Section 3.3

Objectives

- **Describe** the states of matter on Earth.
- **Explain** the reasons that matter exists in these states.
- **Relate** the role of thermal energy to changes in state of matter.

Review Vocabulary

chemical reaction: the change of one or more substances into another substance

New Vocabulary

crystalline structure
glass
evaporation
plasma
condensation
sublimation

States of Matter

MAIN Idea All matter on Earth and in the universe occurs in the form of a solid, a liquid, a gas, or plasma.

Real-World Reading Link When your skin is wet, even on a hot day, it usually feels cool—especially if it is windy. How can warm air feel cold? When the water evaporates, it absorbs heat from your skin. The harder the wind blows, the more water evaporates and the colder your skin becomes.

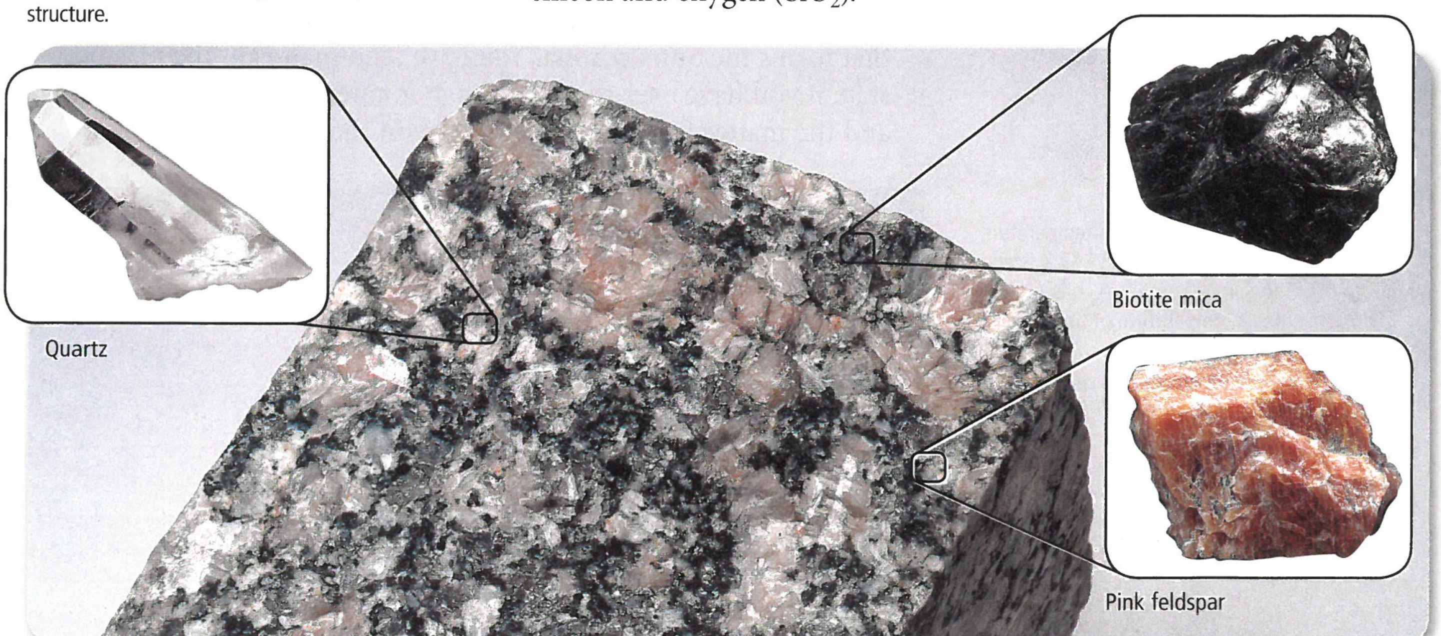
Solids

Solids are substances with densely packed particles, which can be ions, atoms, or molecules. Most solids are **crystalline structures** because the particles of a solid are arranged in regular geometric patterns. Examples of crystals are shown in **Figure 3.16.** Because of their crystalline structures, solids have both a definite shape and volume.

Perfectly formed crystals are rare. When many crystals form in the same space at the same time, crowding prevents the formation of perfect crystals with smooth boundaries. The result is a mass of intergrown crystals called a polycrystalline solid. Most solid substances on Earth, including rocks, are polycrystalline solids. **Figure 3.16** shows the polycrystalline nature of the rock granite.

Some solid materials have no regular internal patterns. **Glass** is a solid that consists of densely packed atoms arranged randomly. Glasses form when molten material is chilled so rapidly that atoms do not have enough time to arrange themselves in a regular pattern. These solids do not form crystals, or their crystals are so small that they cannot be seen. Window glass consists mostly of disordered silicon and oxygen (SiO_2).

