Temperature, Thermal Energy and Heat

Temperature

- You use the words hot and cold to describe temperature.
- Something is hot when its temperature is high.
- When you heat water on a stove, its temperature increases.
- How are temperature and heat related?

Temperature, Thermal Energy and Heat

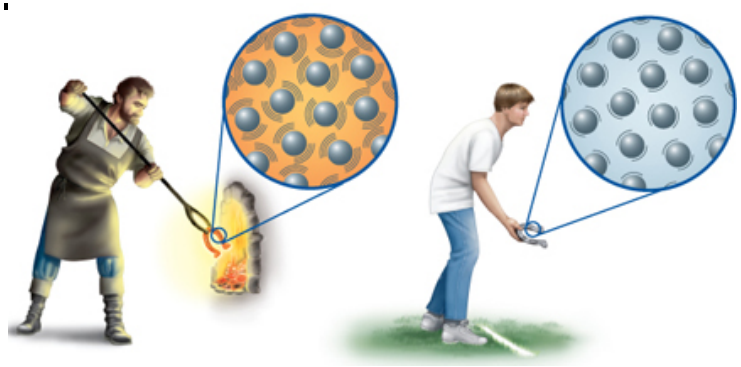
Matter in Motion

- The matter around you is made of tiny particles—atoms and molecules.
- In all materials these particles are in constant, random motion; moving in all directions at different speeds.

Temperature, Thermal Energy and Heat

Matter in Motion

- The faster they move, the more kinetic energy they have.
- This figure shows that the particles that make up hot objects move faster than the particles that make up cooler objects.



Temperature, Thermal Energy and Heat

Temperature

- The **temperature** of an object is a measure of the average kinetic energy of the particles that makes up that object.
- As the temperature of an object increases, the average speed of the particles in that compose that object increases.

Temperature, Thermal Energy and Heat

Temperature

- In SI units, temperature is measured in kelvins (K).
- A more commonly used temperature scale is the Celsius scale.
- One kelvin is the same as one degree Celsius.

Temperature, Thermal Energy and Heat

Thermal Energy

- If you let cold butter sit at room temperature for a while, it warms and becomes softer.
- Because the air in the room is at a higher temperature than the butter, particles that compose air have more kinetic energy than the particles that compose butter.

Temperature, Thermal Energy and Heat

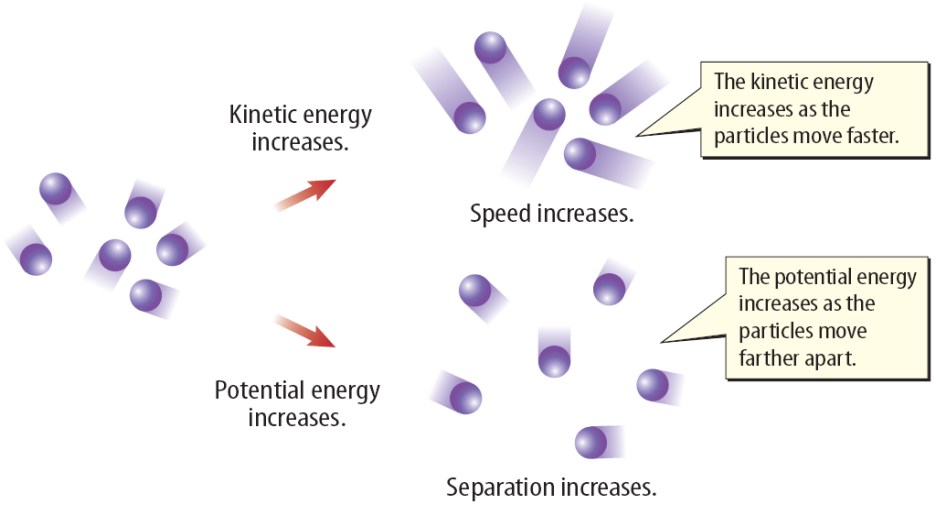
Thermal Energy

- Collisions between the particles that compose butter and the particles that compose air transfer energy from the faster-moving air particles to the slower-moving butter particles.
- The particles that compose butter then move faster and the temperature of the butter increases.

