Background for Science and Technology

“One doesn’t discover new lands without consenting to lose sight of the shore for a very long time.”

Andre Gide
French Novelist and Essayist

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.

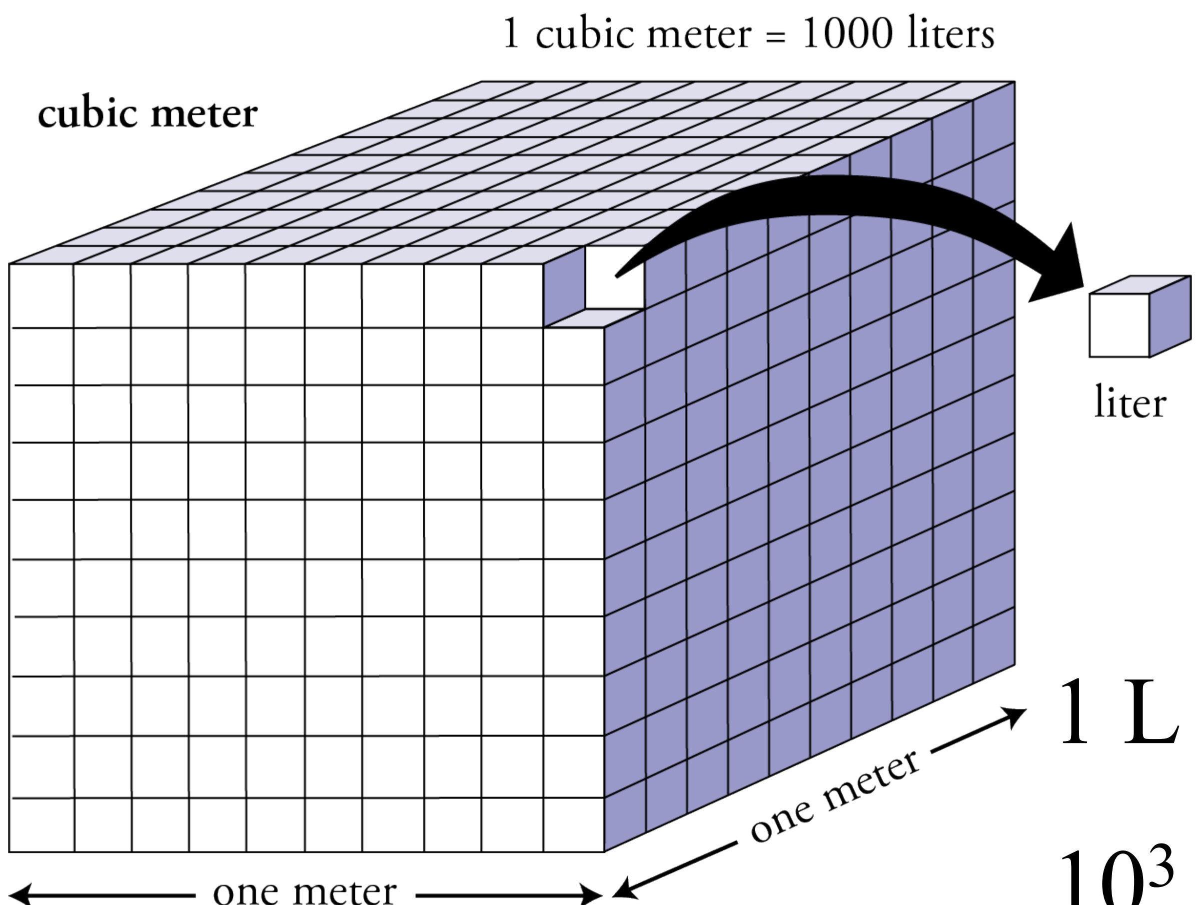
Base Units for the International System of Measurement

- **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

Base Units for the International System of Measurement (less common)

- **Amount of substance mole, mol**, the amount of substance that contains the same number of chemical units as there are atoms in 12 g of carbon-12.
- **Electric current ampere, A**, the amount of electric charge passing a point in an electric circuit per unit time with 6.241×10^{18} electrons, or one coulomb per second constituting one ampere.
- **Luminous intensity candela, Cd**, the luminous intensity of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity of $\frac{1}{683}$ watt per steradian.

Derived Unit



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

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

Derived Units

$$\text{velocity} = \frac{\text{distance}}{\text{time}} = \frac{\text{m}}{\text{s}}$$

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time}} = \frac{\text{m/s}}{\text{s}} = \frac{\text{m}}{\text{s}^2}$$

$$\text{force} = \text{mass} \bullet \text{acceleration} = \frac{\text{kg}\bullet\text{m}}{\text{s}^2} = \text{Newton, N}$$

$$\text{pressure} = \frac{\text{force}}{\text{area}} = \frac{\text{kg}\bullet\text{m}}{\text{s}^2} \bullet \frac{1}{\text{m}^2} = \frac{\text{kg}}{\text{m}\bullet\text{s}^2} = \text{Pascal, Pa}$$

$$\text{energy} = \text{force} \bullet \text{distance} = \frac{\text{kg}\bullet\text{m}}{\text{s}^2}\bullet\text{m} = \frac{\text{kg}\bullet\text{m}^2}{\text{s}^2} = \text{Joule, J}$$

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
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
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}
femto	f	10^{-15}
atto	a	10^{-18}

Scientific 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.

