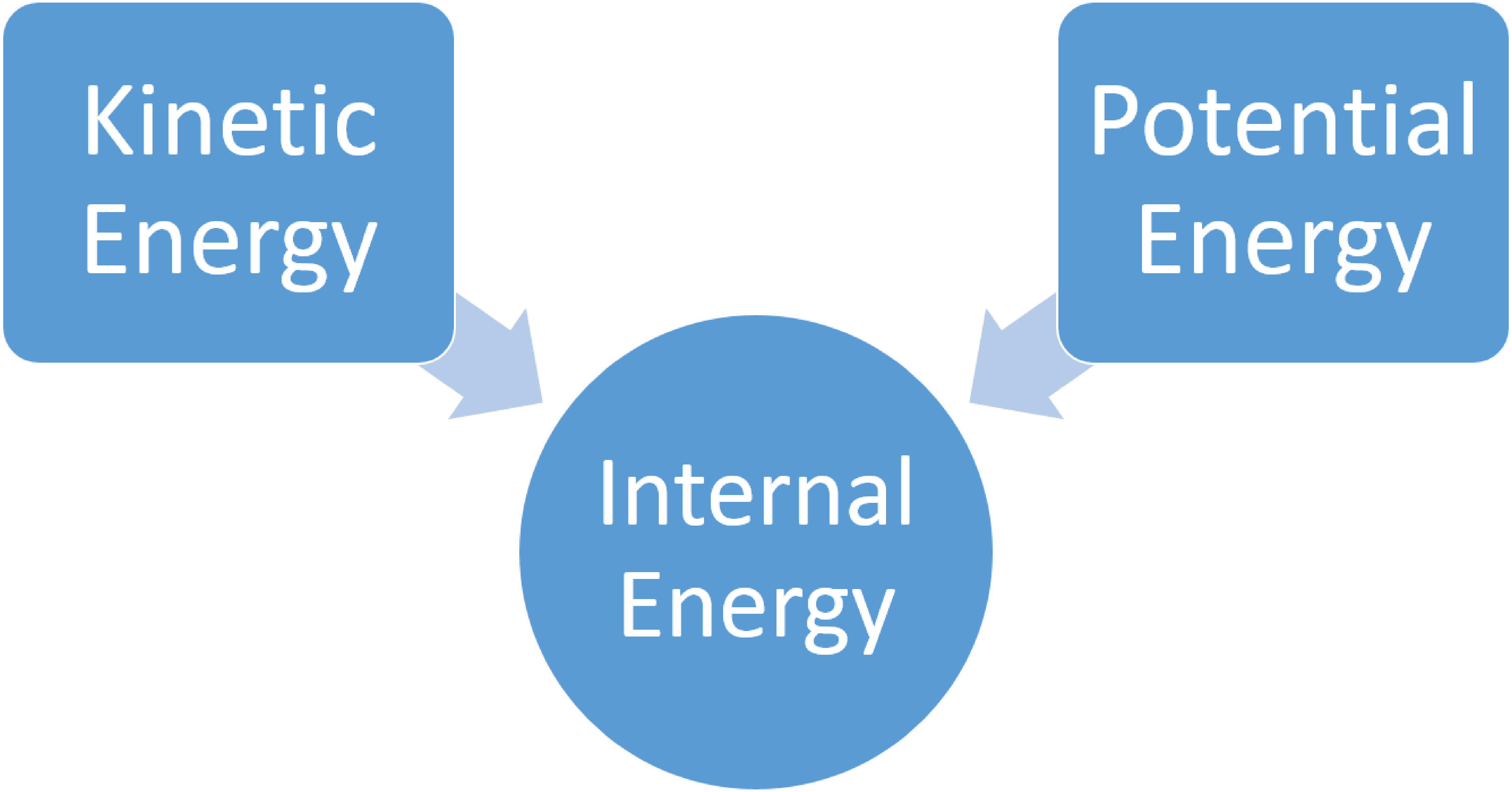
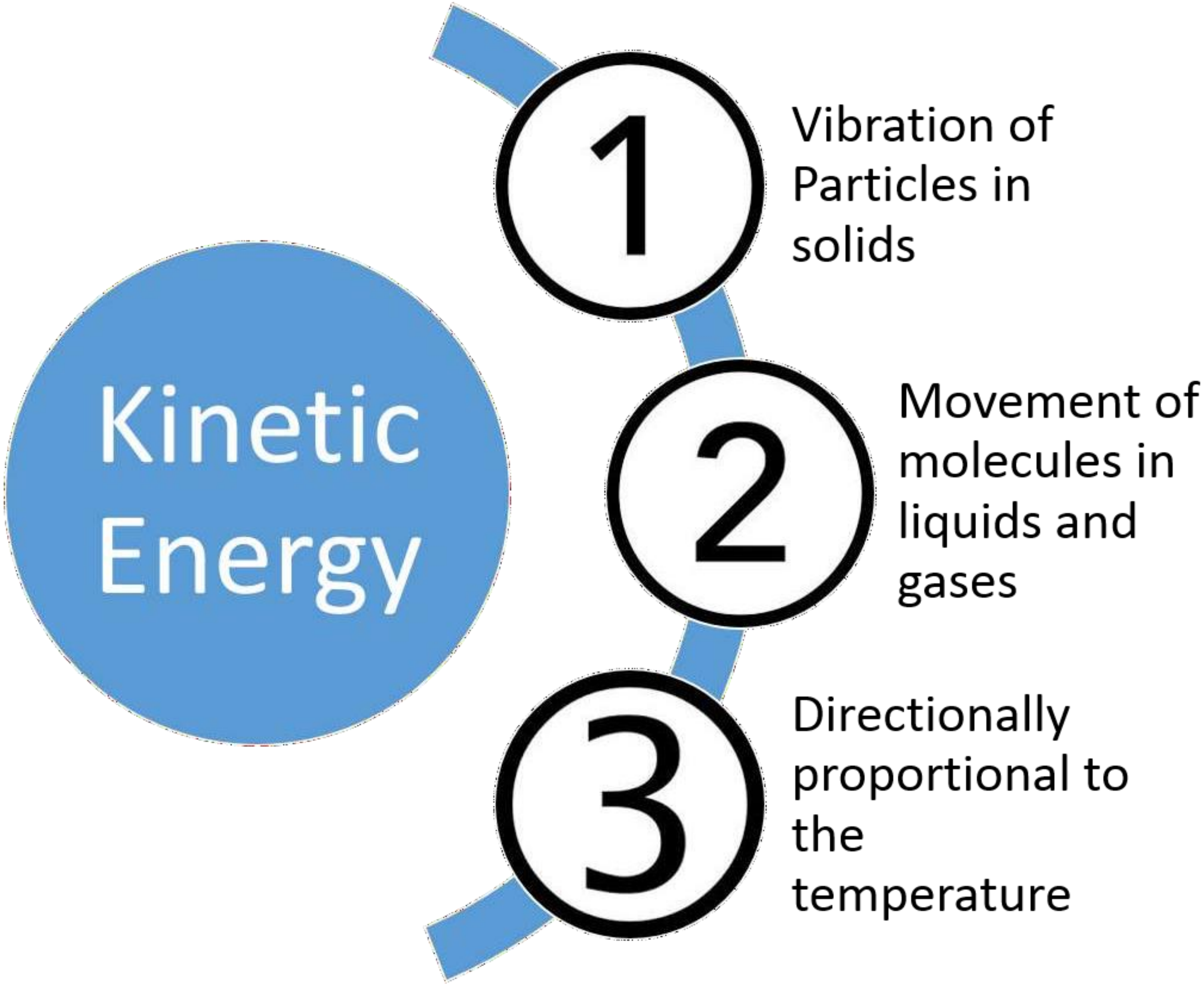
