Measurement and Units

An Introduction to Chemistry

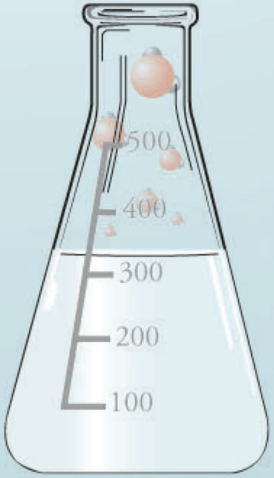
By Mark Bishop

Values from Measurements

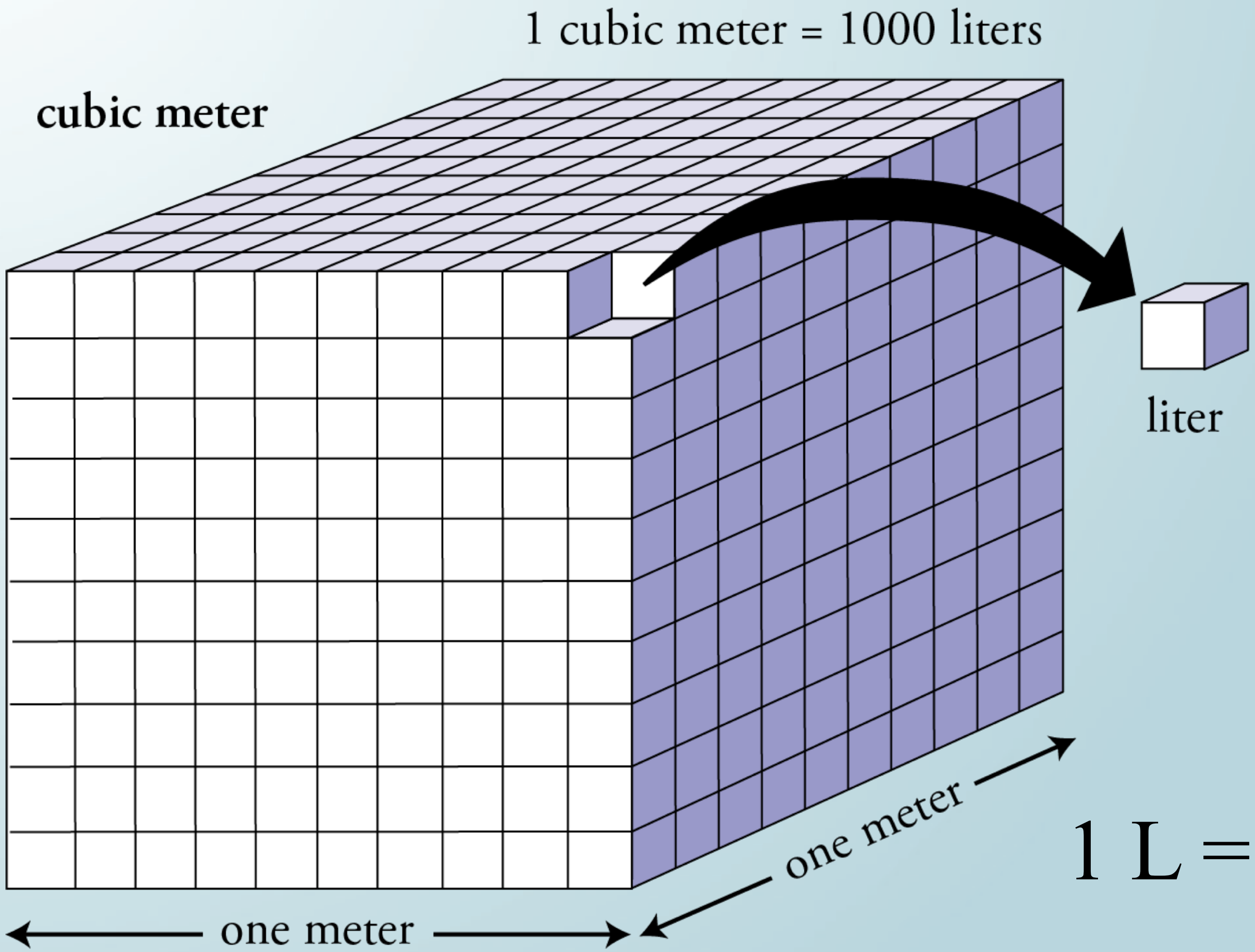
- A ***value*** is a quantitative description that includes both a unit and a number.
- For *100 meters*, the *meter* is a unit by which distance is measured, and the *100* is the number of units contained in the measured distance.
- ***Units*** are quantities defined by standards that people agree to use to compare one event or object to another.

