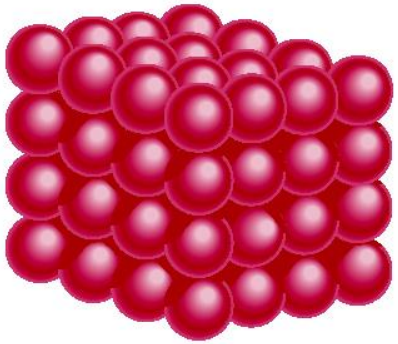
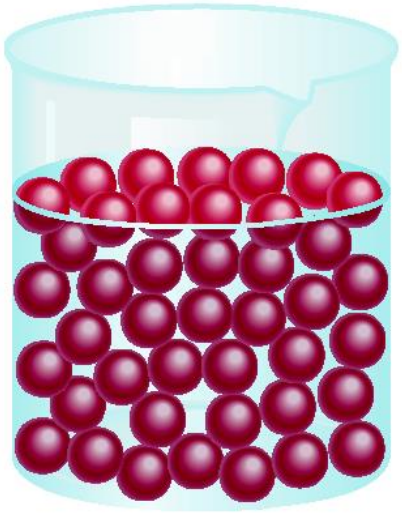
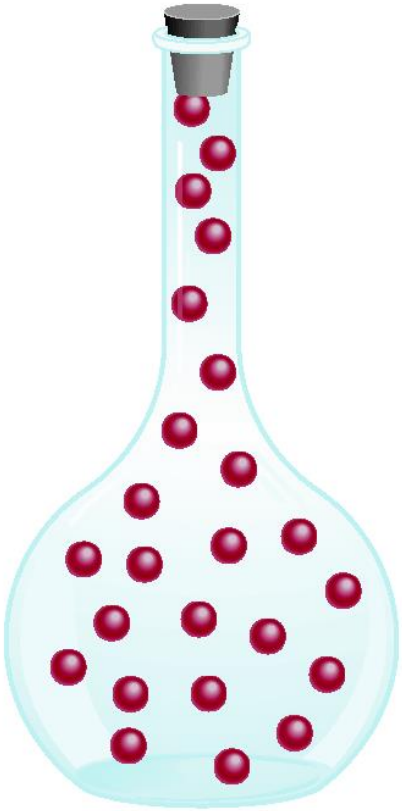
A Comparison: The Three States of Matter



