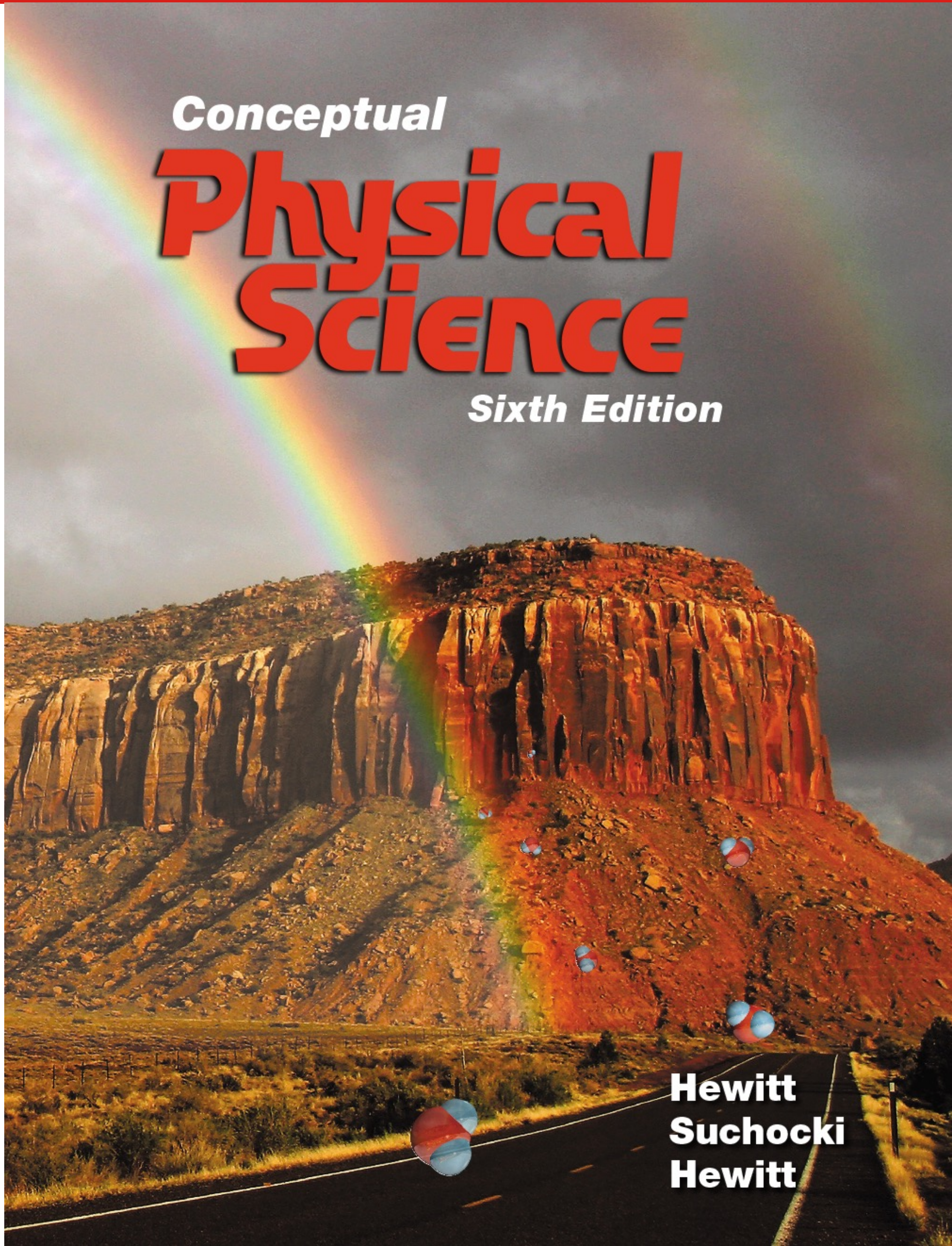
Chapter 7: Heat Transfer and Change of Phase



Heat Transfer

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

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.

