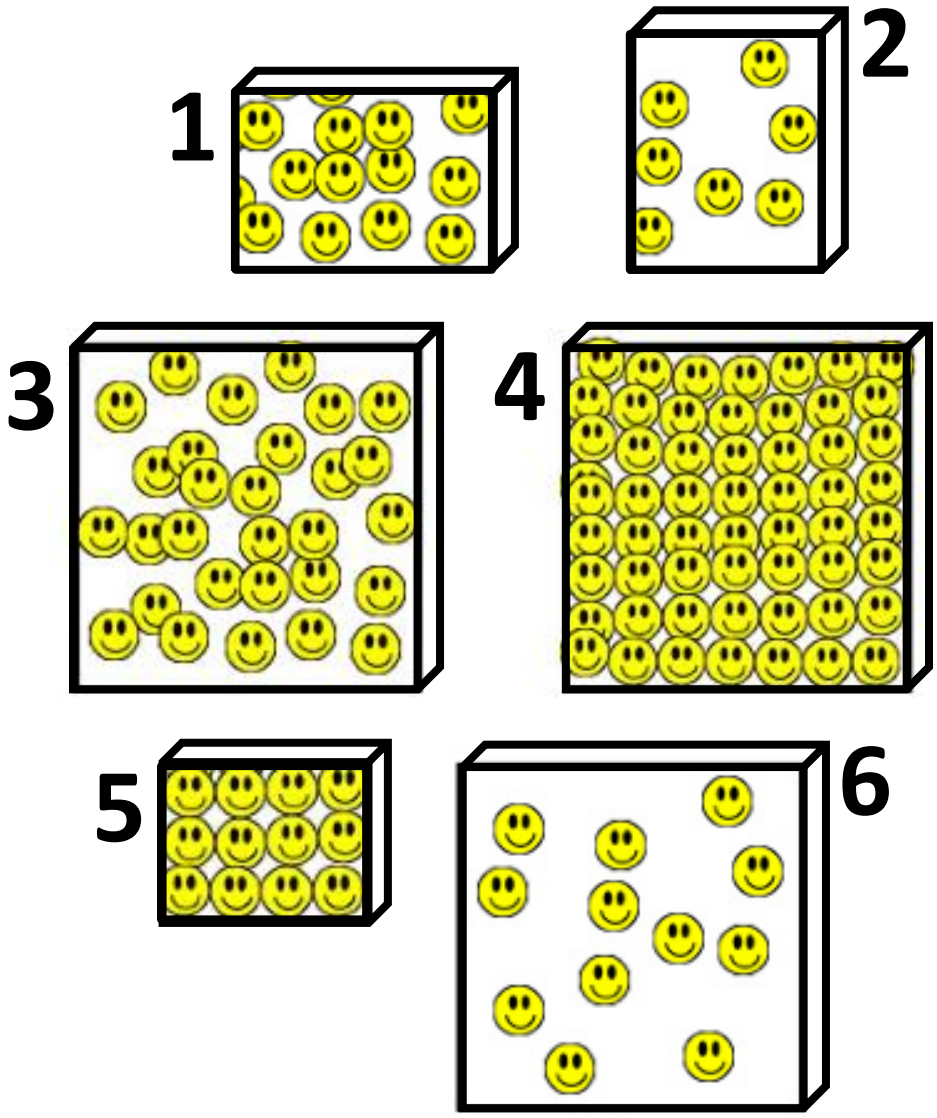
Which of the following objects…



- …have the same volume?
- …have the same density?
- …have different mass?
- …have different volume?
- …have the same mass?
- …have different density?

(note: all atoms here are the same)


States
of
Matter

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

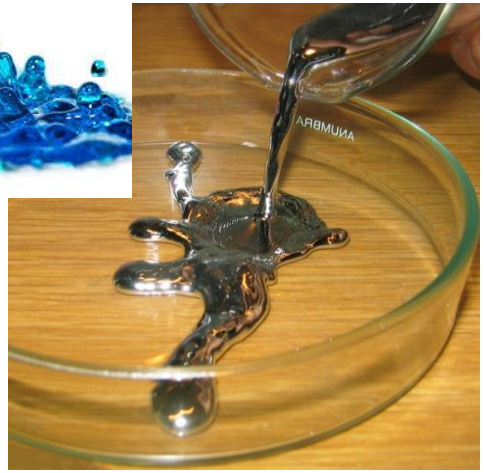
- **Particles of <u>solids</u> are tightly packed.**
- **The intramolecular forces between particles are strong: the particles cannot move freely but <u>can only vibrate about a fixed position</u>.**
- **Solids have a stable, definite shape and a definite volume.**
- **Solids can only change their shape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

