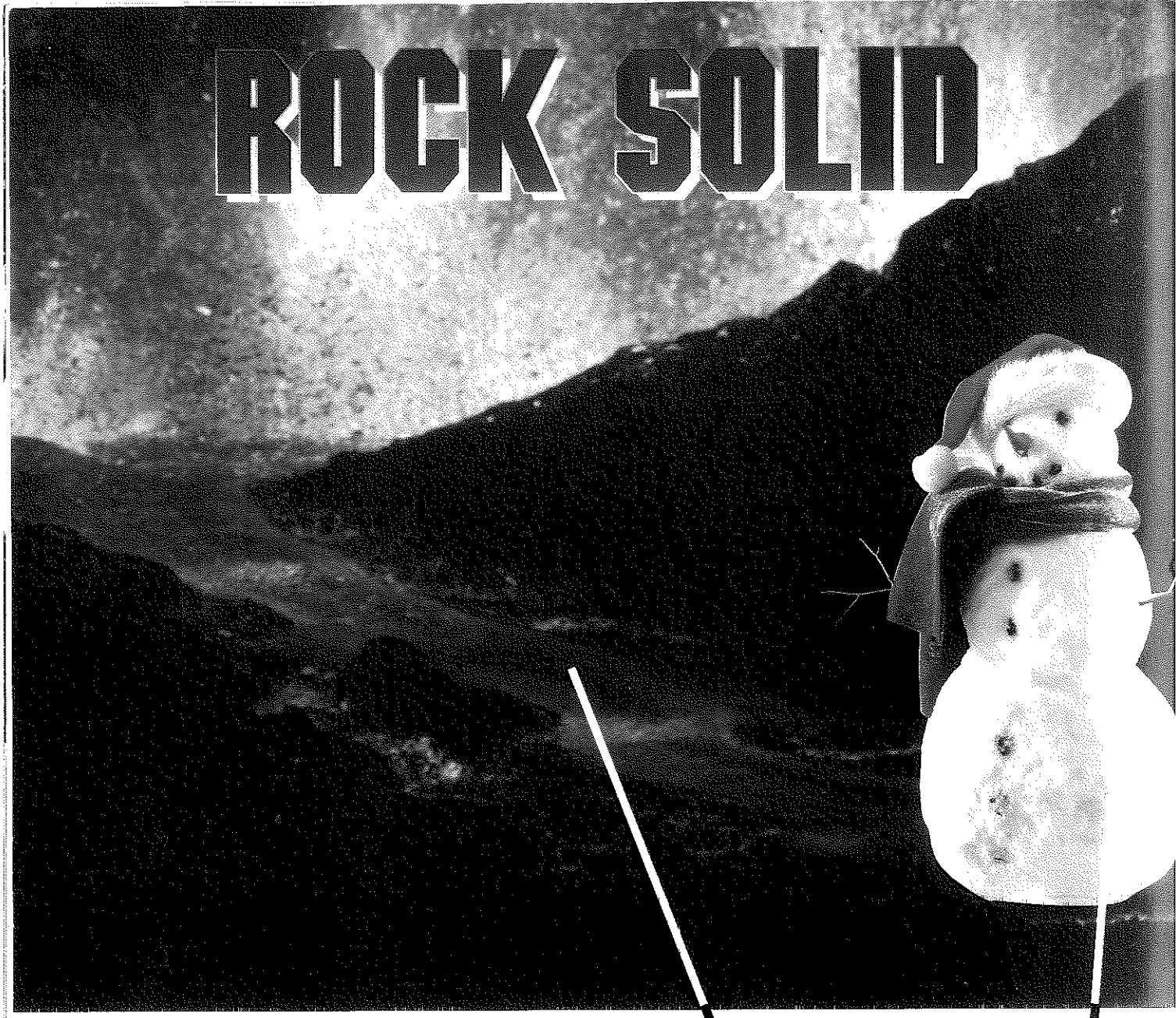
ROCK SOLID



WHAT DOES LAVA POURING OUT OF A VOLCANO HAVE IN COMMON WITH A SNOWMAN?

They are both going to change phase in a short time. The liquid lava will **freeze** and become solid rock. The solid snowman will **melt** and become liquid water.

Most matter on Earth exists in one of three forms, solid, liquid, or gas. The forms are called states or phases of matter.

