States of Matter

***Focus Question**: How do particles in the three states of matter behave differently?*

What's the Matter?

Think about the different states of matter you have observed water in: the **solid** ice you place in a drink on a hot day, the water vapor (**gas**) that you breathe out onto a window on a cold day, and the **liquid** that living things need to survive. All three of these examples, though different in appearance, are actually made of the same exact elements: One oxygen and two hydrogens bonded together. All living and nonliving matter on Earth, like water, are also made up of similar particles called **atoms** that when arranged in different combinations make up all **matter** in the universe. Thus, these microscopic **atoms** can be called the basic building blocks of all matter. Atoms can also bond with each other to create combinations called **compounds** or **molecules**. For example, a carbon dioxide **molecule** is made up of 2 oxygen atoms joined with one carbon atom (diagram on the right).

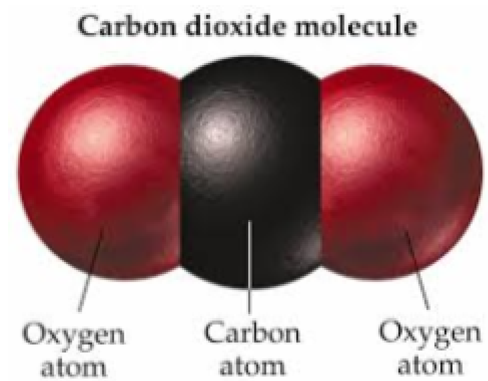

Figure 1. Atoms that make up a carbon dioxide (CO2) molecule. (Taken from CUNY.edu)

Basic States of Matter — Solid, Liquid, Gas On Earth, matter is mostly found either as a solid, liquid, or gas. In all three of these states, water is still made up of the same type and number of atoms: two hydrogen atoms joined to one oxygen atom. To the right are simplified models of the three different states of matter.

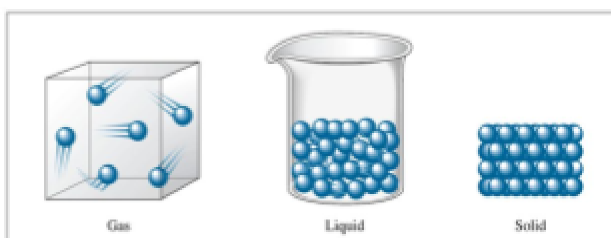

Figure 2

One is a solid, another is a liquid and the other is a gas. In Figure 2, the little motion lines show that the particles (atoms or molecules) moving. The speed of the particles' motion or movement is different in each state of matter. In Figure 2, the particles in the gas states are moving faster than the particles in the solid state.

States of Matter

Focus Question*: How do particles in the three states of matter behave differently?*

Attraction Compared to Motion The atoms or molecules that make up a solid, liquid or gas are also attracted to each other (much like a magnet is attracted to the refrigerator.) In all three states of matter, the molecules that make up the substance want to move around; however, they are also attracted to each other. This attraction tends to keep the atoms or molecules grouped together, while the motion tends to make the atoms or molecules move farther apart. *When in motion, particles of a substance have more* ***kinetic energy*** *(the energy of motion) and thermal energy.* In Figure 3, notice the difference in spacing between the particles of a solid, liquid, and gas. What would happen if one could increase the overall kinetic energy of the particles in one of the states?

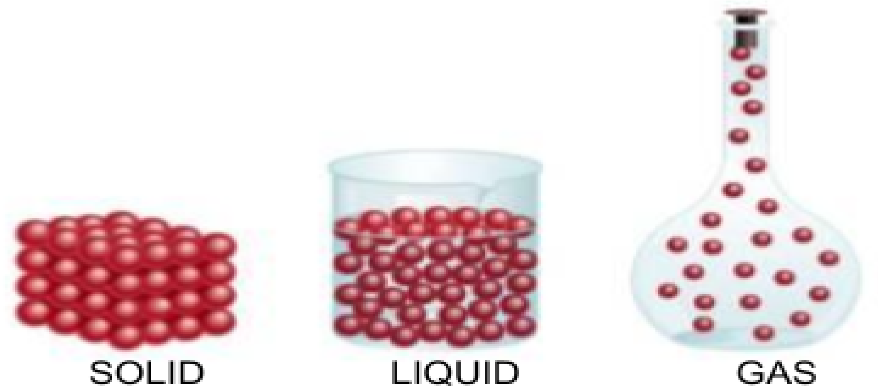

Figure 3. The spacing between the particles in the three states of matter.