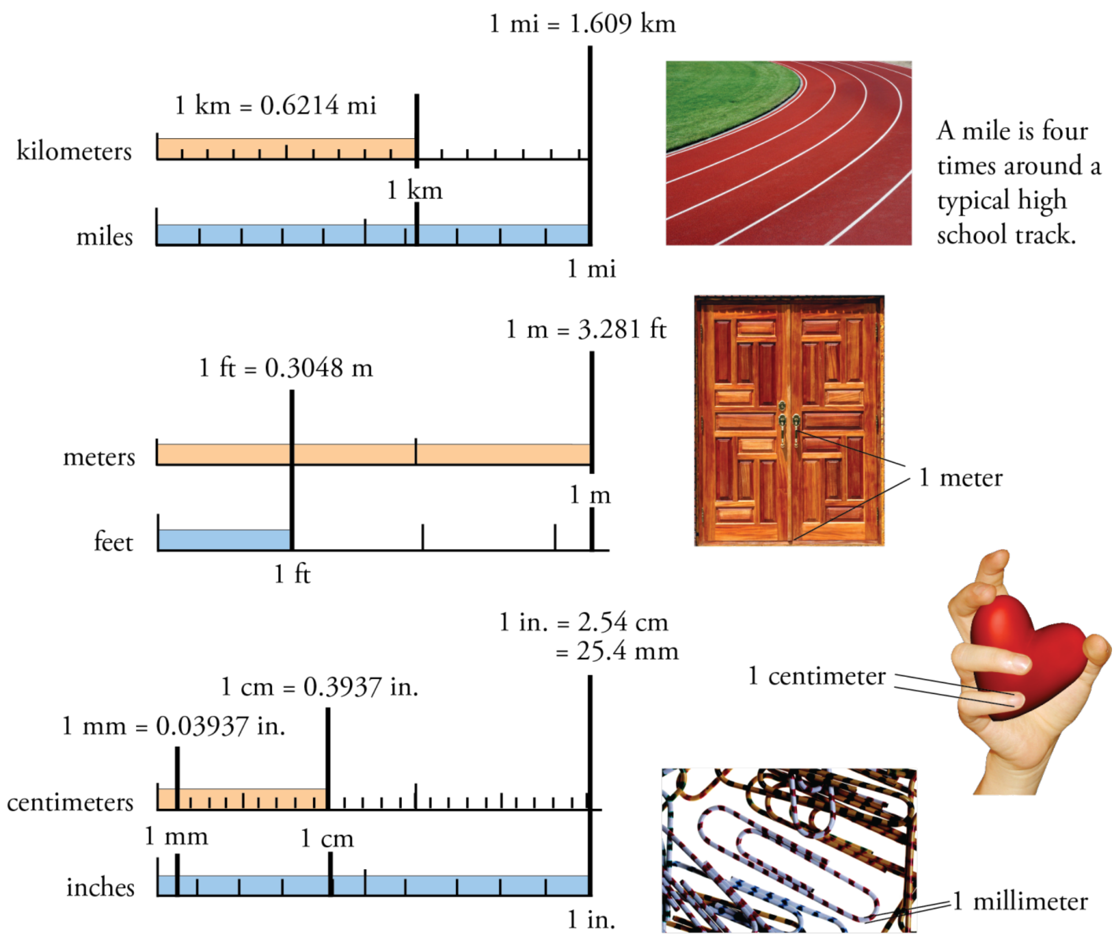
2.2×10^{4} goes to 22,000

5.6×10^{-4} goes to 0.00056

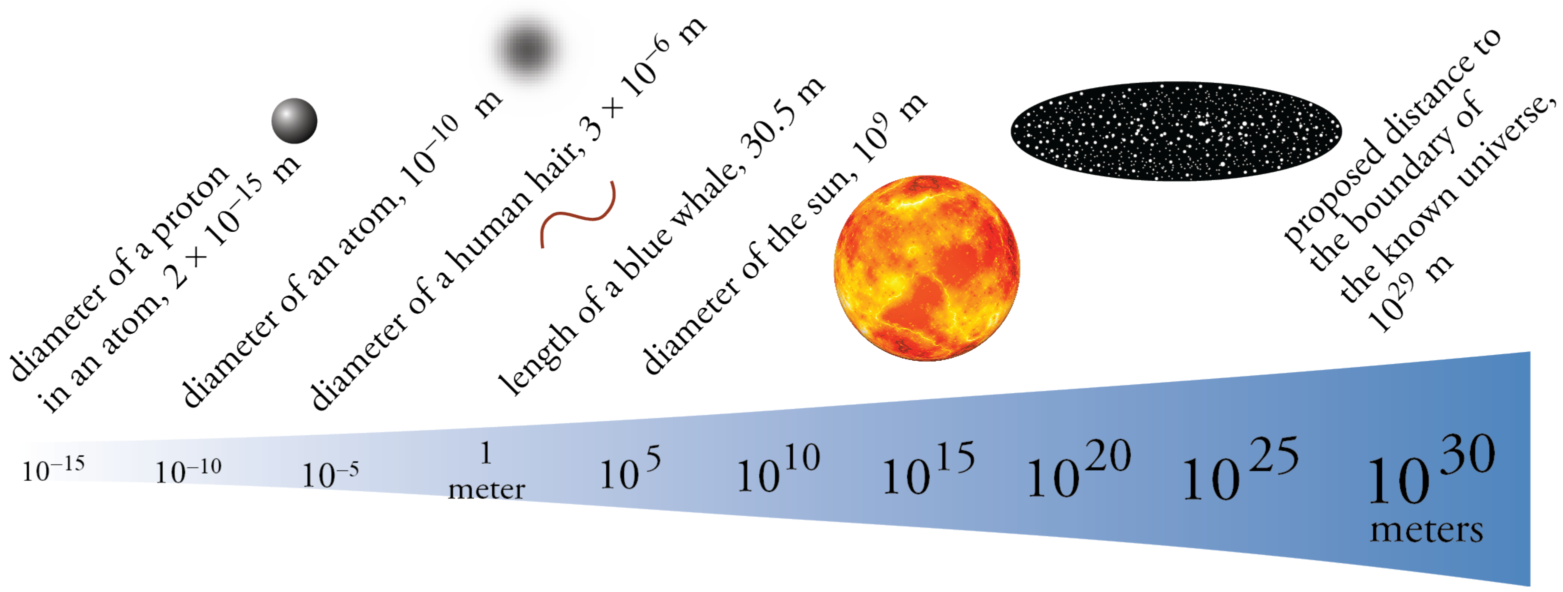
Reasons for Using Scientific Notation

- **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.

Length


1 mi = 1.609 km
1 km = 0.6214 mi
kilometers
1 km
miles
1 mi
A mile is four times around a typical high school track.
1 m = 3.281 ft
1 ft = 0.3048 m
meters
1 m
feet
1 ft
1 meter
1 in. = 2.54 cm
= 25.4 mm
1 cm = 0.3937 in.
1 mm = 0.03937 in.
centimeters
1 mm
1 cm
inches
1 in.
1 centimeter
1 millimeter

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)