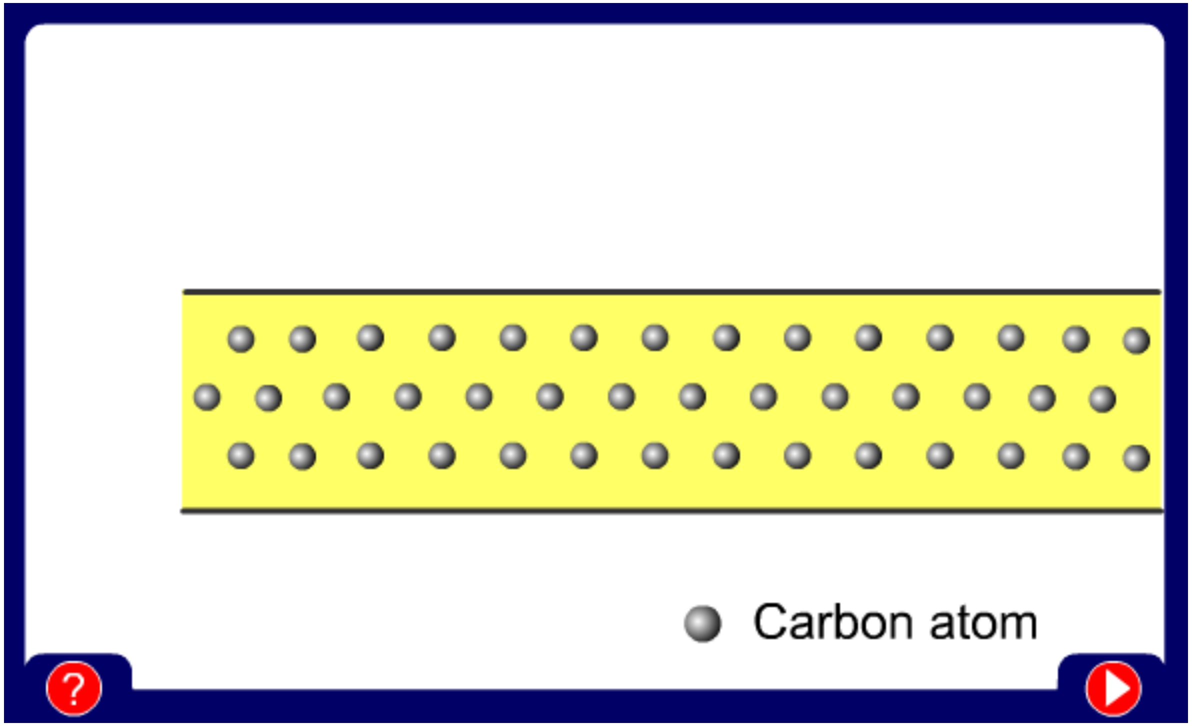
B. In some cases, yes.

C. **No.**

D. In some cases, no.

Explanation:

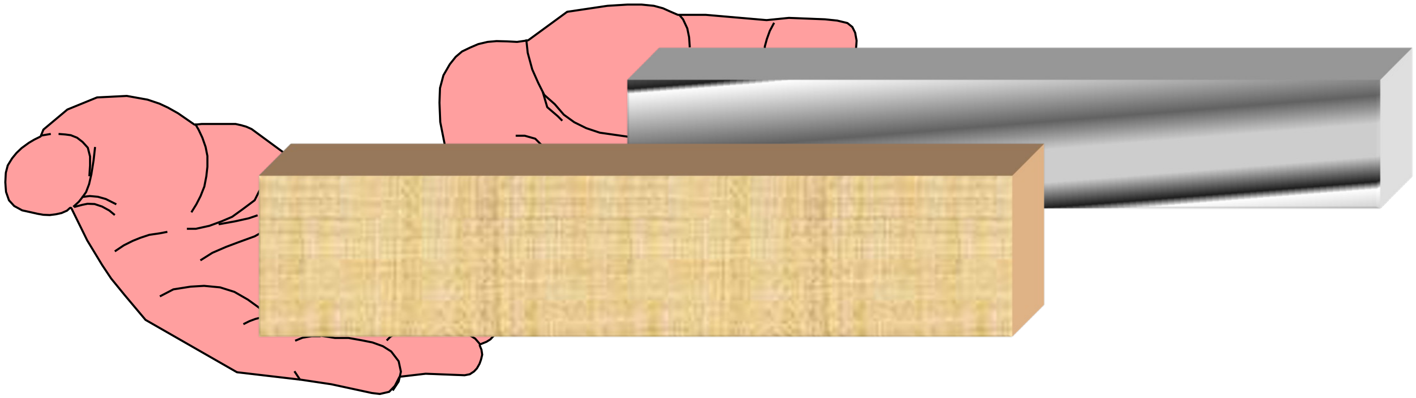
Cold does not flow from the ice to your hand. Heat flows from your hand to the ice. The metal is cold to your touch, because you are transferring heat to the metal.



As you heat the metal, the particles vibrate, these vibrations make the adjacent particles vibrate, and so on and so on, the vibrations are passed along the metal and so is the heat. We call this conduction.