Solid



Liquid

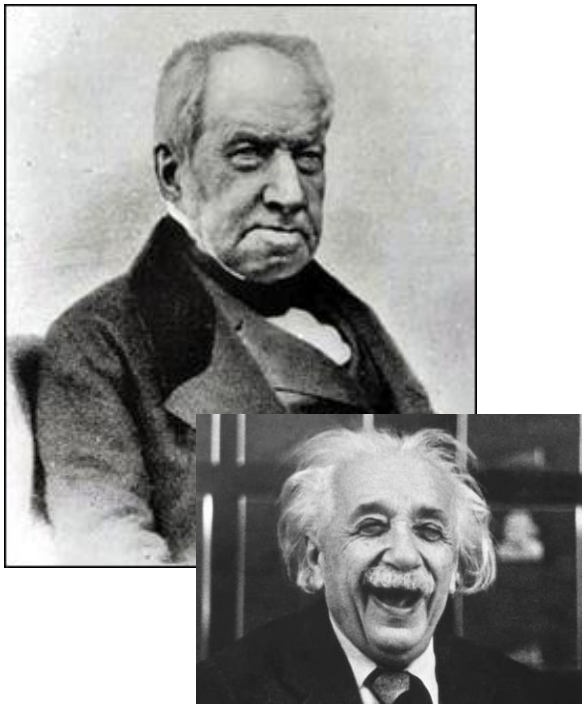


Gas

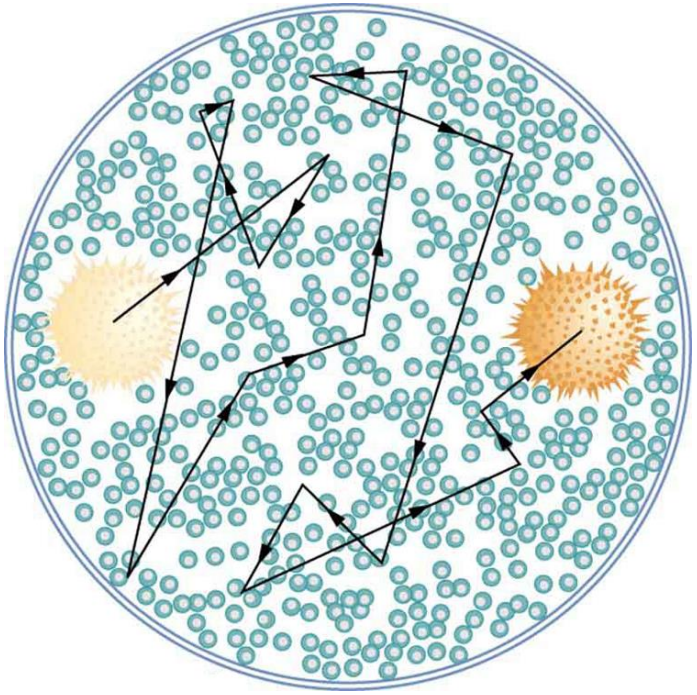
Example: ICE → WATER → WATER VAPOR

Brownian motion

Robert Brown, 1827

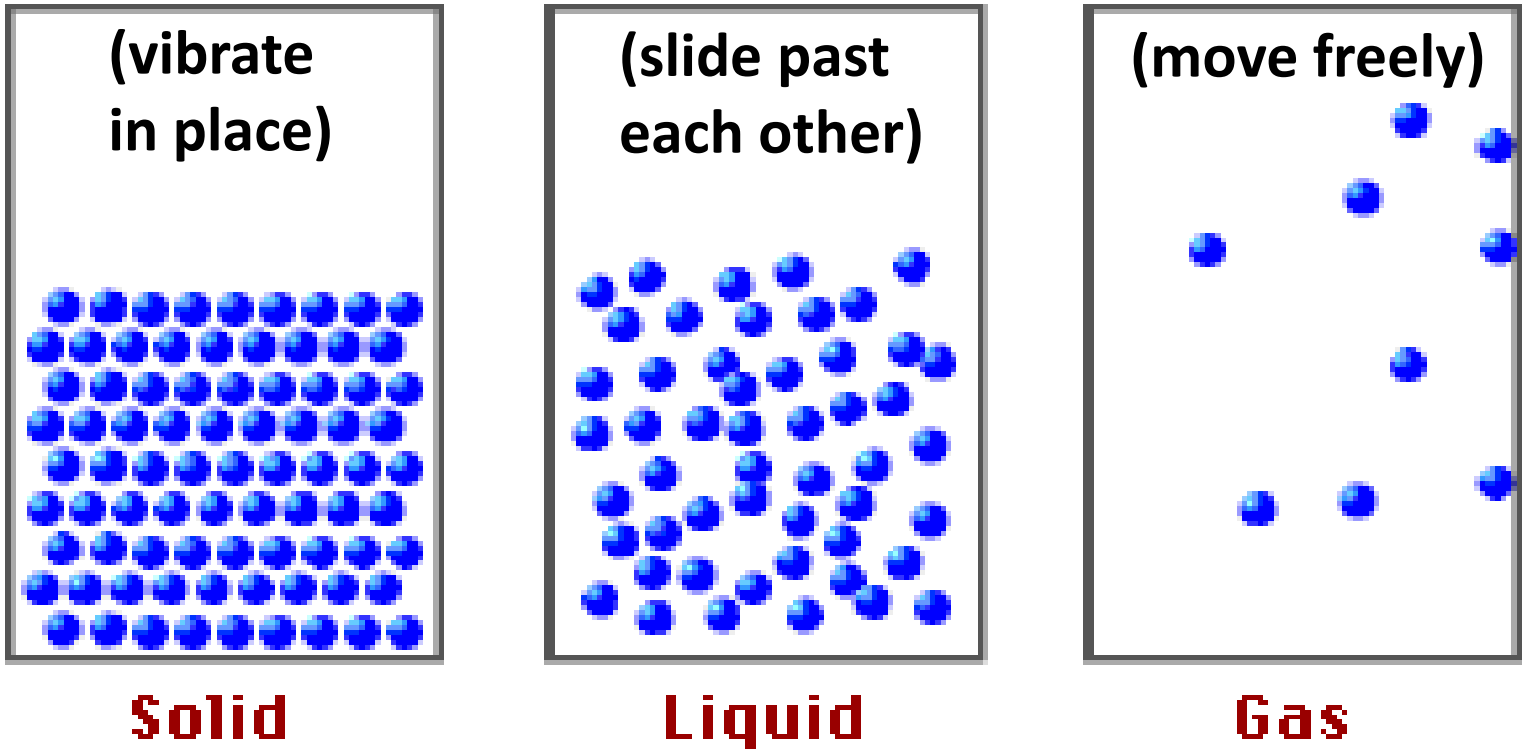


- In 1827, while looking through a microscope at particles found in pollen grains in water, **Brown noted that the particles moved through the water** but was not able to determine the mechanisms that caused this motion.