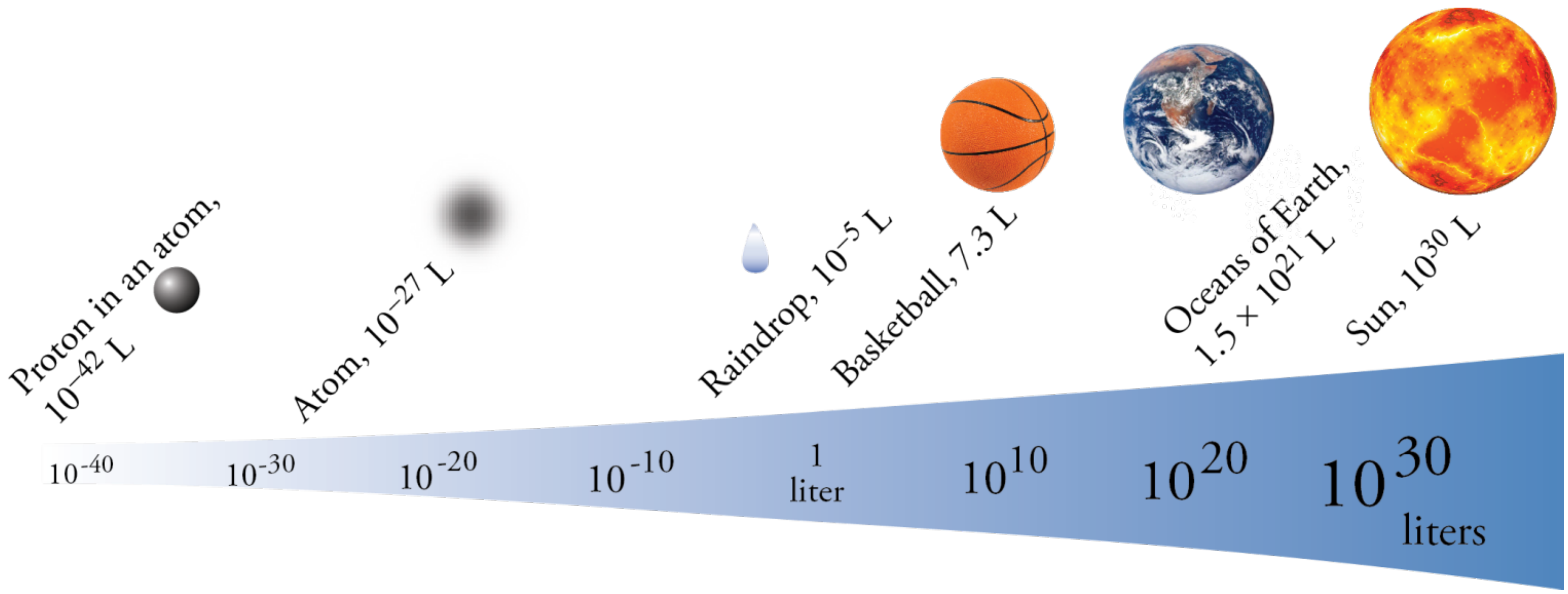
1 qt = 0.9464 L

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)