LIQUIDS

- **Particles of liquids are tightly packed but are far enough apart to slide over one another (*mobile structure*).**

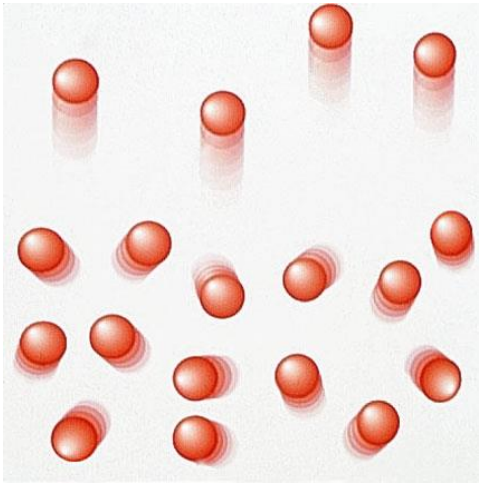
- **The shape of a liquid is not definite but is determined by its container.**

- **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*).**

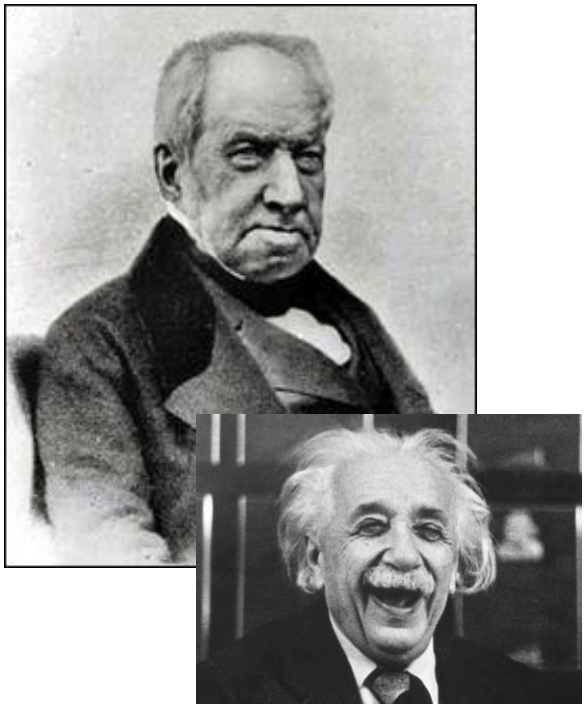
GAS



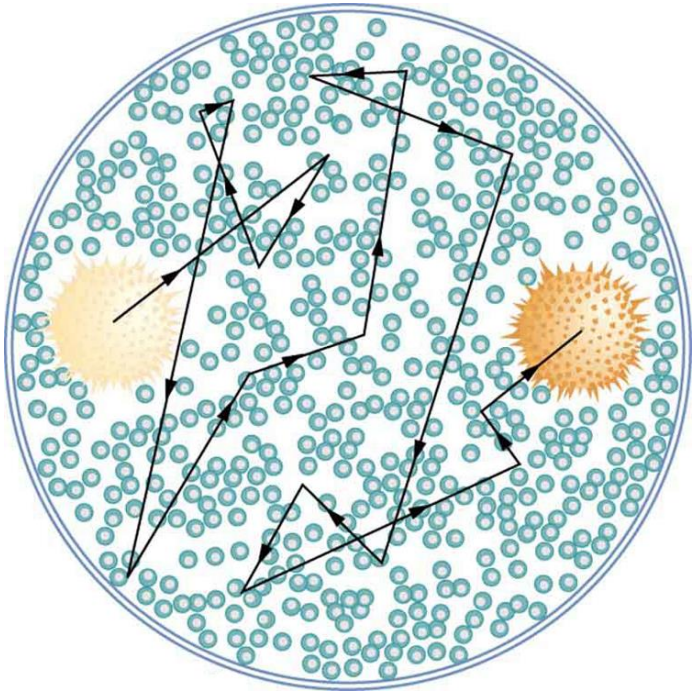
- **Particles of a <u>gas</u> are very <u>far apart</u> and <u>move freely</u>.**
- **A gas has an indefinite shape and an indefinite volume: it will expand to *fill the entire container* in which it is confined.**
    - **A gas is *compressible*.**