Why does metal feel colder than wood, if they are both at the same temperature?

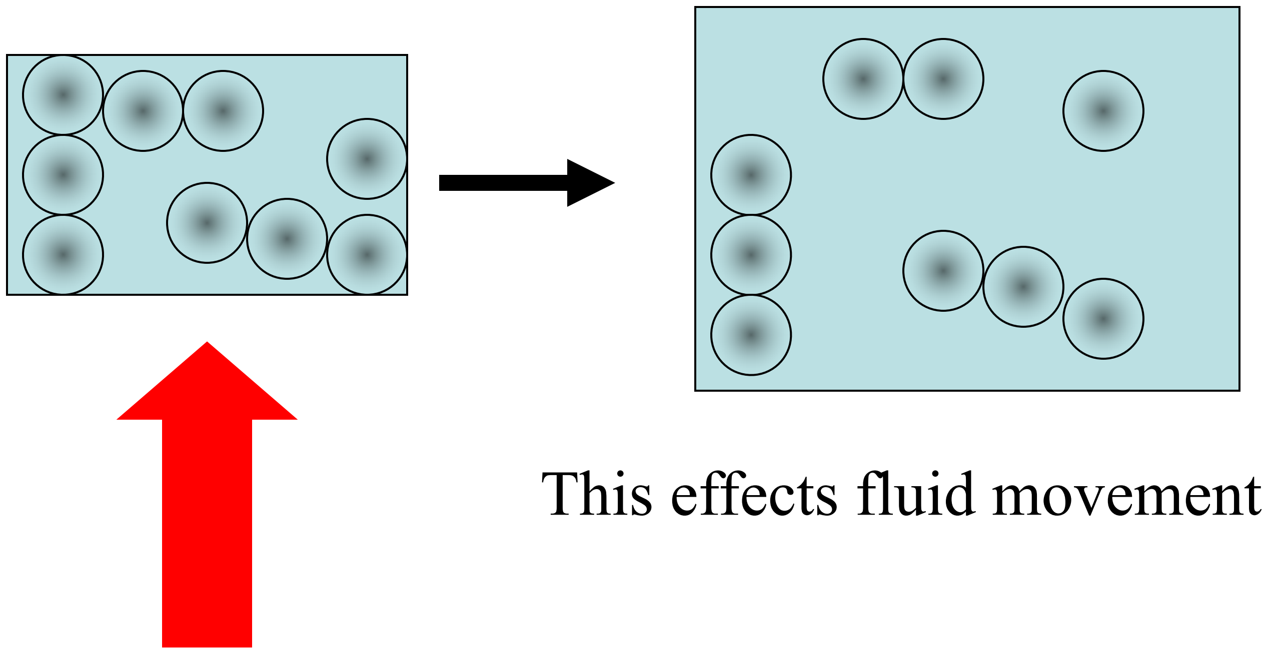
Metal is a conductor, wood is an insulator. Metal conducts the heat away from your hands. Wood does not conduct the heat away from your hands as well as the metal, so the wood feels warmer than the metal.



2) Convection

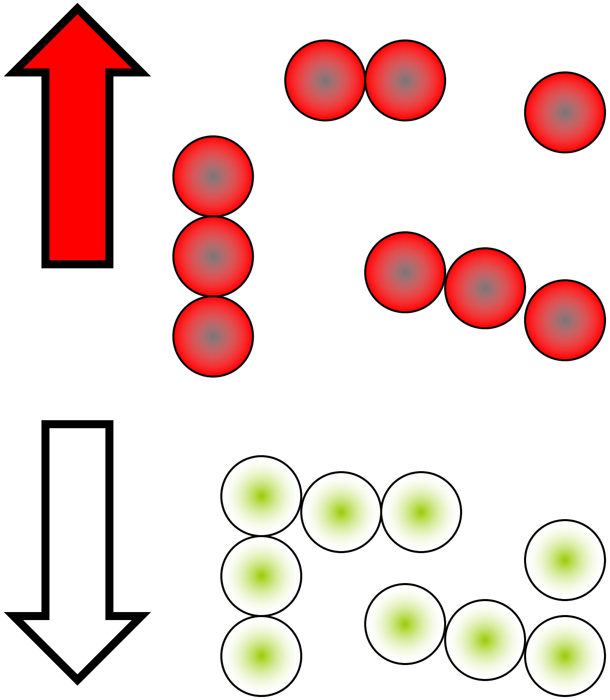
What happens to the particles in a liquid or a gas when you heat them?

The particles spread out and become less dense.



This effects fluid movement.