The clothes you wear, the forks and spoons you eat with, and your books and pencils are a few examples of matter in its solid phase.

The olive oil you put on your salad, the shampoo you use to wash your hair, and a refreshing glass of cold milk are examples of matter in its liquid phase.

The helium in a party balloon, the air you pump into a soccer ball, and the carbon dioxide in your exhaled breath are examples of matter in its gas phase.

PROPERTIES OF THE PHASES OF MATTER

Many substances can exist in more than one phase. The snowman, for instance, is made of solid water. We have many names for solid water, including ice, frost, and snow.

Water can also exist as liquid. Liquid water falls from clouds as rain and flows to your home in pipes. Earth has an ocean filled with liquid water.

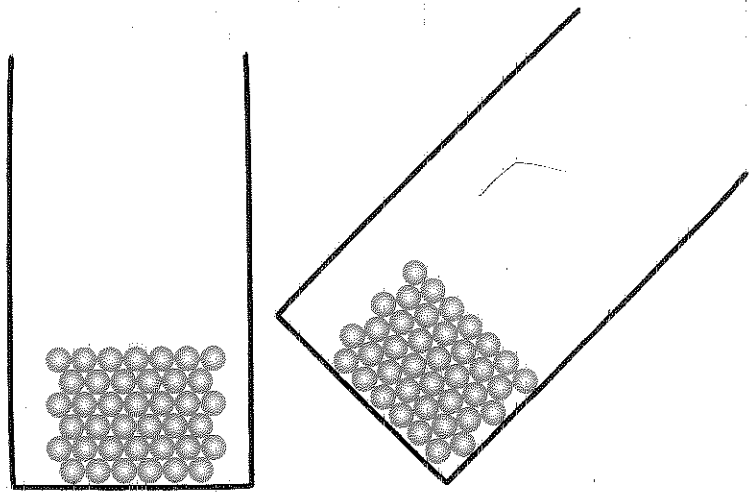
Water also exists as gas. Water in gas phase is called **water vapor**. We are usually not aware of water vapor because it is invisible. Most of the water vapor on Earth is in the atmosphere as part of the air.

Ice, liquid water, and water vapor all look different. But they are all forms of water. What is the same and what is different about ice, water, and water vapor?

All three phases of water are made of exactly the same kind of particle. The chemical formula for the water particle is H_2O. Ice, water, and water vapor are all made of H_2O particles.

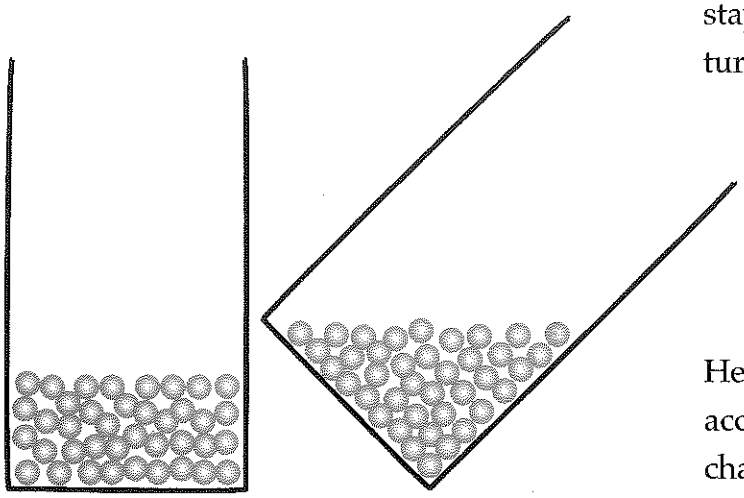
The thing that is different about ice, water, and water vapor is the relationship between the water particles.

In the article called *Three Phases of Matter*, we described how solids, liquids, and gases differ. In solids, the particles are attached to one another. The attachments are called bonds. The bonds in solids are so strong that the particles cannot change positions. That's why solids have definite shape and volume.



