

What is Matter?

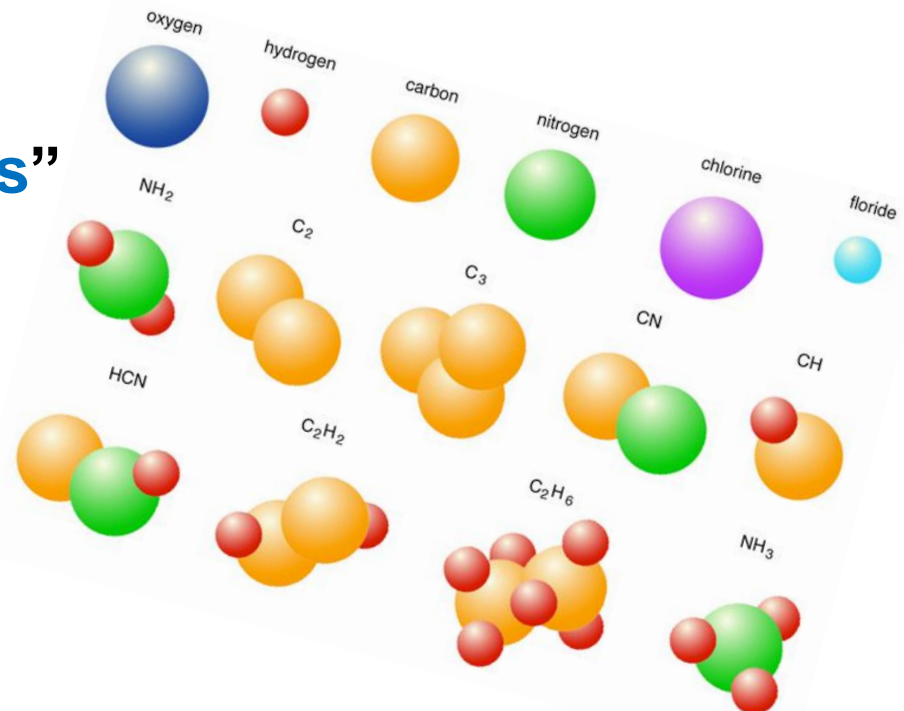
1. Common “classical” definition (known as *mechanical, abstract mathematical*), **René Descartes, Isaac Newton** - 17th century:

“**Matter is anything that has mass and takes up space**”

2. 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.



THERE ARE
MORE ATOMS IN
A SINGLE
GRAIN OF SAND
THAN GRAINS
OF SAND ON
EARTH.

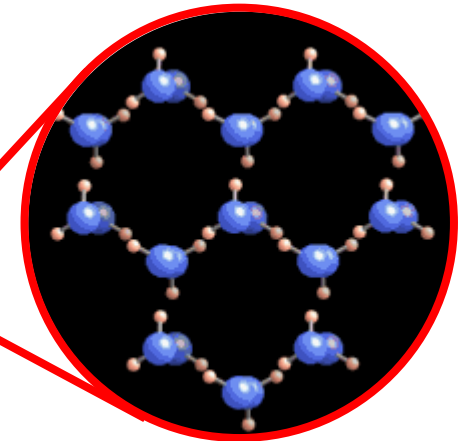
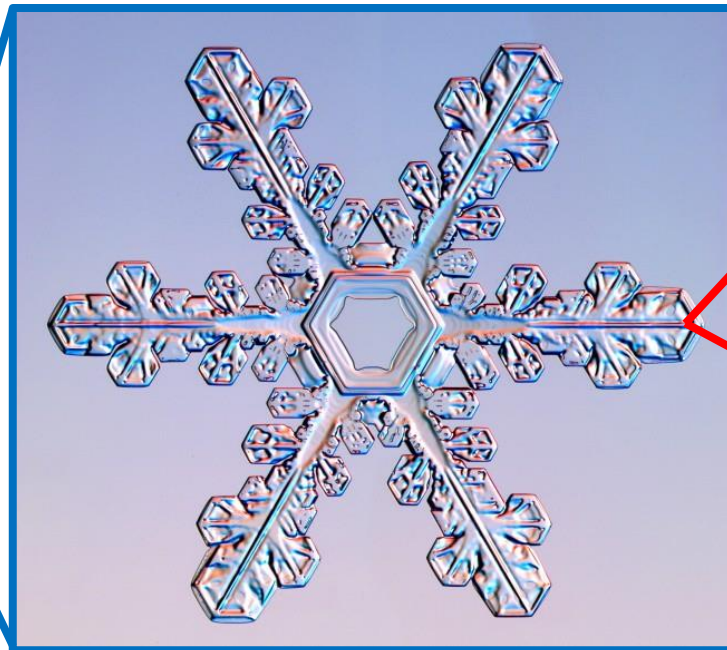
Atoms are very small!

