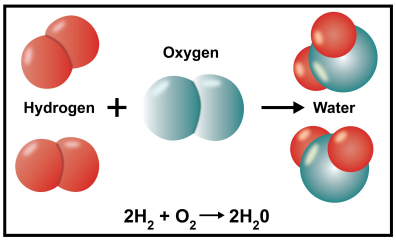
Changes in Energy on the Molecular Level

Reflect

Matter is all around us! Look at the picture of the hot-air balloon on the right. You can see different forms, or **states of matter**, called solids, liquids, and gases. Which matter appears to be solid, where the atoms are closely spaced and very dense? The grass, trees, and mountains are examples of solids. The fabric and the basket on the balloon are also solid. Can you see matter that is liquid that can flow and is less dense than solids? The water in the lake is a liquid. Where in the picture do you see gas, where the particles are widely scattered? Air is a mixture of gases. Hot air inside the balloon is less dense than the air outside the balloon, so it rises. Is matter capable of changing state or form? How are these changes possible? Are they reversible? These are all excellent questions! The answers help us understand the different forms of matter.

states of matter – distinct forms of matter known in everyday experience; solid, liquid, and gas; also referred to as phases



Molecules and Atoms

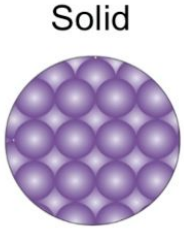
Matter is made up of *molecules* in any state. Molecules are made of small particles, called atoms, that are packed together. You cannot see molecules or atoms easily. You would need to use powerful microscopes to see how these are arranged, or spaced together. In the image on the left, two hydrogen atoms and one oxygen atom combine to form each molecule of water.

Look Out!

Adding or removing thermal energy can change the state of matter.

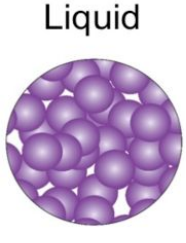
Matter in a Solid State

When a material is in a solid state, the atoms are packed closely together and vibrate, but they do not change relative locations. There is minimal space between them. Solid structures have a specific shape and volume. *Volume* refers to the amount of space an object occupies. Molecules in a solid do not flow. Instead, they stay in the same position, resulting in the solid holding its shape.



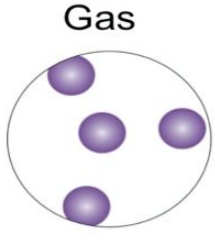
Matter in a Liquid State

Unlike molecules in a solid state, molecules in a liquid form flow. The molecules move about relative to each other. When a material is in a liquid state, the atoms are packed loosely, creating a structure with a definite volume but no definite shape. This means that even though we can measure how much space is being taken up, the actual shape of the substance changes. Can you think of some everyday liquids?



Matter in a Gaseous State

When a material is in a gas state, its molecules (or atoms) are spread out freely; gases have no definite shape or volume. Molecules (or atoms) move about relative to each other and are widely scattered, except during collisions.



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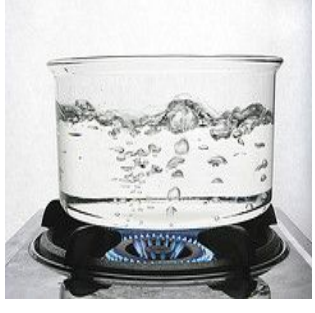
What Do You Think?

We interact with solids, liquids, and gases on a daily basis. Can you think of some examples of when we need these three states of matter for our survival? List one of each state and the rationale, or reason, for why each is necessary.

Changing the State of Matter by Adding Heat

Adding heat (thermal energy) increases the kinetic energy of the molecules in a substance until a change of state occurs, such as melting or boiling.

Melting: Look at the picture on the right of the melting ice cubes. How does adding heat from the surrounding air affect the motion and arrangement of the water molecules as the ice melts? As energy is transferred to the water molecules in the ice, the motion of the molecules increases and they vibrate faster. As they vibrate faster, the space between molecules increases. The motion of the molecules increases enough that it overcomes the attractions the water molecules have for each other, causing the ice to melt from a solid to a liquid. The melting point of water is 0°C.



Boiling: If increased heat were added to a liquid, it is likely that the liquid's atoms would similarly separate and push apart if the temperature were hot enough. This would result in yet another change in the state of matter. You have likely seen this when boiling a substance. With water, for example, a temperature of 100°C would create conditions for the liquid to become a gas. Do note, however, that this exact temperature is a property of water. This is not a universal temperature that fits all materials. It is unique to water!

