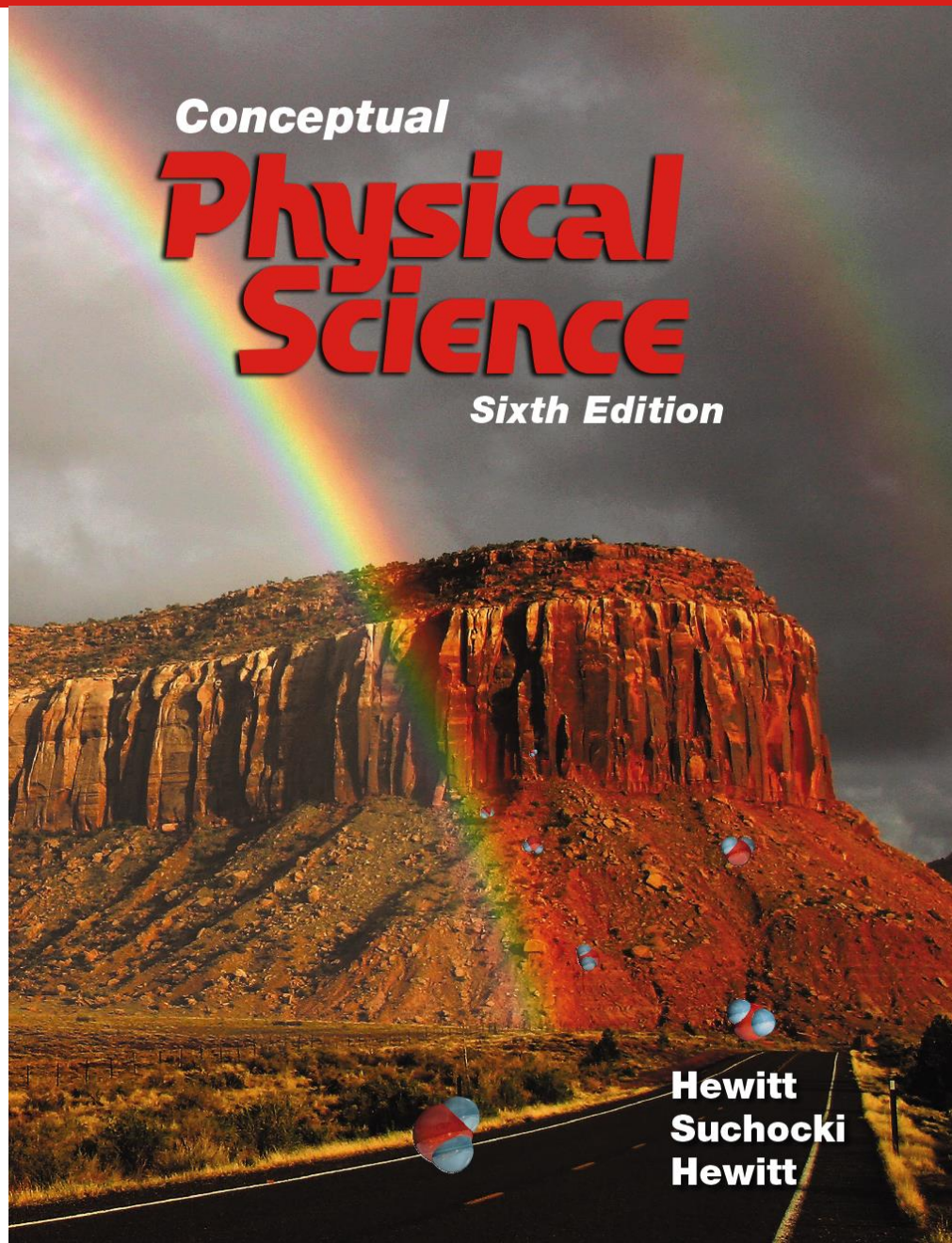
Chapter 8: Heat Transfer and Change of Phase



This lecture will help you understand:

- Conduction
- Convection
- Radiation
- Heat Transfer and Change of Phase
- Boiling

Heat Transfer

- Processes of thermal energy transfer:
  - Conduction
  - Convection
  - Radiation

Conduction

- Conduction
  - Transfer of internal energy by electron and molecular collisions within a substance

Heat Transfer: Conduction

- Conduction occurs predominately in solids where the molecules remain in relatively restricted locations.
- When you stick a nail into ice, does cold flow from the ice to your hand, or heat from your hand to the ice?

