CONCEPT 3

Changes in state result from changes in particle motion.

Activity

The Cold Can

Dry the outside of a metal can with paper towel. Obtain 50 g (about 45 mL) of salt. Divide it into three approximately equal portions. Add the first portion of salt to the can, then half-fill the can with crushed ice. Add the second portion of salt and fill the can with ice. Top with the rest of the salt. Mix the contents well, being careful not to spill the contents of the can. Wait 5 minutes and observe the outside and inside of the can. How do you explain what you observe?

Changes of state (also referred to as phase changes) occur when matter transforms from one state to another. Most pure substances can exist in all three states depending on the temperature and pressure. A few substances, such as water, exist in all three states under ordinary conditions on Earth. Scientists use specific terms to refer to the different state changes that are possible among solids, liquids, and gases, as shown in **Figure 2.16**.

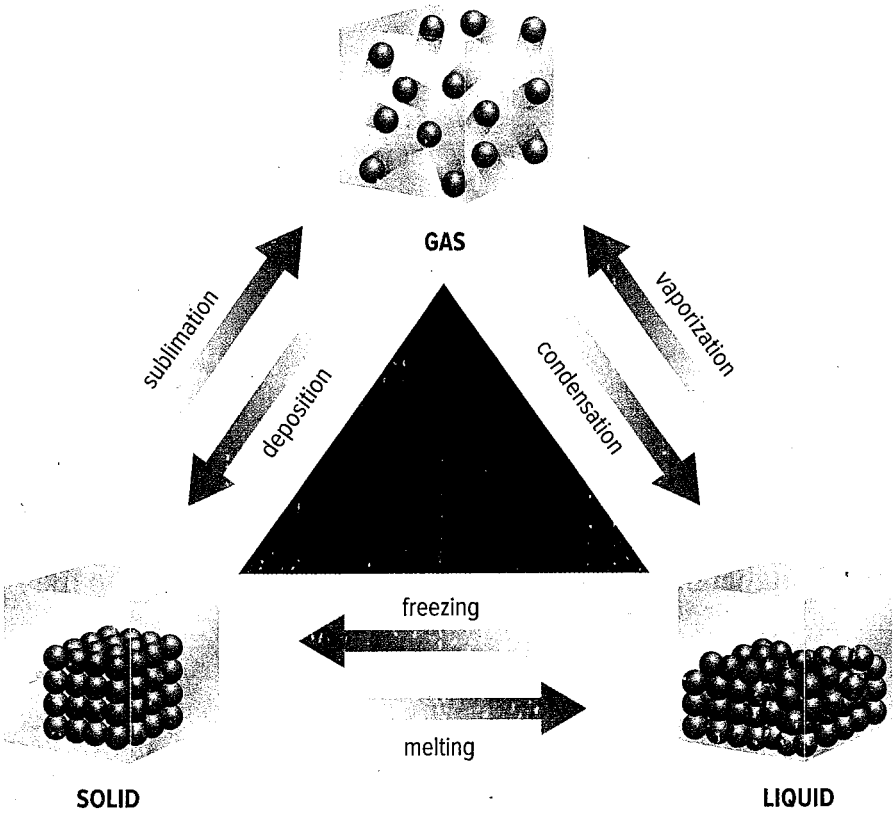


Figure 2.16 Specific terms such as melting and evaporation are used to describe how the state of matter can change.

Changes of State and Temperature

What causes matter to change from one state to another? Consider what is the same about the following examples. You put a scoop of solid butter in a hot frying pan and it melts into a liquid. A kettle full of water begins to "sing" as the heating element inside causes the water to boil. You drop some ice cubes into your orange juice and they begin to melt. You fill the empty ice cube tray with water and pop it in the freezer to make more ice. All of these examples involve adding or removing kinetic energy.

Adding energy to matter or removing energy from matter changes the temperature of the matter. What does that mean? *Temperature* is a measure of the average kinetic energy of the particles in a substance. Increasing the temperature of matter means the particles of the matter are gaining energy. Once the matter reaches a certain temperature, the particles have gained enough energy to change state.

The temperature at which a substance melts is called its *melting point*. The temperature at which a substance boils is called its *boiling point*. The melting and boiling points of pure substances are physical properties that can be used to identify them. A few examples are shown in **Table 2.3**.