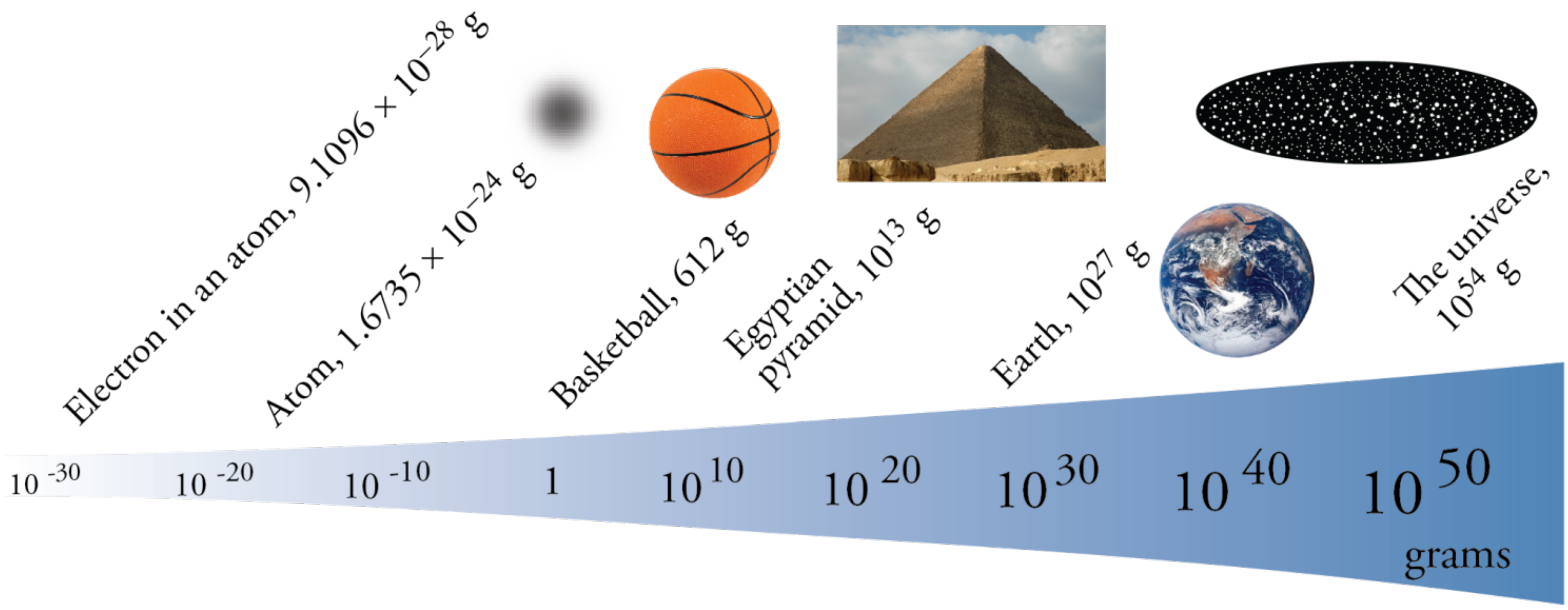
1 lb = 453.6 g
1 kg = 2.205 lb

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

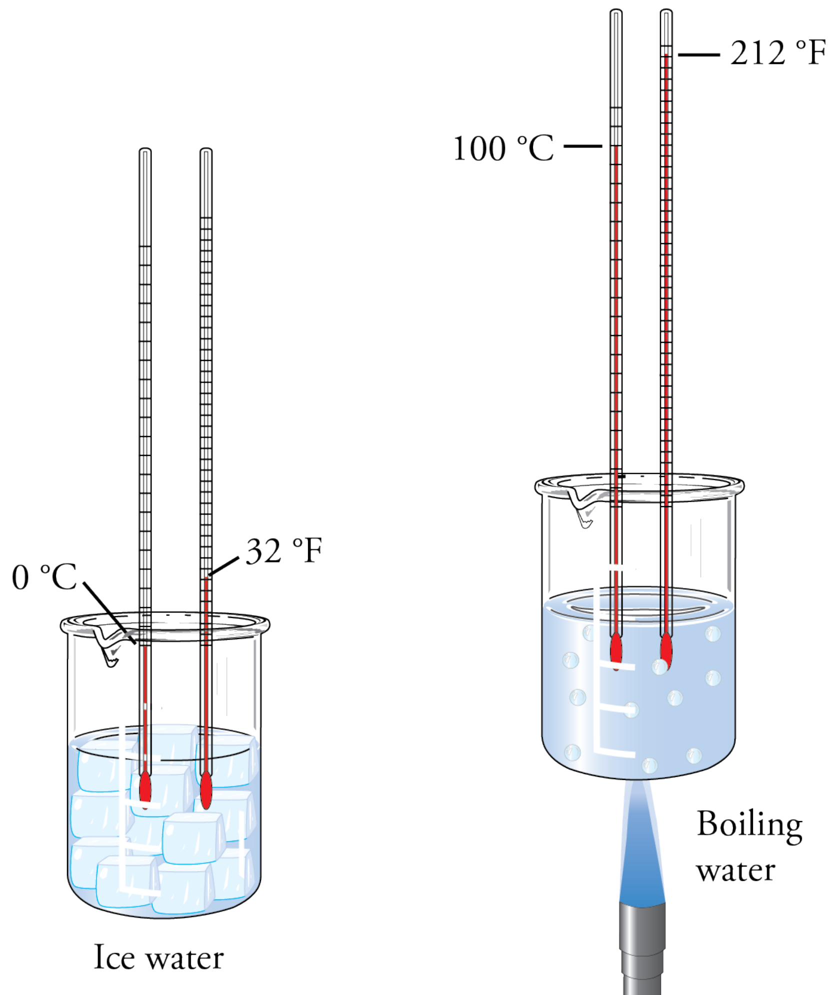
1 Mg = 1000 kg = 1 t

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

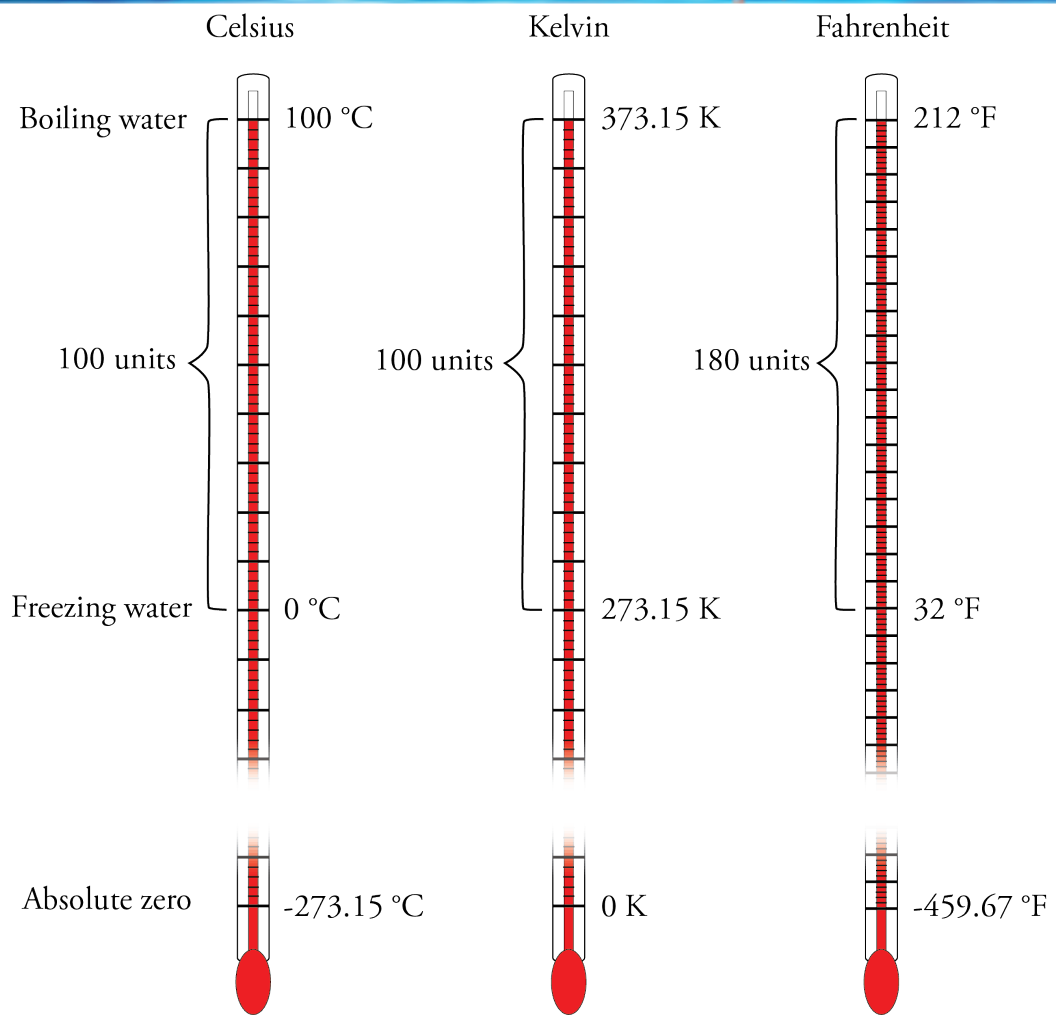
Range of Masses



Celsius and Fahrenheit Temperature



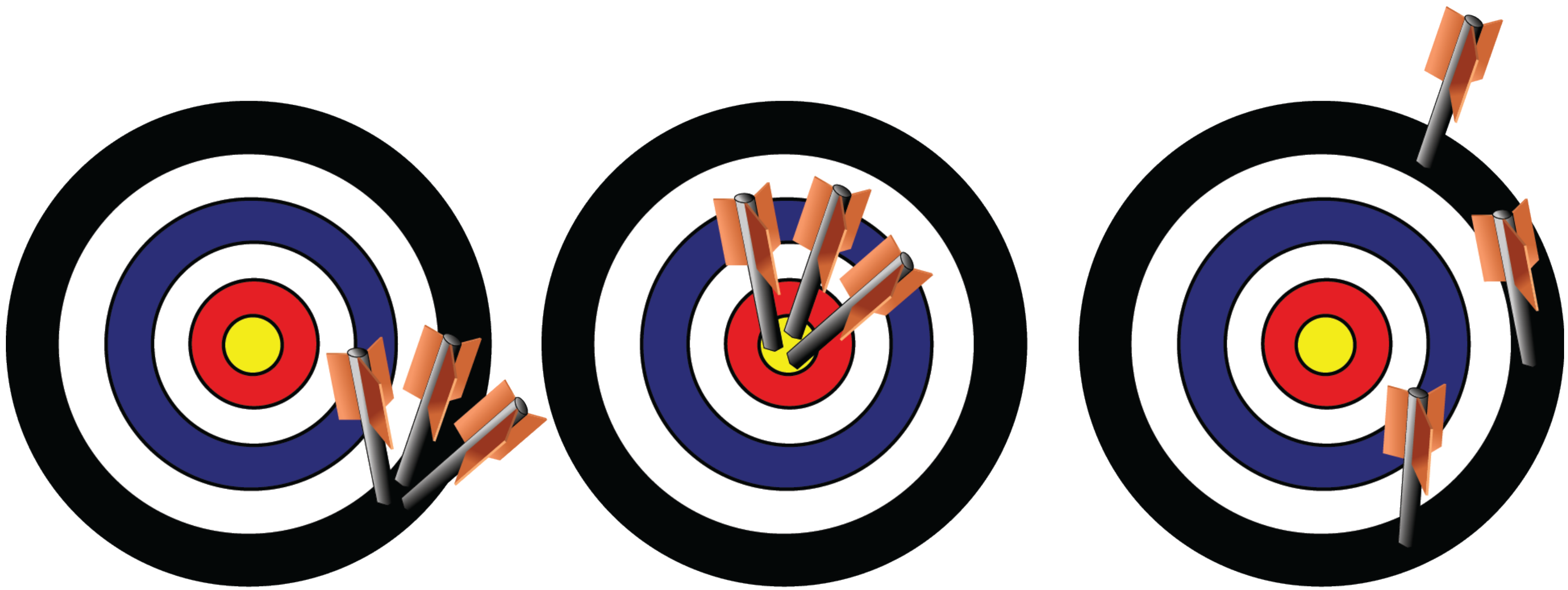
Comparing Temperature Scales



Precision and Accuracy

- ***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.

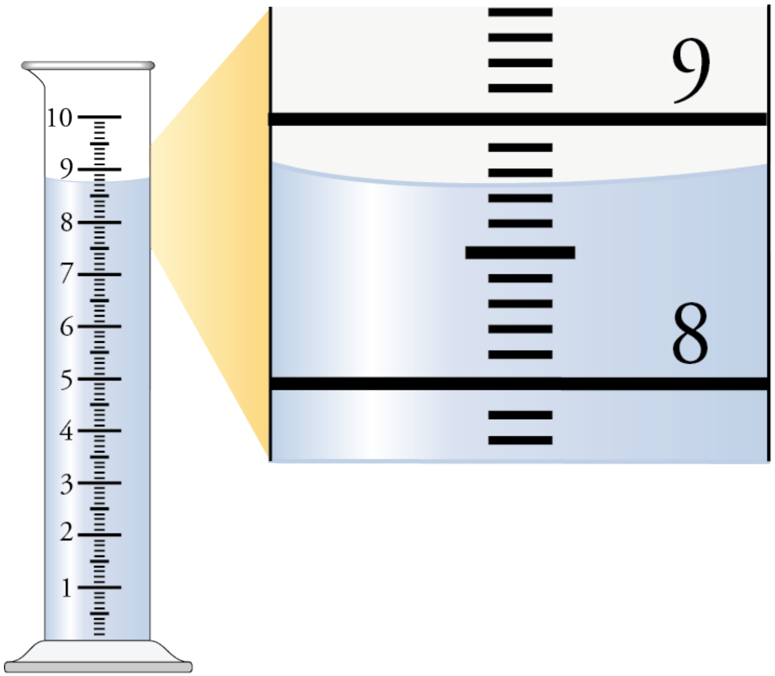
