## 2: ***Packaging Stuff***

So you want to understand stuff, eh? I mean, you want to understand the makeup of matter. Well, you are on your way, bright student.

Once upon a time there was a stuff packager. Her job was to package stuff. She picked the right sized box to put in just the right amount of stuff. But this wasn't just any stuff packager; she had the special ability to pack stuff in space. What I mean is, she could move stuff around in space and it would stay where she put it. That's why they paid her the big bucks. Sometimes she left out the space and packed things tightly. At other times she would put in a little space and pack things more loosely. At yet other times, she would pack things so that there was mostly empty space and very little stuff.

*The "fog" that is often seen lying above a pool of water on a humid morning is water that has evaporated and cooled there. It is no longer a gas because it is not completely spread out; instead, it is tiny droplets of water that have gathered. The droplets are not massive enough to overcome friction with the air and fall to the earth under the pull of gravity, so they linger in the air until the energy from the sun becomes intense enough to evaporate them again.*

Interestingly, when she packed differently, the stuff acted differently. When she packed tightly, the stuff got stiff. Stiff stuff can sometimes be useful. When she packed more loosely, she found that the

A glacier is a large mass of ice that grows forward or shrinks back depending on the temperature of the surrounding air.

stuff filled the container from the bottom up, but the stuff never got stiff. She could put her hand into the stuff and it would move out of the way for her. When she took her hand out of the container, some of the stuff would be on her hand and she would have to wipe it off.

Finally, when she packed with mostly empty space, the stuff moved freely about the box. Sometimes stuff bumped together with other stuff. She had to shut the lid quickly or the stuff would bump right out of the box to spread out within the packaging room. But if she got the box closed on the stuff, it would just spread itself throughout the box.

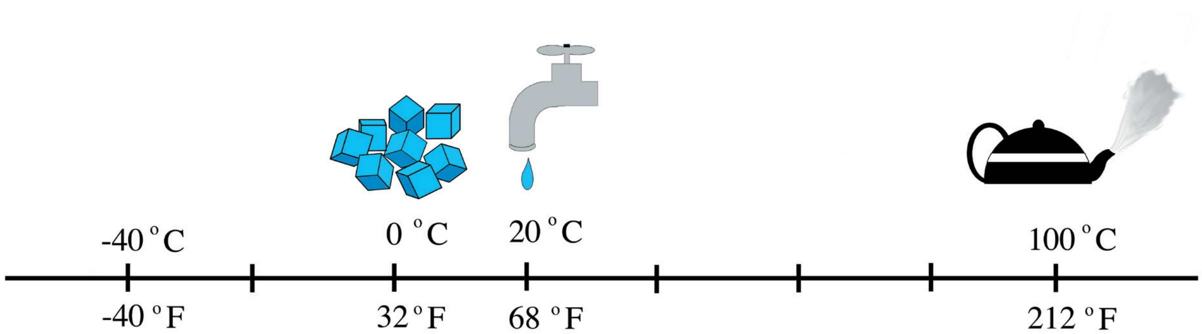
What we have just described are **solids**, **liquids** and **gases**. The stiff stuff is solid, the looser stuff is liquid and the very loose stuff is gas. This story is designed to help you visualize what these three types of matter might look like if you could really see the particles making them up. Solids are stiff, tightly packed particles that don't move freely. Liquids move freely, but fill a container from the bottom up. Gases fill the full volume of any container in which they are placed, and are happy to escape their container to move about the room.

Now let's zoom out from the particles and consider the stuff that we see around us. The floor is solid, water is liquid, and air is gaseous. Almost every kind of matter is either solid, liquid or gas, or some combination of these. There are also a few substances like gelatin and ice cream that we call **semisolids**, but for the most part everything fits nicely into one of these three categories. These are called the **phases** or **states** of matter.