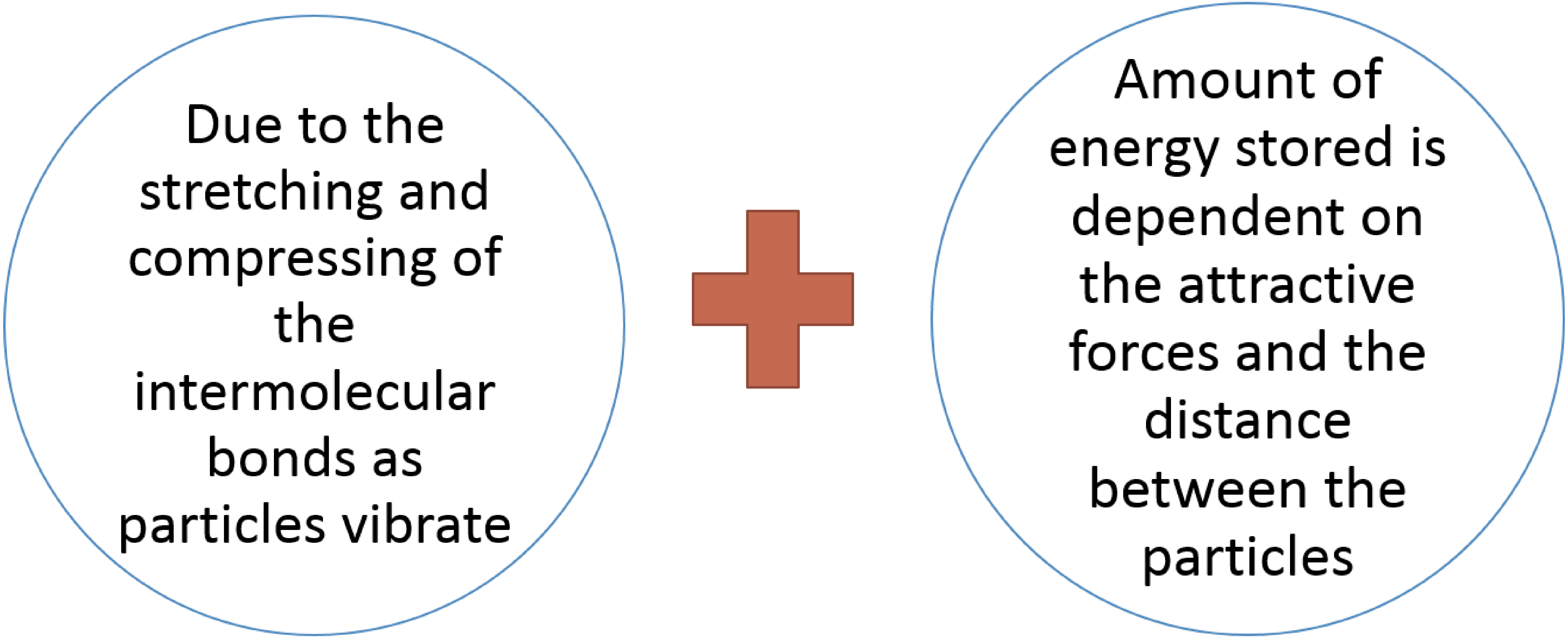
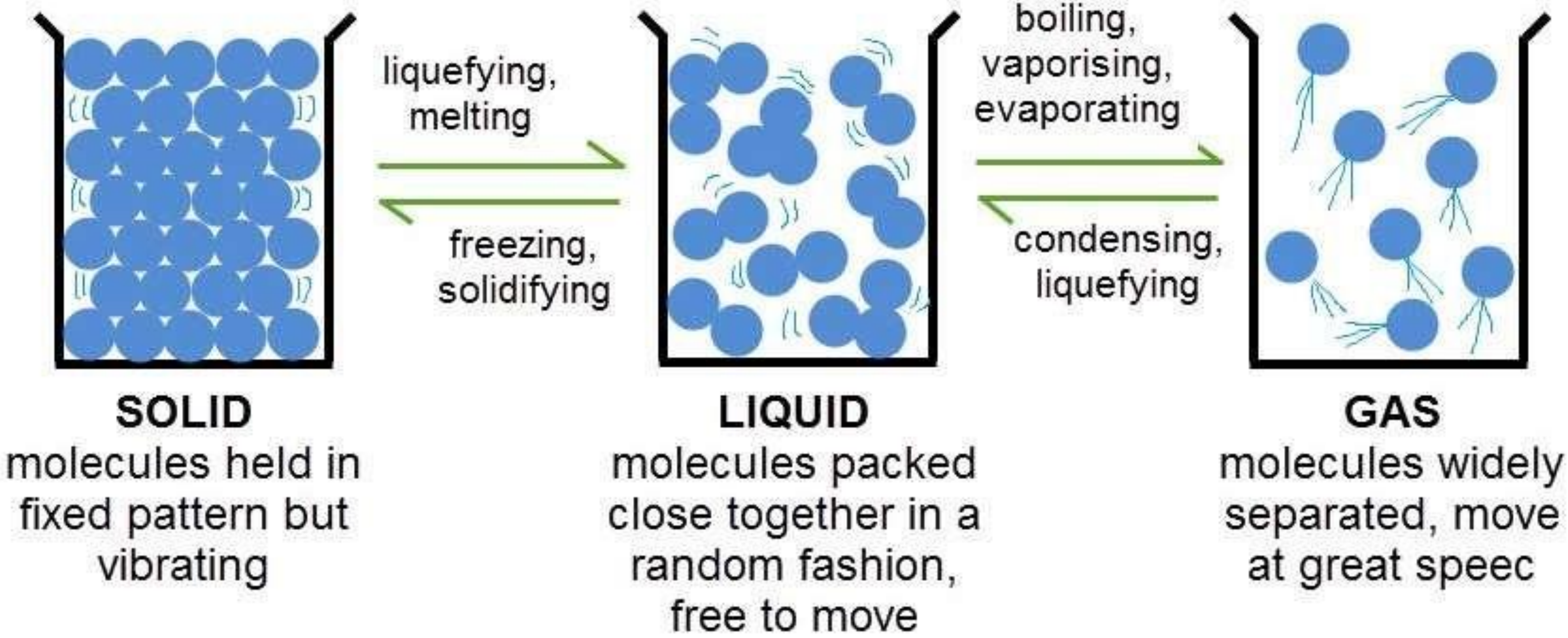
THERMAL PROPERTIES OF FOOD