Temperature, Thermal Energy and Heat

Thermal Energy

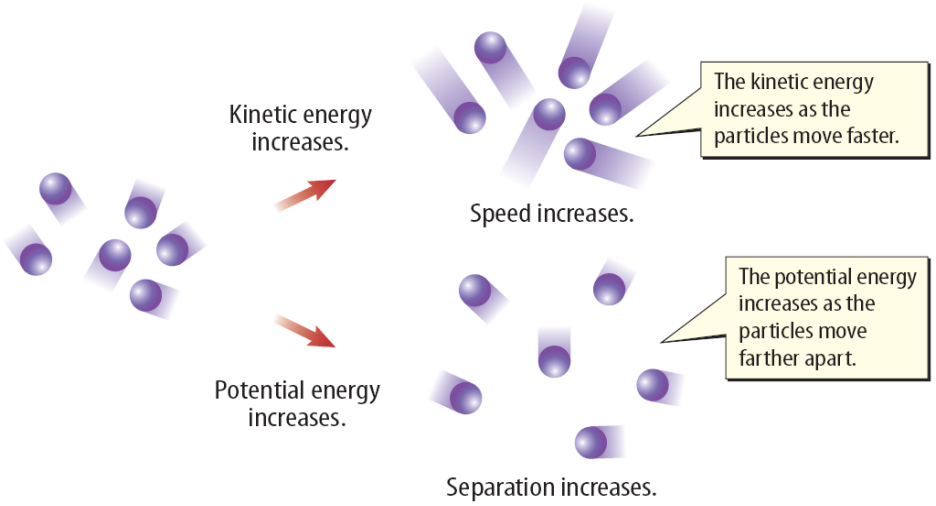
- The sum of the kinetic energy and potential energy of all the particles that compose an object is the thermal energy of that object.



Temperature, Thermal Energy and Heat

Thermal Energy

- Because the kinetic energy of the butter particles increased as the butter warmed, the thermal energy of the butter increased.



Temperature, Thermal Energy and Heat

Thermal Energy and Temperature

- When the temperature of an object increases, the average kinetic energy of the particles that compose the object increases.
- Because thermal energy is the total kinetic and potential energy of all the particles that compose an object, the thermal energy of the object increases when the average kinetic energy of its particles increases.

Temperature, Thermal Energy and Heat

Heat

- **Heat** is thermal energy that is transferred from something at a higher temperature to something at a lower temperature.
- Heat is a transfer of energy, so it is measured in joules—the same units that energy is measured in.

Temperature, Thermal Energy and Heat

Specific Heat

- As a substance absorbs thermal energy, its temperature change depends on the nature of the substance, as well as the amount of thermal energy that is added.
- The amount of heat that is needed to raise the temperature of 1 kg of some material by 1°C is called the **specific heat** of the material.
- Specific heat is measured in joules per kilogram Celsius [J/(kg °C)].

Water as a Coolant

- Compared with the other common materials in the table, water has the highest specific heat.
- The specific heat of water is high because water molecules are strongly attracted to each other.

Table 1 Comparison of Specific Heats*

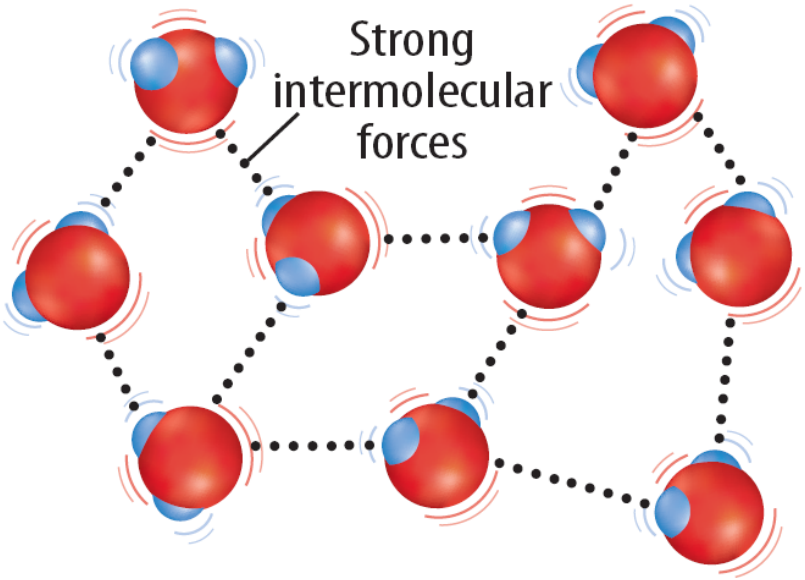
Substance	Specific Heat [J/(kg·°C)]
Water	4,200
Wood	1,700
Sand	830
Carbon (graphite)	710
Iron	450

*Values have been rounded.

Temperature, Thermal Energy and Heat

Water as a Coolant

- When thermal energy is added, some of the added thermal energy has to break some of these bonds before the molecules can start moving faster.