Heat Transfer: Conduction
CHECK YOUR NEIGHBOR

If you hold one end of a metal bar against a piece of ice, the end in your hand will soon become cold. Does cold flow from the ice to your hand?

A. Yes.
B. In some cases, yes.
C. No.
D. In some cases, no.

Heat Transfer: Conduction
CHECK YOUR ANSWER

If you hold one end of a metal bar against a piece of ice, the end in your hand will soon become cold. Does cold flow from the ice to your hand?

A. Yes.

B. In some cases, yes.

C. No.

D. In some cases, no.

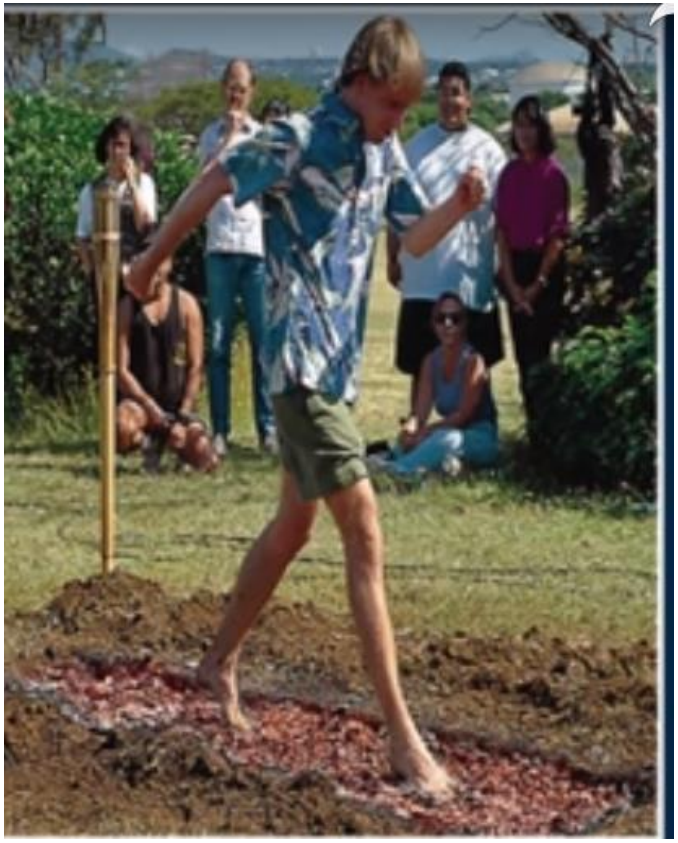
***Explanation*:**

Cold does not flow from the ice to your hand. Heat flows from your hand to the ice. The metal is cold to your touch, because you are transferring heat to the metal.

Conduction

- Insulation
  - Doesn't *prevent* the flow of internal energy
  - *Slows* the rate at which internal energy flows
  - Example:
    - Rock wool or fiberglass between walls slows the transfer of internal energy from a warm house to a cool exterior in winter, and the reverse in summer

Conduction Application



Snow patterns on the roof of a house show areas of conduction and insulation. Bare parts show where heat from inside has conducted through the roof and melted the snow.

Energy Transfer
CHECK YOUR NEIGHBOR

When thermal insulation, such as spun glass or rock wool, is placed beneath the roof of a house, then in cold weather the insulation will

A. create heat to warm the house.
B. keep the cold from coming through the roof.
C. slow the flow of heat from inside the house to the outside.
D. stop the flow of heat from inside the house to the outside.

