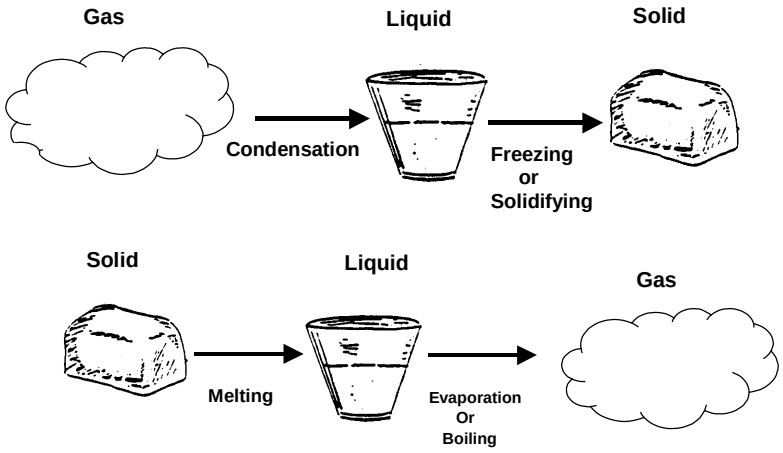
LESSON CLUSTER 7

Explaining Melting and Solidifying

Lesson 7.1: Melting Ice and Freezing Water

Do you remember the first experiment you did in this unit? It was an ice melting race. You learned then about the states of water: ice, liquid water, and water vapor. You also learned how water molecules are arranged and how they move in each state. What you did not learn in the first lesson cluster was how or why water changes from one state to another.

This lesson cluster, as well as Lesson Clusters 8 and 9, is about changes of state in water and other substances. You have seen changes of state many times, and you probably know most of the words that we use to describe them. When a solid changes into a liquid, we call it melting. When a liquid changes into a solid we call it freezing or solidifying. Changes from the liquid state to the gas state are called evaporation or boiling. Changes from the gas state to the liquid state are called condensation. This drawing summarizes all the different changes of state:



Now let's go back to melting ice. When ice melts, one substance (water) is going through a change of state (melting). Can you explain how and why it happened? You already know how molecules are arranged and how they move in solids and liquids. You also know something else important: Molecules move faster when a substance is heated. Let's try putting these ideas together in an explanation of how ice melts.

When ice is warmed it melts into liquid water. The water molecules in ice are locked into a rigid pattern, but as they vibrate faster they break out of that rigid pattern and begin sliding and bumping past each other. Solid ice has melted into liquid water!

(Did the explanation above answer both the question about substances and the question about molecules? Check it and see!)

Ice melts when the water molecules vibrate fast enough to break out of their rigid pattern

Water freezes when it is cooled down and the water molecules move slower. To completely explain how water freezes there is one other thing you need to know about molecules. Water molecules are attracted to each other. This attraction makes the molecules stick together in a rigid pattern if nothing breaks them apart.

But the attraction between molecules keeps them stuck in a rigid pattern only if the molecules are moving slowly. When water molecules are moving fast, their motion keeps them from sticking together. They jiggle apart rather than settling into a rigid pattern. When water gets cold, though, the molecules slow down. Then the attraction between them makes them stick together in a pattern. Liquid water has changed into ice!

Water is not the only substance that melts and solidifies. You will learn about some other substances in the next lesson. First, though, try answering some questions about what you have learned.

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Do Question Set 7.1 in your Activity BooK

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Lesson 7.2: Melting and Solidifying of Other Substances

If you can explain how water melts and freezes, then you can also explain how other substances melt and solidify. Different substances are made of different molecules, so they melt at different temperatures. But the processes of melting and solidifying are about the same for all substances.

Whenever any substance melts, its molecules are moving fast enough to break out of their rigid pattern. Whenever any substance solidifies, its molecules have slowed down enough so that they start sticking together in a rigid pattern.

Can you explain how melting is different from dissolving? In some ways melting and dissolving are alike. Both involve the molecules of a solid breaking out of their rigid array. But the causes of melting and dissolving are very different. Melting is caused by heat: When the molecules of a solid move fast enough, they break out of their rigid pattern. Dissolving, on the other hand, occurs when the molecules of a liquid knock the molecules of a solid apart and carry them away.

Melting is also different from thermal expansion. Both are caused by heat, but in the case of thermal expansion the motion of the molecules just moves them farther apart. Their pattern stays the same. Melting occurs when the motion of the molecules makes them break out of their rigid pattern.

(There are some materials that do not melt and solidify because their molecules break apart when they are heated. This is especially true of substances made from living things, like wood or cloth or paper or meat. When wood is heated, for example, its molecules break apart into smaller molecules. The wood burns if there is oxygen around it. If there is no oxygen, the wood is changed into new substances made of smaller molecules, including charcoal, water, and other liquids.)