Base Units for the International System of Measurement

- **Length - meter, m**, the distance that light travels in a vacuum in 1/299,792,458 of a second
- **mass - kilogram, kg**, the mass of a platinum-iridium alloy cylinder in a vault in France
- **time - second, s**, the duration of 9,192,631,770 periods of the radiation emitted in a specified transition between energy levels of cesium-133
- **temperature - kelvin, K**, 1/273.16 of the temperature difference between absolute zero and the triple point temperature of water



Derived Unit

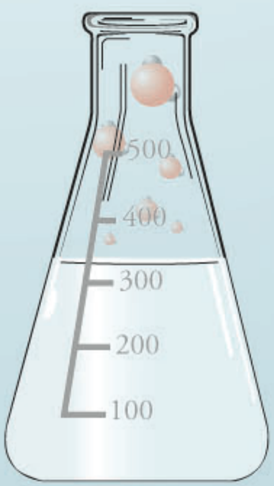


$$1\ L = 10^{-3}\ m^3$$

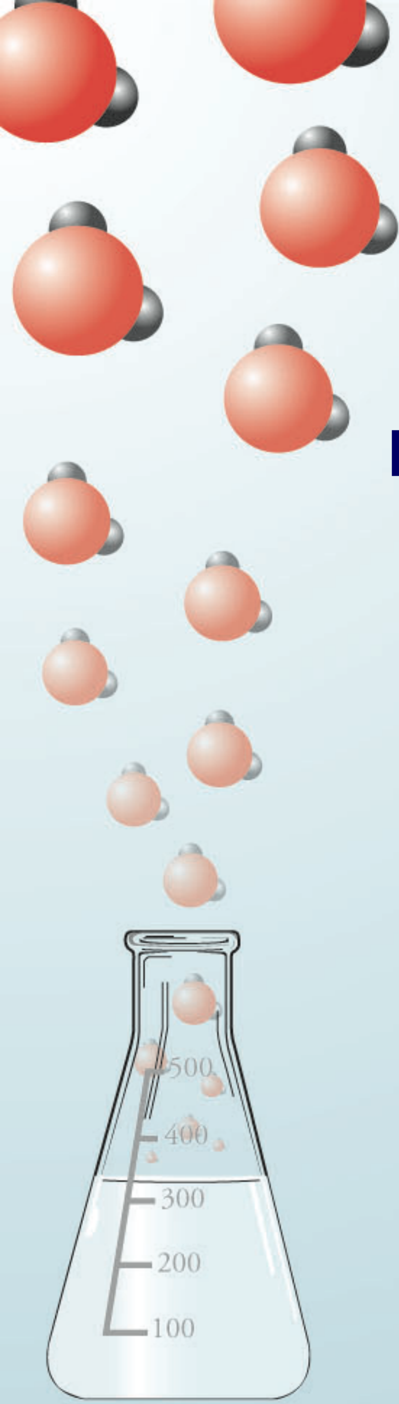
$$10^3\ L = 1\ m^3$$

Some Base Units and Their Abbreviations for the International System of Measurement

Type	Base Unit	Abbreviation
Length	meter	m
Mass	gram	g
Volume	liter	L or l
Energy	joule	J



Metric Prefixes



Prefix	Abbreviation	Number
giga	G	10^{9} or 1,000,000,000
mega	M	10^{6} or 1,000,000
kilo	k	10^{3} or 1000
centi	c	10^{-2} or 0.01
milli	m	10^{-3} or 0.001
micro	μ	10^{-6} or 0.000001
nano	n	10^{-9} or 0.000000001
pico	p	10^{-12} or 0.000000000001

Scientific (Exponential) Notation

- Numbers expressed in scientific notation have the following form.

Exponent, a positive or negative integer

$$a \times 10^{b}$$

Coefficient,
a number with one nonzero digit
to the left of the decimal point

Exponential term

Scientific Notation (Example)

- 5.5×10^{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.

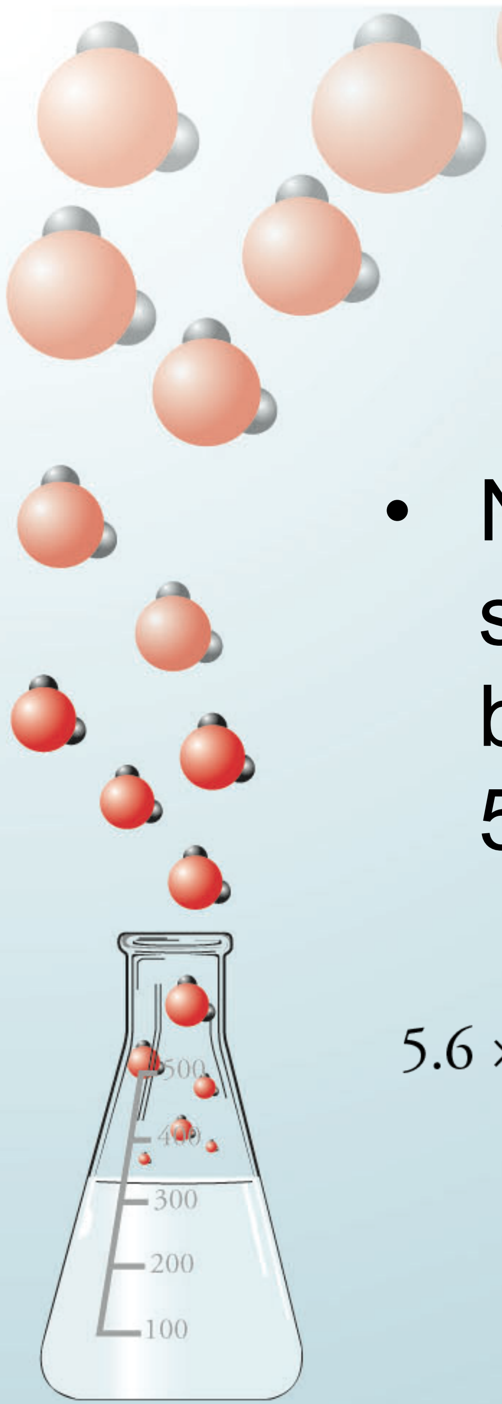
Uncertainty

- 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, 5.5×10^{21} carbon atoms in a 0.55 carat diamond suggests that there are from 5.4×10^{21} to 5.6×10^{21} carbon atoms in the stone.

