7.3 Kinetic Energy, Heat, and Temperature

Warmth and coldness involve the motion of the particles of matter. Since they are always moving, the particles of matter possess a form of energy called **kinetic energy**. All moving objects, large and small, possess kinetic energy (Figure 1). Flying airplanes, the flapping wings of a bird, and invisible vibrating particles all possess kinetic energy.

kinetic energy: energy that all moving objects possess; a particle has more kinetic energy when moving faster and less kinetic energy when moving slower

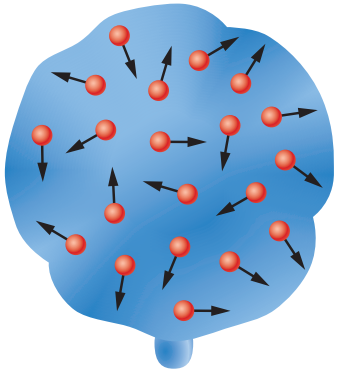


Figure 1 All objects that move have kinetic energy. There are even moving particles inside of a balloon.

All of the particles in a substance are attracted to each other. So, why do the particles not stick together and stop moving? Particles have a lot of kinetic energy, which keeps them moving. When the environment gets colder, they slow down and come closer together. They never slow down enough to come to a complete standstill.

If you could see the particles of an object, you would notice that they are not all moving at the same speed. Particles of matter collide with each other much like bumper boats in an amusement park ride. Bumper boats collide randomly as they move from place to place (Figure 2). Sometimes, several boats collide in such a way that some slow down and some speed up. Particles of matter also move and collide randomly, some speeding up and some slowing down. Particles do not all possess the same amount of kinetic energy at any given time. Some particles have more kinetic energy than others.

Figure 2 Bumper boats move and collide with each other randomly. The particles of matter do the same thing.

Temperature

If you could see the particles of a hot object and the particles of a cold object, you would see that *most* of the particles of the hot object move faster than *most* of the particles of the cold object. Thus, the average kinetic energy of the particles of a hot object is higher than the average kinetic energy of the particles of a cold object.

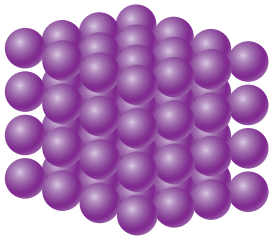
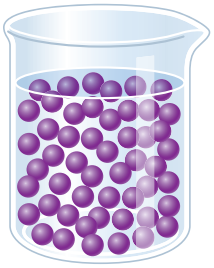
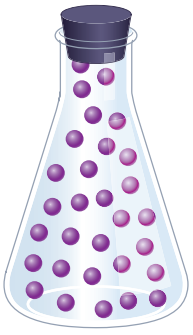
Temperature is a measure of the average kinetic energy of particles. If most of the particles of air in your kitchen are moving faster than most of the particles of air in your bedroom, then the temperature of the air in your kitchen is higher than that of the air in your bedroom.

temperature: a measure of the average kinetic energy of the particles of a substance

Particle Theory and the States of Matter

Matter exists in three common states: solid, liquid, or gas (Table 1). The particle theory can be used to explain the characteristics of solids, liquids, and gases.

Table 1 States of Matter

State of matter	Description	
Solid	The shapes and volumes of solids do not change because the particles of a solid vibrate. They cannot move past each other. The kinetic energy of the particles is too low to overcome the forces holding the particles together. The particles are packed close together, and are difficult to squeeze into a smaller space.	
Liquid	Liquids take the shape of their containers and have fairly constant volumes. The particles of a liquid move faster than the particles in a solid of the same substance. The particles vibrate, rotate, and move past one another. The speeds of the particles prevent the forces of attraction from holding them in one place. However, there is still enough attraction between the particles to keep them from separating completely. The particles of a liquid are slightly more spread out than the particles of a solid. The particles of liquids strongly resist being squeezed closer together.	
Gas	Gases expand to fill an empty container. This means that both their volume and shape can change. The particles of a gas vibrate, rotate, and move past one another much more than the particles of solids and liquids. The fast motions of the particles prevent their forces of attraction from holding them close together. Gas particles have very large spaces between them. Their movement is only limited by the size of the container. Gases are relatively easy to compress.	