Kinetic Energy
Potential Energy
Internal Energy


Kinetic Energy
1
Vibration of Particles in solids
2
Movement of molecules in liquids and gases
3
Directionally proportional to the temperature


Due to the stretching and compressing of the intermolecular bonds as particles vibrate
Amount of energy stored is dependent on the attractive forces and the distance between the particles

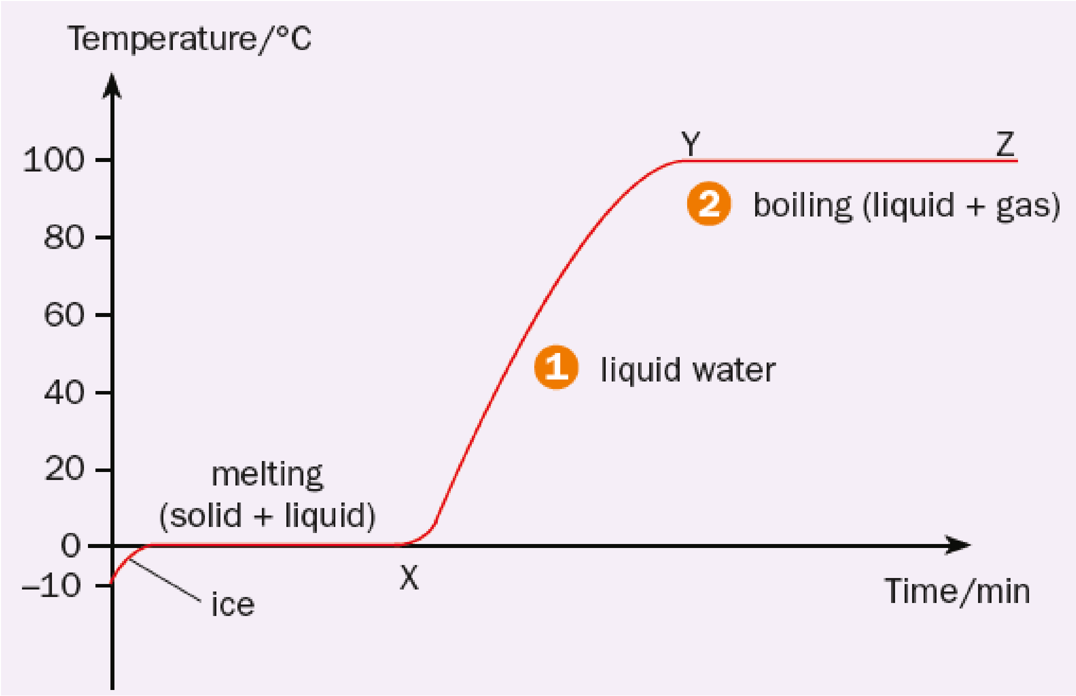

liquefying,
melting
freezing,
solidifying
boiling,
vaporising,
evaporating
condensing,
liquefying
SOLID
molecules held in fixed pattern but vibrating
LIQUID
molecules packed close together in a random fashion, free to move
GAS
molecules widely separated, move at great speec

Boiling

Boiling is the process in which the thermal energy absorbed by a substance changes it from liquid state to gaseous state without a change in temperature.