Energy Transfer
CHECK YOUR ANSWER

When thermal insulation, such as spun glass or rock wool, is placed beneath the roof of a house, then in cold weather the insulation will

A. create heat to warm the house.
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D. stop the flow of heat from inside the house to the outside.

***Explanation*:**

No insulation can *stop* heat flow. Insulation only slows it. (A fortune awaits the inventor who can come up with the "perfect" insulator!)

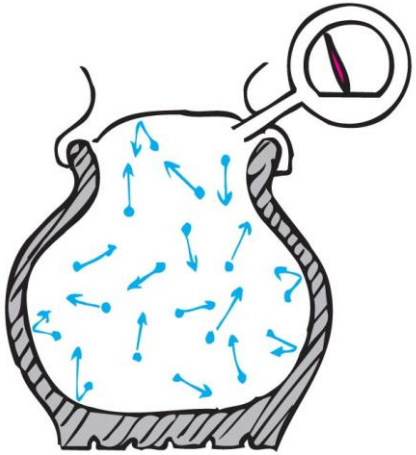
Heat Transfer: Conduction

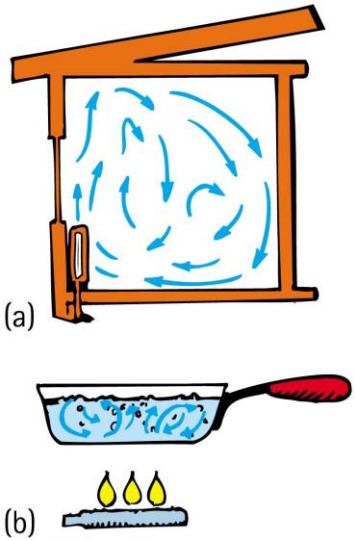
- Good conductors:
  - Composed of atoms with "loose" outer electrons
  - Known as poor insulators
  - Examples—all metals to varying degrees
- Poor conductors:
  - Delay the transfer of heat
  - Known as good insulators
  - Examples—wood, wool, straw, paper, Styrofoam, cork, liquid, gases, air, or materials with trapped air

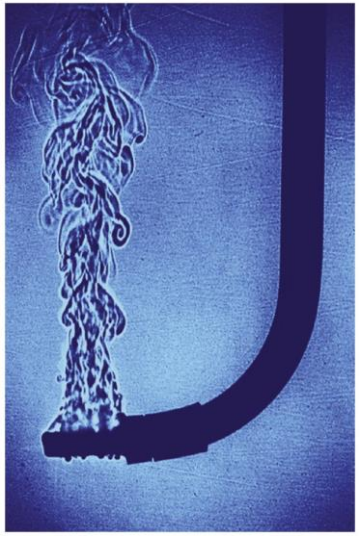
Convection

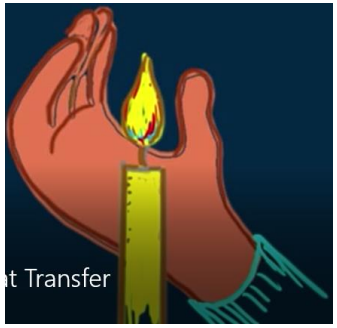
- Convection
  - Transfer of heat involving only bulk motion of fluids

    Examples:
    - Visible shimmer of air above a hot stove or above asphalt on a hot day
    - Visible shimmers in water due to temperature difference