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
 $\sim 1\text{\AA} = 10^{-10}\text{ m}$

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

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 material substances, their composition and change of composition (chemical reactions), as well as matter behavior related to 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:

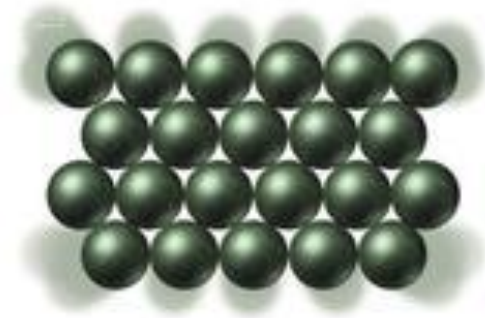
- Solid
- Liquid
- Gas
- Plasma



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

SOLIDS

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

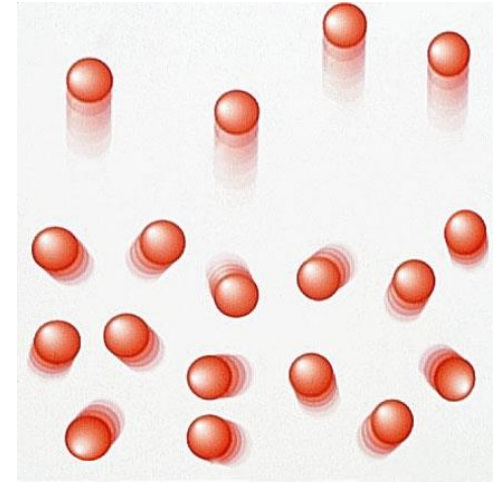


LIQUIDS

- Particles of liquids 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*).



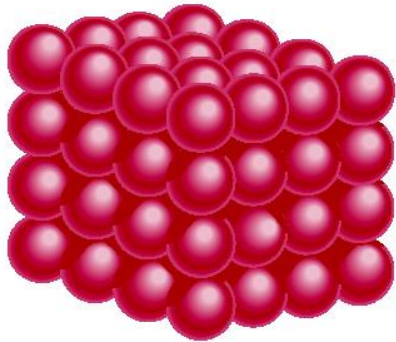
GAS



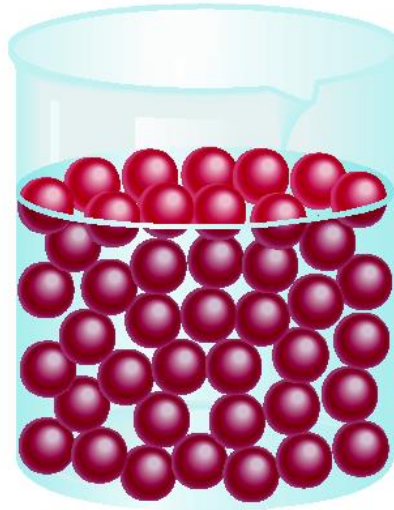
- Particles of a gas are very far apart and move freely.
- A gas has an **indefinite shape** and an **indefinite volume**: it will expand to *fill the entire container* in which it is confined.
 - A gas is *compressible*.