During boiling, thermal energy is absorbed to break the bonds between the liquid particles

Energy Transfer during Boiling

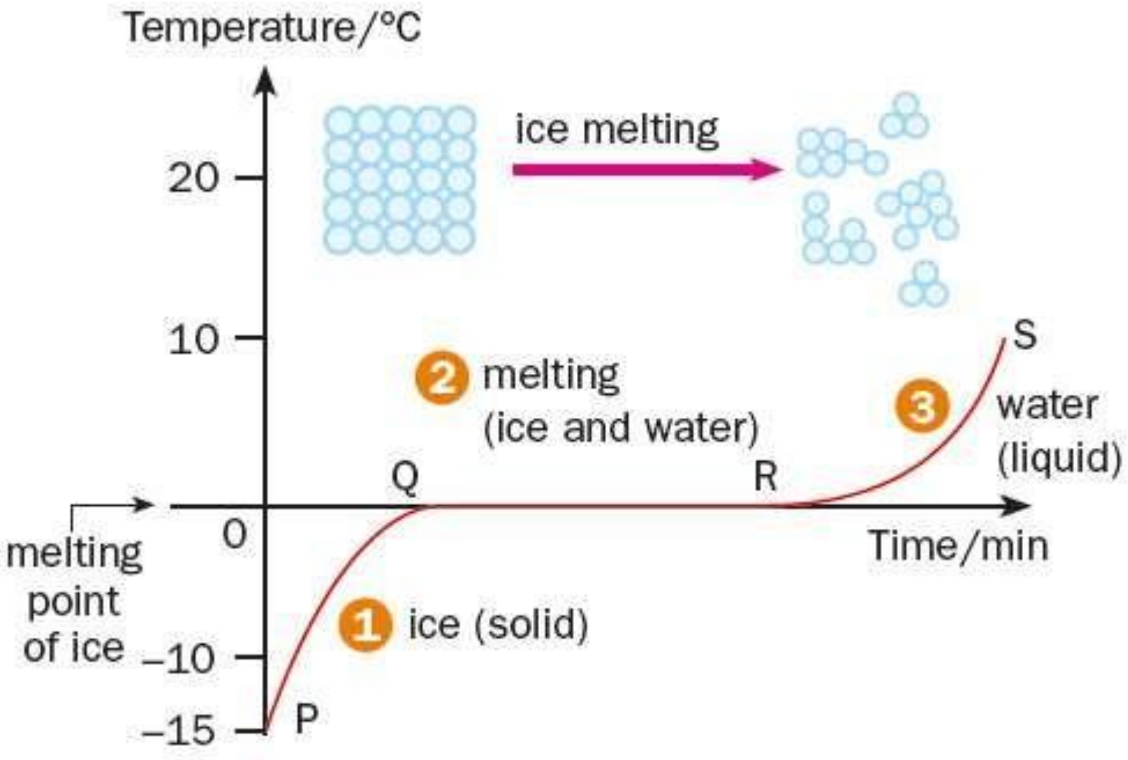


- From X to Y, the temperature of water rises from 0°C to 100°C. The average kinetic energy of the molecules increases.
- From Y to Z, the temperature of water remains steady at 100°C as it boils and turns into steam.
- From Y to Z, the thermal energy is used to break the bonds in between the molecules and provide energy for the molecules to escape into the surroundings

Condensation

- Condensation is the process in which the thermal energy taken away from a substance changes it from gaseous state to liquid state without a change in temperature. At condensation point, the substance releases thermal energy as bonds between the particles are being formed.