Brownian motion

Robert Brown, 1827

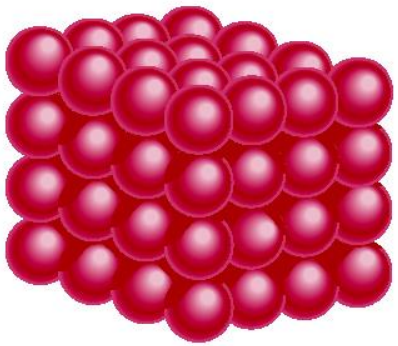


- In 1827, while looking through a microscope at particles found in pollen grains in water, **Brown noted that the particles moved through the water** but was not able to determine the mechanisms that caused this motion.

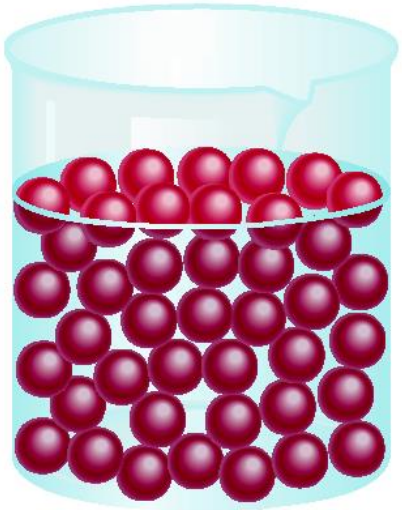


- **Albert Einstein, 1905:** Any minute particle suspended in a liquid (or gas) moves chaotically under the action of collisions with surrounding molecules. The intensity of this chaotic motion is increased with an increase in temperature.
- This explanation of Brownian motion served as **definitive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

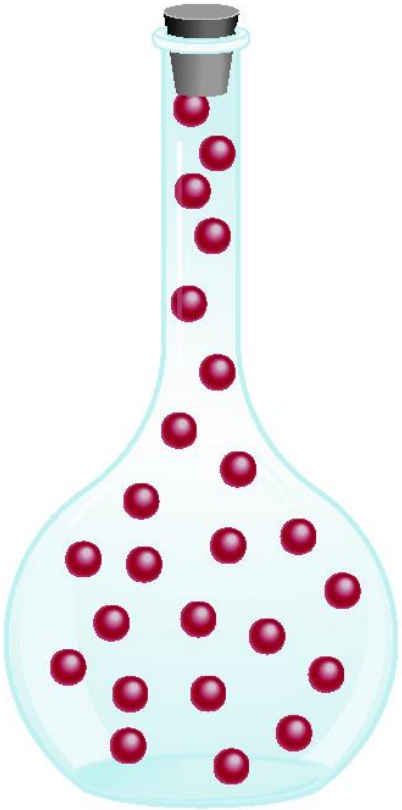
A Comparison: The Three States of Matter