Matter sometimes undergoes a change from one of these phases to another. The way you cause matter to change phases is to put in or take away energy. For example, tightly packed solid molecules, when heated up, start moving more rapidly; this movement expands the substance and creates more distance between the molecules. If enough heat is applied, the forces binding the particles together are overcome by the particle motion, and the particles become more loosely arranged. At that point they become liquid. If you continue to add heat, they can break apart even farther to become gas. To return these particles to their original state, all that is necessary is to let them cool. A nice, everyday example of these phase changes is the changes that take place in water.

When you put water in the freezer, heat leaves it and its temperature drops. When the temperature drops, the water molecules slow down and take on a tighter, crystalline arrangement. The liquid changes to solid—ice. When it warms back up to room temperature, it changes again from solid to liquid. This is not so thrilling because we've seen it since we were little kids. What is nifty is that other liquids also change to solids when they get cold (although some liquids have to get *really* cold before they turn to solids). Also, gases change to liquids. This illustrates that gases are just liquids hanging loose, and that liquids are solids hanging loose. How loose the particles of a substance are depends on the strength of the forces attracting those particles and on the amount of heat energy around them.

What happens when you boil water? **Steam** comes off the water. We say it **evaporates**, or turns to vapor. And if you boil the water long enough, there will be no water left in the pan. That's because it all turns to steam. But what is steam? It's a gas. You might say it's water gas. When steam cools, what happens? It turns back into water.




*This diagram shows the relationship between the Fahrenheit and Celsius scales. Notice that there is nearly a two-degree change in Fahrenheit for each degree change in Celsius. The two scales cross at approximately –40 °.*

Water turns to ice when its temperature falls below 0ºC. It turns to gas if the temperature rises above 100ºC. But what about other liquids? Do they change from solid to liquid or from liquid to gas at the same temperatures? No. Each solid has its own unique **melting point** at which it turns to liquid, and every liquid has its own unique **boiling point** at which it turns to gas. These are just two facts of nature—observations about the way heat affects matter. At a later time, we will learn how important the melting and boiling points of different compounds are. In fact, we will learn that life as we know it would be impossible without the melting and boiling points of water being *just* as they are.

When a pan of water is placed on a burner, the temperature of the water starts going up. The heat passes from molecule to molecule. One molecule heats up and passes some of that heat off to its neighbors. Occasionally a molecule will become so energetic with all of the heat it has received that it will yell "yowee" and break free into the air. Its neighbors will heat up in the same way until they are all bouncing around trying to get out of there. Each time a hotter molecule leaves the pan, it takes some of that heat with it. So while the heat beneath the pan heats up the water, the leaving of the overheated molecules cools it down. The temperature of the water that remains in the pan stays the same until every molecule has escaped and all the water has been boiled out. That temperature, called the boiling point, is precisely 100ºC. How did it turn out to be exactly 100ºC? Simple. Some scientist made up the temperature scale to match water precisely.

Because of this property, the boiling of water can be used to keep a constant temperature. If a recipe tells you to simmer soup in a pot for three hours, the soup will remain at its boiling point (which will be near the boiling point of water) as long as liquid water remains in the pan and the stove provides enough heat to keep the soup boiling. When all of the water is evaporated away, there are no

*There are some scenes where all three phases of matter are present at the same time. Once again, the gaseous water cannot be seen, but where there are droplets of water in the air, they have often formed from the condensation of gaseous water.*

more particles of water to keep taking heat away from the pan. The temperature will rise quickly (and the stuff left in the pan will burn).

Once steam is made by heating water, the steam will go out into the cool air and its temperature will drop to below the boiling point again. Steam will cool and the tiny water droplets will combine to make liquid water again. This conversion of steam to water is called **condensation**. Condensation is the process by which rain forms in clouds, dew forms on morning grass, and fog forms in cool moist air.

*A hoarfrost occurs when fog from the air crystallizes directly on the limbs of trees.*

Exercises:

1. Why doesn't fog form in the middle of the afternoon?
2. On which day is snow more likely—a day when the temperature is –20ºC, 0ºC, or 20ºC?
3. If you wanted to melt a stick of butter without burning it, you could melt it at 100ºC. What is a practical way of doing this?