Determining the Melting Point of Ice

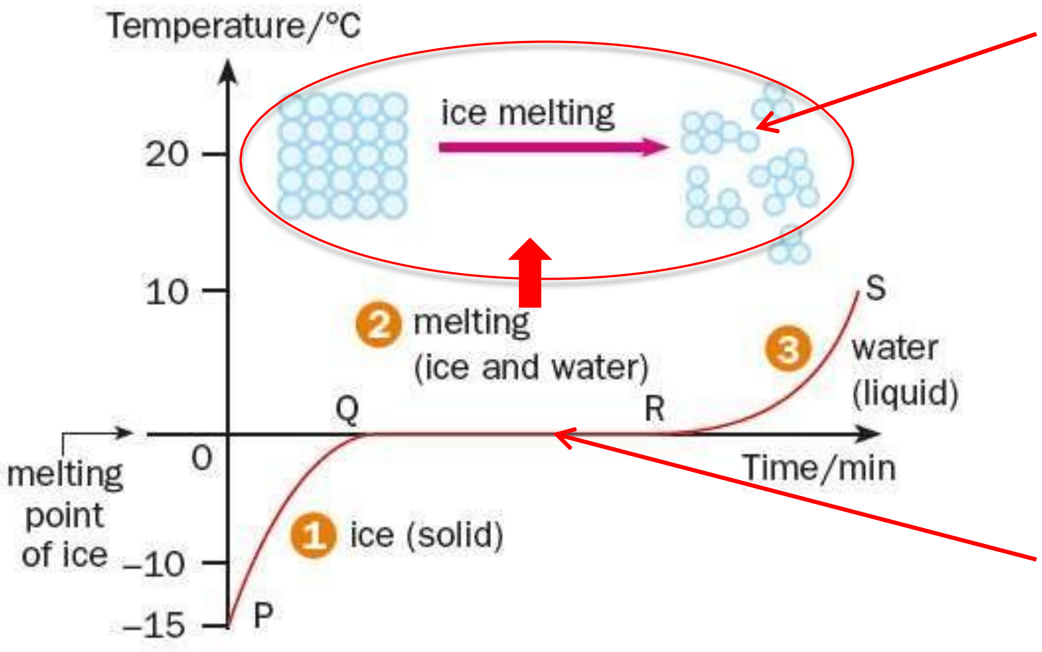


1. From P to Q, the temperature of solid ice rises from −15°C to 0°C.

2. From Q to R, the temperature remains steady at 0°C, even though heat is being absorbed as ice melts.

3. From R to S, the temperature of melted ice rises from 0°C to 10°C.

Energy Transfer During Melting

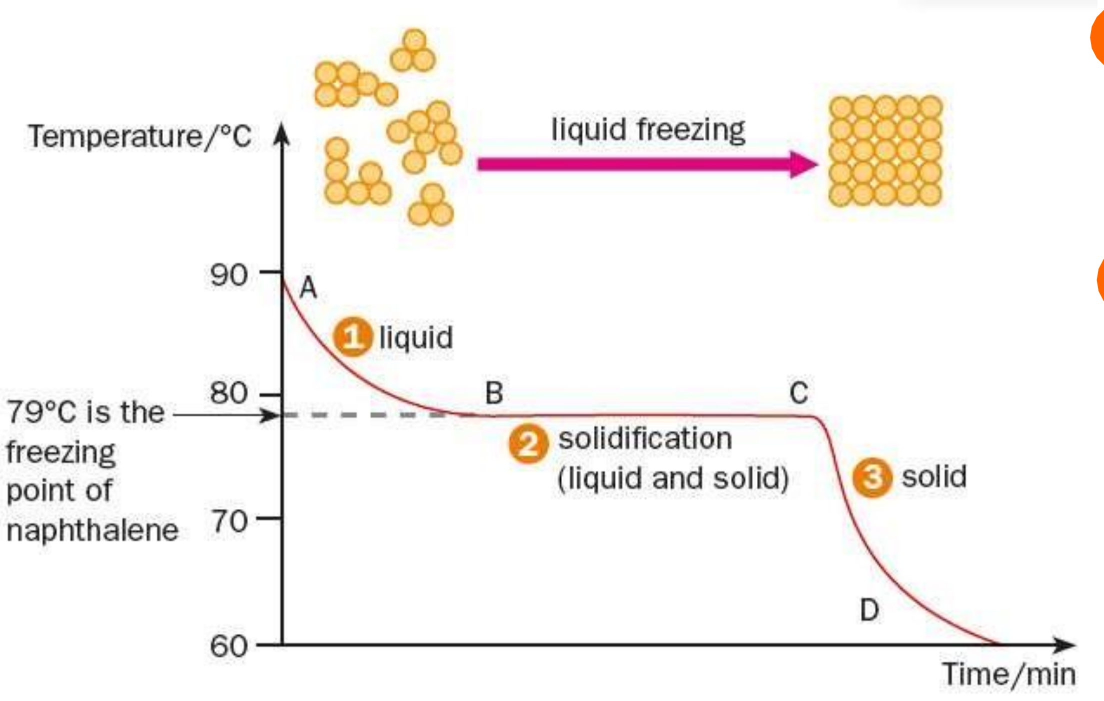


Between **Q and R**, thermal energy is absorbed to break the strong bonds between the particles of the solid ice.

Only the **total internal potential energy** of the particles is increased.

Since **total internal kinetic energy** does not increase, the temperature remains constant during melting.

Determining the Freezing Point of Naphthalene

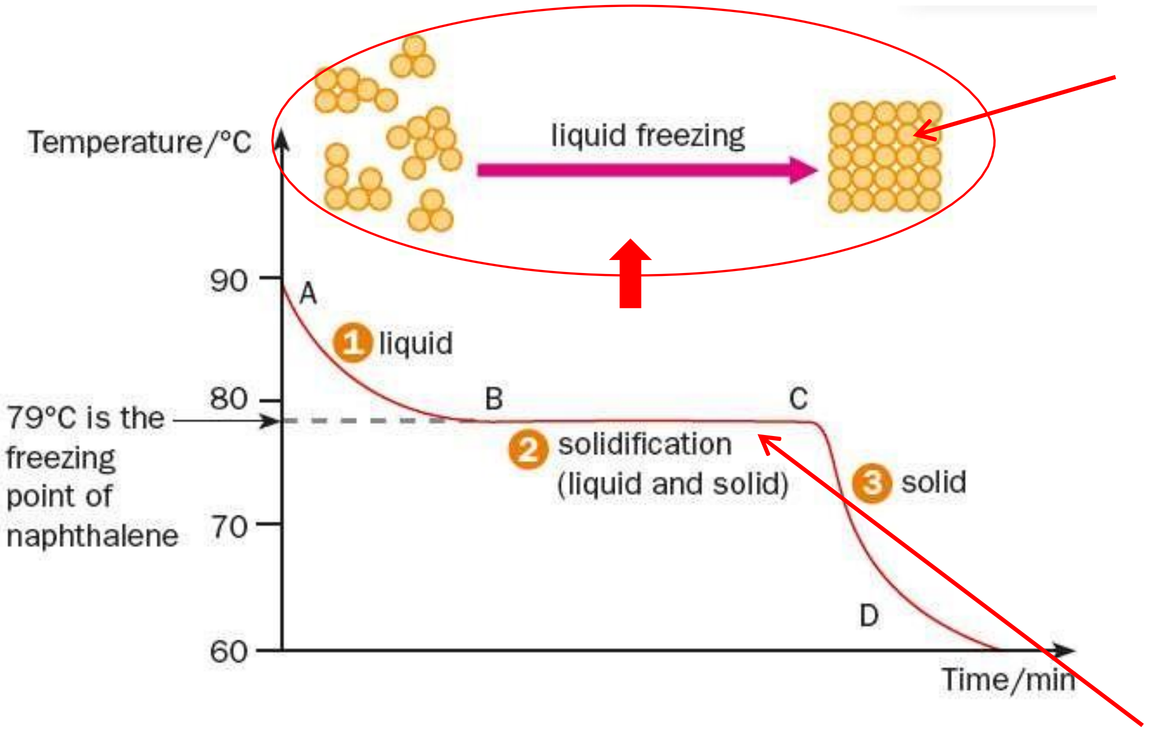


1 From A to B, the temperature of naphthalene falls from 90°C to 79°C.

2 From B to C, the temperature remains steady at 79°C, even though heat is being released as solidification occurs.

3 From C to D, the temperature of solid naphthalene falls from 79°C to 60°C.

Energy Transfer During Solidification



Between **B and C**, strong bonds are formed when particles move close together during freezing.

The **total internal potential energy** of the particles decreases as thermal energy is released and lost to the surroundings.

