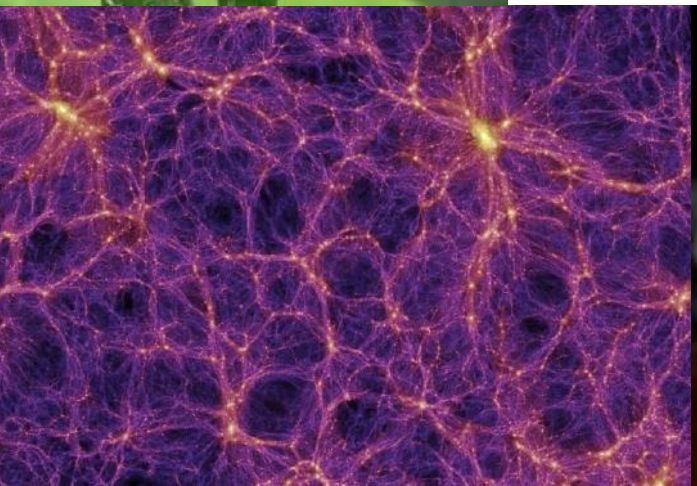



OH DEAR, WHAT CAN THE

MATTER

BE?





What is Matter?

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

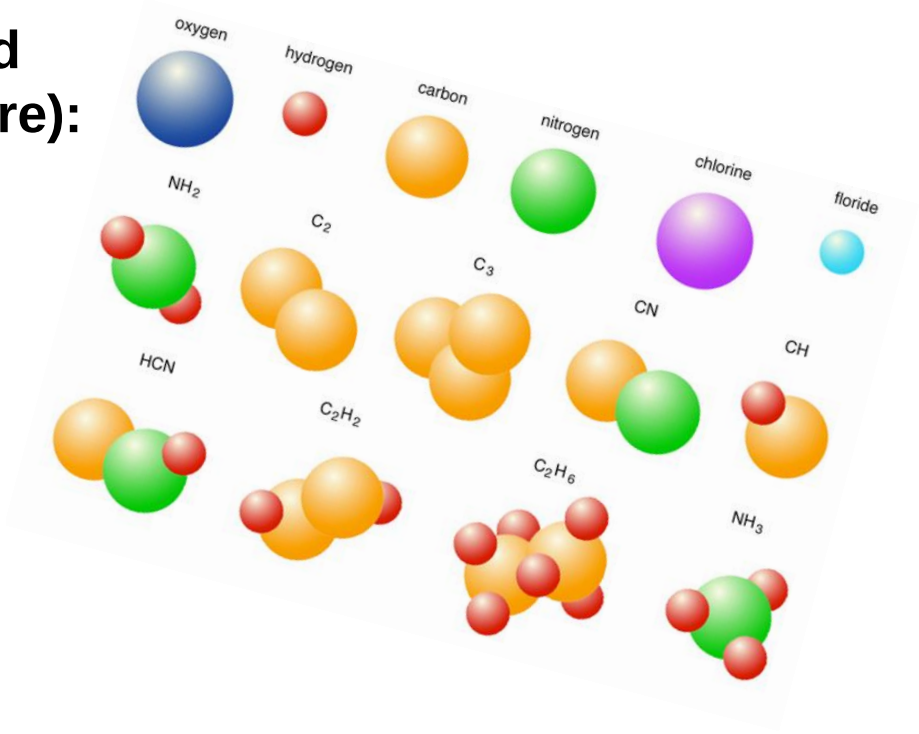
- **Common "classical" definition (mechanical, abstract mathematical),** René Descartes, Isaac Newton - 17th century**:**

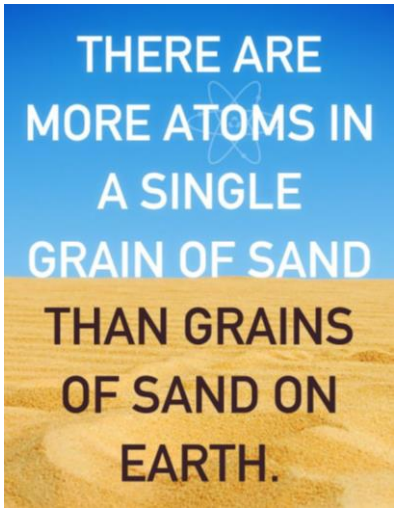
"Matter is anything that has mass and takes up space"