Size (Magnitude) of Number

- 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 2.2×10^4 or 22,000 mi/hr.

$$2.2 \times 10^4 = 2.2 \times 10 \times 10 \times 10 \times 10 = 22{,}000$$



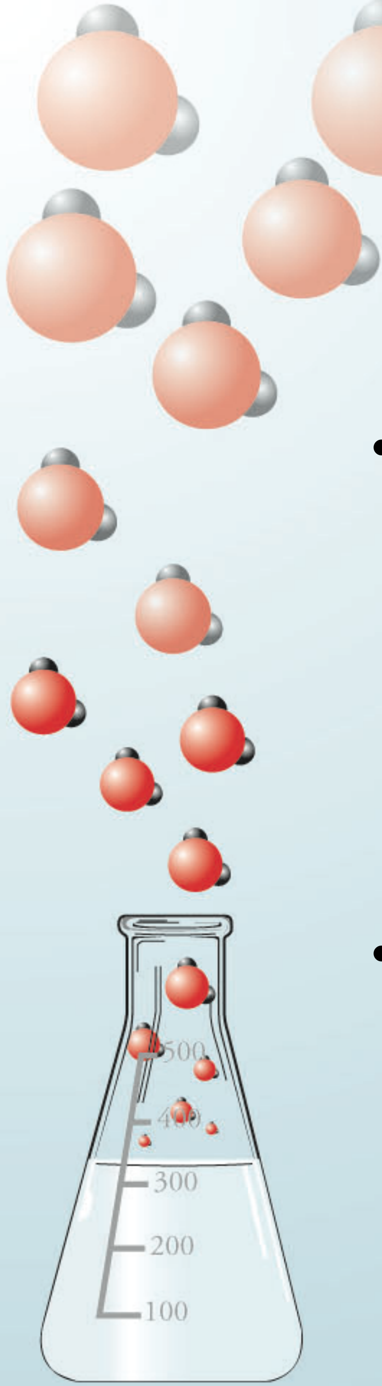
Size (Magnitude) of Number

- Negative exponents are used for small numbers. For example, A red blood cell has a diameter of about 5.6×10^{-4} or 0.00056 inches.

$$5.6 \times 10^{-4} = 5.6 \times \frac{1}{10^4} = \frac{5.6}{10 \times 10 \times 10 \times 10} = 0.00056$$

From Decimal Number to Scientific Notation

- Shift the decimal point until there is one nonzero number to the left of the decimal point, counting the number of positions the decimal point moves.
- Write the resulting coefficient times an exponential term in which the exponent is positive if the decimal point was moved to the left and negative if the decimal position was moved to the right. The number in the exponent is equal to the number of positions the decimal point was shifted.



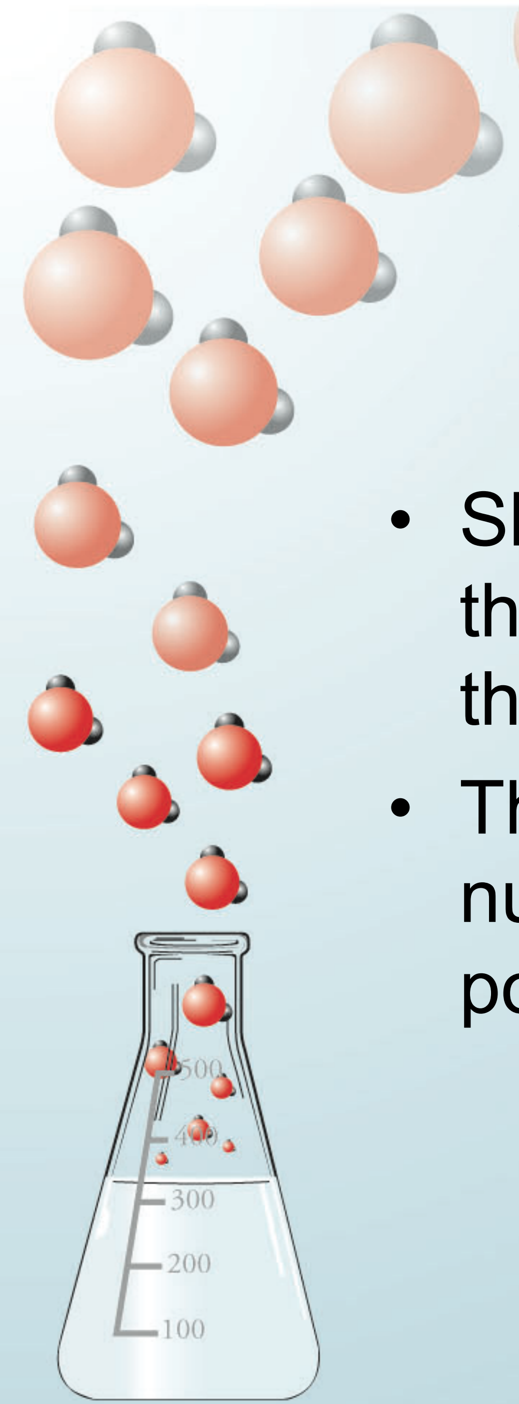
From Decimal Number to Scientific Notation (Examples)

- For example, when 22,000 is converted to scientific notation, the decimal point is shifted four positions to the left so the exponential term has an exponent of 4.

