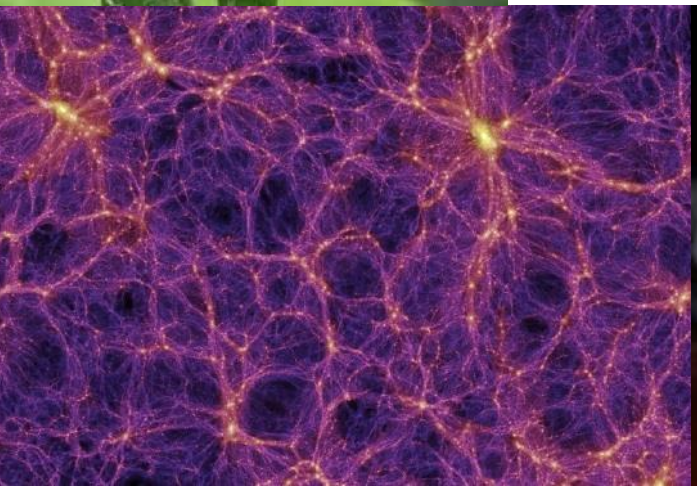



OH DEAR, WHAT CAN THE

MATTER

BE?





What is Matter?

- **Early philosophical approach:** Aristotle (384-322 BC) was deducing the existence of matter from the ***physical reality of change***.

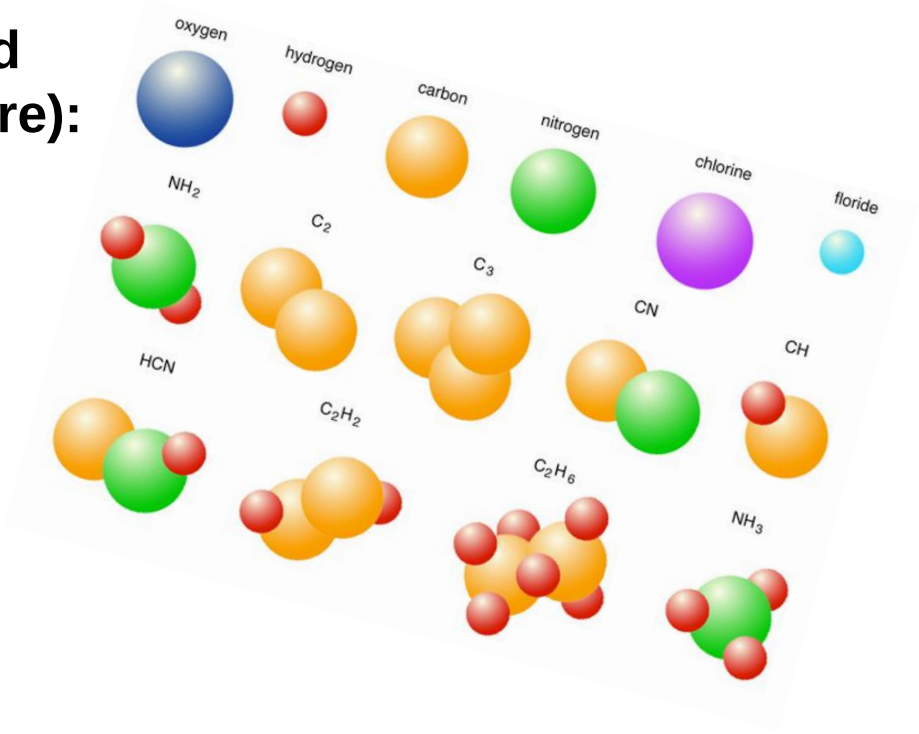
- **Common "classical" definition (mechanical, abstract mathematical),** René Descartes, Isaac Newton - 17th century**:**

"Matter is anything that has mass and takes up space"