Fluid movement



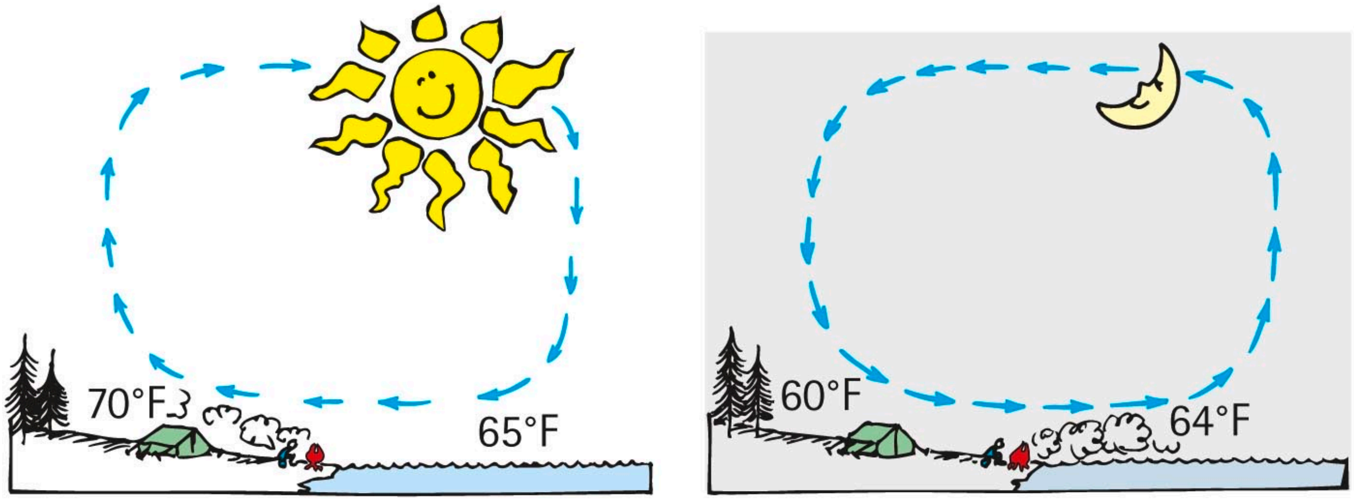
Cooler, more dense, fluids sink through warmer, less dense fluids.

In effect, warmer liquids and gases rise up.

Cooler liquids and gases sink.

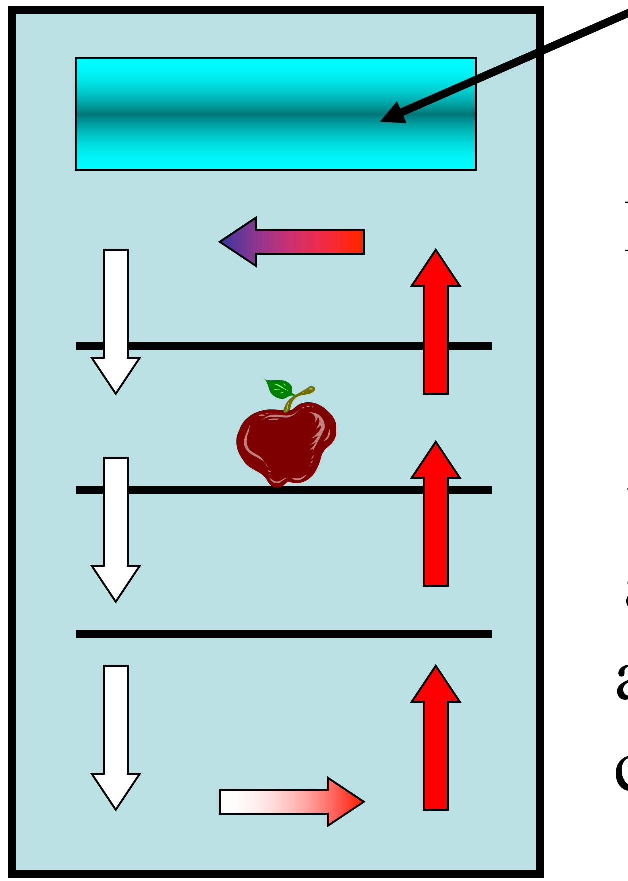
Convection Currents

- Convection currents produced by unequal heating of land and water.
- During the day, warm air above the land rises, and cooler air over the water moves in to replace it.
- At night, the direction of air flow is reversed.



Cold air sinks

Where is the freezer compartment put in a fridge?



