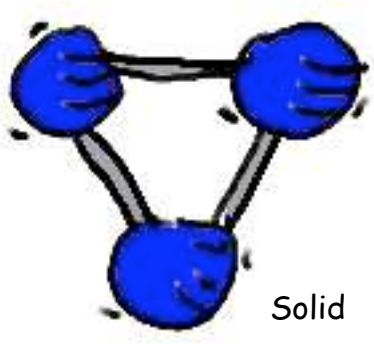
Changes of State

Last lesson we learned about thermal energy and temperature. Objects whose molecules are moving very quickly are said to have high thermal energy or high temperature. The higher the temperature, the faster the molecules are moving. You may remember that temperature is just a speedometer for molecules.

You may have asked yourself the question, "So, if everything is made of molecules, and these molecules are often speeding up and slowing down...what happens to the stuff these molecules are are made of if they change speed a lot? Will my kitchen table start vibrating across the room if the table somehow gets too hot?" No, it's pretty unlikely that your table will begin jumping around the room, no matter how hot it gets. However, some interesting things do happen when molecules change speeds.

Changes of State

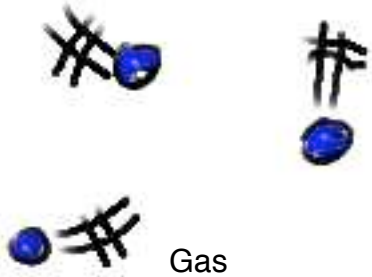
Matter has a tendency to hang out in fairly stable states under normal temperatures. There are three common states of matter; solid, liquid, and gas. There is one more state of matter called plasma but it is not common on Earth. Plasma is a highly energized gas. It is used in florescent lights. I'm going to assume you know a bit about solids, liquids and gasses so I won't go into much detail about them here. What I do want to talk about, is what happens as temperatures change in a substance. Let's take one of the neatest substances on the Earth, water. Water is quite special since it can be in its solid, liquid and gas state at relatively "normal" temperatures. It's quite special for a variety of other reasons too, but we'll leave it at that for now. Pretend we have an ice cube on a frying pan (poor ice cube). Right now the water is in a solid state. It's holding its shape. The molecules in the water are held together by strong, stiff bonds. These bonds hold the water molecules in a tight, very specific pattern called a matrix (yea, like the movie....cool huh?). This matrix holds the water molecules in a crystalline pattern and the solid water holds its shape. Now, let's turn on the heat. The heat is transfered from the stove to the



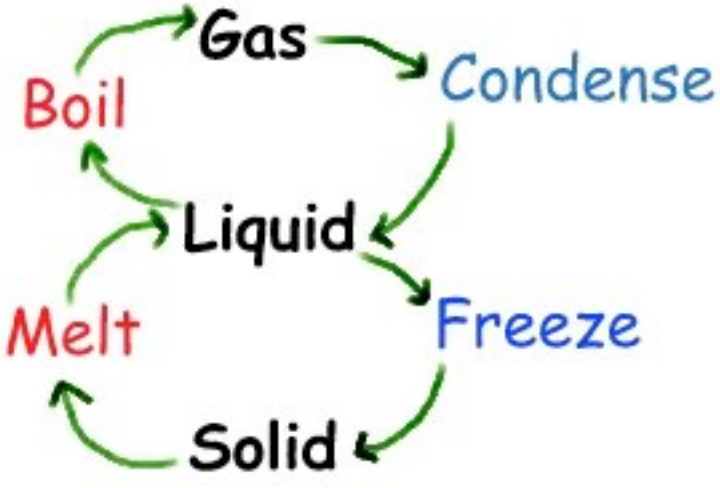
Solid

frying pan to the ice cube. We'll talk about heat transfer in a later lesson. As the ice cube absorbs the heat the molecules begin to vibrate faster (the temperature is increasing). When the molecules vibrate at a certain speed (gain enough thermal energy) they stretch those strong, stiff bonds enough that the bonds become more like rubber bands or springs. When the bonds loosen up, the water loosens up and becomes liquid. There are still bonds between the molecules but they are a bit loose allowing the molecules to move and flow around each other. The act of changing from a solid to a liquid is called melting. The temperature at which a substance changes from a solid to a liquid is called its melting point. For water, that point is 32° F or 0° C. Now, we will watch carefully as our ice cube continues to melt (little is more exiting then watching an ice cube melt…golf maybe). A bit after we see our ice cube go from solid to completely liquid, we notice bubbling. What's going on now? If we were able to see the molecules of water at this point we'd be quite amazed at the fantastic scene before us. At 212° F or 100° C water goes from a liquid state to a gaseous state. This means that the loosey goosey bonds that connected the molecules before have been stretched as far as they go, can't hold on any longer and "POW" they snap. Those water molecules no longer have any bonds and are free to roam aimlessly around the room. Gas molecules move at very quick speeds as they bounce, jiggle, crash and zip around any container they are in. The act of changing from a liquid to a gas is called evaporation or boiling and the temperature that a substance changes from a liquid to a gas is called its boiling point. I don't know about you but I think it's getting a bit hot in here. Let's turn the heat down a bit and see what happens. If our gaseous water molecules get close to something cool, they will combine and turn from gaseous to liquid state. This is what happens to your bathroom mirror during a shower or bath. The gaseous water molecules that are having fun bouncing and jiggling around the bathroom get close to the mirror. The mirror is colder then the air and as the gas molecules get close they slow down due to loss of temperature. If they slow enough they form loosey goosey bonds with other gas molecules and change from gas to liquid state. The act of changing from gas to liquid is called condensation and the temperature that molecules change from a gas to a liquid at is called the condensation point.