- **Late 19th century definition (based on physical and chemical structure):**

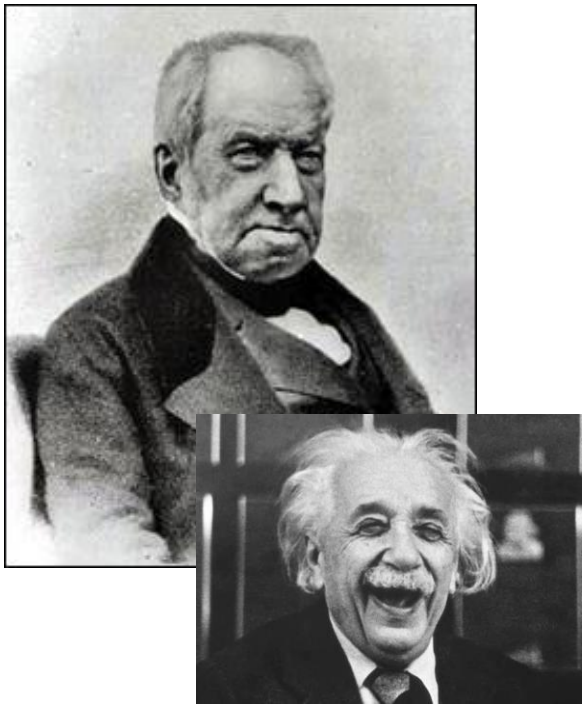
"Matter is made up of atoms"

- **This *atomic*, or *ordinary*, matter is in turn made up of interacting *subatomic particles* — usually a nucleus of protons and neutrons, and a cloud of orbiting electrons.**

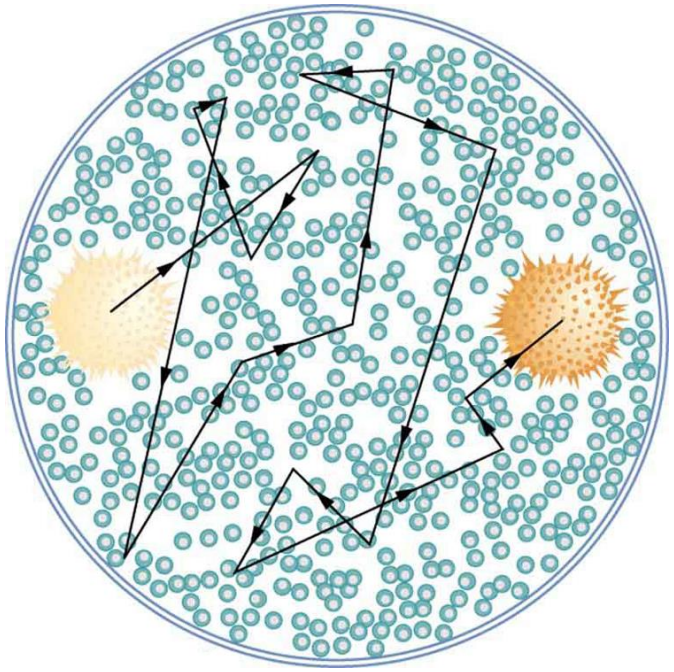


Brownian Motion

Robert Brown, 1827



- In 1827, while looking through a microscope at particles found in pollen grains in water, **Brown noted that the particles moved through the water** but was not able to determine the mechanisms that caused this motion.



- **Albert Einstein, 1905:** Any minute particle suspended in a liquid (or gas) moves chaotically under the action of collisions with surrounding molecules. The intensity of this chaotic motion is increased with an increase in temperature.
- This explanation of Brownian motion served as **definitive confirmation** that **atoms and molecules actually exist**.

Everyday Properties of Matter

We can <u>observe</u> the following about <u>ordinary matter</u>:

- How it **looks** (Shiny, Dull, Color, etc.)
- How it **feels** (Hard, Soft, Rough, Smooth, etc.)
- How it **smells** (Sweet, Sharp, Terrible, No Smell, etc.)
- How it **sounds** (Loud, Soft, Echo, No Sound, etc.)
- What it **does** (Bounce, Stretch, Tear, Break, Magnetize etc.)
- Anything **else**?
- How it **moves**
- How it **changes**

Study of Matter

- **Physics** – ***physical science*** **that studies matter, its change and motion through space-time, and related concepts such as energy and force.**
- **Chemistry** – ***physical science*** **that studies atomic (ordinary) matter, especially its chemical reactions, but also including its properties, structure, composition, behavior, and changes as they relate the chemical reactions.**

Physical science – branch of natural science that studies non-living systems.

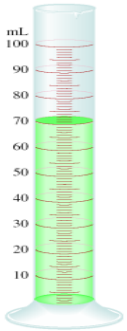
Natural science – major branch of science, that tries to explain and predict nature's phenomena, based on empirical evidence.

Science – systematic effort of acquiring knowledge—through observation and experimentation coupled with logic and reasoning.