Since **total internal kinetic energy** does not decrease, the temperature remains constant during solidification.s

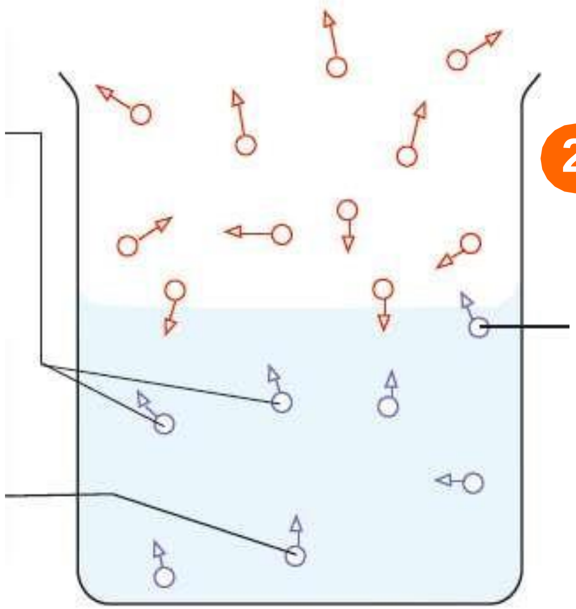
Evaporation

- Evaporation requires **thermal energy** from the surroundings.
- In other words, it absorbs heat from the surroundings to change the state of the substance from liquid to gas.
- If you step out of a swimming pool on a dry and sunny day, your body feels cold. Why?

How does Evaporation Occur?

1 Molecules in a liquid are in **constant**, **random** motion.

3 Less energetic molecules are left behind. The average kinetic energy of the molecules **decreases** and the temperature **decreases**.



2 The more energetic molecules have sufficient energy to **overcome attractive forces** due to other molecules to escape from the surface into the atmosphere.

Evaporation results in **cooling**.

Evaporation vs Boiling

Boiling	Evaporation
Occurs at a particular temperature	Occurs at any temperature
Relatively fast	Relatively slow
Take place throughout the liquid	Take place only at the surface
Bubbles are formed in the liquid	No bubbles are formed in the liquid
Temperature remains constant	Temperature may change
External thermal energy source required	External thermal energy source not required

Factors Affecting Rate of Evaporation

Rate of evaporation is affectedby

Humidity

The more humid the air is, the lower the rate of evaporation.

Temperature

The higher the temperature, the greater the rate of evaporation.

Surface area

The larger the surface area, the higher the rate of evaporation.

Pressure

Reducing atmospheric pressure increases the rate of evaporation.

Movement of air

The rate of evaporation increases if the surrounding air is moving.

Boiling point of liquid

The lower the boiling point, the higher the rate of evaporation.

Effects of Evaporation

- When perspiration evaporates from your skin, you feel cooler.
- Using water to sponge a person having fever will reduce his or her temperature when the water evaporates.
- A refrigerator uses a coolant with a low boiling point to remove heat via evaporation and condensation.

Evaporation

Explain why putting a layer of perfume on the skin produces a cooling effect.

Solution

- Perfume usually contains alcohol (which has a low specific heat capacity) and evaporates easily.
- As evaporation removes heat from the skin, the skin feels cool.

What is Heat?

Heat is the total internal kinetic energy due to molecular motion in an object

Quantity of heat is BTU or Kilo Joule (kJ)

- One BTU is the amount of heat required to raise 1 lb of water by 1 ˚ F
- One calorie is required to raise 1 g of water by 1 ˚ C

  1 cal = 4.187 J

- 1 BTU= 1.055 kJ= 1055 J

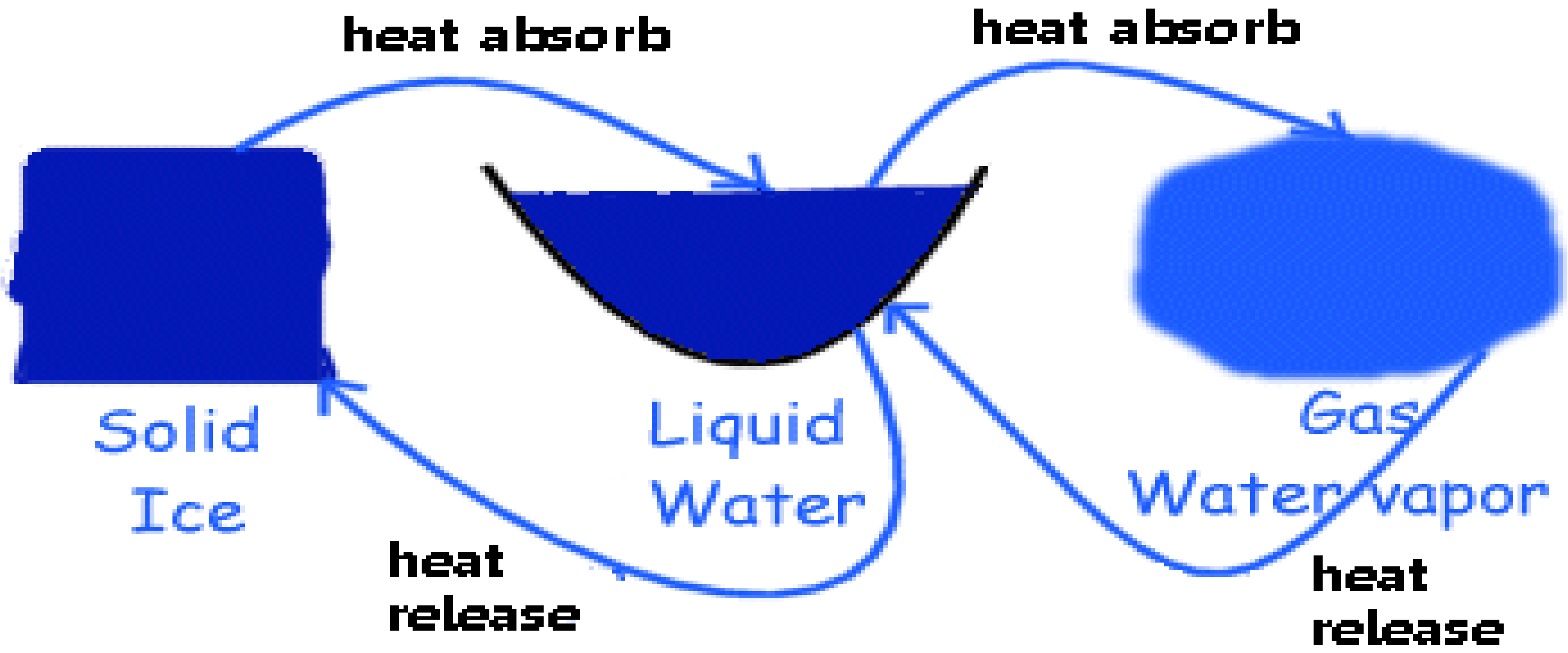
Heat is Energy

When heat (ie energy) goes into a substance, one of two things can happen:

1. Temperature goes up
2. Change of state

Change Of State

- Heat that brings about a change in potential energy of the molecules (temperature remains constant). Also called the latent heat.



Specific Heat

- It is the heat required to the temperature of 1 kg (lb) a substance by 1 ˚ K (F)
- Example:

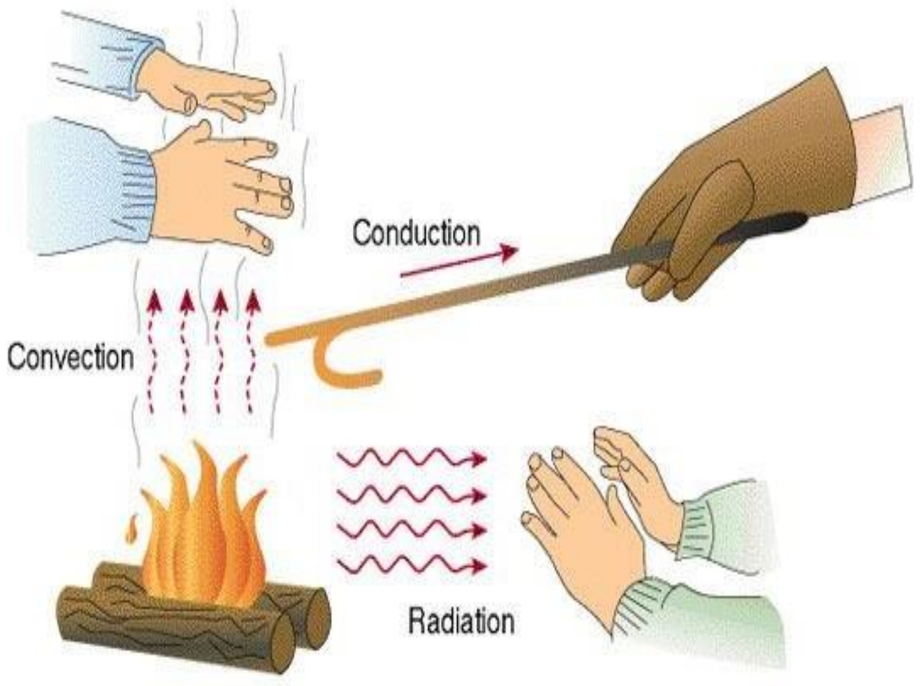
  water's specific heat is 1 btu/ lb F (4.2 kJ/kg K)

  air's specific heat is 0.24 btu/ lb F (1.0 kJ/kg K)

Heat Transfer Modes

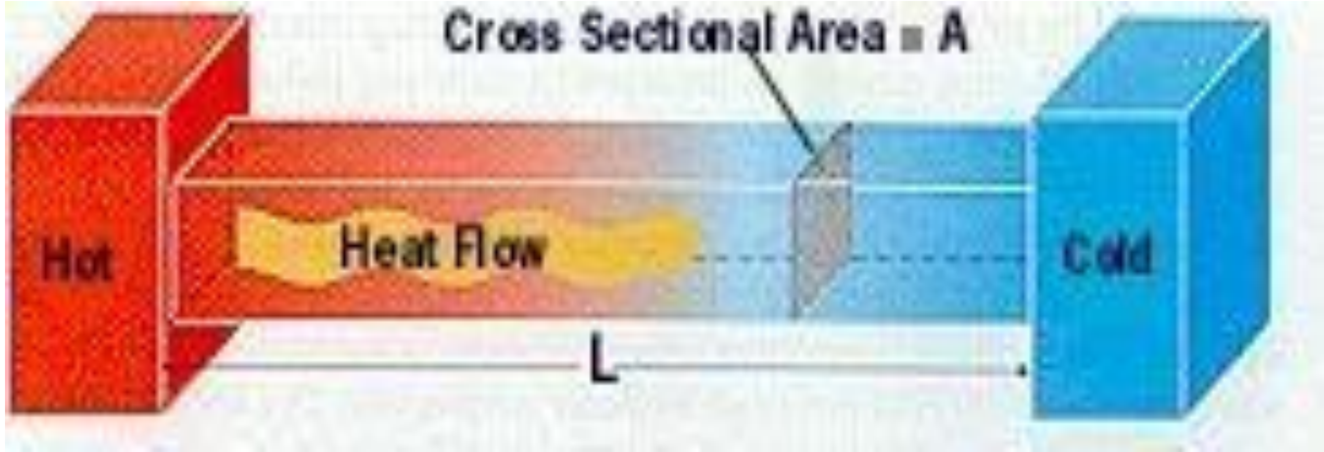
There are 3 modes of heat transfer.