One place where you often see materials melt and solidify is in your kitchen. Have you ever melted butter? What about cheese? Chocolate? Caramel? Sugar? Try some activities with kitchen materials that you can melt and solidify.

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Do Activity 7.2 in your Activity Book

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Lesson 7.3: Adventure into the Hot Zone and the Cold Zone

You can see some substances going through changes of state, like water and other things in the kitchen. Other substances, though, always seem to be the same state. Oxygen and nitrogen, for example, always seem to be gases. Steel and rocks always seem to be solids. Can those substances melt and solidify? In order to find out you will have to venture into the hot zone and the cold zone. Get ready!

As you explore the valleys between the highest Himalayan mountains you stumble across two large caves. One is in the north side of the valley, the other in the south. Each cave is marked by a rock column and a message in Hanzi. After conferring with your guide you understand that the column to the north says “The Cold Zone” and the column to the south “The Hot Zone.” The guide further explains that the deeper you go into the tunnel on the north side the colder it gets

and the further you go into the tunnel on the south side the hotter it gets.

You decide to go into the south tunnel first. As you step inside the tunnel there are two rock columns with weird looking clothing suspended between them. After the guide reads the message in Hanzi on the stone pillars, he informs you that unless you wear the special clothing you cannot survive in the tunnel.

After carefully dressing in the special clothing you proceed into the tunnel. You proceed slowly because you can tell that it is quite hot at the end of the tunnel, but just beyond the pillars you recognize a large rock of ice slowly dripping water on your clothing. A little distance beyond the ice rock there is a rock of sugar that is also melting. Beyond that there are a number of familiar metals. First is solder (similar to what plumbers or electricians use). Beyond that

is a huge chunk of aluminum that is melting. It glistens like silver, but it is not quite the same as silver. You can tell

because just beyond the aluminum is silver and then pure gold. The silver and gold have melted and resolidified so that there are beautiful configurations on the walls and on the bottom of the cave. Beyond this you can see sandstone and a variety of rocks melting.

As you keep going, more and more substances melt. There aren't any solids left! By the time you reach 2700 degrees Celsius, all metals are liquids, and so are all rocks. You are swimming now in your magic suit! You put on your magic eyeglasses and see that the molecules are really moving fast. No wonder they won't stay in a pattern! You look forward and the cave back goes on and on into higher and higher temperatures. Some of the liquids are turning into gases and forming bubbles, boiling up out of sight. But it is time to turn back before your suit loses its magic and you become a bunch of liquids and gases!

You come out of that cave and look across the valley toward the north. The cold zone seems very inviting because you are still very hot. As you step inside the cold zone cave, you again see two pillars with very different clothing than you had in the hot zone. It takes you a long time to put this clothing on and it is so heavy that it is difficult to walk. There is also a special light that you will need in the cold zone.

After you make sure that your clothing is adjusted properly and you figure out how to operate the special light, you proceed into the cold zone. And immediately you find a very familiar rock--ice. But just beyond this ice rock, there is something that you hardly believe. It is solid antifreeze. You had thought that antifreeze would not freeze. But it does, and it makes up a beautiful rock. When you get beyond the antifreeze you see another rock that looks like silver. It is hard like silver, too, but it is mercury. Now, mercury is normally a liquid at room temperature, but it is a solid in the cold zone. Deeper in the cave you find solid carbon dioxide or dry ice. You've seen this before, but not nearly as much as in the cold zone.

By the time you reach $-219^{o}C$, there is no more air to breathe. You look around you and see why: Oxygen and nitrogen have turned into liquids, and now

they are solids. The last gas, helium, becomes a liquid at –272^{o}C. It is the only liquid left. Every other substance has solidified!

You look up and see that the cave stops at –273^{o}C. It doesn't go on and on like the hot zone. Your magic eyeglasses show you why. The molecules have almost stopped moving. You have reached absolute zero, the point at which molecules can go no slower. It is time to turn around and go back. You slowly make your way to the two stone columns again. You take off the clothing from the cold zone, hang it on the two pillars, and are eager to get out into the warm sun light between the two Himalayan mountains.

While resting with your guide you express surprise that gases like nitrogen, oxygen, and hydrogen could be solids. He assures you that all substances can be solid if they are cold enough. As you breathe the fresh mountain air, you have more appreciation for the nitrogen, oxygen, and carbon dioxide in the air, because for the first time in your life, you have seen them. You have seen them as solids. The hot zone was not nearly as surprising as the cold zone, because you had seen pictures of volcanoes spewing out liquid rock on television. But the trip to the cold zone was something you will never forget.

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Do Review Question Set 7.3 Now

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