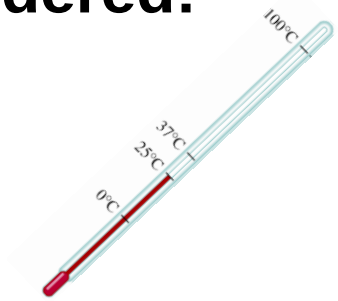
Physical Properties of Matter

We can describe <u>physical properties</u> of matter in terms of physical quantities and laws.

- **An *<u>extensive</u>* property depends upon how much matter is being considered:**
  - **mass**
  - **volume**
  - **electrical charge**



- **An *<u>intensive</u>* property does *<u>not</u>* depend upon how much matter is being considered:**
  - **density**
  - **temperature**
  - **color**



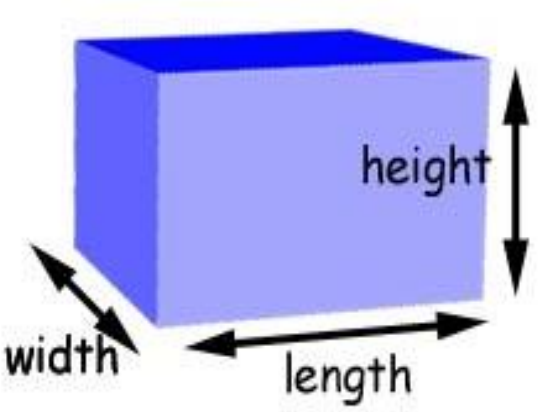
Mass vs Weight

- **Weight** is a measure of how strongly gravity is pulling on an object (decreases as elevation increases).
- **Mass** is the amount of material in an object (doesn't change).
- Note: on the Earth's surface, terms "weight" and "mass" are used interchangeably since we use a **weighing scale** to determine mass.

- Example: **What is the weight of a Martian on Mars and Moon if it weighs 50 kg on Earth?**
  - Gravity on Moon is 0.16 of Earth gravity while gravity on Mars is 0.38 of Earth gravity.
  - **Answer:** this Martian weighs 8.3 kg on Moon and 18.8 kg on Mars (the numbers shown by the scale), but **his/her mass is still 50 kg!!!**

Volume and Density

- **Volume** is the amount of three-dimensional space that a substance or shape occupies or contains:
  - volume = length × width × height
  - SI unit is m^3



- **Density** is a measure of how much matter is contained in a unit of volume:
  - $\text{density} = \frac{\text{mass}}{\text{volume}}$
  - SI unit is kg/m^3

  - The density of a material varies with temperature and pressure (variation is typically small for solids and liquids but much greater for gases).

States of Matter

- **Matter can exist in several different forms, or *states of aggregation*.**

- **Matter commonly exists in four fundamental states:**
  - Solid
  - Liquid
  - Gas
  - Plasma

- **Different states of matter are based upon distance between particles (atoms and/or molecules), particle arrangement, and energy of particles.**

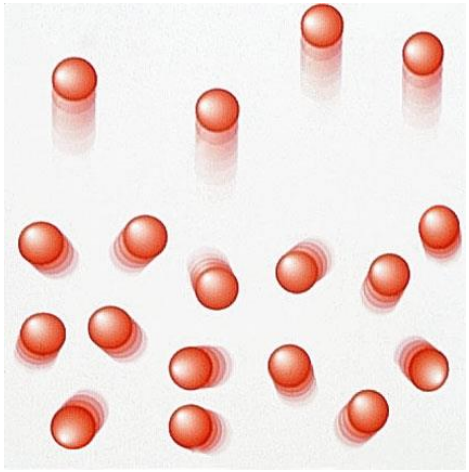
SOLIDS

- **Particles of <u>solids</u> are tightly packed.**
- **The forces between particles are strong: the particles cannot move freely but <u>can only vibrate about a fixed position</u>.**
- **Solids have a stable, definite shape and a definite volume.**
- **Solids can only change their shape *by force*, as when broken or cut.**

