

# Preview of Period 5: Thermal Energy, the Microscopic Picture

## 5.1 Temperature and Molecular Motion

What is evaporative cooling?

## 5.2 Temperature and Phase Changes

How much energy is required for a phase change?

What is the difference between heat capacity, specific heat, and latent heat?

## Review of Definitions

**Temperature** is the **average** kinetic energy of the molecules of a substance.

**Thermal Energy** is the **total** amount of internal energy of the molecules of an object.

(The total energy is the kinetic energy of the motion of all of the molecules **plus** the potential energy stored in molecular attractions.)

**Heat** is thermal energy in transit from one location to another.

**Thermal conductivity** is a measure of how quickly a material transports thermal energy.

(The larger the thermal conductivity constant **K**, the more rapidly heat is conducted through the material.)

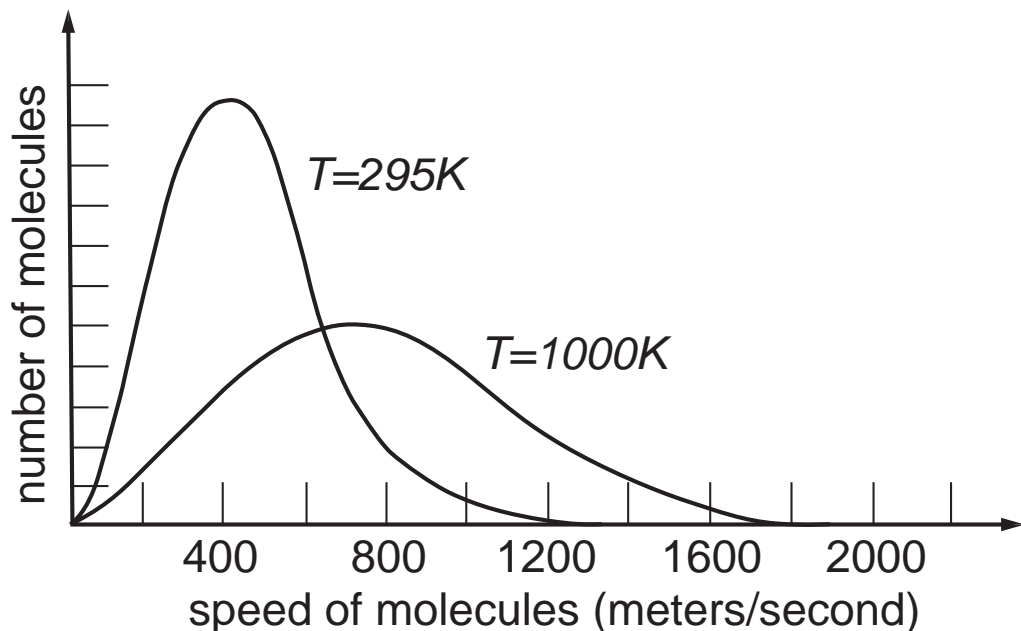
## The Microscopic Picture of Thermal Energy

The atoms and molecules of a substance move at different speeds and with **random motions** known as **Brownian motion**.

**Diffusion** is the mixing of molecules due to their random motion.

The higher the temperature of an object, the faster the average speed of the molecules.

### Speeds of Gas Molecules at Different Temperatures



## States of Matter:

In **Solids**, molecules or atoms are held in a fixed position by electromagnetic bonds between the electrons and protons.

**Solids** have a fixed shape and volume.

In **Fluids**, molecules or atoms feel an attraction to one another, but there are no fixed bonds between them.

**Fluids** have a fixed volume, but not a fixed shape.

In **Gases**, molecules move independently of one another.

**Gases** have no fixed volume or shape.

In **Plasma**, electrons are stripped from the atom's nucleus.

## Evaporative Cooling

- ✚ The molecules with the most kinetic energy are most likely to leave (evaporate) from the surface of a substance.
- ✚ When the molecules with the most energy leave, the average kinetic energy of the remaining molecules goes down.
- ✚ Thus, the substance is cooled.