$$22{,}000 = 2.2 \times 10^{4}$$

- When 0.00056 is converted to scientific notation, the decimal point is shifted four positions to the right so the exponential term has an exponent of -4.

$$0.00056 = 5.6 \times 10^{-4}$$



Scientific Notation to Decimal Number

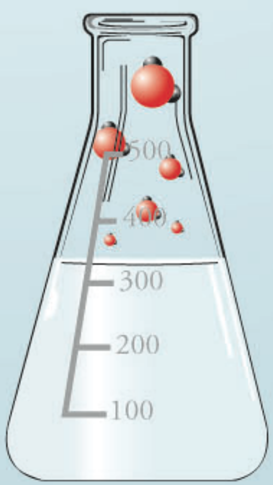
- Shift the decimal point in the coefficient to the right if the exponent is positive and to the left if it is negative.
- The number in the exponent tells you the number of positions to shift the decimal point.

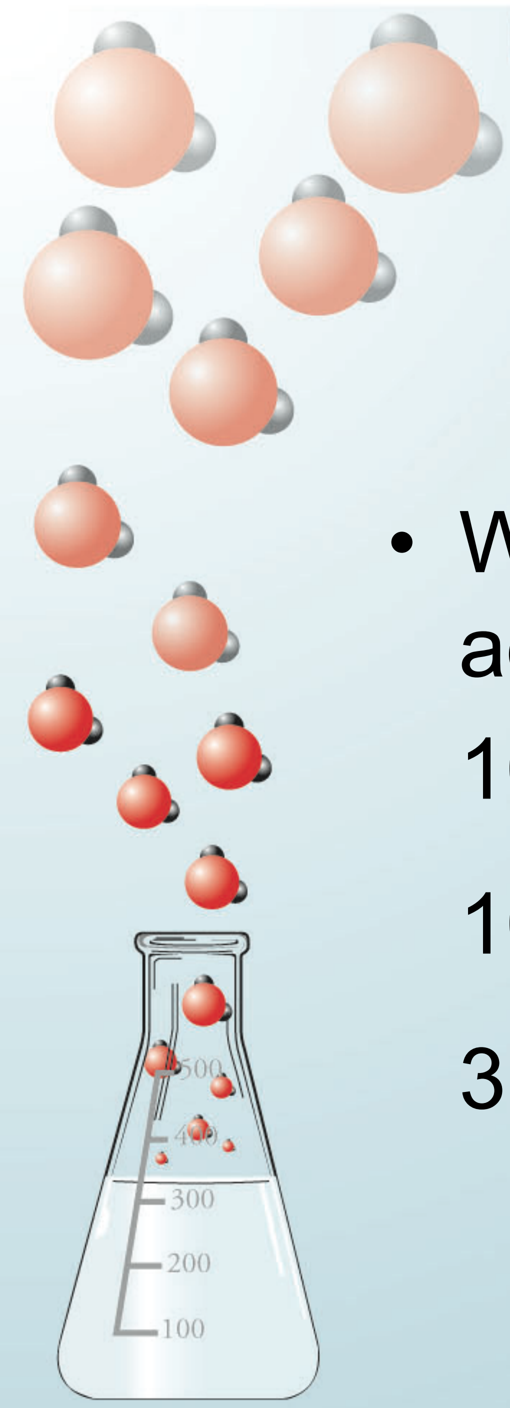
2.2×10^{4} goes to 22,000

5.6×10^{-4} goes to 0.00056

Reasons for Using Scientific Notation

- **Convenience -** It takes a lot less time and space to report the mass of an electron as 9.1096×10^{-28}, rather than 0.00000000000000000000000000091096 g.
- **To more clearly report the uncertainty of a value -** The value 1.4×10^3 kJ per peanut butter sandwich suggests that the energy from a typical peanut butter sandwich could range from 1.3×10^3 kJ to 1.5×10^3 kJ. If the value is reported as 1400 kJ, its uncertainty would not be so clear. It could be 1400 ± 1, 1400 ± 10, or 1400 ± 100.





Multiplying Exponential Terms

- When multiplying exponential terms, add exponents.

$10^3 \times 10^6 = 10^{3+6} = 10^9$

$10^3 \times 10^{-6} = 10^{3+(-6)} = 10^{-3}$

$3.2 \times 10^{-4} \times 1.5 \times 10^9$
$= 3.2 \times 1.5 \times 10^{-4+9}$
$= 4.8 \times 10^5$

When dividing exponential terms, subtract exponents.

$$\frac{10^{12}}{10^3} = 10^{12-3} = 10^9$$

$$\frac{10^6}{10^{-3}} = 10^{6-(-3)} = 10^9$$

$$\frac{9.0 \times 10^{11}}{1.5 \times 10^{-6}} = \frac{9.0}{1.5} \times 10^{11-(-6)} = 6.0 \times 10^{17}$$

$$\frac{10^2 \cdot 10^{-3}}{10^6} = 10^{2+(-3)-6} = 10^{-7}$$

$$\frac{1.5 \times 10^4 \cdot 4.0 \times 10^5}{2.0 \times 10^{12} \cdot 10^3} = \frac{1.5 \cdot 4.0}{2.0} \times 10^{4+5-12-3} = 3.0 \times 10^{-6}$$