LIQUIDS

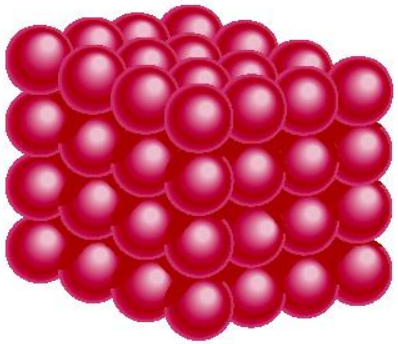
- **Particles of <u>liquids</u> are tightly packed, but are far enough apart to slide over one another (*mobile structure*).**
- **The shape of a liquid is not definite but is determined by its container.**
- **Liquids are known to be *nearly incompressible*. At constant temperature and pressure, liquids have a definite volume.**
- **The volume of liquid is usually greater than the volume of the corresponding solid (the best known *exception* being *water*).**

GAS

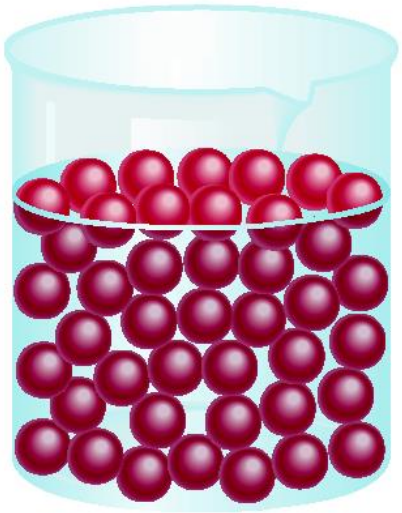


- **Particles of a gas are very far apart and move freely.**
- **A gas has an indefinite shape and an indefinite volume: it will expand to *fill the entire container* in which it is confined.**
- **A gas is *compressible*.**

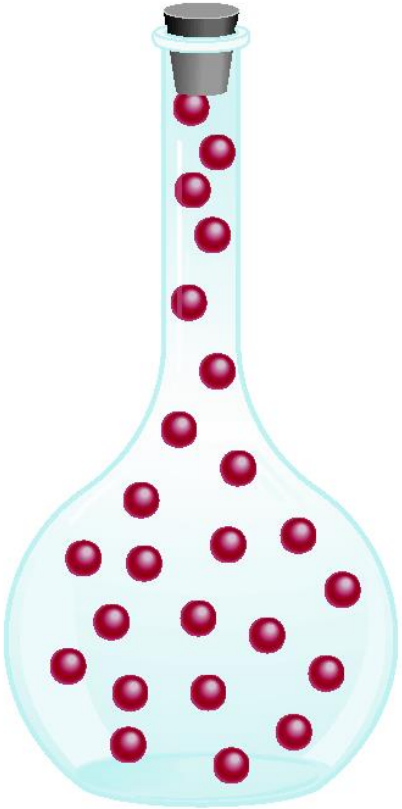
A Comparison: The Three States of Matter



Solid



Liquid

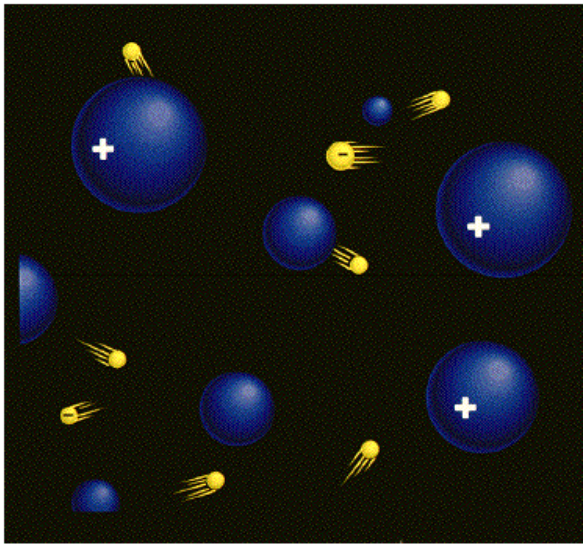


Gas

But what happens if you raise the temperature to super-high levels... between 1000°C and 1,000,000,000°C ?

Will everything just be a gas?

PLASMA



- **A plasma is an ionized gas: positively charged nuclei swim in a "sea" of freely-moving dissociated electrons.**
- **A plasma is a very good conductor of electricity: it produces and responds to magnetic fields.**
- **Plasmas, like gases have an indefinite shape and an indefinite volume.**
- **A gas is usually converted to a plasma in one of the following two ways:**
  - **from a huge voltage difference between two points**
  - **by exposing gas to extremely high temperatures that cause electrons to leave the atoms**

Plasma is the common state of matter!

Some places where plasmas are found…

How many states of matter can you find in each picture?