- **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**.

A Comparison: The Three States of Matter

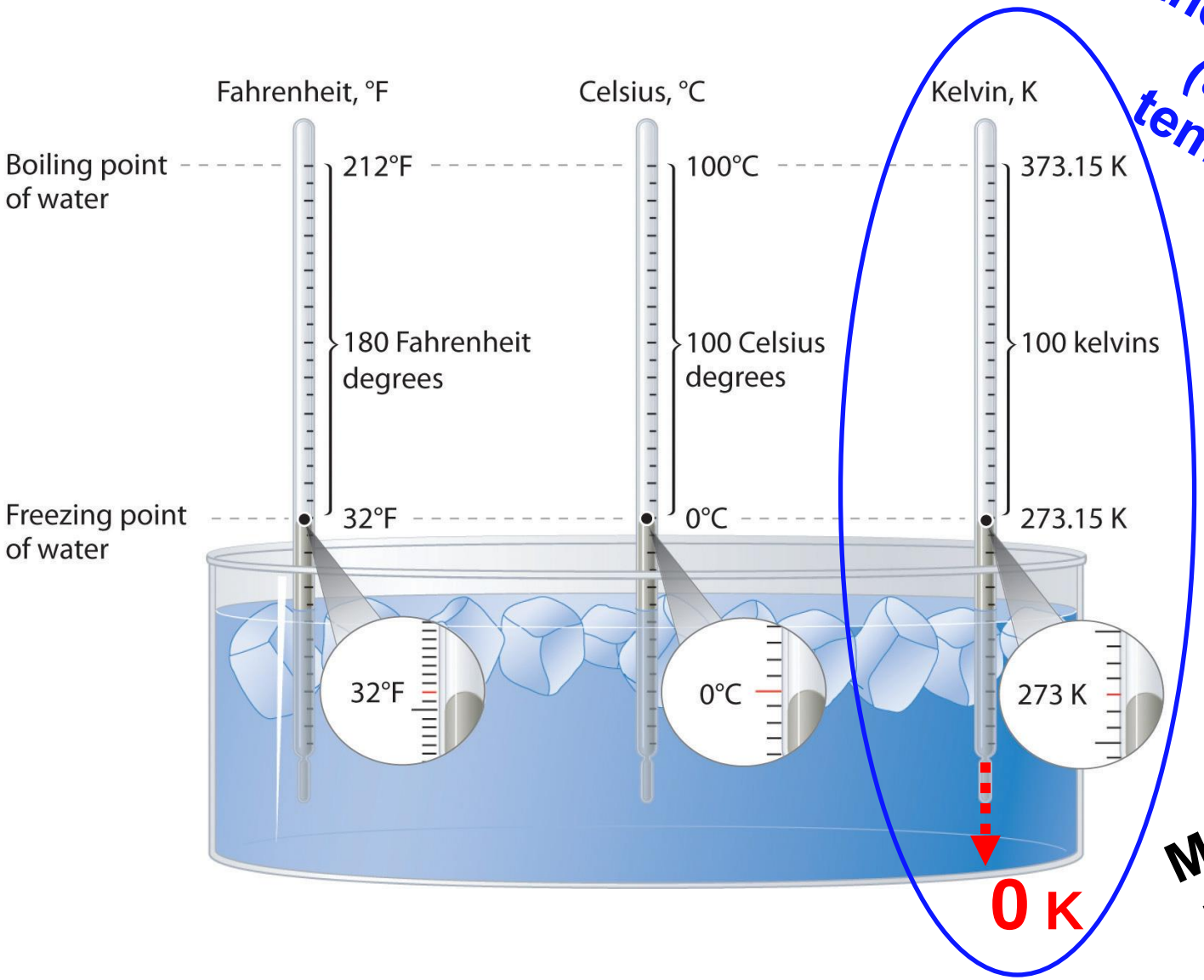


Example: ICE ⟶ WATER ⟶ WATER VAPOR

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 <u>motion</u>* 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