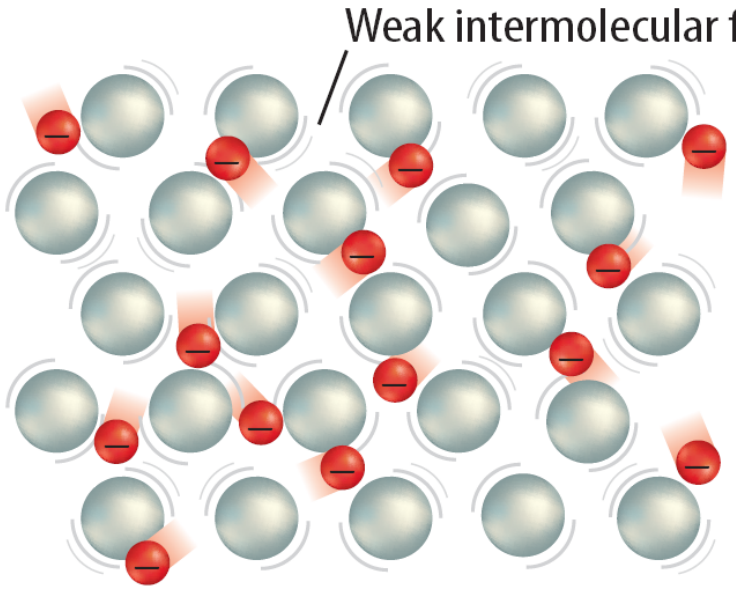


Water as a Coolant

- Because water can absorb thermal energy without a large change in temperature, it is useful as a coolant.
- A coolant is a substance that is used to absorb thermal energy.

Temperature, Thermal Energy and Heat

Water as a Coolant



- In metals, electrons can move freely. When thermal energy is added, no strong bonds have to be broken before the electrons can start moving faster.

Temperature, Thermal Energy and Heat

Changes in Thermal Energy

- The thermal energy of an object changes when thermal energy is transferred into or out of the object.
- If Q is the change in thermal energy and C is specific heat, the change in thermal energy can be calculated from the following equation:

Thermal Energy Equation

change in thermal energy (J) =

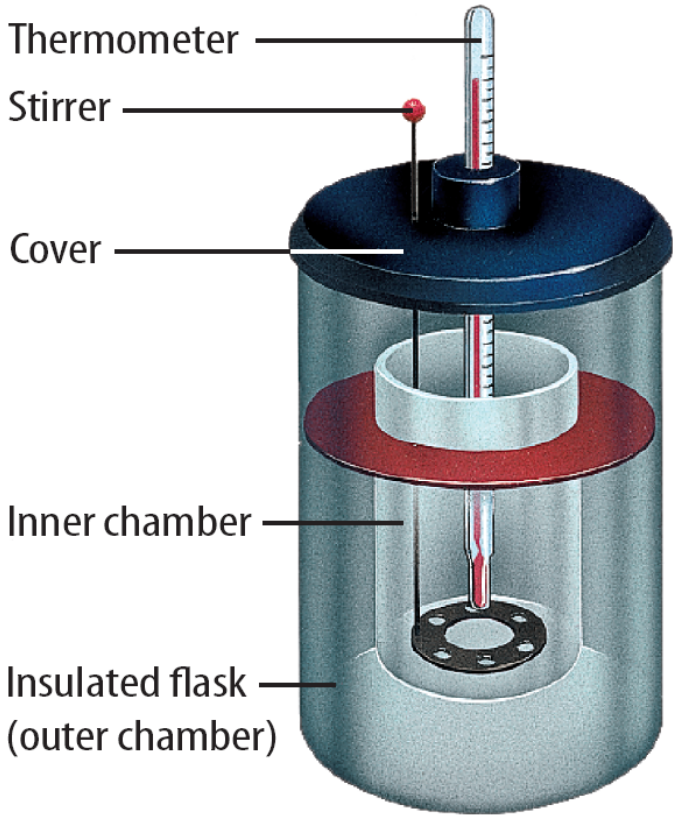
mass (kg) · **temperature change**(°C) · **specific heat** $\left(\frac{\text{J}}{\text{kg} \cdot \text{°C}}\right)$

$$Q = m(T_f - T_i)C$$

Temperature, Thermal Energy and Heat

Measuring Specific Heat

- The specific heat of a material can be measured using a device called a calorimeter.
- In a calorimeter, a heated sample transfers thermal energy to a known mass of water.



Temperature, Thermal Energy and Heat

Measuring Specific Heat

- The energy absorbed by the water can be calculated by measuring the water's temperature change.
- Then the thermal energy released by the sample equals the thermal energy absorbed by the water.