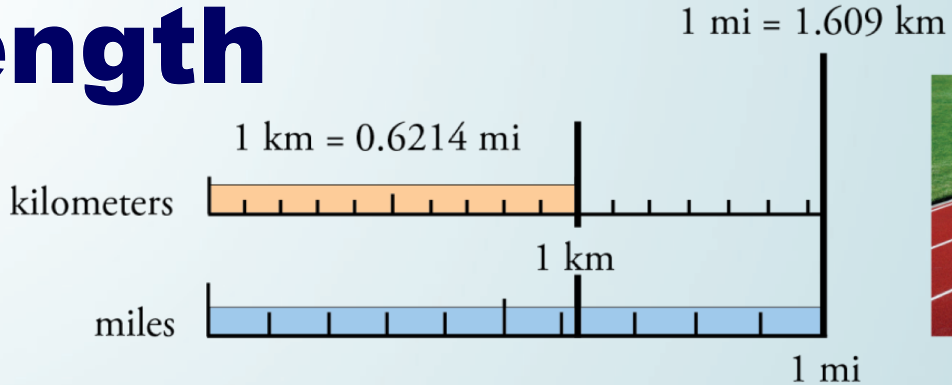
Raising Exponential Terms to a Power

- When raising exponential terms to a power, multiply exponents.

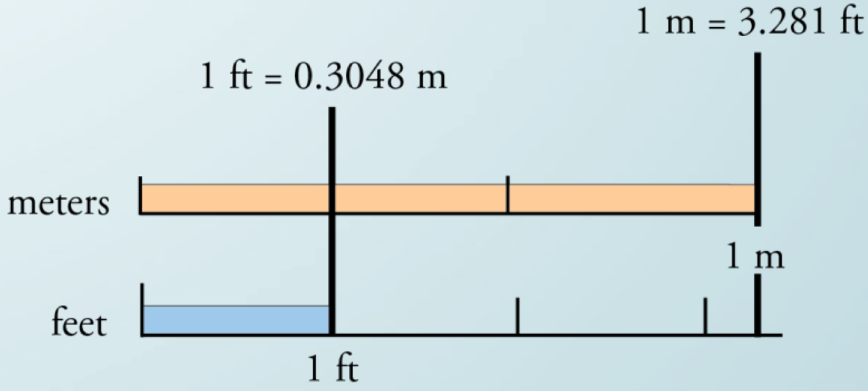
  $(10^4)^3 = 10^{4 \cdot 3} = 10^{12}$

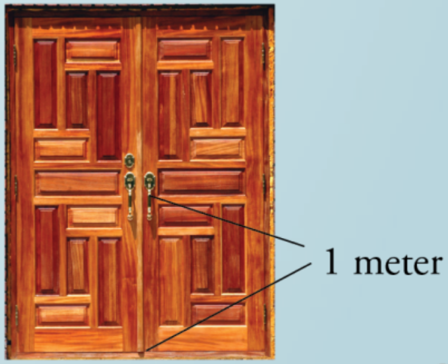
  $(3 \times 10^5)^2 = (3)^2 \times (10^5)^2 = 9 \times 10^{10}$

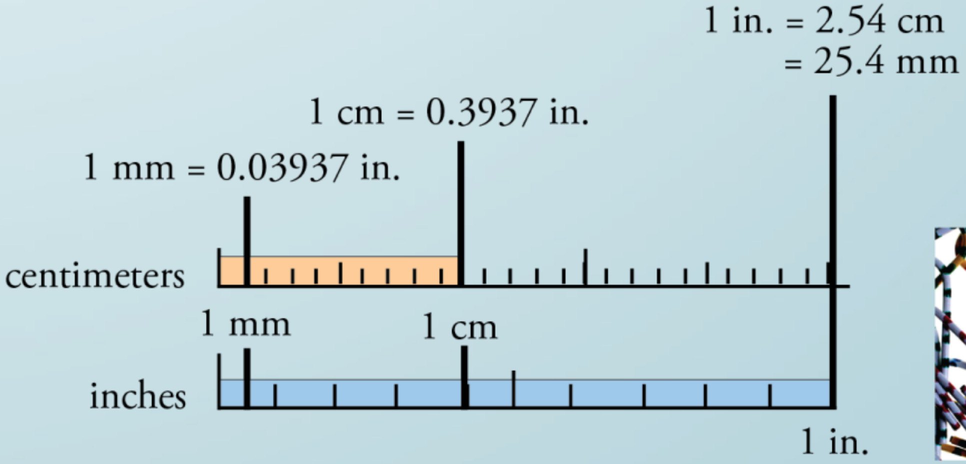
Length

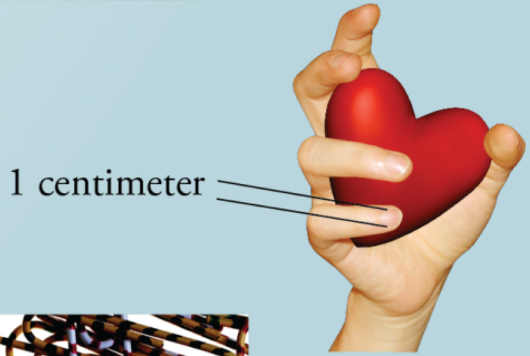


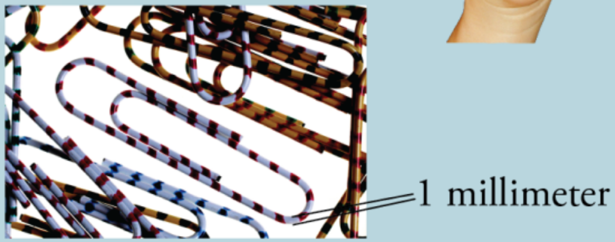
A mile is four times around a typical high school track.