This archer is precise and accurate.

This archer is imprecise and inaccurate.

Reporting Values from Measurements

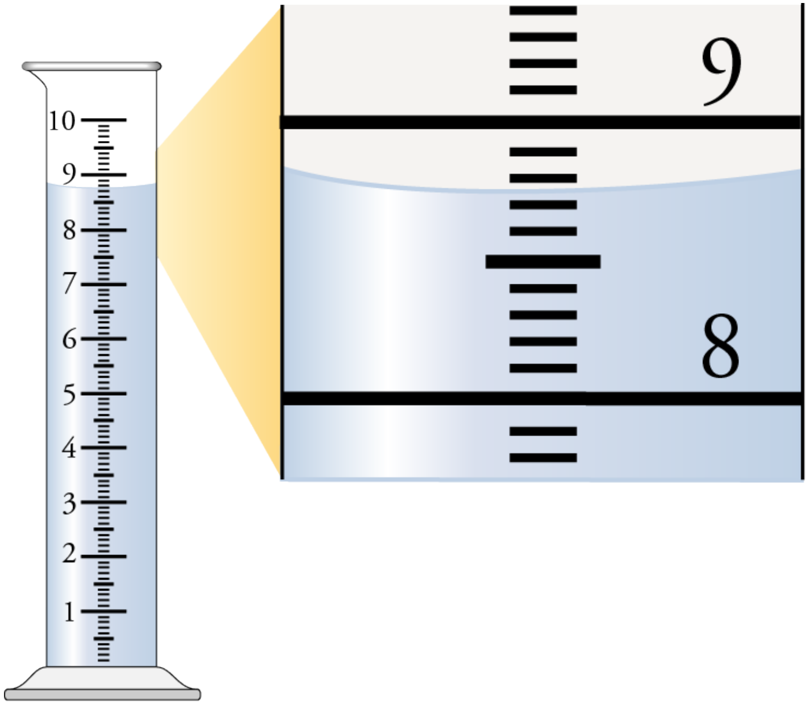
- One of the conventions that scientists use for reporting numbers from measurements is to report all of the certain digits and one estimated (and thus uncertain) digit.

Graduated Cylinder



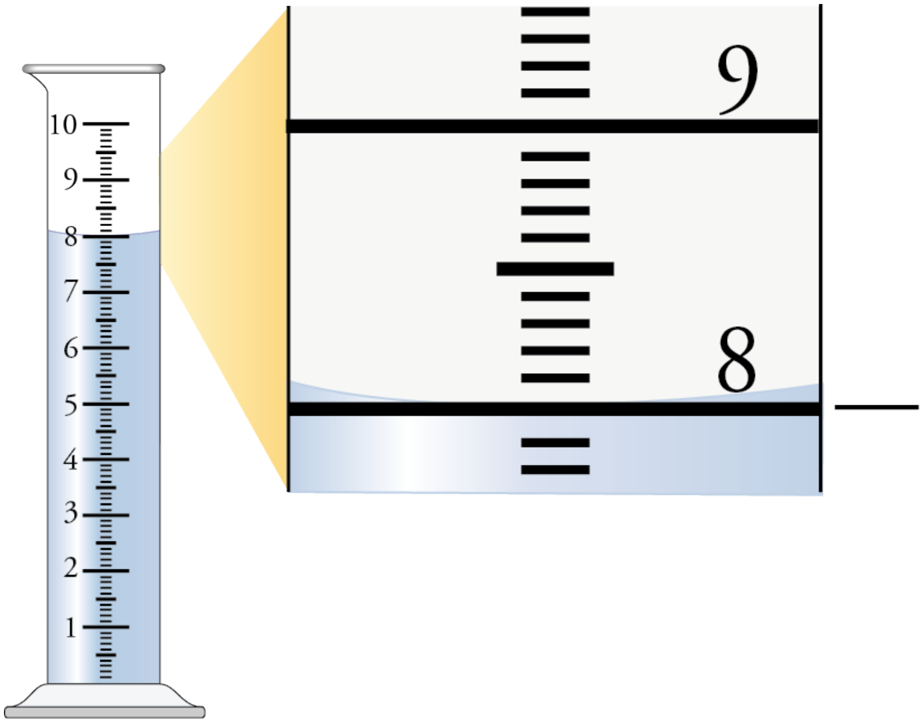
Comparing the position of the bottom of the meniscus and the milliliter scale yields a measurement of 8.74 mL.