Freezer compartment

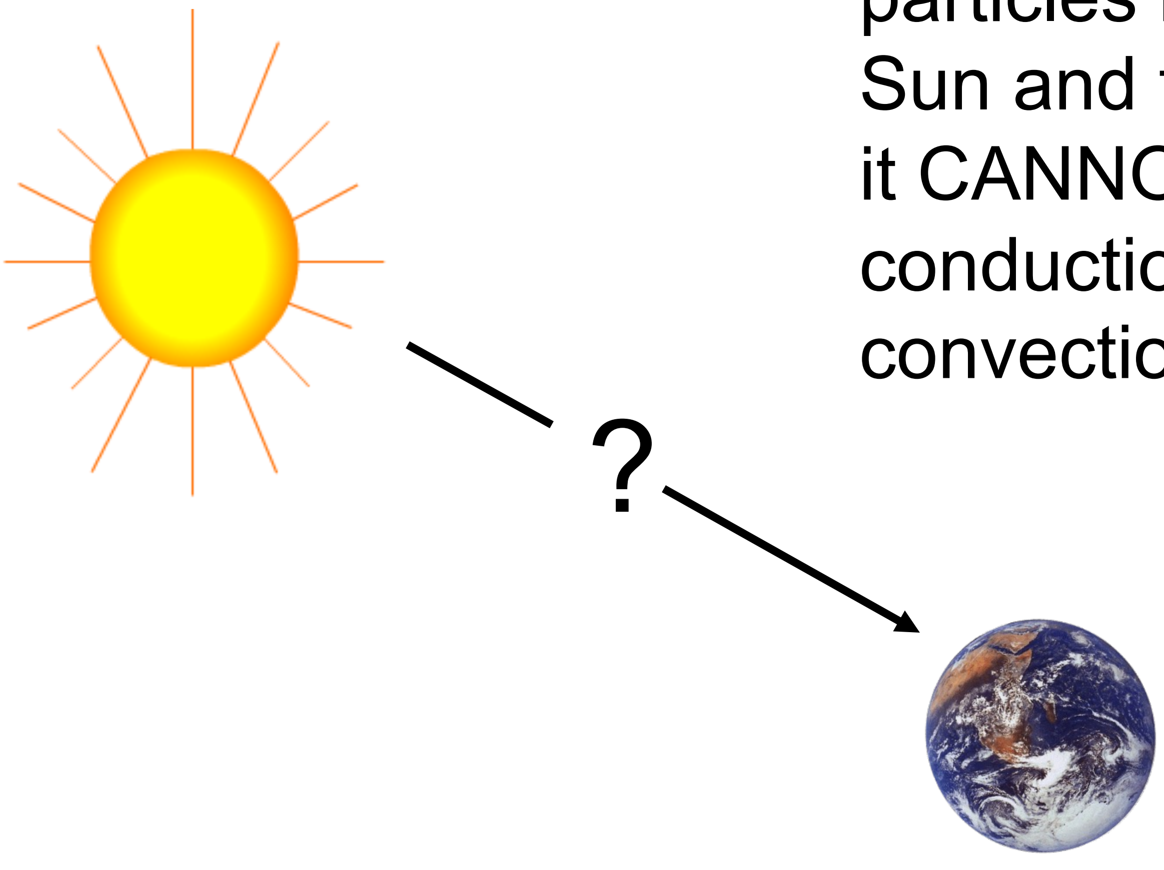
It is put at the top, because cool air sinks, so it cools the food on the way down.

It is warmer at the bottom, so this warmer air rises and a convection current is set up.

Radiation

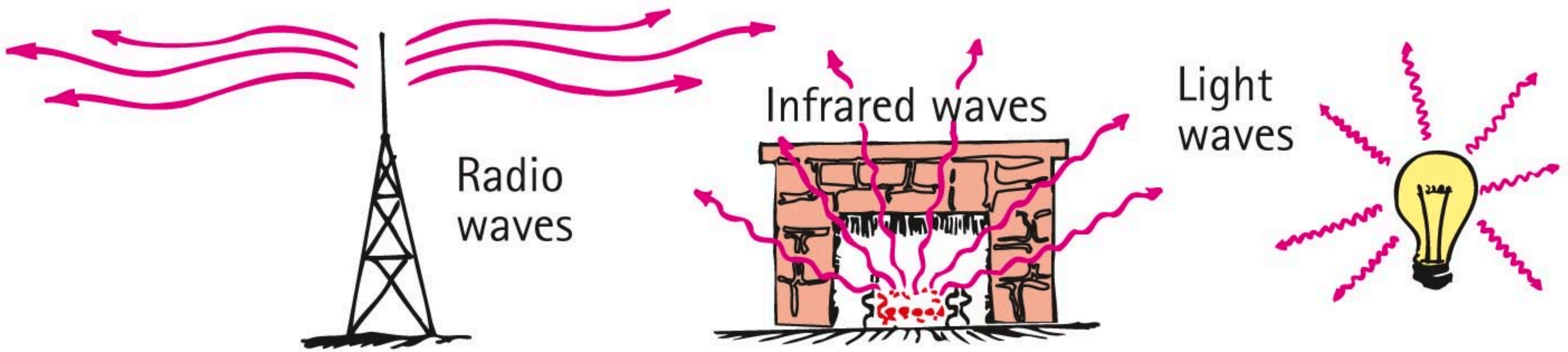
How does heat energy get from the Sun to the Earth?