Liquid


Gas

Clouds are made of hundreds of billions of tiny little droplets of liquid water that have condensed onto particles of some sort of dust. Now let's turn the heat down a bit more and see what happens.



As the temperature drops and the molecules continue to slow the bonds between the molecules can pull them together tighter and tighter. Eventually the molecules will fall into a matrix, a pattern, and stick together quite tightly. This would be the solid state. The act of changing from a liquid to a solid is called freezing and the temperature that it changes at is called (say it with me now…) freezing point.

Think about this for a second…is the freezing point and melting point of an object at the same temperature? Does something go from solid to liquid or from liquid to solid at the same temperature? If you said yes you're right! The freezing point of water and the melting point of water are both 32° F or 0° C. The temperature is the same. It just depends on whether it is getting hotter or colder as to whether the water is freezing or melting. The boiling and condensation point is also the same point. Now I'm going to mess things up a little bit. Substances can change state at temperatures other than their different freezing or boiling points. Many liquids change from liquid to gas and from gas to liquid relatively easily at room temperatures. And, believe it or not, solids can change to liquids and even gases and vice versa at temperatures other than the usual melting, freezing, or boiling points. So what's the point of the points? At a substance's boiling, freezing, etc, points, all of the substance must change to the next state. The condition of the bonds cannot remain the same at that temperature. For example, at 100° C water must change from a liquid to a gas. That is the speed limit of liquid water molecules. At 100° C the liquid bonds can no longer hold on and all the molecules convert to gas.

Let's take a look at some phase changes.

Experiment 1

Changing Some Phases

Caution: This experiment does use flame and flame can hurt or cause damage! Please be careful and get adult approval for this.

You Need:

Candle

Candle holder

Match

Metal spoon

Long pointy object (pen, toothpick, etc.)

1. **Light the candle.**
2. **Let the candle burn for a little bit and watch as the wax near the flame melts.**
3. **Put the long pointy object into the melted (liquid) wax and pull it out. Watch carefully as it freezes (turns back to solid).**
4. **Take the spoon and put the bowl of the spoon into the flame. Hold it there for less then a second and take it out. Quickly look at the spoon where it was in the flame. You will see that something condensed on the spoon. Try holding the spoon in different parts of the flame. You may be able to get different gases to condense on the spoon.**

Good job you phase changer you! The flame of the candle gave enough heat to turn the frozen wax (bet you never thought of wax as frozen before but it's solid so it's frozen) into liquid, in other words, melt the wax. The flame also provided enough heat to turn that liquid into gas. Or, in other words, boil the liquid. When you stuck the spoon in, you condensed some of the gas back into liquid which very

quickly refroze to either carbon, or wax. You may have gotten different gases to condense on the spoon depending on where you stuck the spoon into the flame. Sometimes you can get water to condense on the spoon as well.

Experiment 2

The Condensonator

You need:

Ice

Glass of water

Preferably a humid day

1. Fill the glass with cold water.
2. Put the ice into the water.
3. Wait.

Okay we're back to the excitement of melting ice cubes, sorry about that. But what I hope you see is water gathering on the outside of the glass. Where does that water come from? Does it ease it's way through the glass? Did someone come by and squirt the glass with water? No of course not. You guys know that some of the gaseous water molecules in the air came close enough to the cold glass to lose some molecular speed. Since they lost speed, they formed bonds between each other and liquified. They condensed on the cold surface of the glass. Imagine though, if you will, that you live several hundred years ago and the process of condensation wasn't understood. You happen to be an inquisitive, highly perceptive, person (which of course you are) and you notice this film of water showing up on cold things. Water appearing out of apparently nowhere! You'd be pretty amazed wouldn't you?!? Personally, I still find it amazing that every time I pick up a cold can of soda there are molecular interactions happening right in front of my eyes! This is

why science is so wonderful. It provides the skills to see these amazing things and the skills to investigate and perhaps understand them.

In a Nutshell

There are four states of matter: Solid, liquid, gas and plasma.

Solids have strong, stiff bonds between molecules that hold the molecules in place.

Liquids have loose, stringy bonds between molecules that hold molecules together but allow them some flexibility.

Gasses have no bonds between the molecules.

Plasma is similar to gas but the molecules are very highly energized.

Materials change from one state to another depending on the temperature and these bonds.

Changing from a solid to a liquid is called melting.

Changing from a liquid to a gas is called boiling, evaporating, or vaporizing.

Changing from a gas to a liquid is called condensation.

Changing from a liquid to a solid is called freezing.

All materials have given points at which they change from state to state.

Melting point is the temperature at which a material changes from solid to liquid.

Boiling point is the temperature at which a material changes from liquid to gas.

Condensation point is the temperature at which a material changes from gas to liquid.

Freezing point is the temperature at which a material changes from liquid to gas.

Did You Get It

1. What are the four states of matter?
2. Which states have no bonds between the molecules?
3. Which state has bonds that hold the molecules in a tight matrix?
4. As the temperature increases, what happens to the bonds that allow a substance to go from solid to liquid?
5. What happens to the bonds as a substance reaches its boiling point?
6. What happens to the bonds as a substance reaches its freezing point?

Answers

1. Solid, liquid, gas, plasma
2. Gases and plasma
3. Solid
4. The bonds are forced to stretch and loosen up since the molecules are moving at greater speeds.
5. As a substance reaches its boiling point it changes from a liquid to a gas. As this happens the bonds that are holding the molecules together break allowing the molecules to wander off on their own as a gas.
6. As a substance reaches its freezing point it turns from a liquid to a solid. The bonds tighten up pulling the molecules into a matrix and forming a nice solid substance.