## Why does the **Dippy Duck** dip?

- 1) Water evaporates from the duck's head, cooling it.
- 2) Cooling the freon gas inside the duck's head causes the gas molecules to condense.
- 3) This reduces the volume of the gas and, thus, lowers the gas pressure in the head.
- 4) As a result, liquid freon flows up the tube from the region of higher pressure in the duck's tail to the region of lower pressure in the head.
- 5) As the freon moves up, the center of mass is raised until the duck topples over into the cup of water.
- 6) While the duck's head is in the water, freon flows from the head into the tail, and the duck stands up again. The process repeats.

**Thermal expansion:** Most materials expand when heated and contract when cooled.

Water is an exception. Frozen water (ice) expands.

**Phase changes:**

Phase changes occur when matter changes from one state of matter to another state.

solid  $\longleftrightarrow$  liquid

liquid  $\longleftrightarrow$  gas

solid  $\longleftrightarrow$  gas (sublimation)

Phase changes occur with a change in

- ◆ temperature
- ◆ pressure
- ◆ both temperature and pressure.

**Heat capacity of an object:** The amount of energy needed to raise an object's temperature by 1 degree C.

$$Q = H_{cap} \times \Delta T$$

$Q$  = heat added or subtracted (calories or joules)

$H_{cap}$  = heat capacity (calories/ °C or joules/ °C)

$\Delta T$  = change in temperature =  $T_{final} - T_{initial}$  (°C)

**Specific heat of a substance:** The amount of energy needed to raise the temperature of 1 gram of a substance by 1 degree C.

The specific heat of water is 1 calorie/gram °C.

$$Q = S_{heat} \times M \times \Delta T$$

$Q$  = heat added or subtracted (calories or joules)

$S_{heat}$  = specific heat (calories/gram °C or joules/kilogram °C)

$M$  = mass (grams or kilograms)

$\Delta T$  = change in temperature =  $T_{final} - T_{initial}$  (°C)

**Latent heat:** The amount of energy needed to **change the phase** of 1 gram of a substance.

Heat added or subtracted for a phase change = **Latent heat** x **Mass**

$$Q = L_{heat} M$$

$Q$  = heat (calories or joules)

$L_{heat}$  = latent heat (calories/gram or J/kg)

$M$  = mass (grams or kilograms)

Latent **heat of vaporization** of water = 540 cal/gram

Latent **heat of fusion** of water = 80 cal/gram

## Period 5 Summary

**5.1:Evaporation** cools a substance because the molecules with the most kinetic energy are most likely to leave (evaporate) from the surface of a substance.

The average kinetic energy of the remaining molecules goes down and the temperature is lower.

**Diffusion** occurs due to the random (Brownian) motion of molecules.

**5.2:Heat capacity:** The amount of heat needed to change an object's temperature by one Celsius degree.  $Q = H_{cap} \Delta T$

**Specific heat:** The amount of heat needed to change the temperature of one gram of a substance by one Celsius degree.

$$Q = s_{heat} M \Delta T$$

**Latent heat:** The amount of heat needed to change the phase of one gram of a substance.  $Q = L_{heat} M$

## Period 5 Review Questions

- R.1** In class, we discussed convection, conduction, and diffusion. Which of these three processes can occur in solids, liquids and in gases?
- R.2** "Wind chill" refers to the cooling effect of wind. Why does it feel colder on a windy day than it does on a calm day?
- R.3** In class you graphed the temperature of water as it was being heated versus the time elapsed. What was the shape of your graph? Why did it have this shape? What quantity does the slope of the graph represent?
- R.4** What does the specific heat of an object depend upon? The shape of the object? The material from which the object is made? The mass of the object? The temperature of the object?
- R.5** Which contains more thermal energy - a cup full of hot coffee or a bathtub full of warm water? Why?