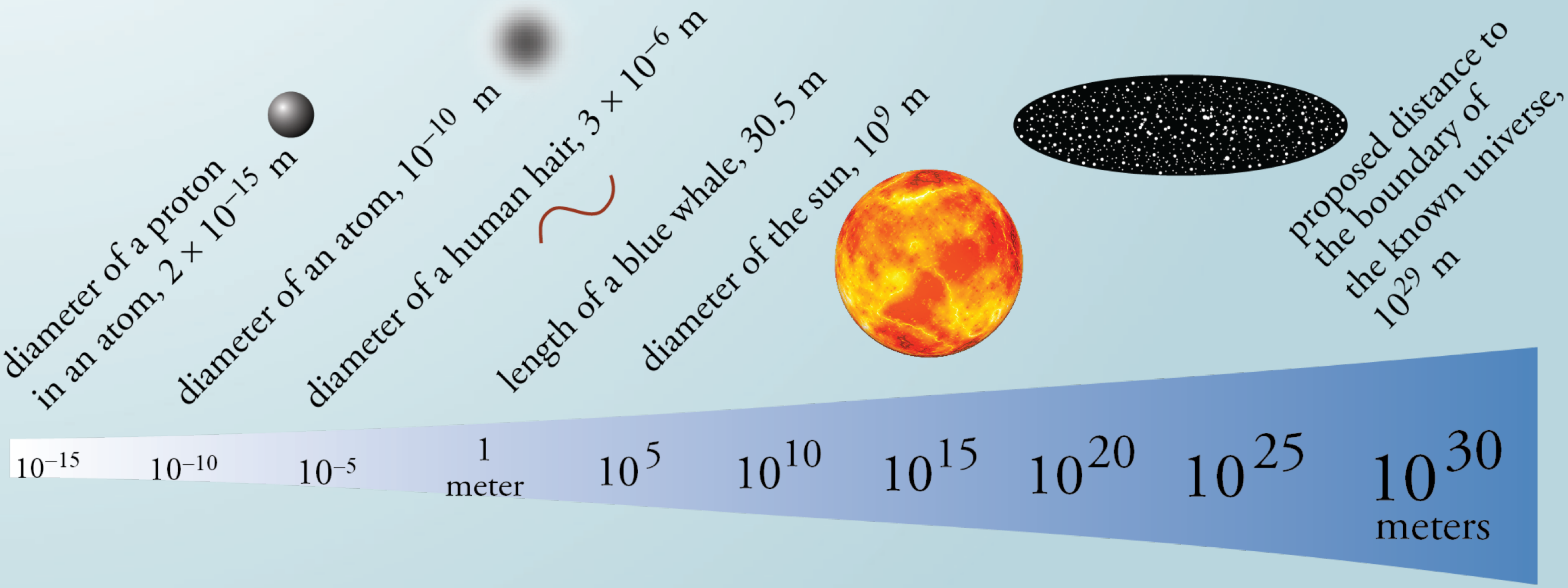








Range of Lengths



Volume

1 fluid ounce (fl oz)

1 fl oz = 29.57 mL

1 mL = 0.03381 fl oz

1 milliliter (mL)
= about 20 drops

1 gal = 3.785 L

1 gallon (gal)
or 4 quarts (qt)