Solid



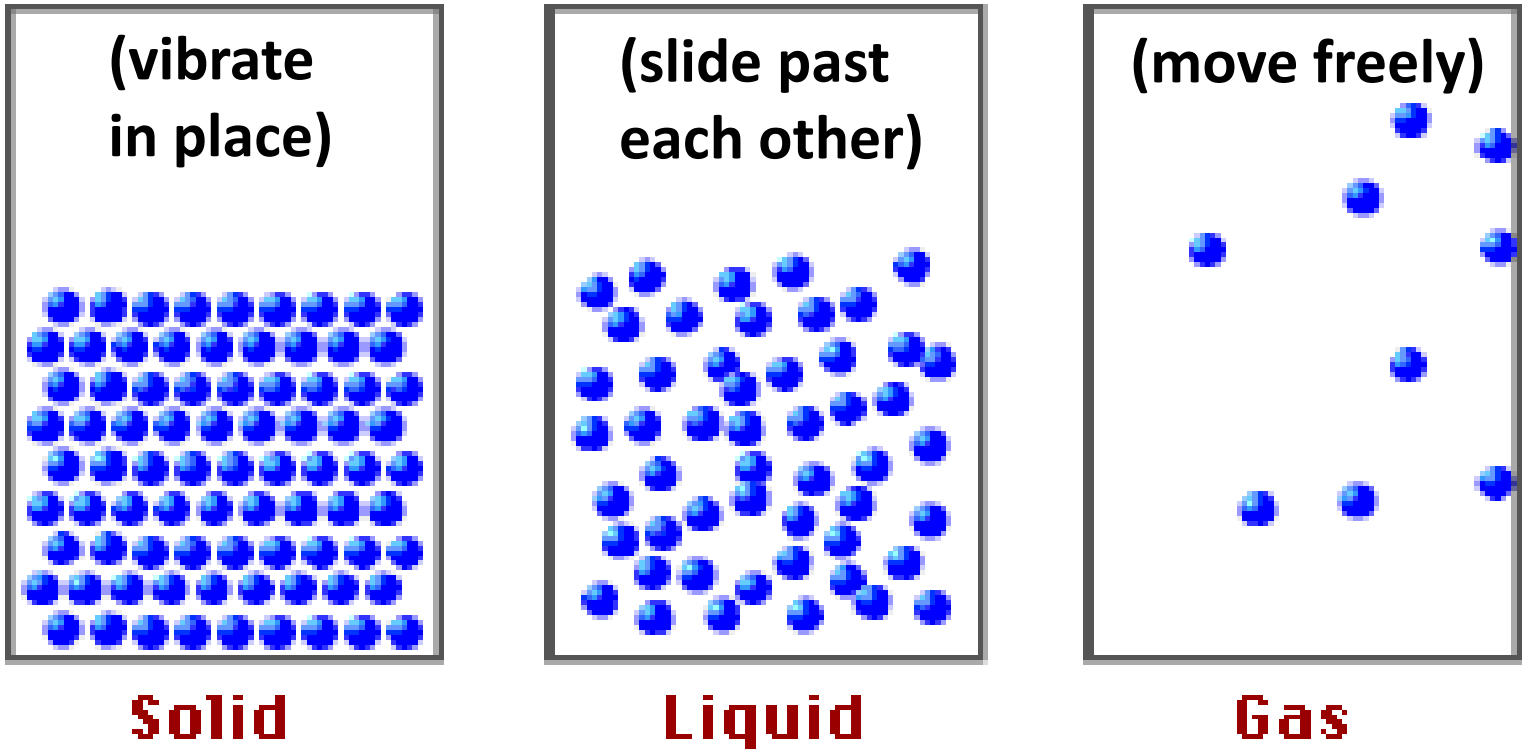
Liquid



Gas

Example: ICE → WATER → WATER VAPOR

A Comparison: The Three States of Matter

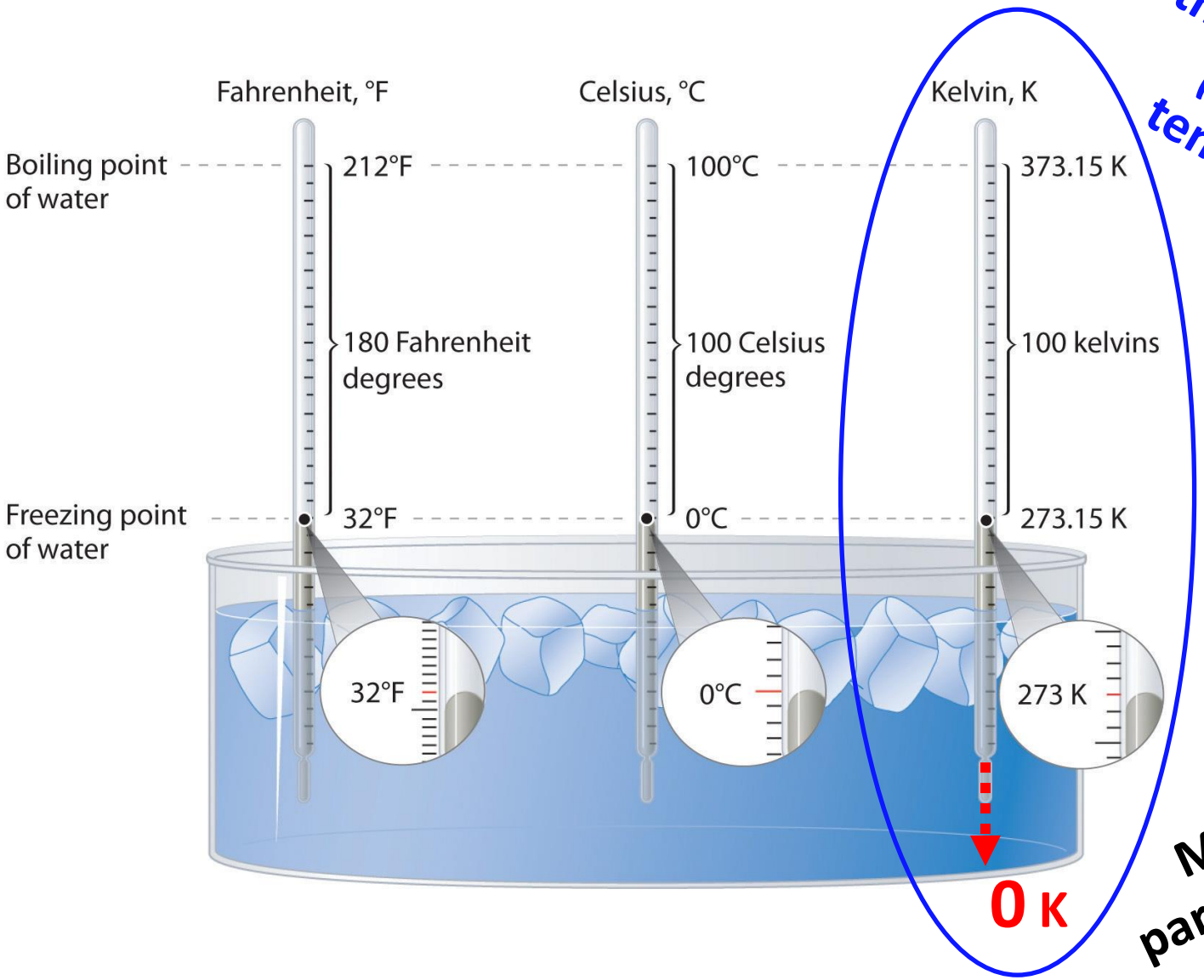


Example: ICE ⟶ WATER ⟶ WATER VAPOR

What is Temperature?

- **Particles of matter are in constant motion** (*vibrating* in place in solids, *sliding past each other* in liquids, *flying around freely* in gases)**, but they don't all move at the same speed and in the same direction all the time.**