There are no particles between the Sun and the Earth so it CANNOT travel by conduction or by convection.

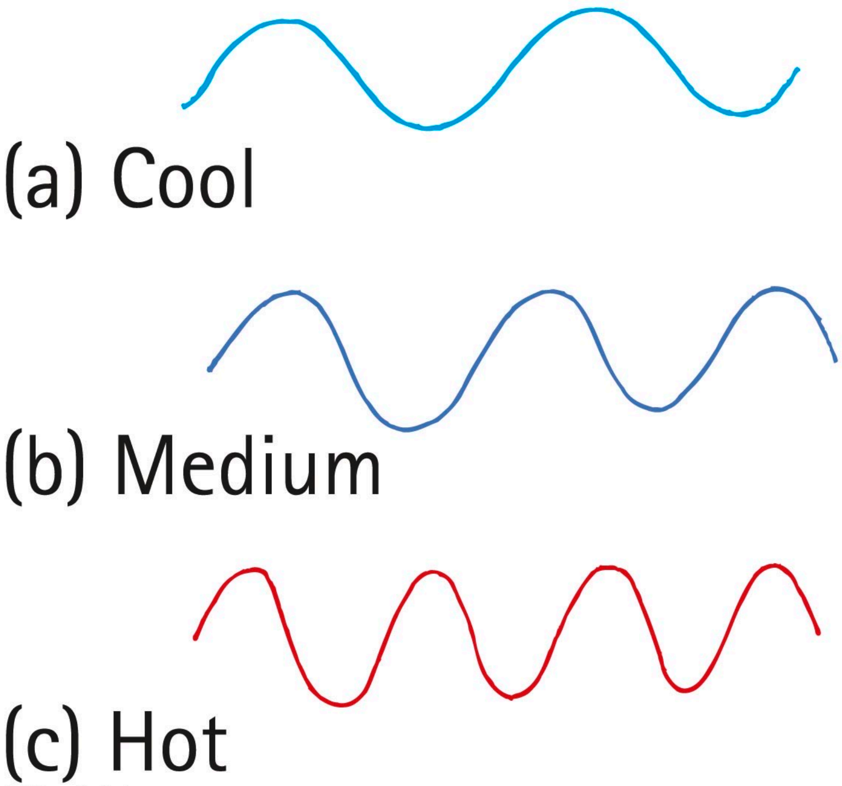


Radiation

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



Wave Frequency - Temperature



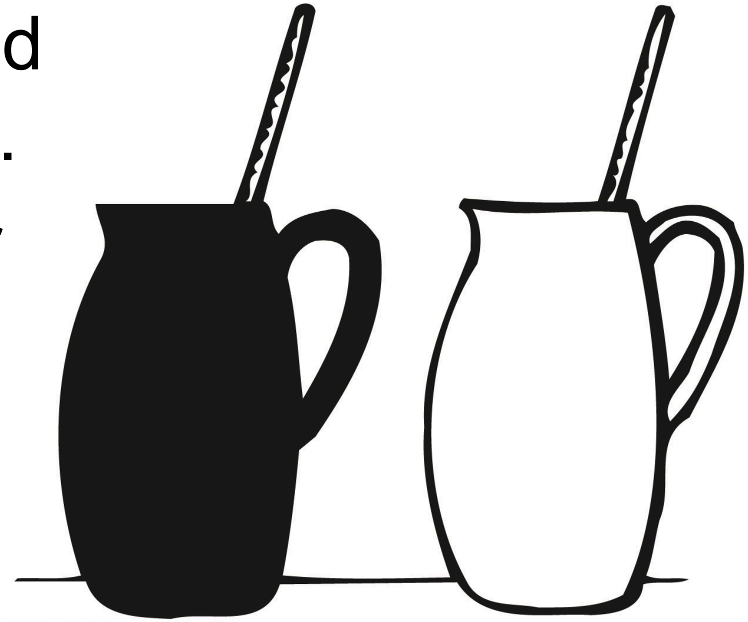
a) A low-temperature (cool) source emits primarily low-frequency, long wavelength waves.
b) A medium-temperature source emits primarily medium-frequency.
c) A high-temperature source emits primarily high-frequency, short wavelength waves.