Graduated Cylinder Accurate to ±0.1



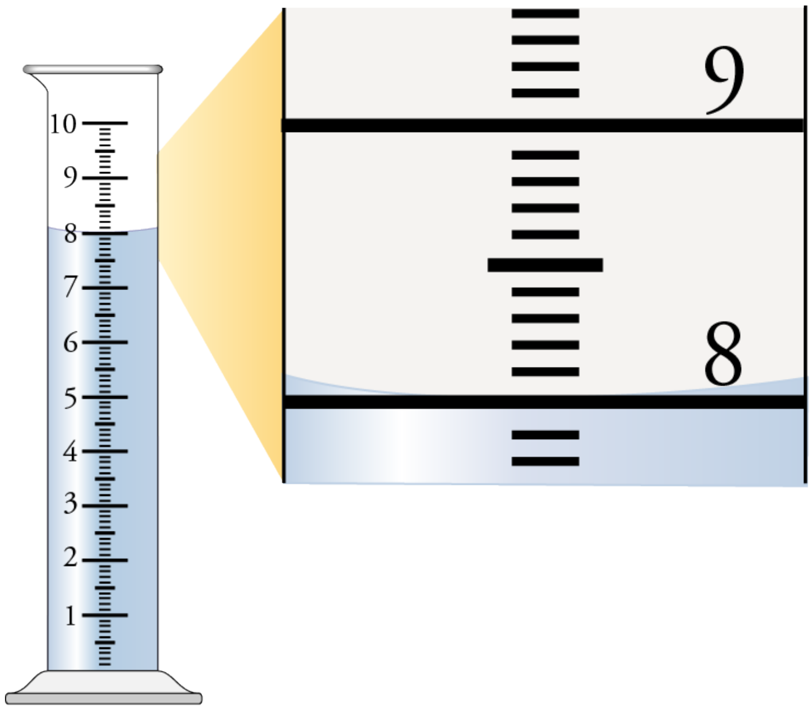
If the graduated cylinder is only accurate to ±0.1 mL, we report 8.7 mL.

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.

Digital Readout (2)

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.

Chemistry

The science that deals with the structure and behavior of matter

Scientific Models

- A ***model*** is a simplified approximation of reality.
- Scientific models are simplified but *useful* representations of something real.

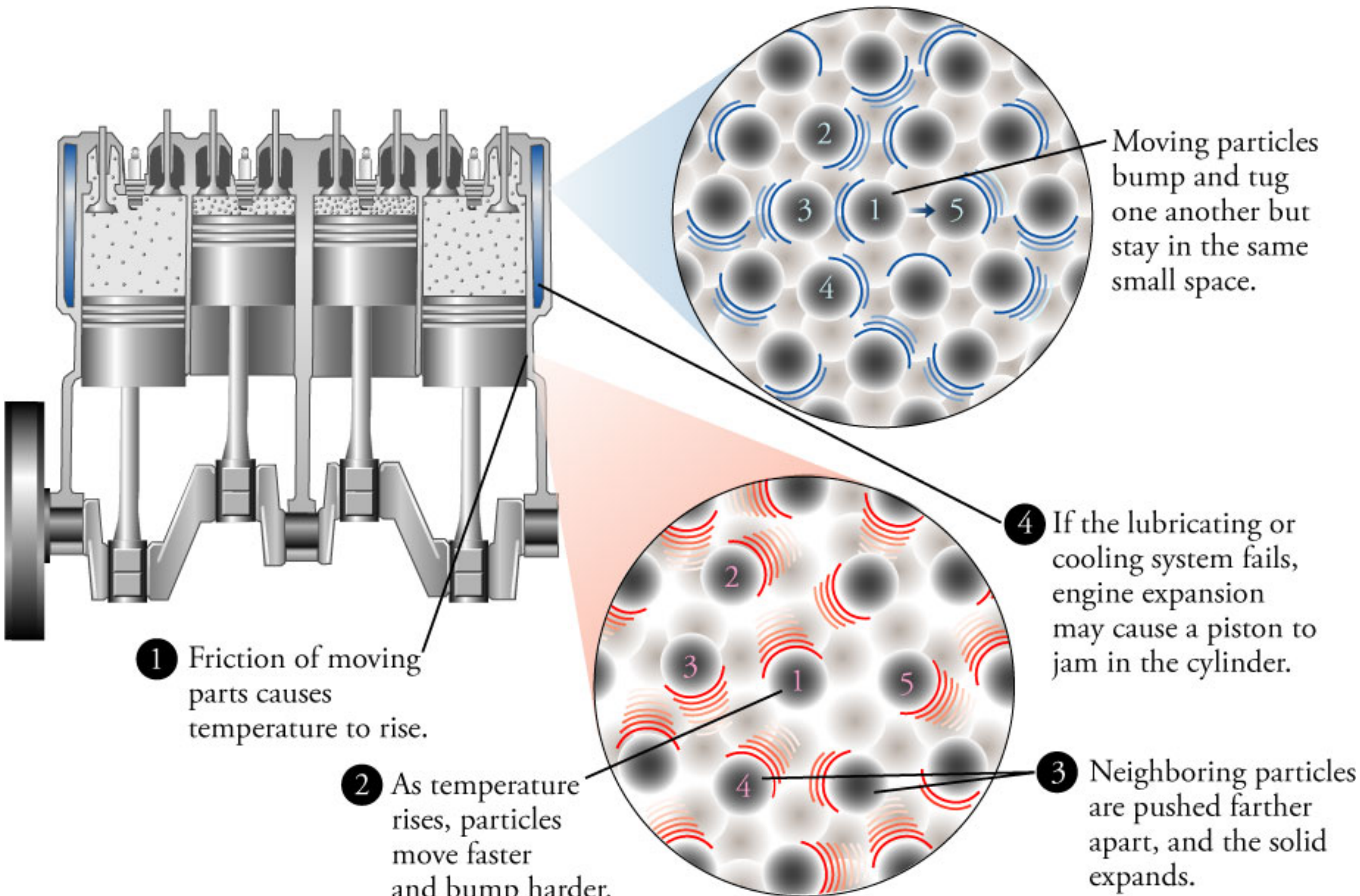
Kinetic Molecular Theory

- All matter is composed of tiny particles.
- The particles are in constant motion.
- Increased temperature reflects increased motion of particles.
- Solids, liquids and gases differ in the freedom of motion of their particles and in how strongly the particles attract each other.