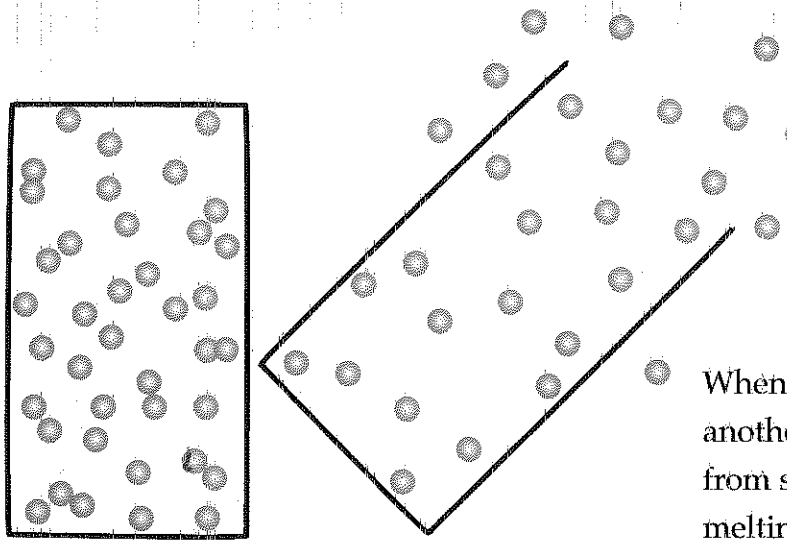
Ice in a vial will move from side to side, but will not change volume or shape.

In liquids, the bonds are weaker. The particles are still held close together, but they can move around and past one another. As a result, liquids flow. That's why liquids have definite volume, but their shape changes.



Liquid water has definite volume, but its shape changes to fit the container it is in.

In gases, the particles are not held together by bonds. Individual particles of gas fly around in space. That's why gases do not have definite volume or shape.



Water vapor does not have definite volume or shape. If the container is open, the gas will expand, and the particles will leave the container.

PHASE CHANGE

The snowman wasn't always solid. And it won't stay solid. The solid snowman will melt and turn to liquid water. The liquid **lava** wasn't always liquid. And it won't stay liquid. The liquid lava will freeze and turn to solid rock.

Change from solid to liquid, and change from liquid to solid, are examples of phase change. What causes substances to change phase?

Heat causes phase change. Or, more accurately, energy transfer causes phase change. Here's how it works.

When a piece of ice is placed in a warm room, energy transfers from the air particles to the water particles in the ice. The kinetic energy of the water particles increases until the ice reaches 0°C.

As more and more energy transfers to the 0°C ice, the bonds holding the water particles together start to break. When most of the bonds are broken, the water particles are no longer held in place. They start to move over and around one another.

When particles flow over and around one another, we say the substance changed from solid to liquid. The process is melting. Substances melt when enough energy transfers to the particles of a solid.

That's why the snowman melts. Energy from the Sun transfers to the water particles in the snow crystals. The bonds holding the snow crystals together break, and the solid water changes to liquid water. The snowman changes into a hat and scarf on top of a puddle of water.

What about the lava? How does it change phase? When lava pours out on Earth's surface, it is extremely hot. The kinetic energy of the rock particles is so great that most of the bonds holding them together have been broken. The rock particles move over and around one another. The rock is liquid, and it flows down the side of the volcano.

Air is cooler than lava. Energy from the rock particles transfers to the air particles. The rock particles lose kinetic energy, and the mass of lava cools. As the lava cools, bonds form between the rock particles. When enough energy has transferred from the rock particles, strong bonds form and the particles are locked in place.

When particles stop flowing over and around one another, we say the substance changed from liquid to solid. The process is freezing. Substances freeze when enough energy transfers away from the particles of a liquid.

That's why the liquid lava freezes and becomes rock solid. Energy transfers from the rock particles, bonds form, and the rock changes from liquid to solid.

MORE HEAT

What happens to the snowman next? After a day or two, all that remains is the hat and scarf. Even the puddle of liquid water has disappeared. Where did the water go?

As sunshine falls on the puddle of liquid water, energy transfers to the water particles. The kinetic energy of the particles increases. When enough energy transfers to a particle, the particle breaks all the bonds holding it to the mass of liquid. The particle breaks free and flies into space. The water changes phase again, but this time from liquid to gas.

The phase change from liquid to gas is called **evaporation** (or vaporization). Water in the gas phase is called water vapor. The individual water particles are too small to see, so water vapor is invisible. Water vapor enters the air and becomes part of Earth's atmosphere.

Water can change from gas to liquid, too. The process involves energy transfer. Can you predict where the energy transfer takes place?

