Key Question: What is the relationship between kinetic energy and temperature of a substance?

A book on a table might be sitting still, but all the particles that make up the book never stop moving.

This constant motion gives the particles a special kind of energy. The energy of a moving object is called kinetic energy. All moving objects have kinetic energy. Flying airplanes, the flapping wings of a bird, and invisible vibrating particles all possess kinetic energy (Figure 1).

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

**How Particles Move**

You know that the particles of an object are always moving. These particles have kinetic energy.

Particles don’t move at the same speed. Some move very fast. Others move very slowly. Some just vibrate back and forth. Particles can also move around and bump into one another. Some particles will have more kinetic energy than other particles.
Think about bumper boats at an amusement park. There are many boats and they all move in different ways. Bumper boats will often run into each other (Figure 2). Sometimes a faster boat will hit a slower boat. The slower boat might go faster then. Particles in an object move in a similar way.

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

**TEMPERATURE**

You know that the particles in hot and cold objects act differently. Most of the particles in a hot object move faster. Most of the particles in a cold object move slower.

This tells us something about the kinetic energy of the particles. The average kinetic energy in a hot object is higher than the average kinetic energy in a cold object.

**Temperature** is a measure of the average kinetic energy of particles. Think about the air in a house. It may be warmer in one room and cooler in another. The room with the higher temperature has faster moving air particles. The room with the lower temperature has slower air particles.
**STATES OF MATTER**

There are three main states of matter:

1. solid
2. liquid
3. gas

The particle theory can be used to explain the characteristics of solids, liquids, and gases (Table 1).

<table>
<thead>
<tr>
<th>State of matter</th>
<th>Description</th>
<th>Kinetic energy</th>
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</table>
| Solid           | The particles in a solid  
• vibrate  
• cannot move around each other  
• are packed close together  
The shapes and volumes of solids do not change.  
Kinetic energy = low |
| Liquid          | The particles in a liquid  
• move quickly  
• vibrate, rotate, and move around each other  
• are more spread out  
• resist being squeezed close together  
• will not break all the way apart from each other  
Liquids take the shape of their container.  
Kinetic energy = medium |
| Gas             | The particles in a gas  
• move very quickly  
• vibrate, rotate, and move past each other more than solids or liquids  
• have very large spaces between them  
• are easy to compress  
Gases expand to fill an empty container.  
Kinetic energy = high |
**Changes of State**

The particle theory of matter states that particles are always moving. It also states that particles are attracted to each other. This motion (the kinetic energy) and attraction determine if the particles will form a solid, liquid, or gas.

The kinetic energy of particles plus the energy of attraction of those particles is called **thermal energy**. Thermal energy increases as a substance is heated. Thermal energy decreases as a substance is cooled.

As thermal energy changes, the state of matter changes (Figure 3).

![Figure 3 Changes in thermal energy can cause a change of state.]

**Expansion and Contraction**

When most solids, liquids, and gases are heated, their volume increases. In other words, they expand, or get larger. **Thermal expansion** is an increase in volume because of heating.

Heating causes particles to speed up. This causes the kinetic energy to increase. Fast-moving particles bump into one another more than slow-moving particles.

Thermal expansion does not change the mass of an object. The number of particles in the object does not increase. The volume changes because there is more space between the particles.
When solids, liquids, and gases are cooled, their volume usually goes down. In other words, they will get closer together and fill less space. Thermal contraction is a decrease in volume because of cooling.

Cooling causes particles to slow down. This causes the kinetic energy to go down. Slow-moving particles bump into one another less than fast-moving particles.

Thermal contraction will also not change the mass of an object. The number of particles in the object does not decrease. The volume changes because there is less space between the particles.

CHECK YOUR UNDERSTANDING

1. In your own words, write a definition of “kinetic energy.”

2. In your own words, write a definition of “temperature.”

3. List the three states of matter in order of kinetic energy of the particles.
   Most kinetic energy: ________________________________
   Less kinetic energy: ________________________________
   Least kinetic energy: ________________________________

4. Think back to the Key Question. What have you learned about the relationship between kinetic energy and the temperature of an object?

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