico</td>
<td>p</td>
<td>$10^{-12}$ or 0.0000000001</td>
</tr>
</tbody>
</table>
Numbers expressed in scientific notation have the following form.

\[ a \times 10^b \]

- **Coefficient**, a number with one nonzero digit to the left of the decimal point
- **Exponent**, a positive or negative integer
- **Exponential term**
Scientific Notation
(Example)

• $5.5 \times 10^{21}$ carbon atoms in a 0.55 carat diamond.
  – 5.5 is the coefficient
  – $10^{21}$ is the exponential term
  – The $21$ is the exponent.

• The coefficient usually has one nonzero digit to the left of the decimal point.
• The coefficient reflects the number’s uncertainty.
• It is common to assume that coefficient is plus or minus one in the last position reported unless otherwise stated.
• Using this guideline, \(5.5 \times 10^{21}\) carbon atoms in a 0.55 carat diamond suggests that there are from \(5.4 \times 10^{21}\) to \(5.6 \times 10^{21}\) carbon atoms in the stone.
The exponential term shows the size or magnitude of the number.

Positive exponents are used for large numbers. For example, the moon orbits the sun at $2.2 \times 10^4$ or 22,000 mi/hr.

\[
2.2 \times 10^4 = 2.2 \times 10 \times 10 \times 10 \times 10 = 22,000
\]
Negative exponents are used for small numbers. For example, a red blood cell has a diameter of about $5.6 \times 10^{-4}$ or 0.00056 inches.

\[
5.6 \times 10^{-4} = 5.6 \times \frac{1}{10^4} = \frac{5.6}{10 \times 10 \times 10 \times 10} = 0.00056
\]
Reasons for Using Scientific Notation

- **Convenience** - It takes a lot less time and space to report the mass of an electron as $9.1096 \times 10^{-28}$, rather than $0.00000000000000000000000000091096$ g.

- **To more clearly report the uncertainty of a value** - The value $1.4 \times 10^3$ kJ per peanut butter sandwich suggests that the energy from a typical peanut butter sandwich could range from $1.3 \times 10^3$ kJ to $1.5 \times 10^3$ kJ. If the value is reported as 1400 kJ, its uncertainty would not be so clear. It could be $1400 \pm 1$, $1400 \pm 10$, or $1400 \pm 100$. 
Length

- 1 km = 0.6214 mi
- 1 m = 3.281 ft
- 1 m = 100 cm
- 1 in. = 2.54 cm
- 1 cm = 0.3937 in.
- 1 mm = 0.03937 in.

A mile is four times around a typical high school track.
Range of Lengths

- Diameter of a proton in an atom: $2 \times 10^{-15}$ m
- Diameter of an atom: $10^{-10}$ m
- Diameter of a human hair: $3 \times 10^{-6}$ m
- Length of a blue whale: 30.5 m
- Diameter of the sun: $10^9$ m
- Proposed distance to the boundary of the known universe: $10^{30}$ m
Volume

1 fluid ounce (fl oz): 1 mL = 0.03381 fl oz

1 milliliter (mL) = about 20 drops

1 gallon (gal) or 4 quarts (qt): 1 gal = 3.785 L

1 quart (qt) or 32 fl oz: 1 qt = 0.9464 L

1 liter (L) or 1000 mL: 1 L = 1.057 qt = 0.2642 gal
Range of Volumes

- Proton in an atom: $10^{-42}$ L
- Atom: $10^{-27}$ L
- Raindrop: $10^{-5}$ L
- Basketball: 7.3 L
- Oceans of Earth: $1.5 \times 10^{21}$ L
- Sun: $10^{30}$ L

Values:
- $10^{-40}$
- $10^{-30}$
- $10^{-20}$
- $10^{-10}$
- 1 liter
- $10^{10}$
- $10^{20}$
- $10^{30}$ liters
Mass and Weight

- **Mass** is usually defined as a measure of the amount of matter in an object. Mass can be defined as the property of matter that leads to gravitational attractions between objects and therefore gives rise to weight.
- **Matter** is anything that occupies a volume and has a mass.
- The **weight** of an object, on the Earth, is a measure of the force of gravitational attraction between the object and the Earth.
<table>
<thead>
<tr>
<th></th>
<th>On Earth</th>
<th>Between Earth and Moon</th>
<th>On Moon</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mass</strong></td>
<td>65 kg</td>
<td>65 kg</td>
<td>65 kg</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>637 N</td>
<td>≈0 N</td>
<td>1/6(637 N) = 106 N</td>
</tr>
</tbody>
</table>
Mass

1 oz = 28.35 g

About 2.5 grams (g) or about 0.088 ounce (oz)

1 lb = 453.6 g
1 kg = 2.205 lb

About 1 kilogram (kg) or about 2.2 pounds (lb)

1 Mg = 1000 kg = 1 t

About 1 megagram (Mg) or 1 metric ton (t)
Range of Masses

- Electron in an atom: $9.1096 \times 10^{-28}$ g
- Atom: $1.6735 \times 10^{-24}$ g
- Basketball: 612 g
- Egyptian Pyramid: 10^13 g
- Earth: $10^{27}$ g
- The universe: $10^{54}$ g

Mass range displayed from $10^{-30}$ to $10^{50}$ grams.
Comparing Temperature Scales

Celsius
- Boiling water: 100 °C
- Freezing water: 0 °C
- Absolute zero: -273.15 °C

Kelvin
- Boiling water: 373.15 K
- Freezing water: 273.15 K
- Absolute zero: 0 K

Fahrenheit
- Boiling water: 212 °F
- Freezing water: 32 °F
- Absolute zero: -459.67 °F
• **Precision** describes how closely a series of measurements of the same object resemble each other. The closer the measurements are to each other, the more precise the measurement. The precision of a measurement is not necessarily equal to its accuracy.

• **Accuracy** is a measurement’s relationship to the property’s true value.
Precision and Accuracy (cont.)

This archer is precise but not accurate.

This archer is precise and accurate.

This archer is imprecise and inaccurate.
One of the conventions that scientists use for reporting numbers from measurements is to report all of the certain digits and one estimated (and thus uncertain) digit.
Comparing the position of the bottom of the meniscus and the milliliter scale yields a measurement of 8.74 mL.
Graduated Cylinder
Accurate to ±0.1

If the graduated cylinder is only accurate to ±0.1 mL, we report 8.7 mL.
Trailing Zeros

We report 8.00 mL to show an uncertainty of ±0.01 mL.
Trailing Zeros (2)

If the graduated cylinder is only accurate to ±0.1 mL, we report 8.0 mL.
Digital Readout

Report all digits unless otherwise instructed.
In many cases, it is best to round the number in the value to fewer decimal positions than displayed. For the mass displayed above, 100.432 g would indicate ±0.001 g.