Convection

- Cooling by expansion

Opposite to the warming that occurs when air is compressed

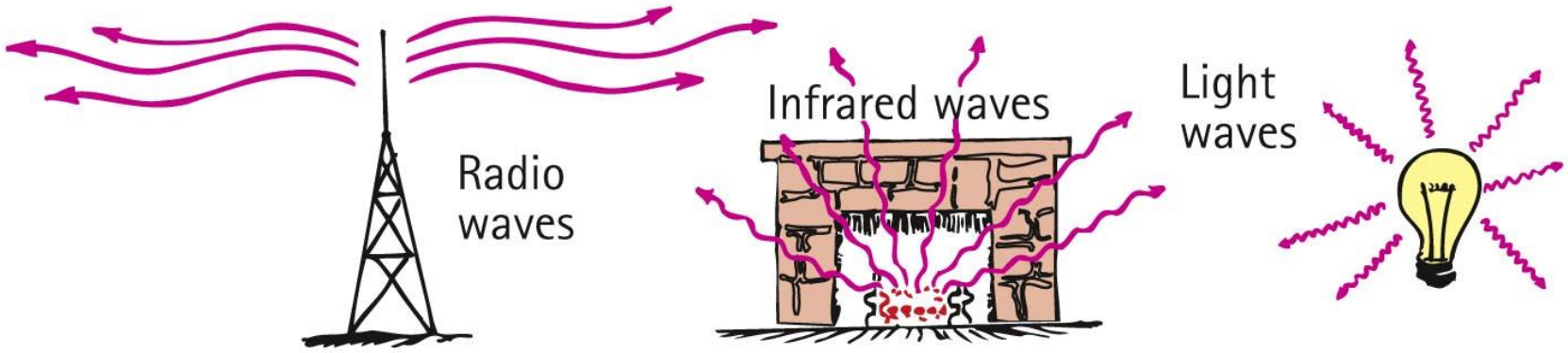
Example: The "cloudy“ region above hot steam issuing from the nozzle of a pressure cooker is cool to the touch (a combination of air expansion and mixing with cooler surrounding air). Careful, the part at the nozzle that you can't see is steam—ouch!

Convection

- Reason warm air rises
  - Warm air expands, becomes less dense, and is lifted upward
  - Air rises until its density equals that of the surrounding air
  - Example:
    - Smoke from a campfire rises and blends with the surrounding cool air.

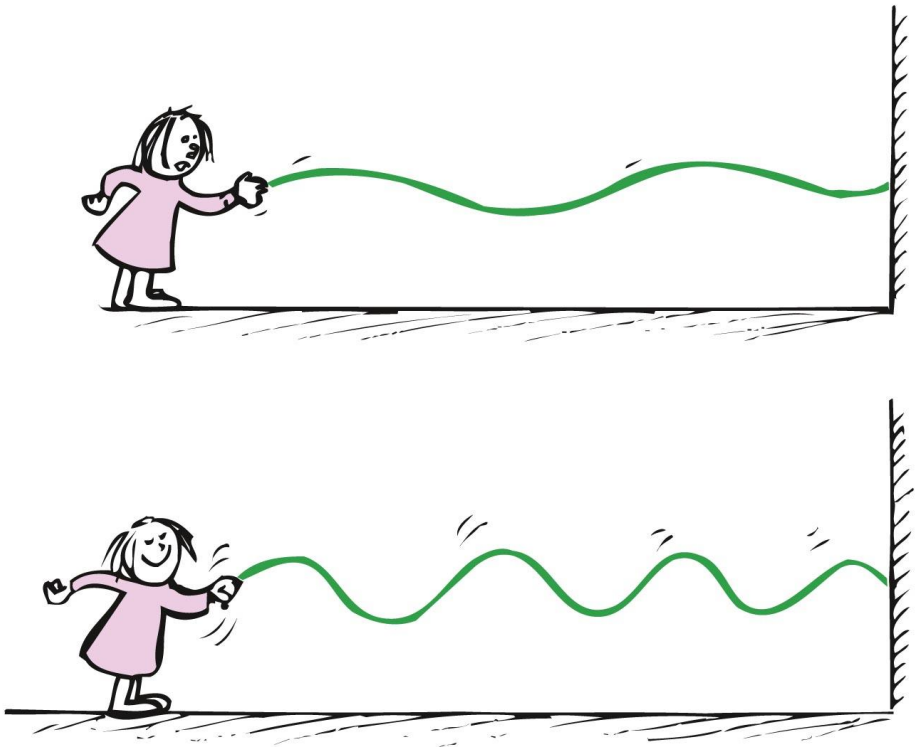
Radiation

- Radiation
  - Transfer of energy via electromagnetic waves that can travel through empty space