Emission and Absorption

- The surface of any material both absorbs and emits radiant energy.
- When a surface absorbs more energy than it emits, it is a *net absorber*, and temperature tends to rise.
- When a surface emits more energy than it absorbs, it is a *net emitter*, and temperature tends to fall.

Emission and Absorption

- Absorption of Radiant Energy:
  - The ability of a material to absorb and radiate thermal energy is indicated by its color.
  - Good absorbers and good emitters are dark in color.
  - Poor absorbers and poor emitters are reflective or light in color.



Emission and Absorption

- Whether a surface is a net absorber or net emitter depends on whether its temperature is above or below that of its surroundings.
- A surface hotter than its surroundings will be a net emitter and tends to cool.
- A surface colder than its surroundings will be a net absorber and tends to warm.

Emission and Absorption
CHECK YOUR NEIGHBOR

If a good absorber of radiant energy were a poor emitter, its temperature compared with its surroundings would be

A. lower.
B. higher.
C. unaffected.
D. None of the above.

Emission and Absorption
CHECK YOUR ANSWER

If a good absorber of radiant energy were a poor emitter, its temperature compared with its surroundings would be

A. lower.

B. higher.

C. unaffected.

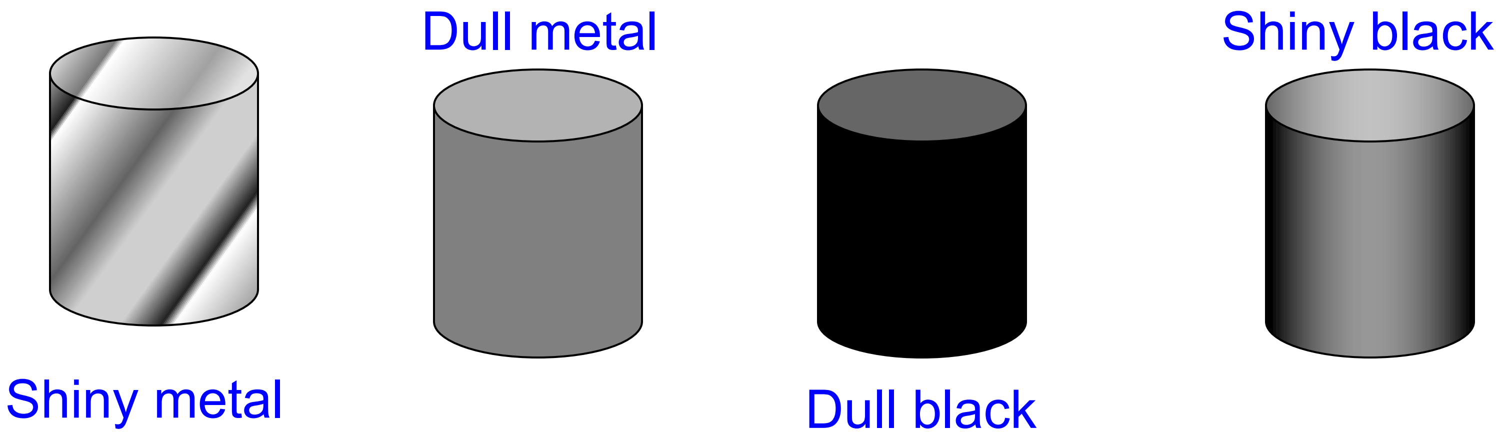
D. None of the above.

Explanation:

If a good absorber were not also a good emitter, there would be a net absorption of radiant energy, and the temperature of a good absorber would remain higher than the temperature of the surroundings. Nature is not so!