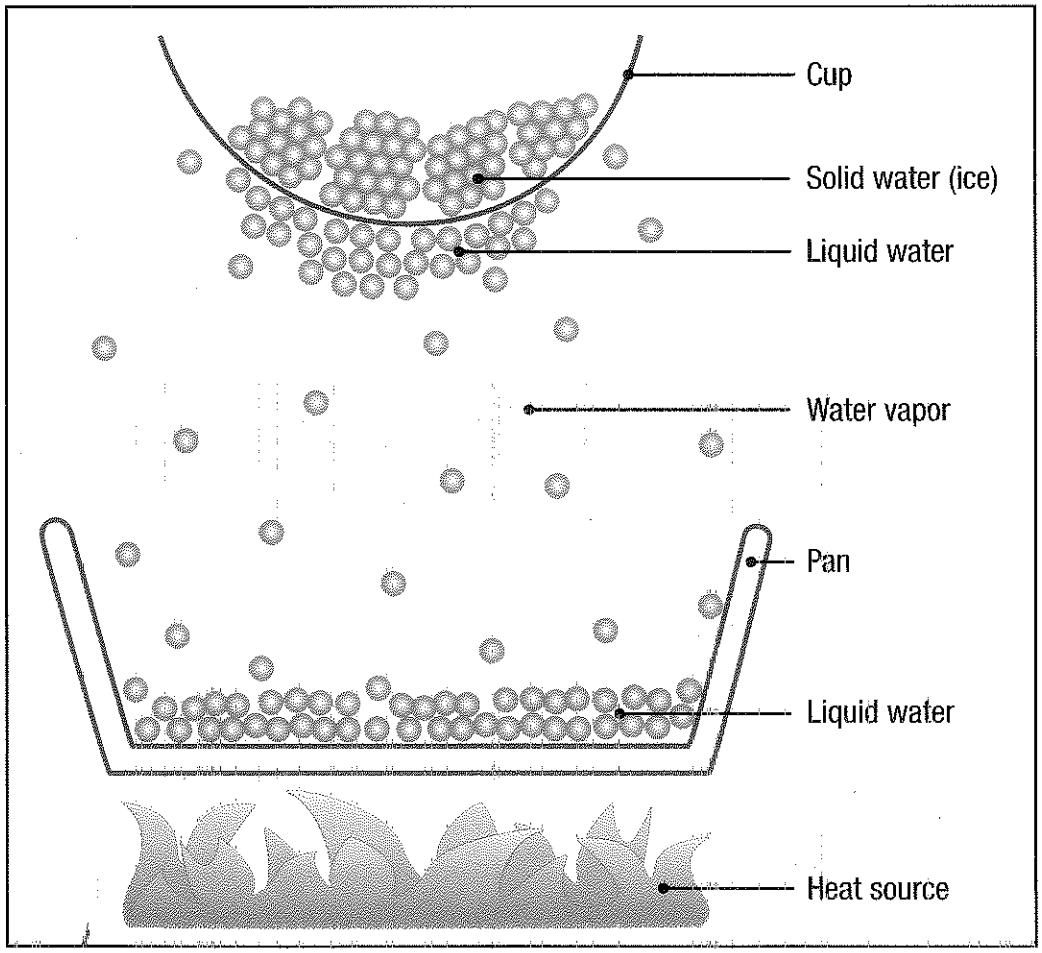
When energy transfers from the water vapor particles, they lose kinetic energy. When enough energy has transferred away from the particles, bonds form between them. The water changes phase from gas to liquid. The process is **condensation**. Substances condense when energy transfers away from the particles of a gas.

Below is an illustration of an experiment similar to the one you did in class. A pan of liquid water is heated. Water evaporates. The water vapor condenses on a cup filled with ice. Study how the water particles change phase from liquid to gas, and then back to liquid. You should be able to see where evaporation and condensation are taking place.

MELT AND FREEZE

There are three important things to understand about melting and freezing.

Substances don't have to be cold to freeze. *Freeze* just means changing phase from liquid to solid. Granite freezes at about 1,650°C. On the other hand, oxygen freezes at –218°C. Every substance has its own freezing temperature.



Liquid water evaporates when it is heated. Water vapor condenses on the outside of a cup containing ice.