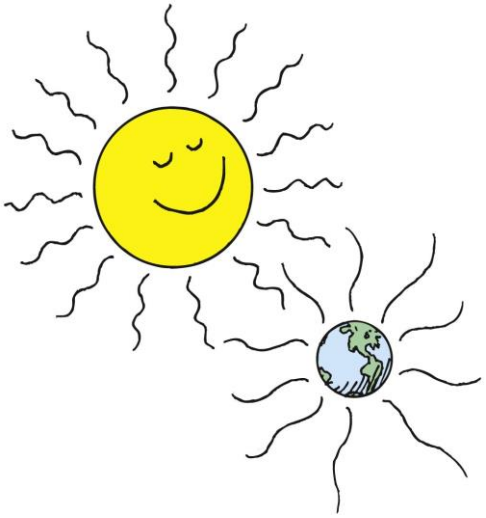


Heat Transfer: Radiation

- Wavelength of radiation is related to the frequency of vibration.
- Low-frequency vibrations ⇒ long waves
- High-frequency vibrations ⇒ short waves



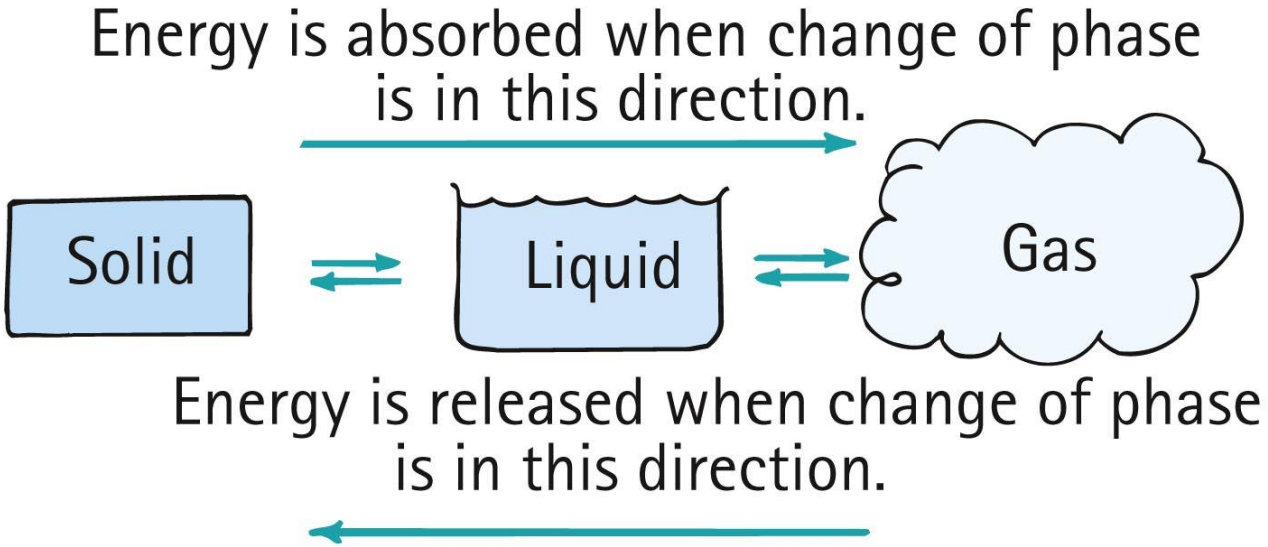
Radiation



- Emission of radiant energy
  - Every object above absolute zero radiates
  - From the Sun's surface comes light, or solar radiation
  - From the Earth's surface is terrestrial radiation in the form of infrared waves.