Figure 3.16 This granite is composed of mineral crystals that fit together like interlocking puzzle pieces. The minerals that make up the rock are composed of individual atoms and molecules that are aligned in a crystalline structure.



■ **Figure 3.17** Each of these containers has the same volume of liquid in it.
Explain ***why the liquids are not all at the same level in the containers.***

Liquids

At any temperature above absolute zero (−273°C), the atoms in a solid vibrate. Because these vibrations increase with increasing temperature, they are called thermal vibrations. At the melting point of the material, these vibrations become vigorous enough to break the forces holding the solid together. The particles can then slide past each other, and the substance becomes liquid. Liquids take the shape of the container they are placed in, as you can see in **Figure 3.17.** However, liquids do have definite volume.

Reading Check **Explain** the effect that increasing temperature has on the atoms in solids.

Gases

The particles in liquids vibrate vigorously. As a result, some particles can gain sufficient energy to escape the liquid. This process of change from a liquid to a gas at temperatures below the boiling point is called **evaporation**. When any liquid reaches its boiling point, it vaporizes quickly as a gas.

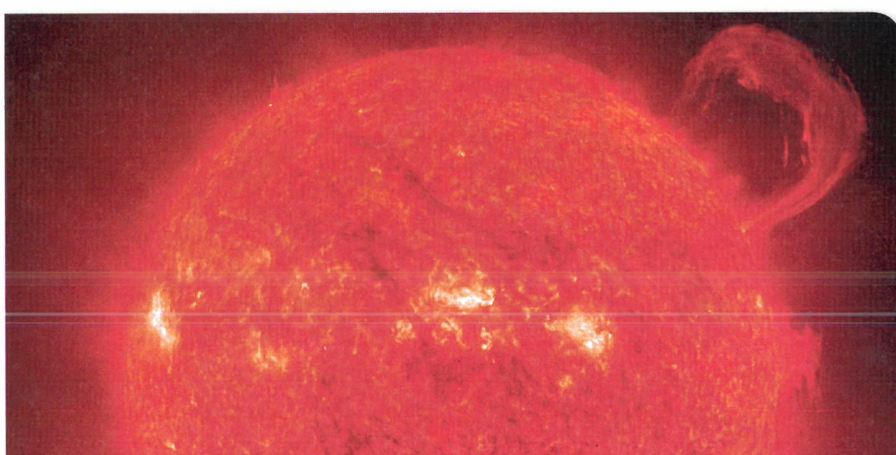
In gases, the particles are separated by relatively large distances and they travel at high speeds in one direction until they bump into another gas particle or the walls of a container. Gases, like liquids, have no definite shape. Gases also have no definite volume unless they are restrained by a container or a force such as gravity. For example, Earth's gravity keeps gases in the atmosphere from escaping into space.

FOLDABLES
Incorporate information from this section into your Foldable.

Plasma

When matter is heated to a temperature greater than 5000°C, the collisions between particles are so violent that electrons are knocked away from atoms. Such extremely high temperatures exist in stars and, as a result, the gases of stars consist entirely of positive ions and free electrons. These hot, highly ionized, electrically conducting gases are called **plasmas. Figure 3.18** shows the plasma that forms the Sun's corona. You have seen matter in the plasma state if you have ever seen lightning or a neon sign. Both lightning and the matter inside a neon tube are in the plasma state.

■ **Figure 3.18** The Sun's temperature is often expressed in kelvins; 273 K is equal to 0°C. The Sun's corona, which is a plasma, has a temperature of about 15,000,000 K.
Compare ***the temperature of the corona to lightning, which is 30,000 K.***



Changes of State

Solids melt when they absorb enough thermal energy to cause their orderly internal crystalline arrangement to break down. This happens at the melting point. When liquids are cooled, they solidify at that same temperature and release thermal energy. The temperature at which liquids solidify is called the freezing point.

When a liquid is heated to the boiling point and absorbs enough thermal energy, vaporization occurs and it becomes a gas. When a gas is cooled to the boiling point it becomes a liquid in a process called **condensation,** shown in **Figure 3.19.** Energy that was absorbed during vaporization is released upon condensation.

Evaporation can occur below the boiling point when thermal vibrations enable individual atoms or molecules to escape from a solid. You might have noticed that even on winter days with temperatures below freezing, snow gradually disappears. This slow change of state from a solid (ice crystals) to a gas (water vapor) without an intermediate liquid state is called **sublimation.**

Figure 3.19 As the hot, moist air from the shower encounters the cool glass of the mirror, the water vapor in the air condenses on the glass.
Predict *What would happen if the glass were the same temperature as the air?*

Conservation of Energy

The identity of matter can be changed through chemical reactions and nuclear processes, and its state can be changed under different thermal conditions. You have learned that a chemical equation must be balanced because matter cannot be created or destroyed. This fundamental fact is called the law of conservation of matter. Like matter, energy cannot be created or destroyed, but it can be changed from one form to another. For example, electric energy might be converted into light energy. This law, called the conservation of energy, is also known as the first law of thermodynamics.