- **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.**





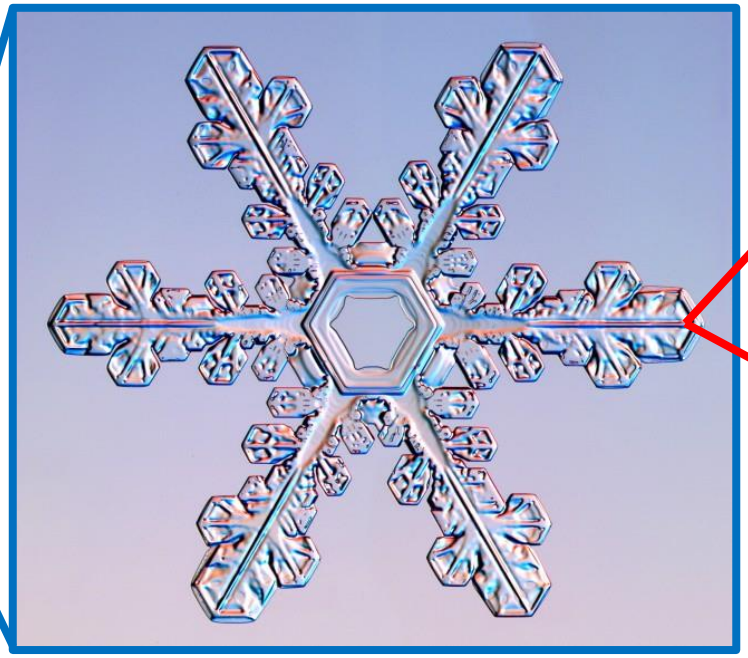
Atoms are very small!

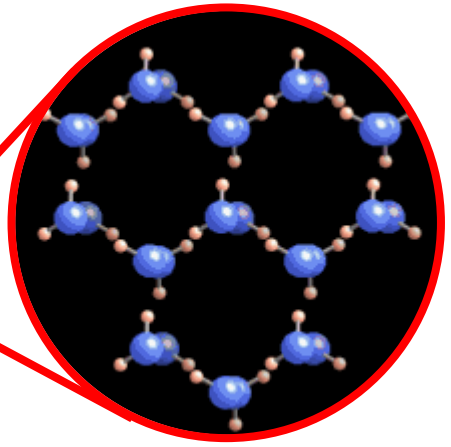
Voyage into the World of Atoms:

https://www.youtube.com/watch?v=7WhRJV_bAiE

Snowflake ~1-3 mm

Ice crystal unit cell 5 nm



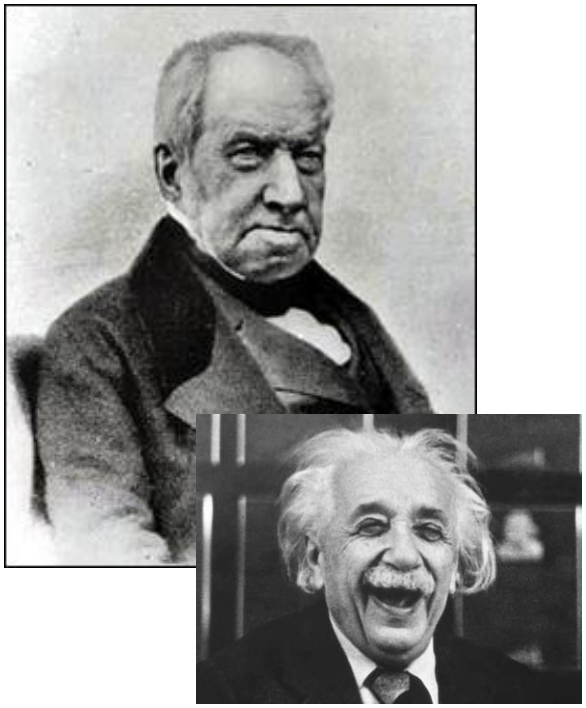


Single atom ~1Å=10^{-10} m

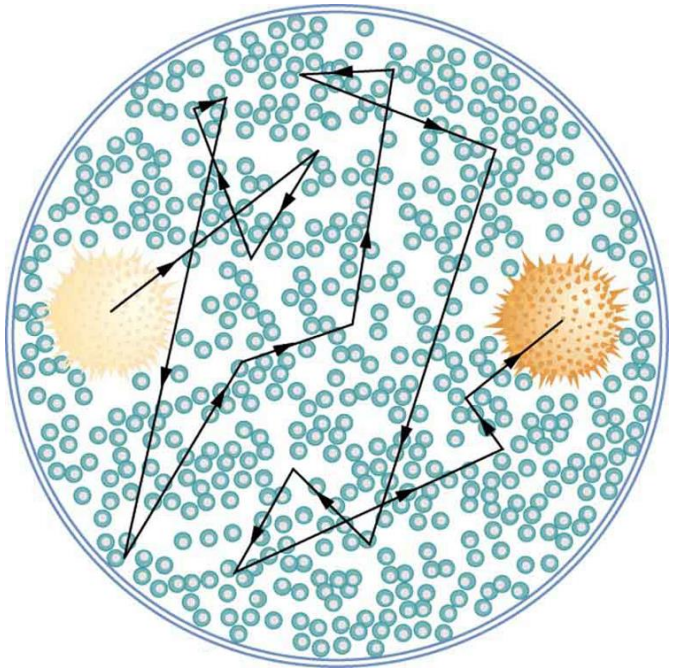
A typical snowflake is made of about 10^{18}-10^{19} atoms.