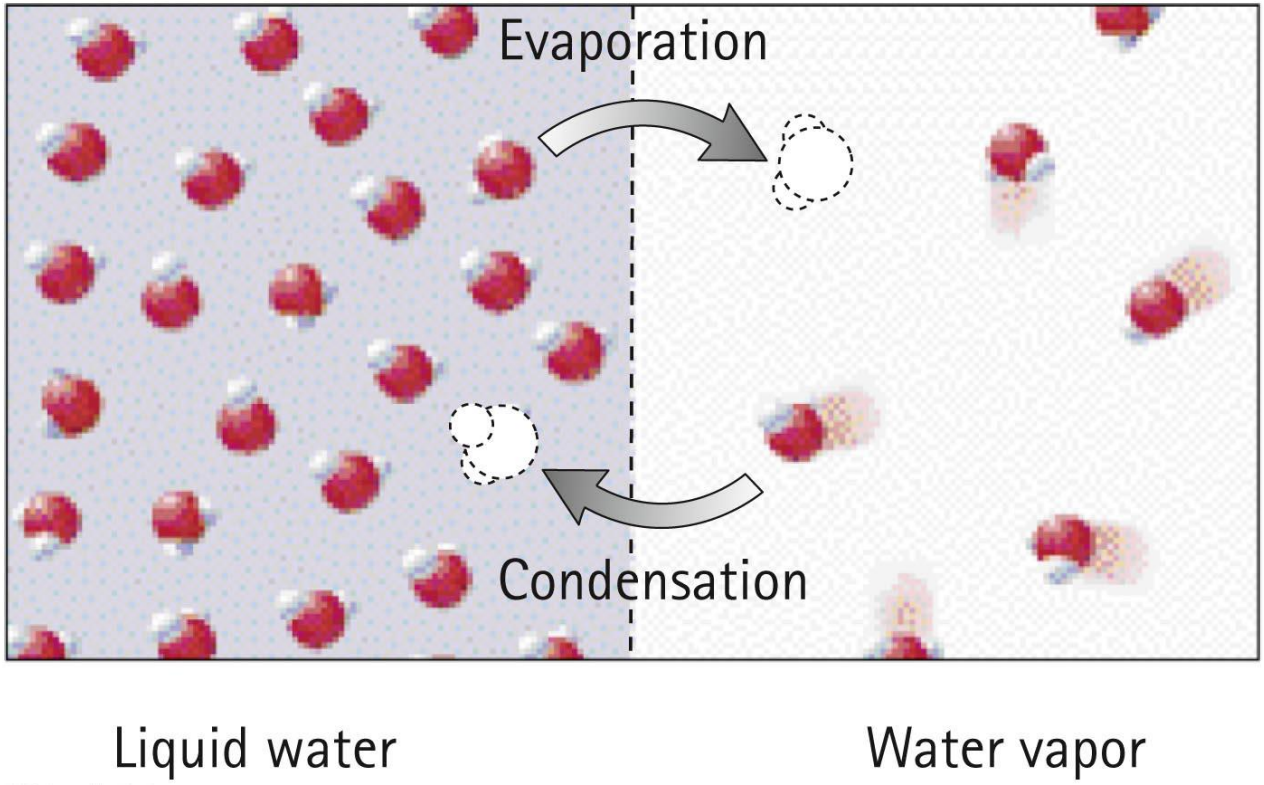
Phases of Matter

- Matter exists in the three common phases: *solid*, *liquid*, and *gas* (a fourth phase of matter is *plasma*).
- When matter changes from one phase to another, energy is transferred.