Phase is a relationship between particles. The phase of a substance is determined by what is happening between the particles in the substance. Particles in solids have strong bonds, particles in liquids have weak bonds, and particles in gases have no bonds.

Freezing temperature = melting temperature. A substance freezes and melts at the same temperature. Water, for instance, freezes and melts at 0°C. If you move a piece of ice from a freezer to a warm room, the ice will warm up until it reaches 0°C. Then it will melt. If you put a cup of warm water in a freezer, the water will cool until it gets to 0°C. Then it will freeze.

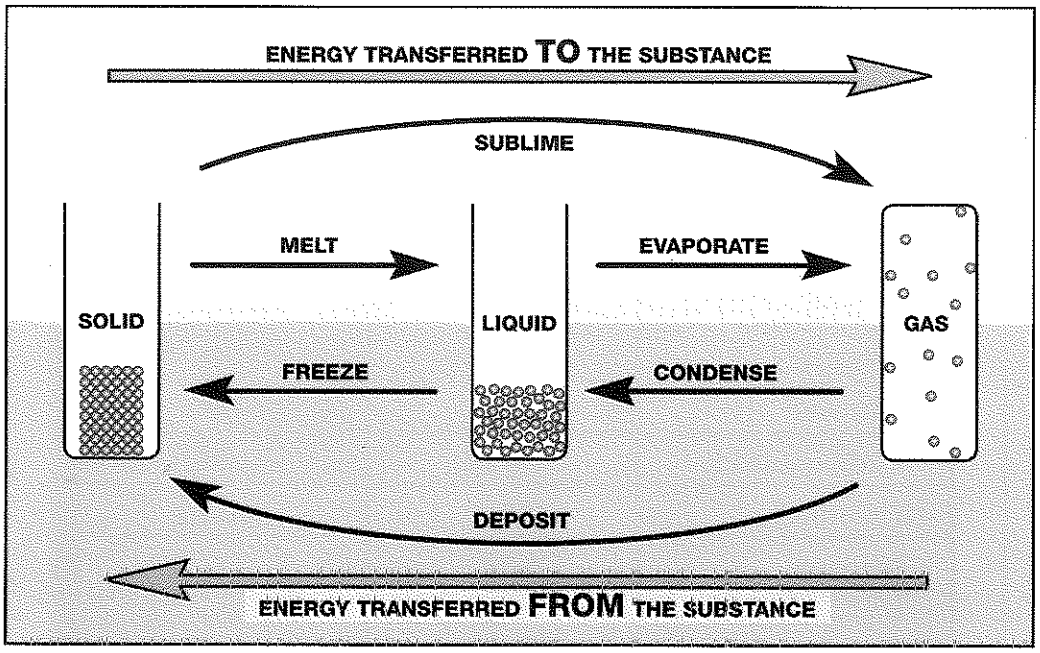
The temperature at which a substance evaporates is the same as the temperature at which it condenses. Water, for instance, evaporates and condenses at 100°C.

Substance	Freeze/melt (°C)	Condense/evaporate (°C)
Helium	–272	–269
Oxygen	–218	–183
Nitrogen	–210	–198
Carbon dioxide	—	–78
Chlorine	–101	–34
Mercury	–39	357
Water	0	100
Sodium	98	883
Lead	327	1,749
Aluminum	660	2,519
Calcium chloride	775	1,936
Sodium chloride	801	1,465
Silver	962	2,162
Gold	1,064	2,856
Copper	1,085	2,562
Iron	1,538	2,861
Tungsten	3,422	5,555

The freeze/melt temperatures and condense/evaporate temperatures for some common substances

This illustration summarizes how energy transfer affects phase change. The top half shows how substances go from solid to liquid to gas as energy transfers to the particles of the substance. The bottom half shows how substances go from gas to liquid to solid as energy transfers from the particles of the substance.

Notice that it is possible for a substance to go straight from solid to gas. Carbon dioxide is an example of a substance that **sublimes**. And, when energy transfers from carbon dioxide gas, it **deposits** as solid without going through a liquid phase. Solid carbon dioxide is called **dry ice**.



Phase-change vocabulary

REVIEW QUESTIONS

1. What causes a substance to change from one phase to another?
2. What are the three important things to know about freezing and melting?
3. Why does liquid water form on the bottom of a cup of ice placed over warm water?
4. What happens to water particles as a cup of ice melts and then evaporates?