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 atoms and 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**.

Study of Matter

- **Physics – *physical science* that studies forms of 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 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.

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

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

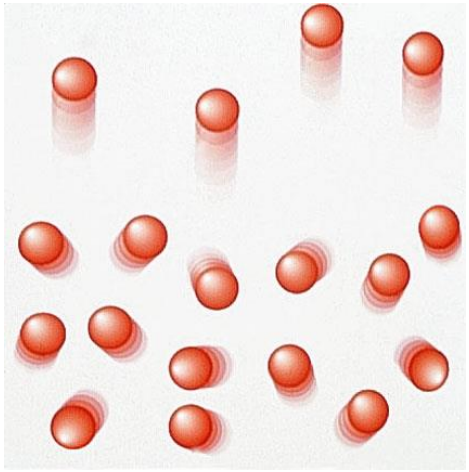
SOLIDS

- **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

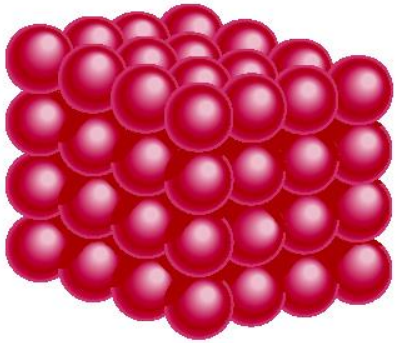
- **Particles of <u>liquids</u> are tightly packed, but are far enough apart to slide over one another (*mobile structure*).**
- **The shape of a liquid is not definite but is determined by its container.**
- **Liquids are known to be *nearly incompressible*. At constant temperature and pressure, liquids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

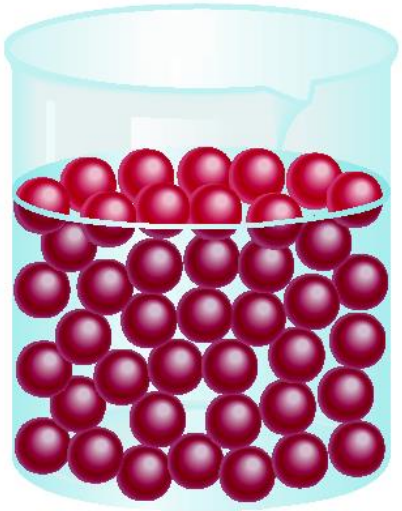


- **Particles of a gas are very far apart and move freely.**
- **A gas has an indefinite shape and an indefinite volume: it will expand to *fill the entire container* in which it is confined.**
- **A gas is *compressible*.**

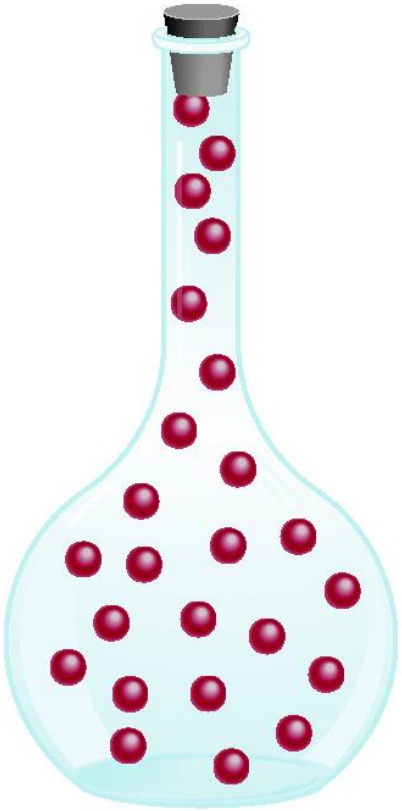
A Comparison: The Three States of Matter



Solid



Liquid



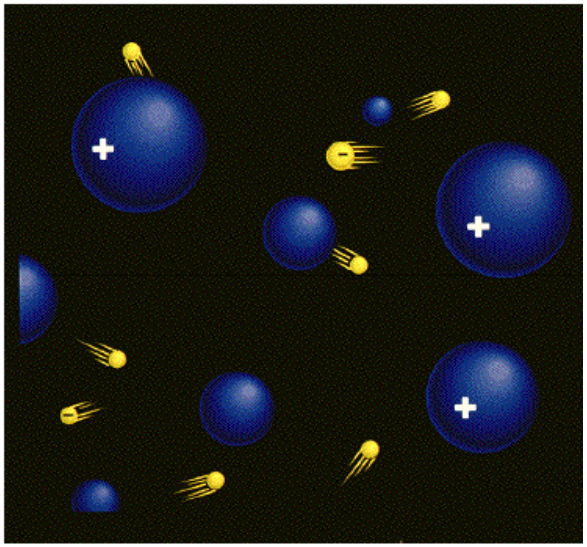
Gas

Example: ICE → WATER → WATER VAPOR

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 a common state of matter!