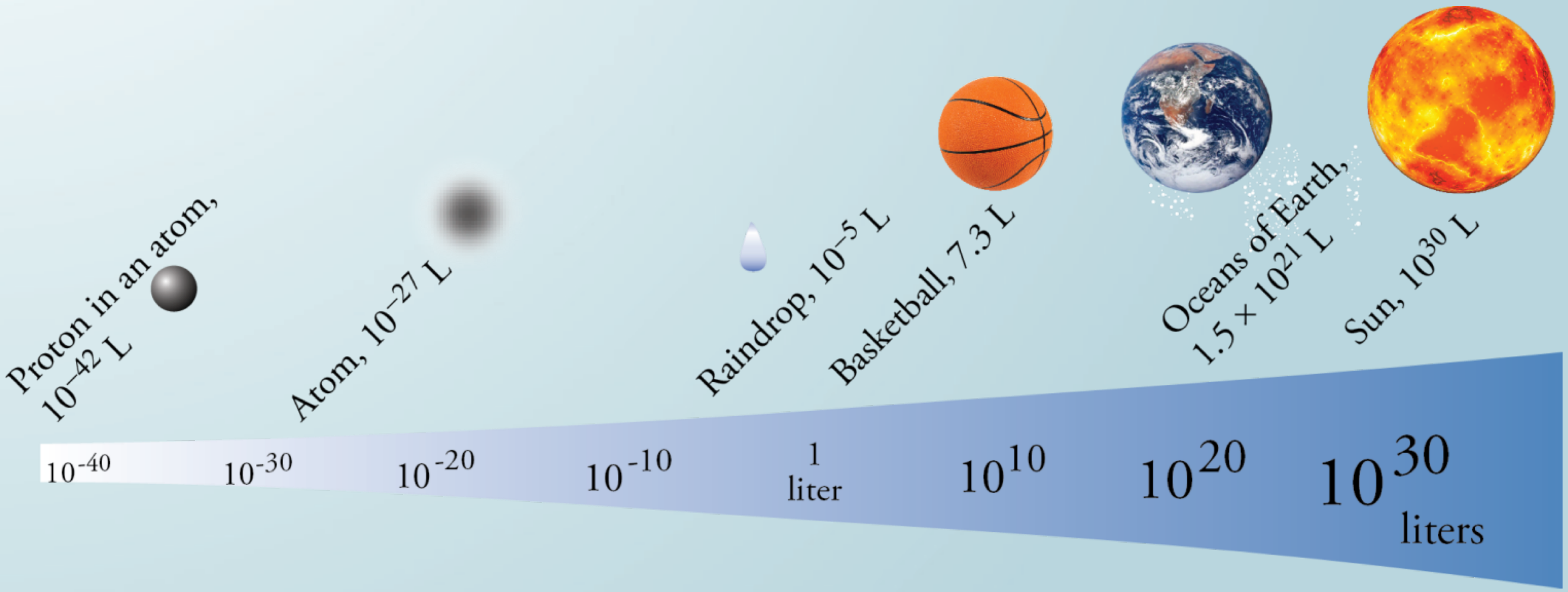
1 qt = 0.9464 L

1 qt or 32 fl oz

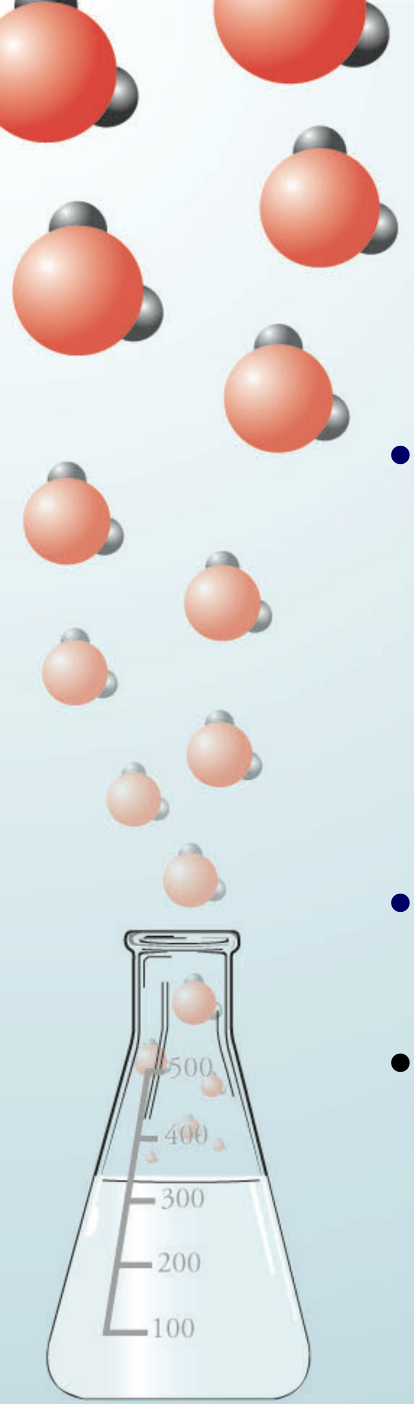
1 L = 1.057 qt
= 0.2642 gal

1 liter (L)
or 1000 mL

Range of Volumes



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.

Comparison of the Mass and Weight of a 65 kg Person

	On Earth	Between Earth and Moon	On Moon
Mass	65 kg	65 kg	65 kg
Weight	637 N	≈0 N	1/6(637 N) = 106 N