Heat Transfer and Change of Phase

- Evaporation
  - Change of phase from liquid to gas

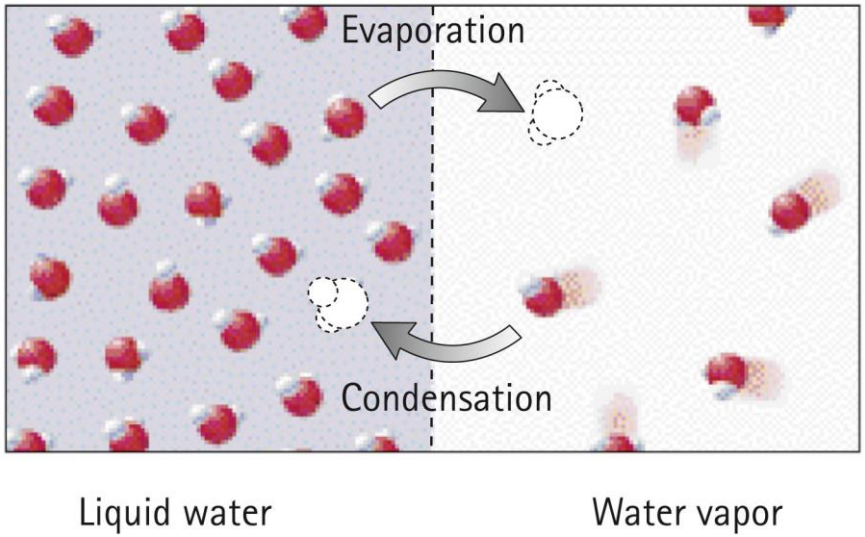


Heat Transfer and Change of Phase

- Evaporation process
  - Molecules in liquid move randomly at various speeds, continually colliding with one another
  - Some molecules gain kinetic energy while others lose kinetic energy during collision
  - Some energetic molecules escape from the liquid and become gas
  - Average kinetic energy of the remaining molecules in the liquid decreases, resulting in cooler water