- **<u>Temperature</u> is a measure of the *average* energy associated with *random motion* of the particles of a substance.**
- **The *higher* the temperature of an object, the *faster* on average its particles move.**

Temperature Scales



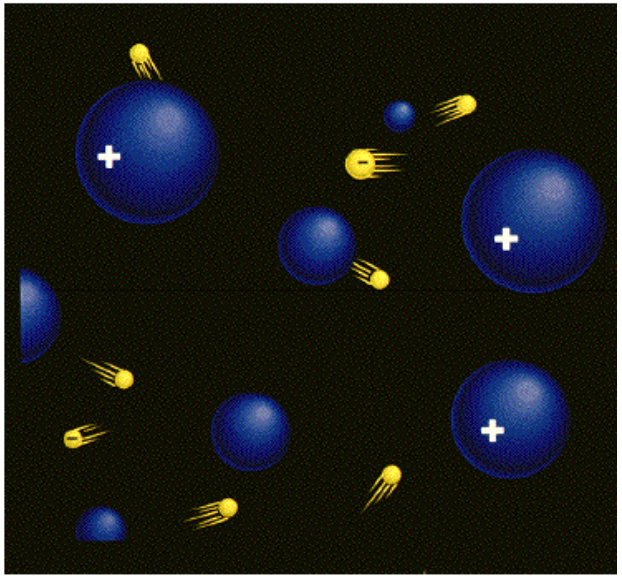
thermodynamic (absolute) temperature

Motion of particles stops!

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!

Some places where plasmas are found…