Table 2.3 Melting and Boiling Points

Substance	Melting Point (°C)	Boiling Point (°C)
nitrogen, N_2	–210.0	–195.8
mercury, Hg	–38.8	356.7
water, H_2O	0.00	100.0
iron, Fe	1538	2862

The Kinetic Molecular Theory and Changes of State

The difference between the properties of solids, liquids, and gases can be explained by the difference in the kinetic energy of the particles of substances in those states. For any given substance, the average kinetic energy of the particles in the solid will be lower than that of the particles in the liquid. The particles in the gas will have the greatest average kinetic energy.

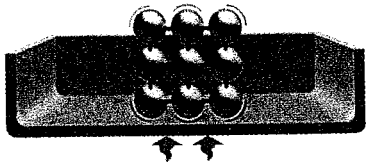
But why do substances change from one state to another when they are heated or cooled? Why does a heated solid melt instead of just becoming a very hot solid? **Figure 2.17** shows how the KMT explains changes of state.

Connect to Investigation 2-F on pages 148–149

Adding Energy to Mercury

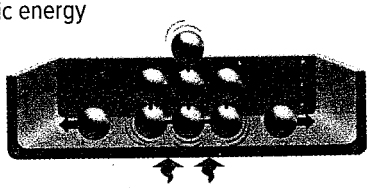
1. Solid mercury

Particles are very close to one another, are fixed in position, and vibrate. They strongly attract one another.



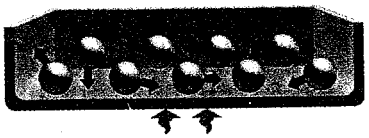
2. Melting mercury

As the temperature of the solid mercury increases, the kinetic energy of the particles increases. Eventually, the increased kinetic energy of the particles allows them to partially overcome their attraction to one another, and they break free of their rigid formation. They now begin to revolve around and slide past one another. The solid is melting.



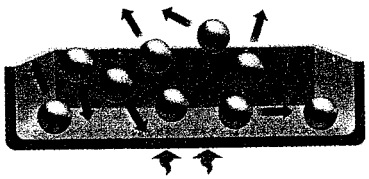
3. Liquid mercury

The particles move freely around one another, but are still close together and strongly attracted. They have taken the shape of their container.



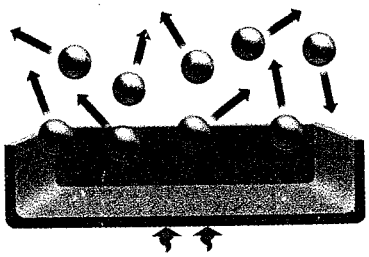
4. Boiling mercury

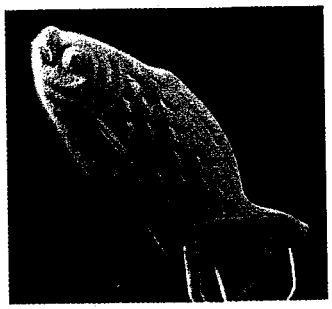
As the temperature continues to increase, the kinetic energy increases and the particles move more vigorously. Some particles gain enough energy to completely overcome the attractive forces between them and other particles in the liquid. They escape into the surrounding air.



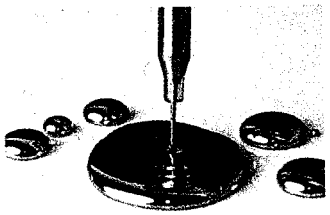
5. Gaseous mercury

All particles are highly energetic and move freely to fill their container. Further heating will increase the speed of the gas particles, which increases their kinetic energy. If in a sealed container, particles will collide with each other and with the walls of the container more forcefully and more often. This increases the pressure of the gas.





This piece of solid mercury was formed by cooling it to below −38.8°C, the melting point of mercury.



Mercury is the only metal that is a liquid at room temperature.

Figure 2.17 As a sample of solid mercury absorbs energy (shown by the orange arrows), it undergoes two changes of state.

Extending the Connections

Applying Deposition

The metallic colours of modern electronics such as phones are due to specialized materials applied using physical vapour deposition (PVD). Research PVD and choose one specific application to explore.

Before you leave this page . . .

1. Define temperature.
2. What is the melting point of a substance?
3. Use the KMT to explain how a liquid changes into a solid.