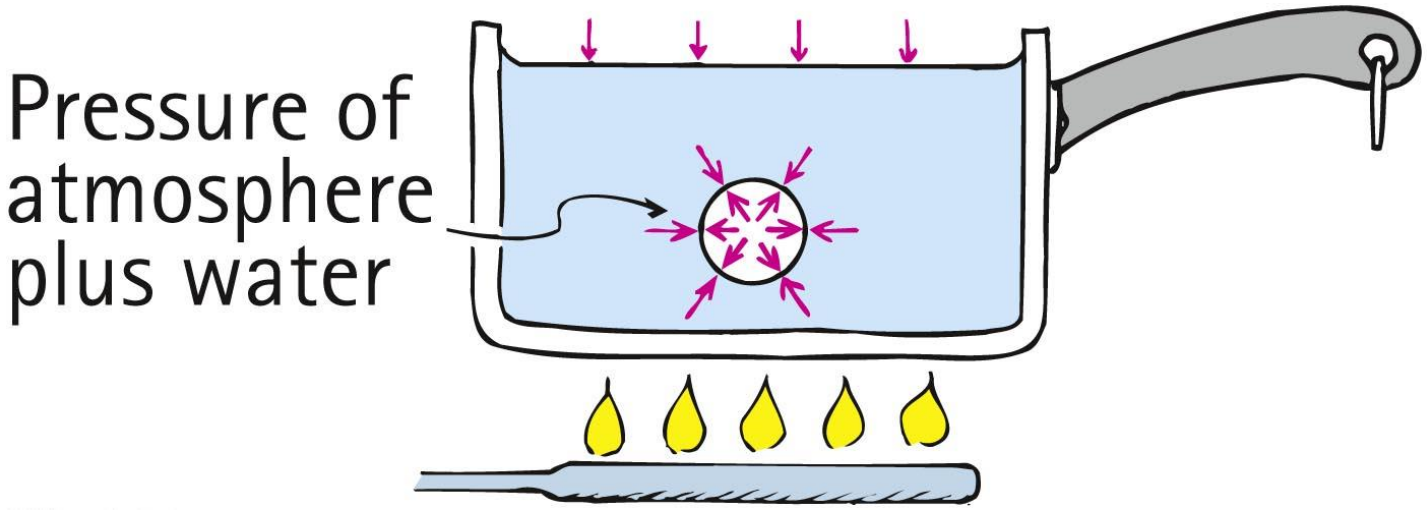
Heat Transfer and Change of Phase

- Condensation process
  - Opposite of evaporation
  - Warming process from a gas to a liquid
  - Gas molecules near a liquid surface are attracted to the liquid
  - They strike the surface with increased kinetic energy, becoming part of the liquid



Boiling

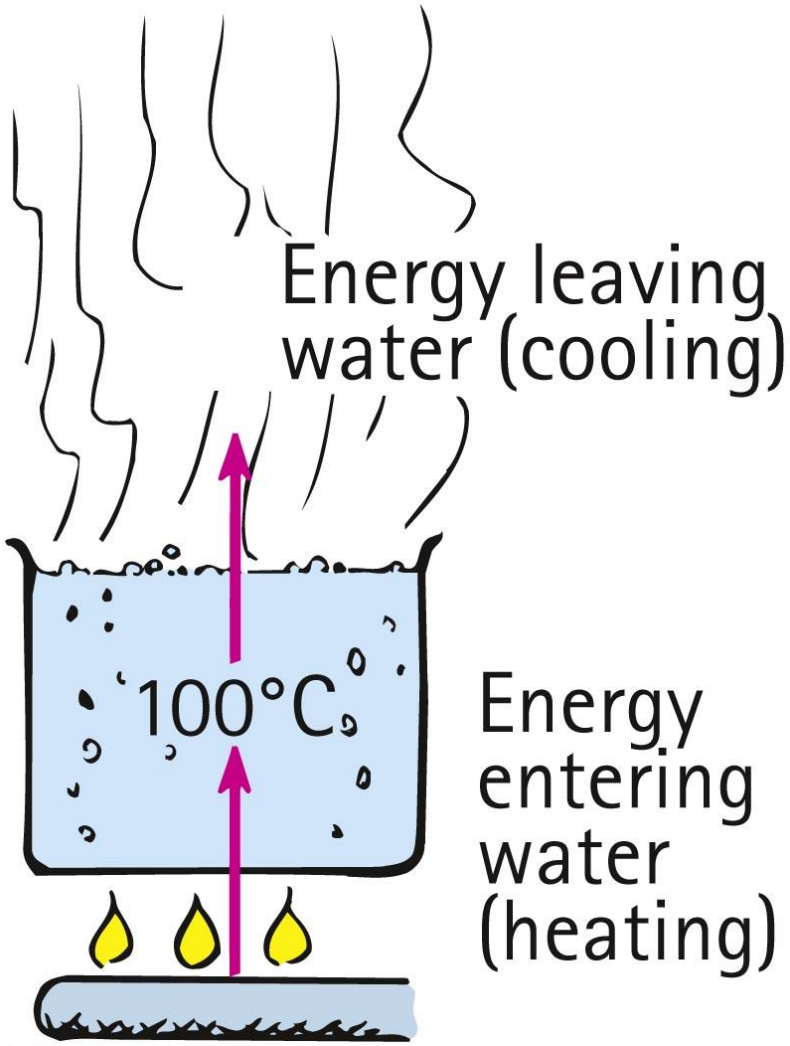
- Boiling process
  - Rapid evaporation occurs beneath the surface of a liquid



Boiling

- Boiling process (continued)
  - evaporation beneath the surface forms vapor bubbles
  - bubbles rise to the surface
  - if vapor pressure in the bubble is less than the surrounding pressure, then the bubbles collapse
  - hence, bubbles don't form at temperatures below boiling point when vapor pressure is insufficient

Boiling



- Heating warms the water from below.
- Boiling cools the water from above.