1. Conduction
2. Convection
3. Radiation



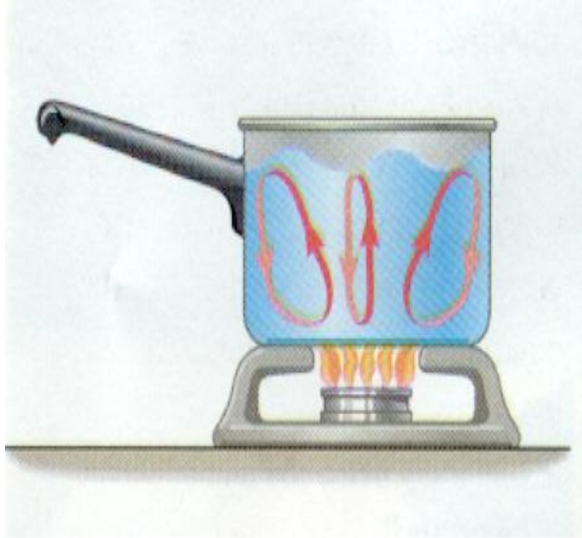
Conduction

- Heat transfer through a solid medium via direct contact
- Expressed by Fourier's Law



Convection

- Energy transfer by fluid motion
- Two kinds of convection
  - Forced convection: Fluid is forced
  - Natural or free convection: fluid is induced by temperature difference



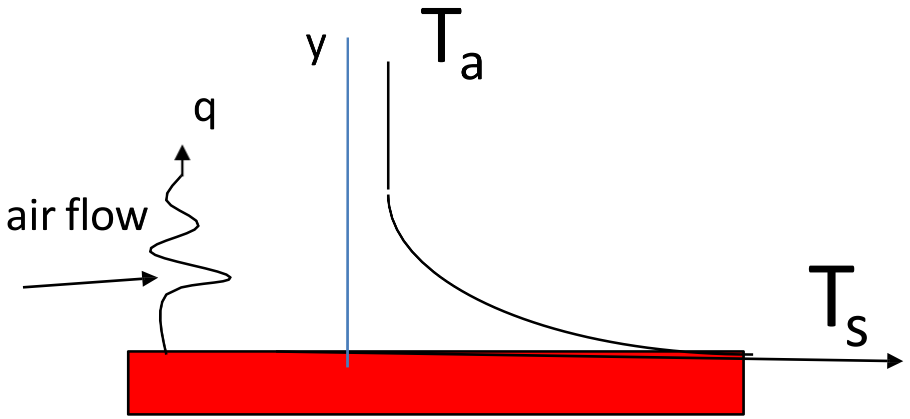
Convective Heat Transfer

Newton's Law of cooling

$$q'' = h_c(T_s - T_a)$$

$$q'' = \frac{(T_s - T_a)}{\frac{1}{h_C}}$$

$$R_c = \frac{1}{h_c}$$

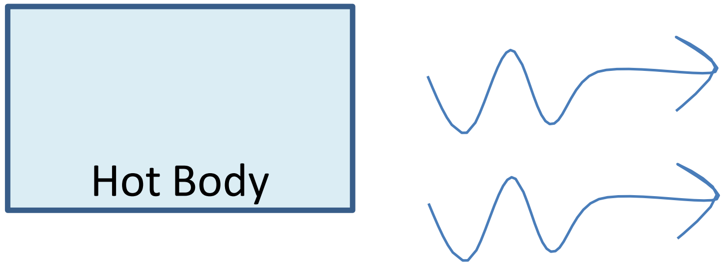


where:
h_c is convection coefficient (W/m^2C),
T_s is surface temperature (°C),
T_a is surrounding air temperature (°C)

Rc= unit convective resistance.

Radiation

- Energy emitted by object that is at any temperature above absolute zero
- Energy is in the form electromagnetic waves
- No medium needed and travel at speed of light



Example :

Solar radiation

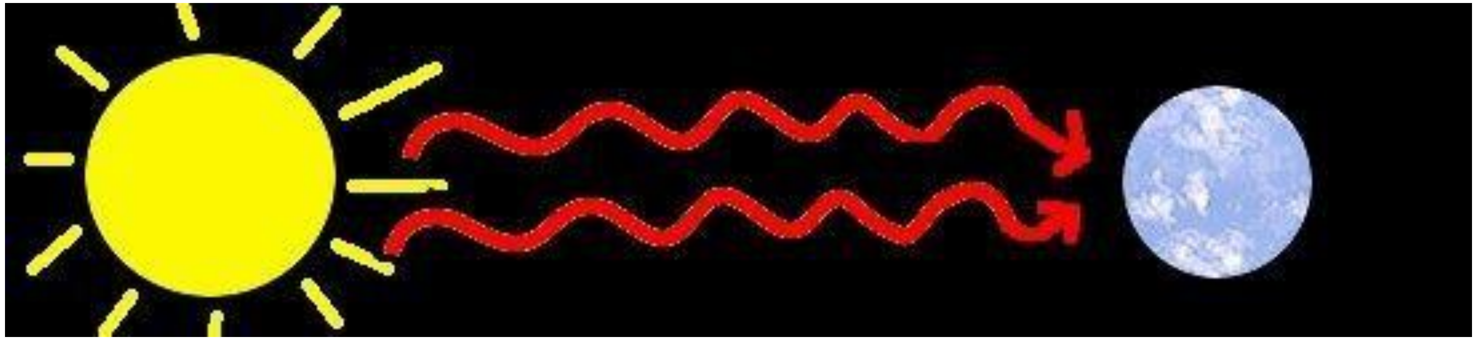
Radiator

Radiation

- Important mode of heat at high temperatures, e.g. combustion furnace
- At room temperature it may just be measurable.
- Intensity depends on body temperature and surface characteristics

Solar Radiation

- **Solar radiation** is the radiation emitted by the sun due to nuclear fusion reaction
- **Solar Constant**: The amount of solar energy arriving at the top of the atmosphere perpendicular to the sun's rays.
- = 1375 W m^{-2}



Heat transfer optimization

- We have the following relations for heat transfer:
  - Conduction: $Q = k A \Delta T / d$
  - Convection: $Q = A h_c \Delta T$
  - Radiation: $Q = A h_r \Delta T$
- As a result, when equipment designers want to improve heat transfer rates, they focus on:
  - Increasing the area A, e.g. by using profiled tubes and ribbed surfaces.
  - Increasing ΔT (which is not always controllable).
  - For conduction, increasing k/d.
  - Increase h_c by not relying on natural convection, but introducing forced convection.
  - Increase h_r, by using "black" surfaces.