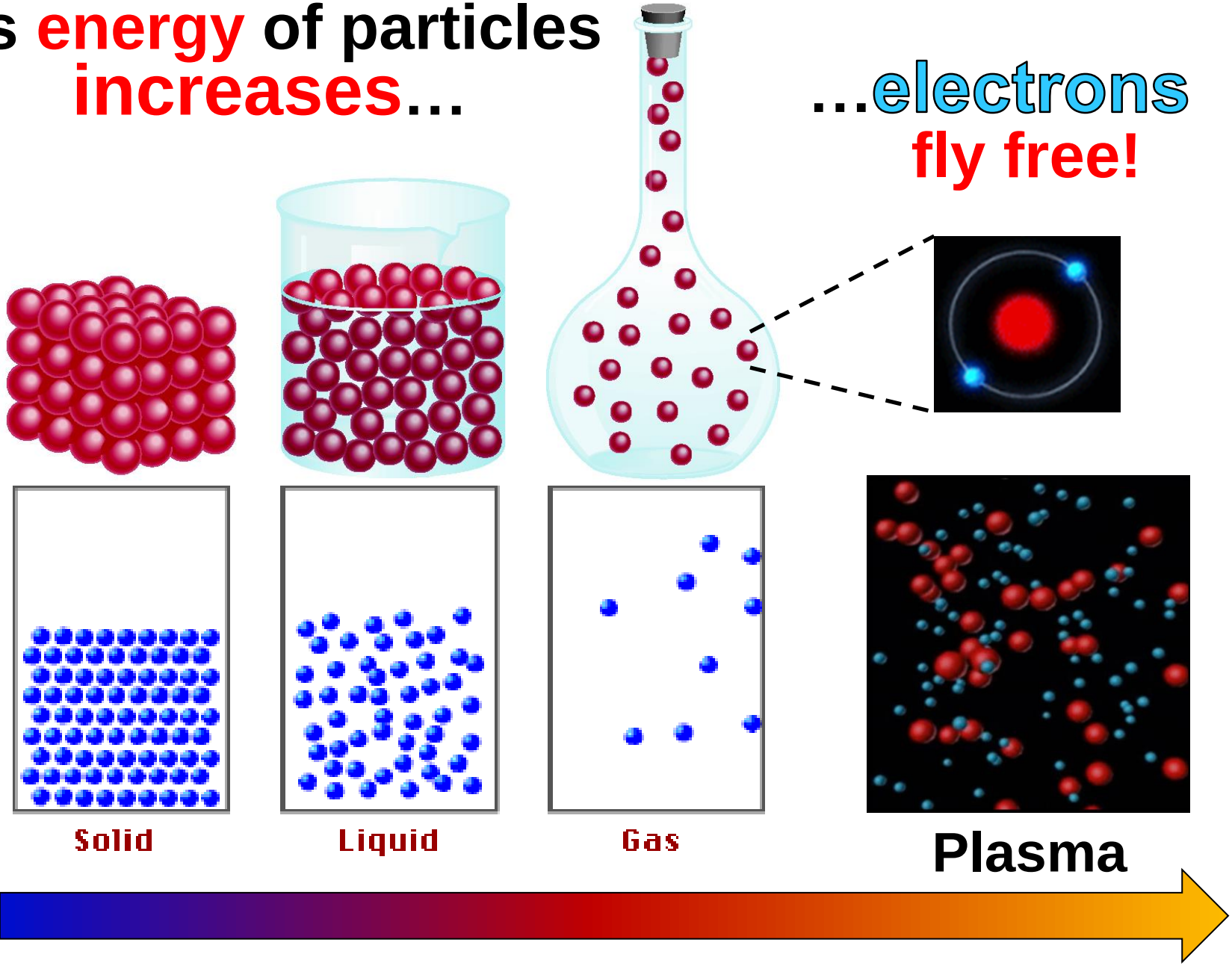
Motion of particles stops!

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

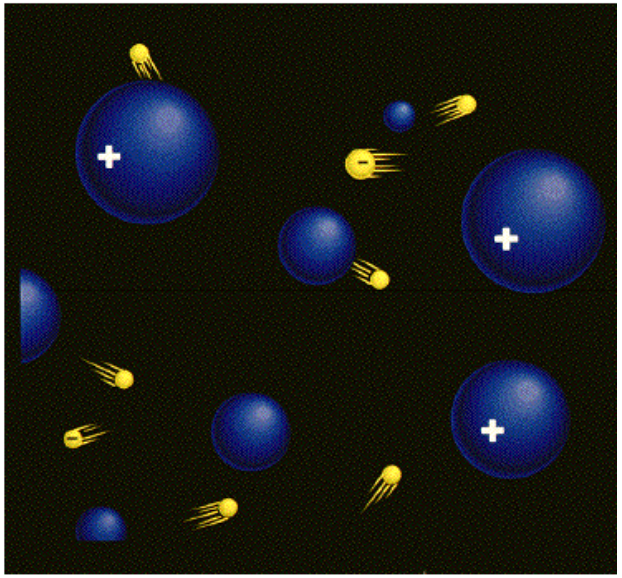
Will everything just be a gas?

As energy of particles increases…

…electrons fly free!



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:**
  - **by exposing gas to extremely high temperatures that cause electrons to leave the atoms**
  - **from a huge voltage difference between two points**

Plasma is a common state of matter!

Some places where plasmas are found…