Try Now

In the picture of the water in the pot above, there are some changes happening to the liquid. What are they? List three changes that are occurring. Be sure to use science terminology that includes matter and thermal energy. For example, the water in its liquid state is boiling.

Changes in Energy on the Molecular Level

Reflect

Changing the State of Matter by Removing Heat
Removing heat (thermal energy) decreases the kinetic energy of the molecules in a substance until a change of state occurs, such as condensation or freezing.

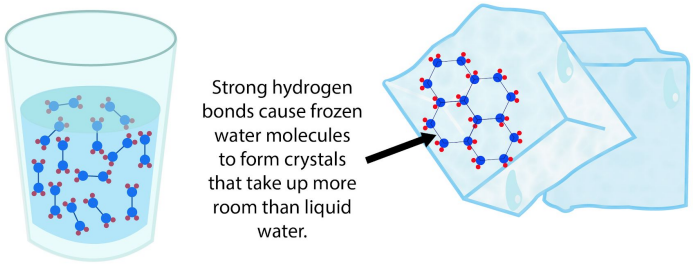
Condensation: Removing heat from a gas decreases the movement of molecules. When water in its gaseous state, called *water vapor*, cools, it changes state and condenses as liquid water droplets onto the surrounding window pane.

Freezing: Removing heat from a liquid causes the molecules to slow down as they lose kinetic energy and just vibrate in place. The molecules form a solid with a definite shape and volume. Liquid water freezes into solid ice at 0°C.

Look Out!

Water's Unique Property
Most liquids take up less space when they freeze. Their molecules slow down and become densely packed. Water has a special property in which it does the opposite—it expands when it freezes! During winter, uninsulated pipes can burst when water freezes and expands. Water molecules form a hexagonal lattice when they freeze and take the form of an elaborate snowflake or ice cube.

Water Expands When It Freezes



Water molecules in a liquid state have too much kinetic energy to become a solid. The constantly moving molecules in water cannot form strong hydrogen bonds and continue to flow past one another.

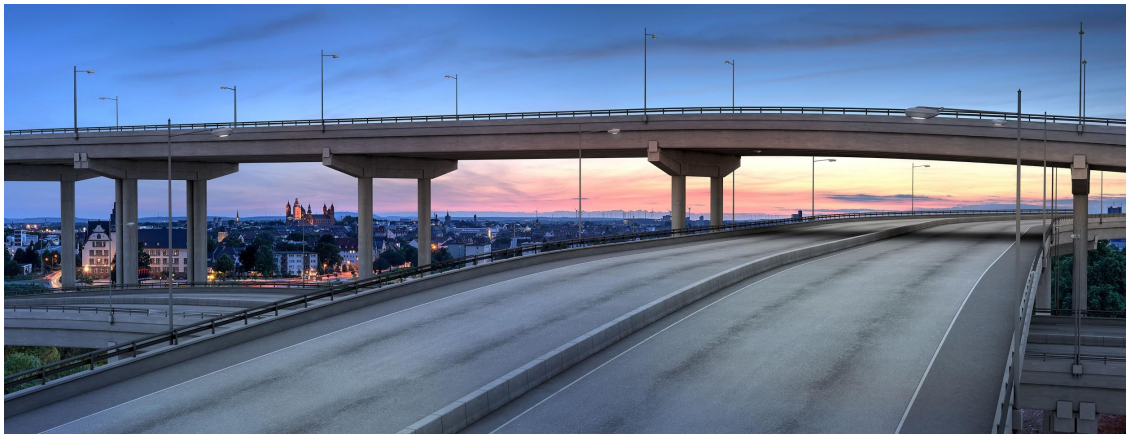
Water molecules lose kinetic energy when heat is removed during the freezing process. As water molecules slow down, they form strong hydrogen bonds, creating a hexagonal lattice shape. The molecules are farther apart in solid ice than in liquid water.

Changes in Energy on the Molecular Level

Try Now

Picture A

Picture B



Engineers must consider how removing or adding thermal energy changes the energy in materials on the molecular level. Describe how the different weather conditions would affect the concrete in the roads and what the construction teams might need to consider when choosing materials for each road.

Changes in Energy on the Molecular Level

In the chart below, write “true” or “false” to determine which statements are accurate and which are not. After writing down your reply on the black line, provide the evidence in favor of or against the statement. Use the last column to provide a visual.

Statement	Evidence	Illustration
The effects of adding heat are reversible. _____		
Substances’ kinetic energy always stays the same. _____		
When heat is added to atoms, the molecules vibrate much more slowly. _____		
As atoms vibrate faster, the space between them decreases. _____		