Mass

1 oz = 28.35 g

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

1 lb = 453.6 g

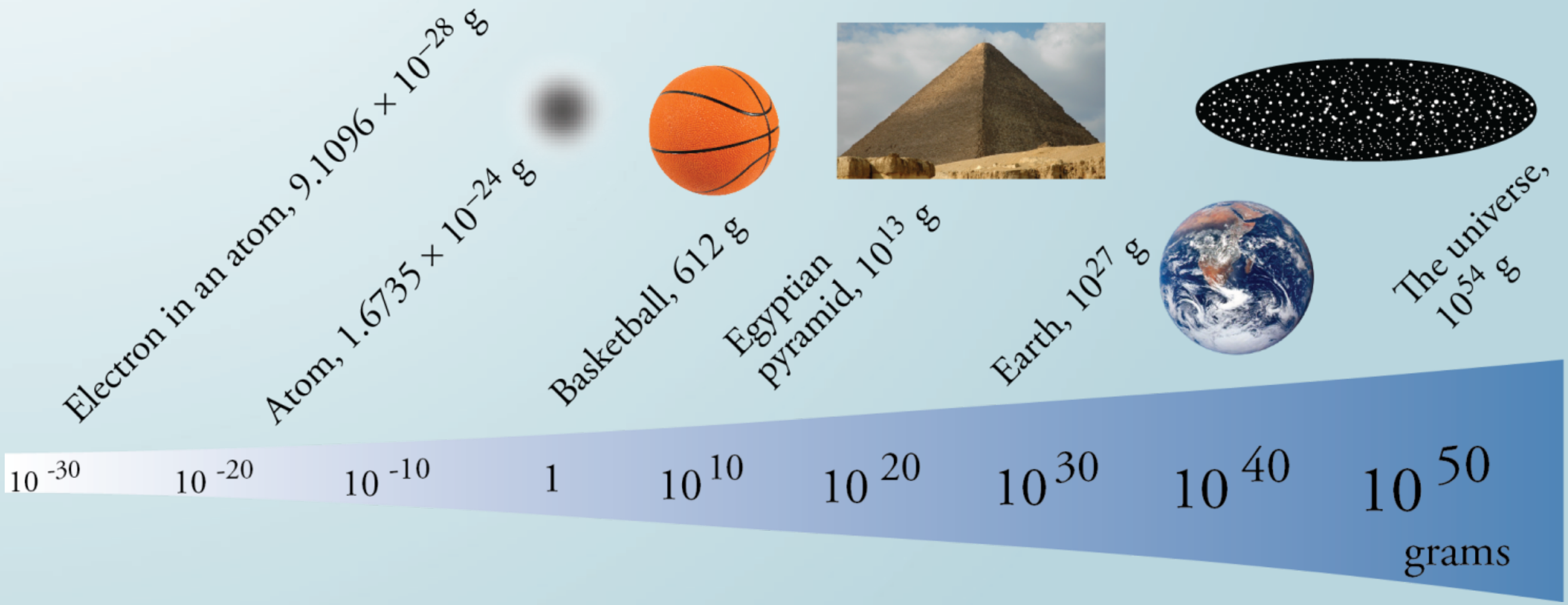
1 kg = 2.205 lb

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

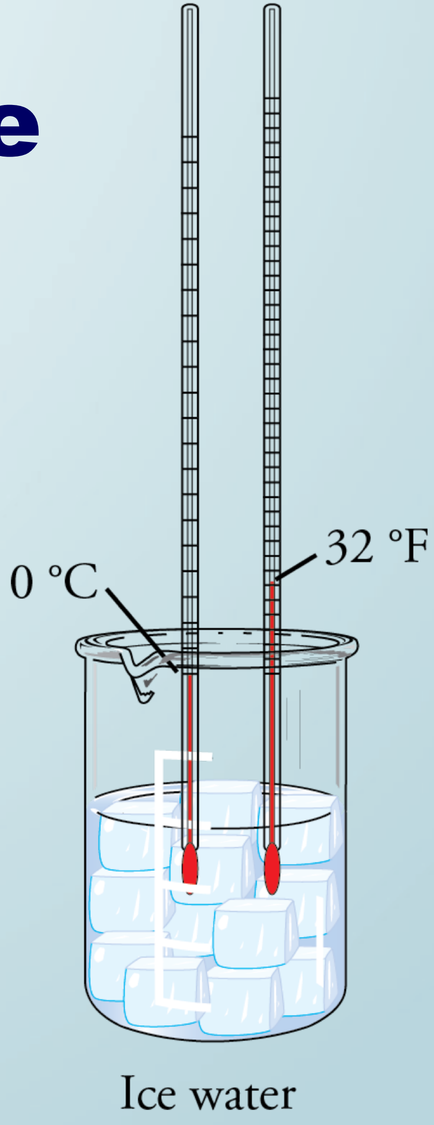
1 Mg = 1000 kg = 1 t

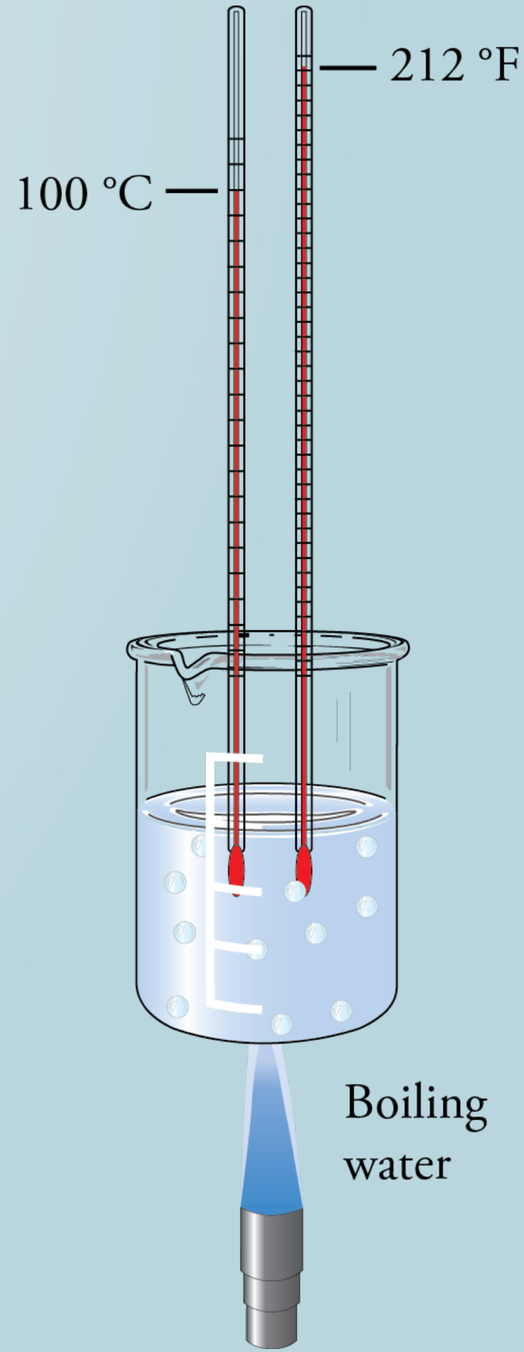
About 1 megagram (Mg) or 1 metric ton (t)

Range of Masses



Celsius and Fahrenheit Temperature





Comparing Temperature Scales