

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 <u>ordinary</u>, 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: <u>https://www.youtube.com/watch?v=7WhRJV_bAiE</u>

Snowflake ~1-3 mm

Ice crystal unit cell 5 nm



A typical snowflake is made of about 10¹⁸-10¹⁹ 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.





- <u>Albert Einstein, 1905</u>: 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**.

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.

Science - systematic Natural science -Physical science effort of acquiring major branch of science, that - branch of natural knowledge-through tries to explain and predict science that studies observation and nature's phenomena, based non-living systems. experimentation coupled on empirical evidence. with logic and reasoning.

States of Matter

- <u>Matter</u> can exist in several different forms, or <u>states</u> of <u>aggregation</u>.
- Matter commonly exists in <u>four</u> <u>fundamental</u> <u>states</u>:

≻Solid
≻Liquid
≻Gas
≻Plasma



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













- Particles of a <u>gas</u> are very <u>far apart</u> and <u>move freely</u>.
- 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



Gas

Example: ICE -----> WATER ----> WATER VAPOR

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

Will everything just be a gas?

PLASMA

- A <u>plasma</u> 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 **<u>common state of matter</u>**!

Some places where plasmas are found...