Particle Theory and Changes of State

According to the particle theory, particles of matter are constantly moving and are attracted to each other. The motions of the particles of a substance (their kinetic energies), and their attraction for each other, determine whether the particles form a solid, a liquid, or a gas. The kinetic energy of the particles *and* the energy of attraction between them are called **thermal energy**. We can increase the thermal energy of a substance by heating it, and we can decrease the thermal energy by cooling the substance. Changes in thermal energy can also cause a substance to change state (Figure 3 on the next page). For example, increasing the thermal energy of a solid may cause it to melt, becoming a liquid.

thermal energy: the total kinetic energy and energy of attraction of all the particles of a material

To review the particle theory and the states of matter,

Go to Nelson Science

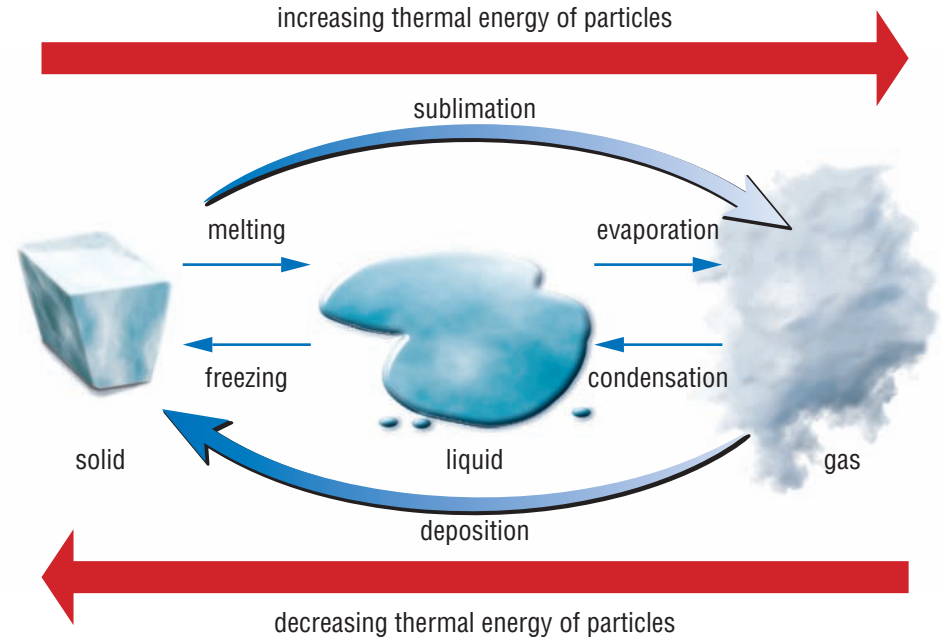


Figure 3 Changes of state involve changes in thermal energy.

Thermal Expansion and Contraction

When solids, liquids, and gases are heated, their volumes usually increase. This process is called **thermal expansion** (Figure 4). Heating a substance speeds up its particles, so they have more kinetic energy. The faster-moving particles travel greater distances, so they occupy more space.

When solids, liquids, and gases are cooled, their volumes usually decrease. This process is called **thermal contraction**. Cooling a substance slows down its particles, so that they have less kinetic energy. The slower-moving particles travel shorter distances, so they occupy less space.

During thermal expansion and contraction, the mass of the object stays the same. The change in volume is not due to an addition or removal of particles, or to a change in the size of the particles. The change in volume is due to an increase or decrease in the spaces between particles. In general, for a given change in temperature, gases expand and contract more than liquids and solids, and liquids expand and contract more than solids.

LINKING TO LITERACY

Skimming

Good readers realize that they may not have understood all of the ideas presented when reading. They verify understanding by skimming through the section to locate important information to reread. Skim the text to recall the meanings of thermal energy, thermal expansion, and thermal contraction.

thermal expansion: an increase in the volume of a substance caused by heating

thermal contraction: a decrease in the volume of a substance caused by cooling

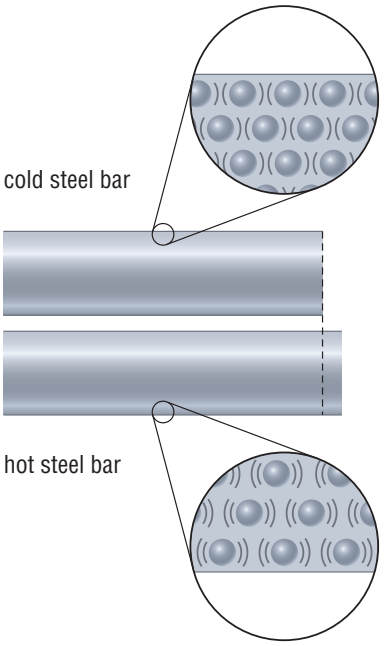


Figure 4 Thermal expansion occurs when particles move farther apart.

CHECK YOUR LEARNING

1. Name and briefly describe the two kinds of energy that all particles possess.
2. Describe the relationship between temperature and energy.
3. List the three states of matter in order of decreasing kinetic energy.
4. **(a)** Which state of matter is most easily compressed to take up a smaller volume?
   (b) Write a sentence explaining this observation.
5. When a substance is cooled, what happens to its particles? How does cooling affect the volume of the substance?