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?

5.3 Pressure, Temperature, and Volume

What is the Ideal Gas Law?

How are pressure and volume of a gas related to its temperature?
**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.

**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.

This random movement is known as Brownian motion.

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

Thermal energy is the kinetic energy of the motion of all of the molecules plus the potential energy stored in molecular attractions.

Speeds of Gas Molecules at Different Temperatures
What Happens When Substances Change Temperature?

**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.

**Thermal expansion:** Most materials expand when heated and contract when cooled. Water is an exception. Frozen water (ice) expands.
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.

**Phase changes** occur when matter changes from one state of matter to another state. Phase changes occur with a change in temperature, pressure, or both temperature and pressure.
Heat capacity of an object: The amount of energy needed to raise an object’s temperature by 1 degree C.

\[ Q = H_{\text{cap}} \times \Delta T \]

\( Q \) = heat added or subtracted (calories or joules)
\( H_{\text{cap}} \) = heat capacity (calories/ °C or joules/ °C)
\( \Delta T \) = change in temperature = \( T_{\text{final}} - T_{\text{initial}} \) (°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.

\[ Q = s_{\text{heat}} \times M \times \Delta T \]

\( Q \) = heat added or subtracted (calories or joules)
\( s_{\text{heat}} \) = specific heat (calories/gram °C or joules/kilogram °C)
\( M \) = mass (grams or kilograms)
\( \Delta T \) = change in temperature = \( T_{\text{final}} - T_{\text{initial}} \) (°C)
**Latent heat:** The amount of energy needed to change the phase of 1 gram of a substance.

The latent heat of water is 540 cal/gram.

Heat added or subtracted for a phase change = Latent heat $\times$ Mass

$\begin{align*}
Q &= L_{\text{heat}} \times M \\
Q &= \text{heat (calories or joules)} \\
L_{\text{heat}} &= \text{latent heat (calories/gram or j/kg)} \\
M &= \text{mass (grams or kilograms)}
\end{align*}$
The Relationship among Pressure, Temperature, and Volume

♦ At a fixed volume, what happens to the pressure \( P \) of a gas when its temperature \( T \) is increased?

♦ At a fixed temperature, what happens to the pressure of a gas \( P \) when its volume \( V \) is decreased?

♦ At a fixed volume and temperature, what happens to the pressure of a gas \( P \) when the number of gas molecules \( N \) is increased?

The result is the Ideal Gas Law

\[
P V = N k T
\]

- \( P \) = pressure the gas exerts (newtons/meters\(^2\))
- \( V \) = the volume of the gas (meters\(^3\))
- \( N \) = the number of gas molecules
- \( k \) = Boltzmann’s constant (1.38 x 10\(^{-23}\) J/K)
- \( T \) = temperature (Kelvin)
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, 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.
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. \( Q = H_{\text{cap}} \Delta T \)

**Specific heat:** The amount of heat needed to change the temperature of one gram of a substance by one Celsius degree. \( Q = s_{\text{heat}} M \Delta T \)

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

5.3: **The ideal gas law** describes the relationship among the pressure, temperature, and volume of a gas and number of molecules in a gas: \( PV = NkT \)
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 Why do car tires require less air in summer than in winter?

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?