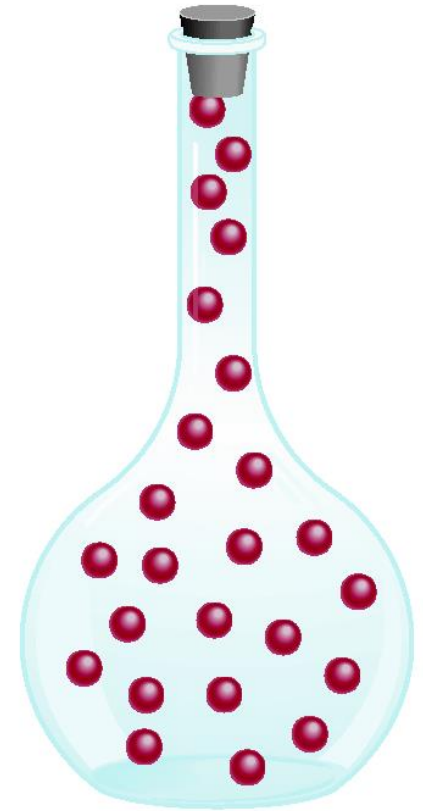
A Comparison: The Three States of Matter



Solid



Liquid



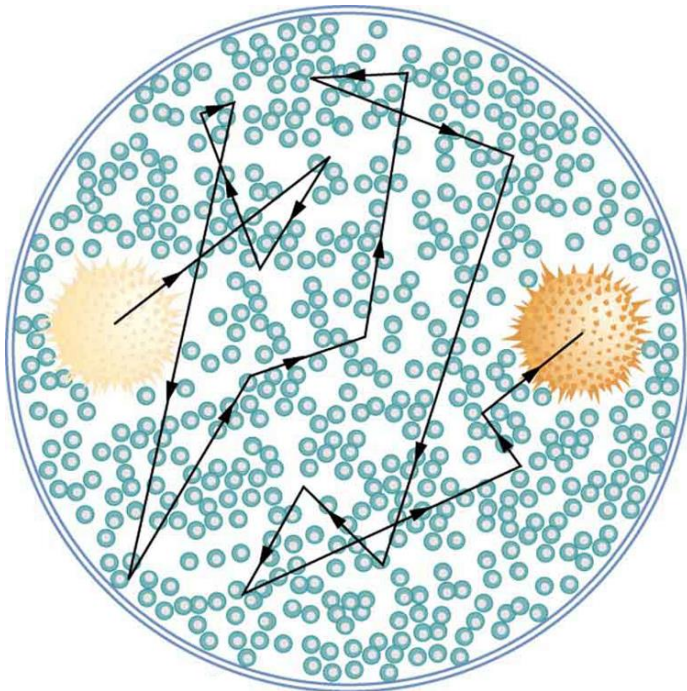
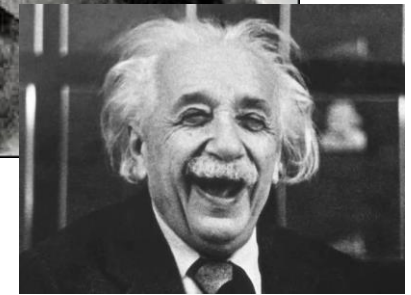
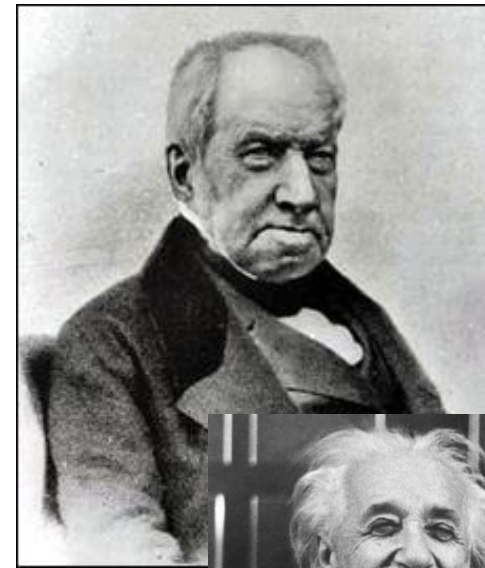
Gas

Example: ICE \longrightarrow WATER \longrightarrow WATER VAPOR

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**.