In a **solid**, the atoms are very attracted to one another. Because of this strong attraction, the atoms are held tightly together. The attractions are strong enough that the atoms can only vibrate where they are. They cannot move past one another. This is why a solid keeps its shape, meaning solid has a definite shape and occupies a definite space (volume).

In a **liquid**, the molecules are also in motion. The attraction between the molecules in liquids are strong enough to keep the molecules close to each other, but they don’t have to stay in the same place and can move past one another. This is why a liquid can easily change its shape, meaning that liquid has undefined shape (copies the shape of its container) but occupies a definite space (volume).

States of Matter

***Focus Question**: How do particles in the three states of matter behave differently?*

In a **gas**, the molecules are also moving. *The attraction between the molecules of a gas are too weak to bring the molecules together*. This is why gas molecules barely interact with one another and are very far apart compared to the molecules of liquids and solids.

Heating and Cooling:

Heating and cooling a substance can affect how far apart or close together the molecules are. One example is the red alcohol inside the thin tube of a thermometer. When *heat is added to the thermometer*, the molecules of alcohol move faster. This faster motion competes with the attraction between the molecules which causes them to spread out a little. Thus, the molecules now have **more kinetic energy** and spread out more. They have nowhere else to go so they move up the tube.

When *the thermometer is cooled*, the molecules of alcohol *slow down.* Since the molecules slow down, their attraction to each other increases and they move closer together. As a result, the molecules have **less kinetic energy** and the stronger attraction between the molecules brings the alcohol down in the tube.

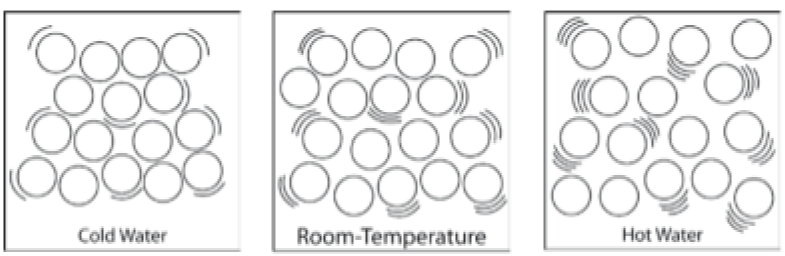

Figure 4. Images of water molecules and different temperature. Notice the difference in movement and spacing.

States of Matter

***Focus Question**: How do particles in the three states of matter behave differently?*

Kinetic Energy, Energy Transfer and Changing Phases:

Since molecules are always moving, every substance has a specific amount of **kinetic energy.** For example, if you place a cold spoon in a hot liquid, the molecules of the hot liquid move so quickly they hold high amounts of kinetic energy. The fast-moving molecules from the hot liquid *transfer some of their kinetic energy to the slower atoms of the cool spoon.* The slower atoms of the cold spoon now have more kinetic energy. *This process of transferring energy by direct contact is called **conduction**.* The opposite is also true when a hot metal spoon is put into a freezer. *The atoms in the spoon transfer some of their energy to the air molecules in the fridge*, making the spoon cool down and lose energy.

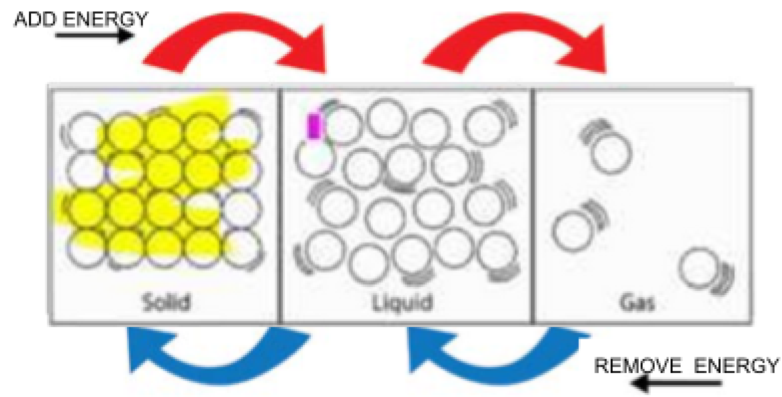

Figure 5. The phase changes caused by adding and removing energy.

This transfer of energy can also lead to a **phase change**, where enough kinetic energy has been added to or removed from a substance so that the particles that make up that substance change how they behave. For example in Figure 5, as energy is added to a solid, the particles move more and spread out. However, as energy is removed, the gas particles slow down and move closer together. Yet, not all substances behave the same, e.g. water is the only substance whereas a liquid, the molecules are closer together than as a solid. Thus, solid water floats on top of liquid water.