Solid

- Constant shape and volume
- The particles are constantly moving, colliding with other particles, and changing their direction and velocity.
- Each particle is trapped in a small cage whose walls are formed by other particles that are strongly attracted to each other.

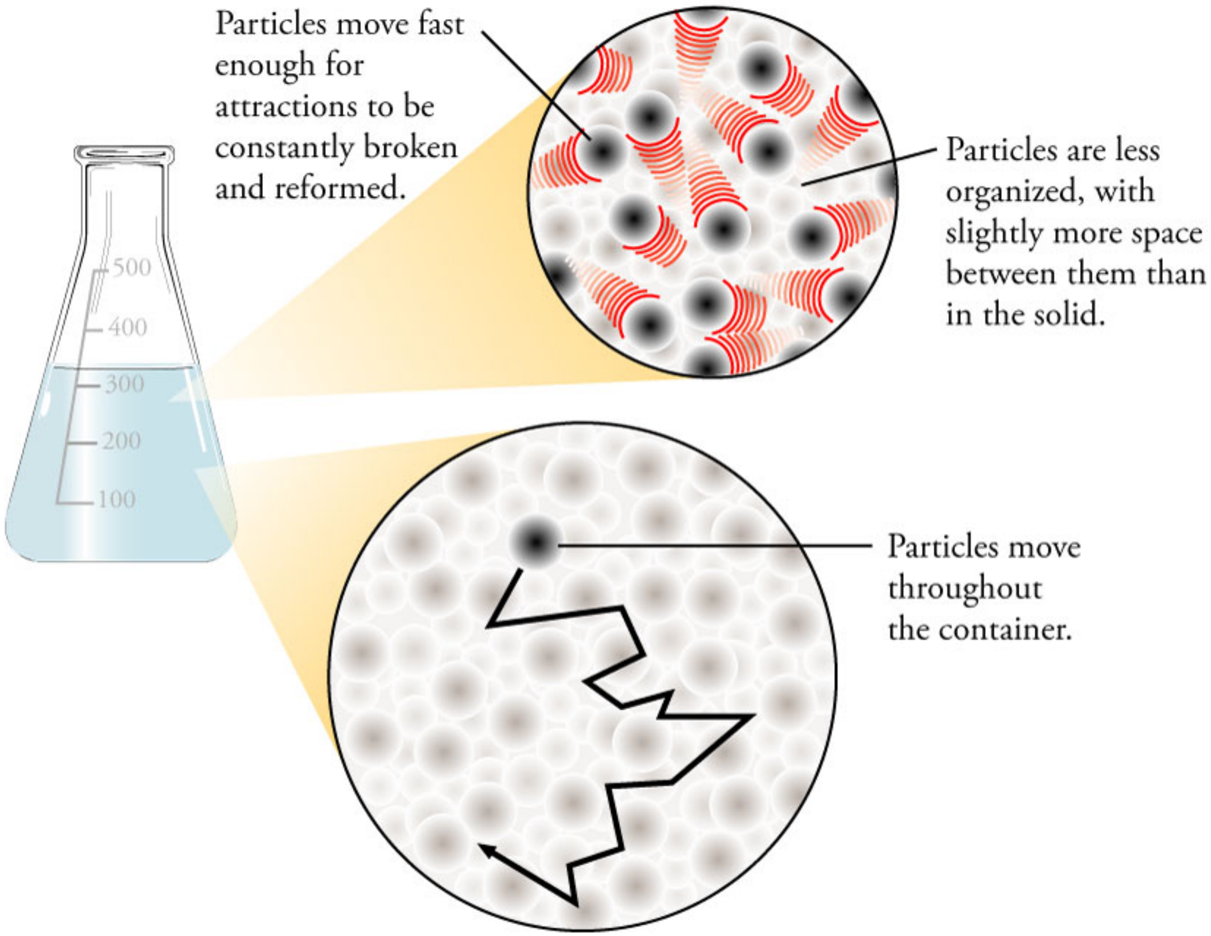
The Nature of Solids



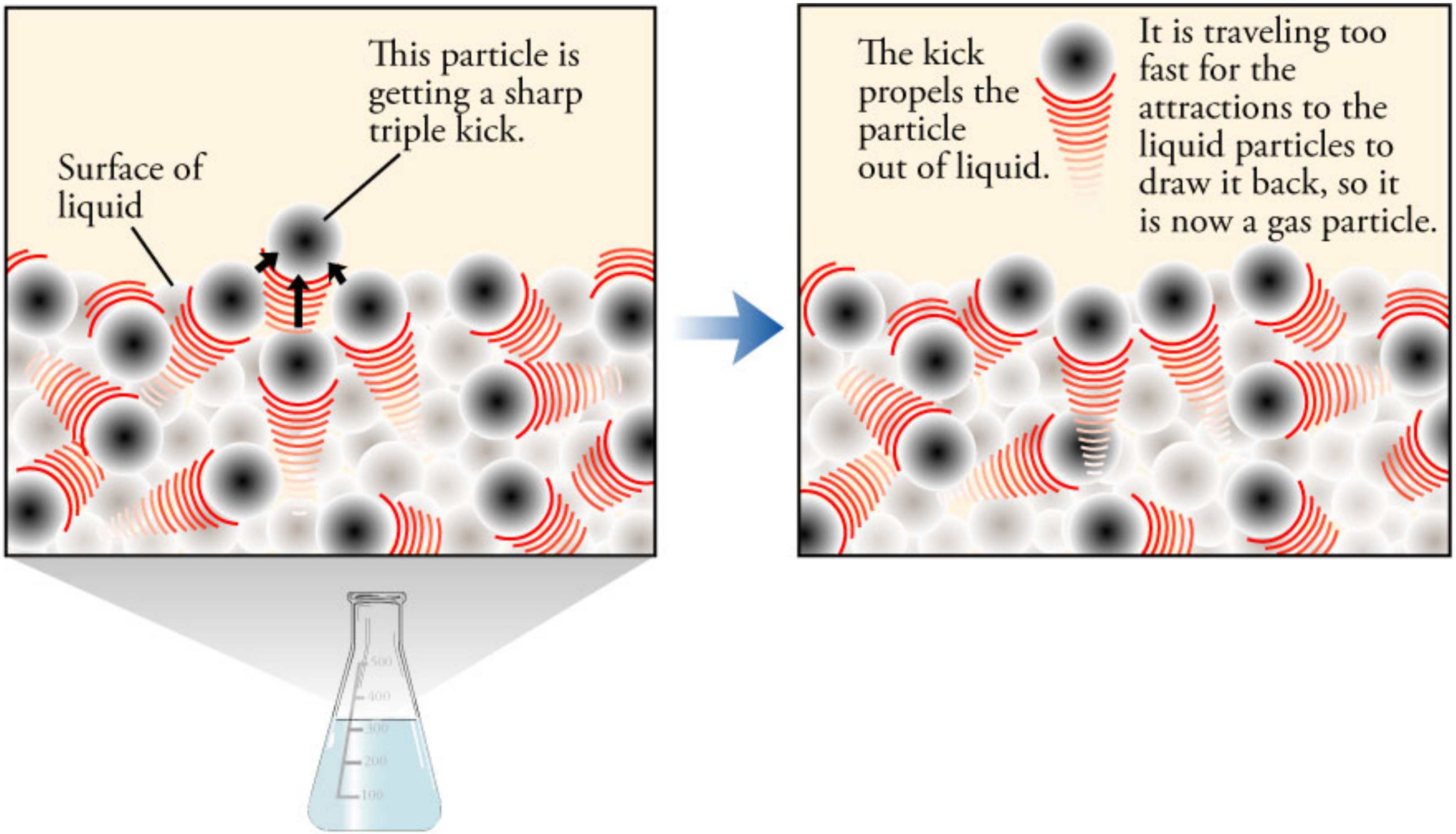
Liquid

- Constant volume but variable shape
- The particles are moving fast enough to break the attractions between particles that form the walls of the cage that surround particles in the solid form.
- Thus each particle in a liquid is constantly moving from one part of the liquid to another.

Liquids


Particles move fast enough for attractions to be constantly broken and reformed.
Particles are less organized, with slightly more space between them than in the solid.
Particles move throughout the container.
500
400
300
200
100

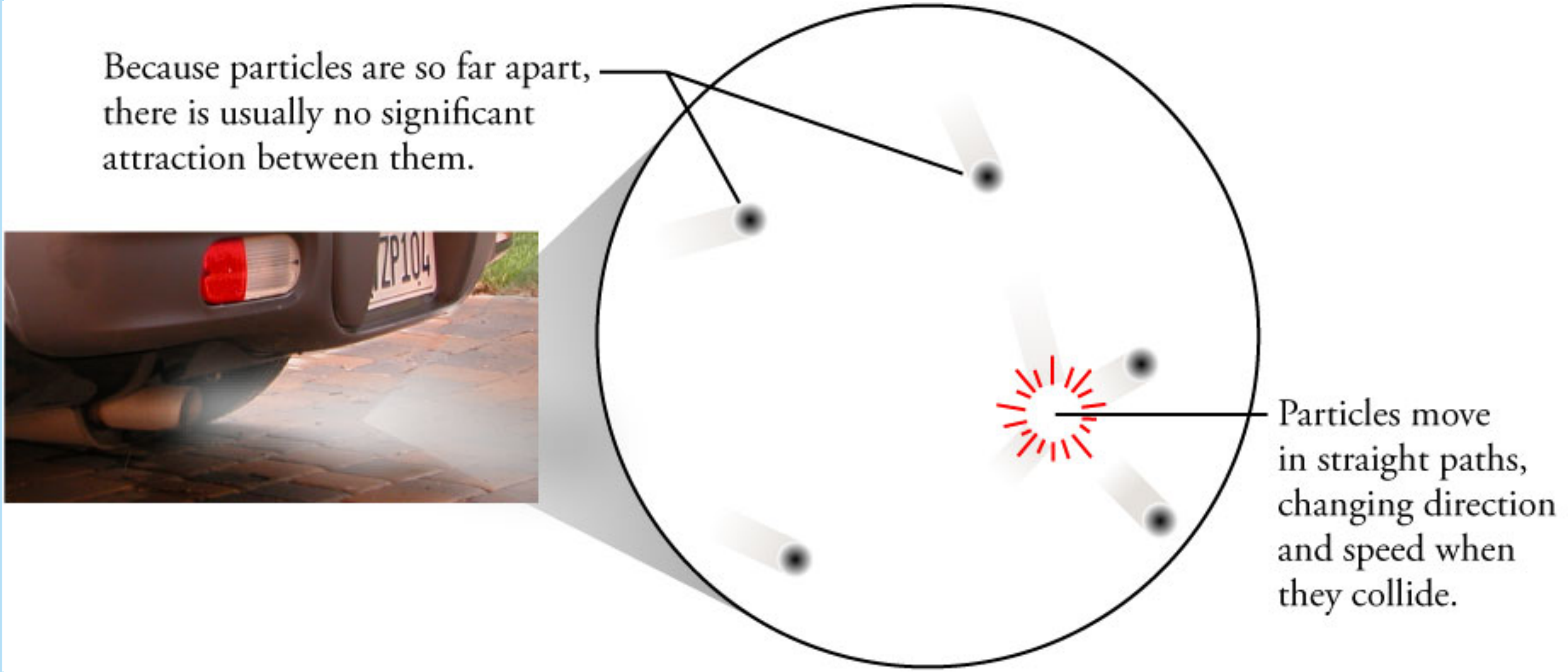
Evaporation



Gas

- Variable shape and volume
- Large average distances between particles
- Little attraction between particles
- Constant collisions between particles, leading to constant changes in direction and velocity

The Nature of Gases



Description of Solid

- Particles constantly moving.
- About 70% of volume occupied by particles…30% empty.
- Strong attractions keep particles trapped in cage.
- Constant collisions that lead to changes in direction and velocity.
- Constant volume and shape due to strong attractions and little freedom of motion.

Description of Liquid

- Particles constantly moving.
- About 70% of volume occupied by particles… 30% empty
- Attractions are strong but not strong enough to keep particles from moving throughout the liquid.
- Constant collisions that lead to changes in direction and velocity.
- Constant volume, due to significant attractions between the particles that keeps the particles at a constant average distance, but not constant shape, due to the freedom of motion.

Description of Gas

- Particles constantly moving in straight-line paths
- About 0.1% of volume occupied by particles…99.9% empty.
- Average distance between particles is about 10 times their diameter.
- No significant attractions or repulsions.
- Constant collisions that lead to changes in direction and velocity.
- Variable volume and shape, due to lack of attractions and a great freedom of motion.