Section 3.3 Assessment

Section Summary

- Changes of state involve thermal energy.
- The law of conservation of matter states that matter cannot be created or destroyed.
- The law of conservation of energy states that energy is neither created nor destroyed.

Understand Main Ideas

1. MAIN Idea **Explain** how thermal energy is involved in changes of state.
2. **Evaluate** the nature of the thermal vibrations in each of the four states of matter.
3. **Apply** what you know about thermal energy to compare evaporation and condensation.

Think Critically

4. **Infer** how the boiling point of water (100°C) would change if water molecules were not polar molecules.
5. **Consider** glass and diamond—two clear, colorless solids. Why does glass shatter more easily than diamond?

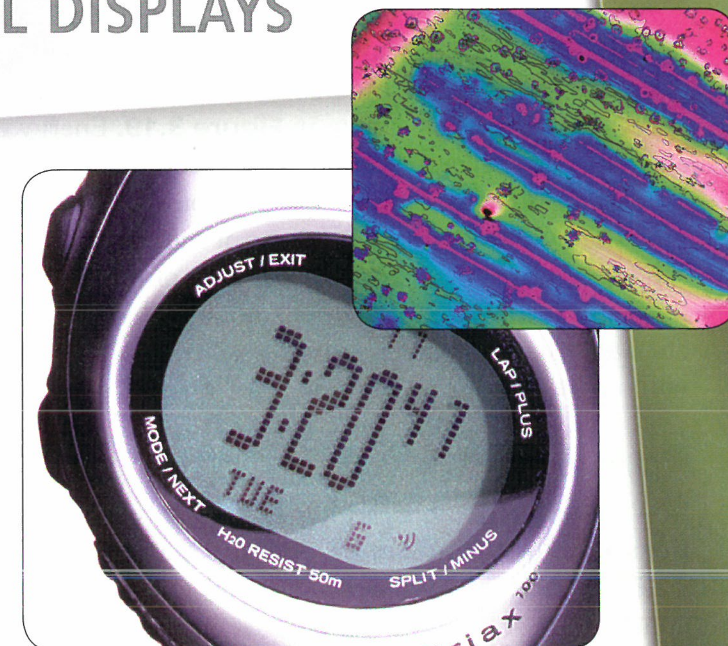
MATH in Earth Science

6. Refer to **Figure 3.18.** Calculate the corona's temperature in degrees. Remember that 273 K is equal to 0°C.

EARTH SCIENCE AND TECHNOLOGY

LIQUID CRYSTAL DISPLAYS

You wake up in the morning, glance at your alarm clock, and get ready for school. You microwave your breakfast, grab your music player and dash out the door, checking your wristwatch as you go. Once at school, you pull out your calculator and get ready for the big math exam. Did you know you have used liquid crystal display (LCD) technology five times already? LCD is common display technology, used often because it is thin, lightweight, and energy efficient.



Digital watch displays are made possible through LCD technology. The inset photograph shows a polarized light micrograph of a LCD.

What is a liquid crystal? You know that liquids and crystals are two states of matter; but how is it possible to be both a liquid and a crystal? Recall that particles in a liquid can slide past each other in a container, while particles in a solid are packed together and cannot move separately. Liquid crystals are long molecules that keep their orientation—if they were oriented side-to-side in a thin layer on a glass plate, they would keep that side-to-side orientation. Because of their liquid property, the crystals can move around almost like a school of fish. Therefore, they share characteristics with both solids and liquids. This unique property makes them useful for a variety of electronic applications.

How do LCDs work? Consider a digital watch, for example. If you look closely at it, you can see the numbers, even when they are not darkened. These are the tracks that are engraved in the middle layer of a display "sandwich." Two plates of glass make up the outer portion of this sandwich. The inner portion of the sandwich, the tracks, contains liquid crystals that are in their natural, "relaxed" state. In the relaxed state, light passes through the plates of glass, and is reflected out.

If an electric current is applied across a track of liquid crystals, the crystals lose their original orientation. As long as a small current passes through them, light entering the plates of glass will not be reflected. In other words, that track will appear black.

Seems simple enough, right? That is why LCD displays are becoming more and more popular. They can be all black or color. There are, however, some flaws with LCD technology that need to be corrected. For example, it has a narrow viewing angle; if you tilt your watch slightly you can no longer see the numbers as clearly, if at all. With further research, however, LCD might just become the vision of the future.

WRITING in Earth Science

Diagram Visit glencoe.com to research the different layers of an LCD. Create a drawing showing all the different layers and how they fit together.