Emission experiment

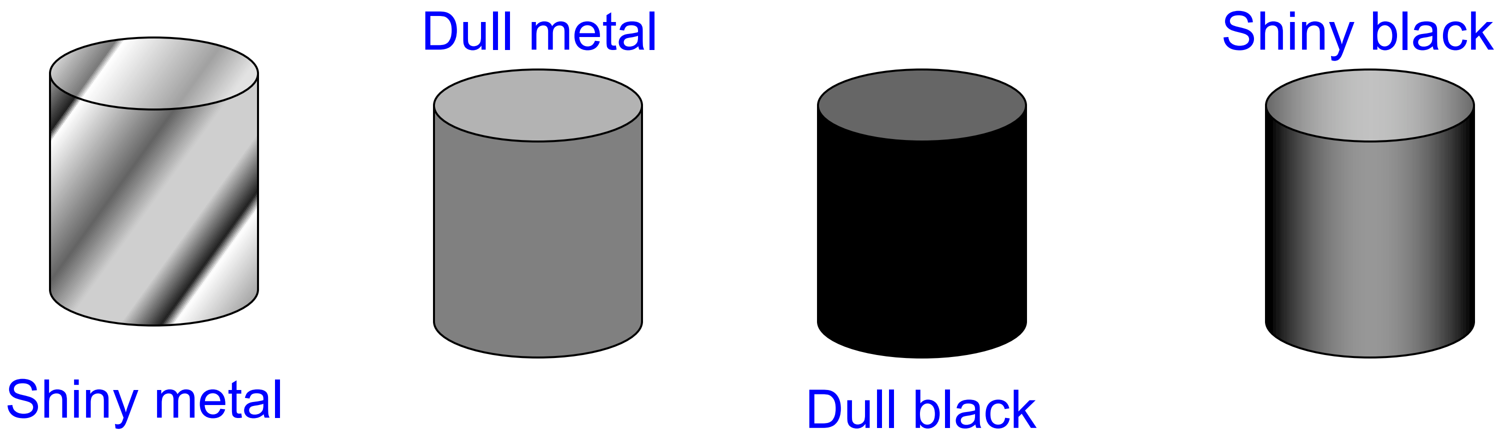
Four containers were filled with warm water. Which container would have the warmest water after ten minutes?



The shiny metal container would be the warmest after ten minutes because its shiny surface reflects heat radiation back into the container so less is lost. The dull black container would be the coolest because it is the best at emitting heat radiation.

Absorption experiment

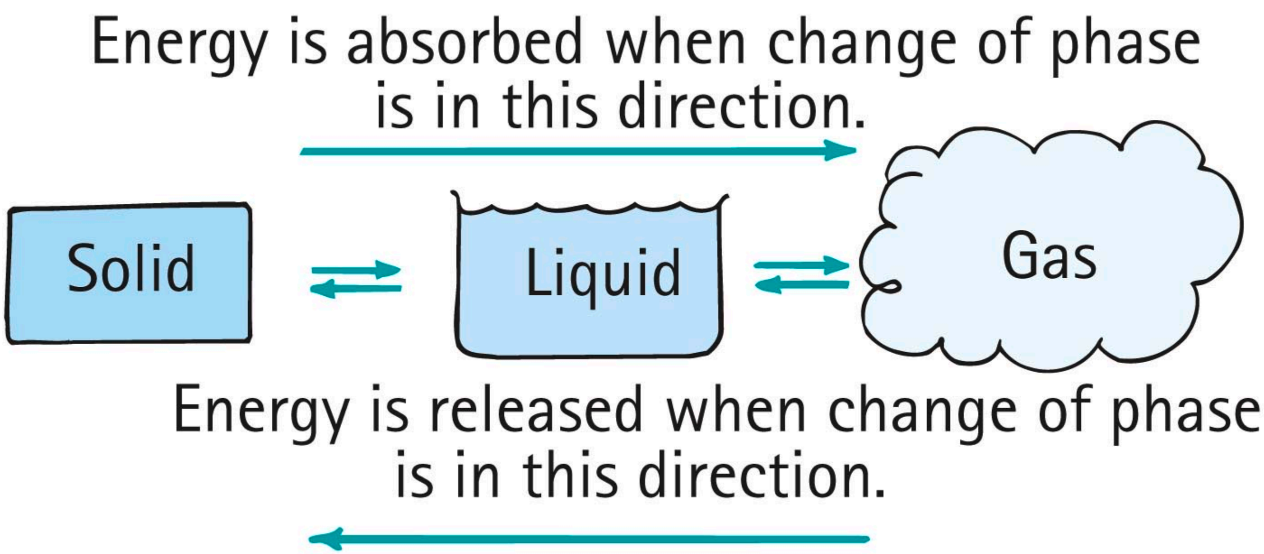
Four containers were placed equidistant from a heater. Which container would have the warmest water after ten minutes?



The dull black container would be the warmest after ten minutes because its surface absorbs heat radiation the best. The shiny metal container would be the coolest because it is the poorest at absorbing heat radiation.

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.

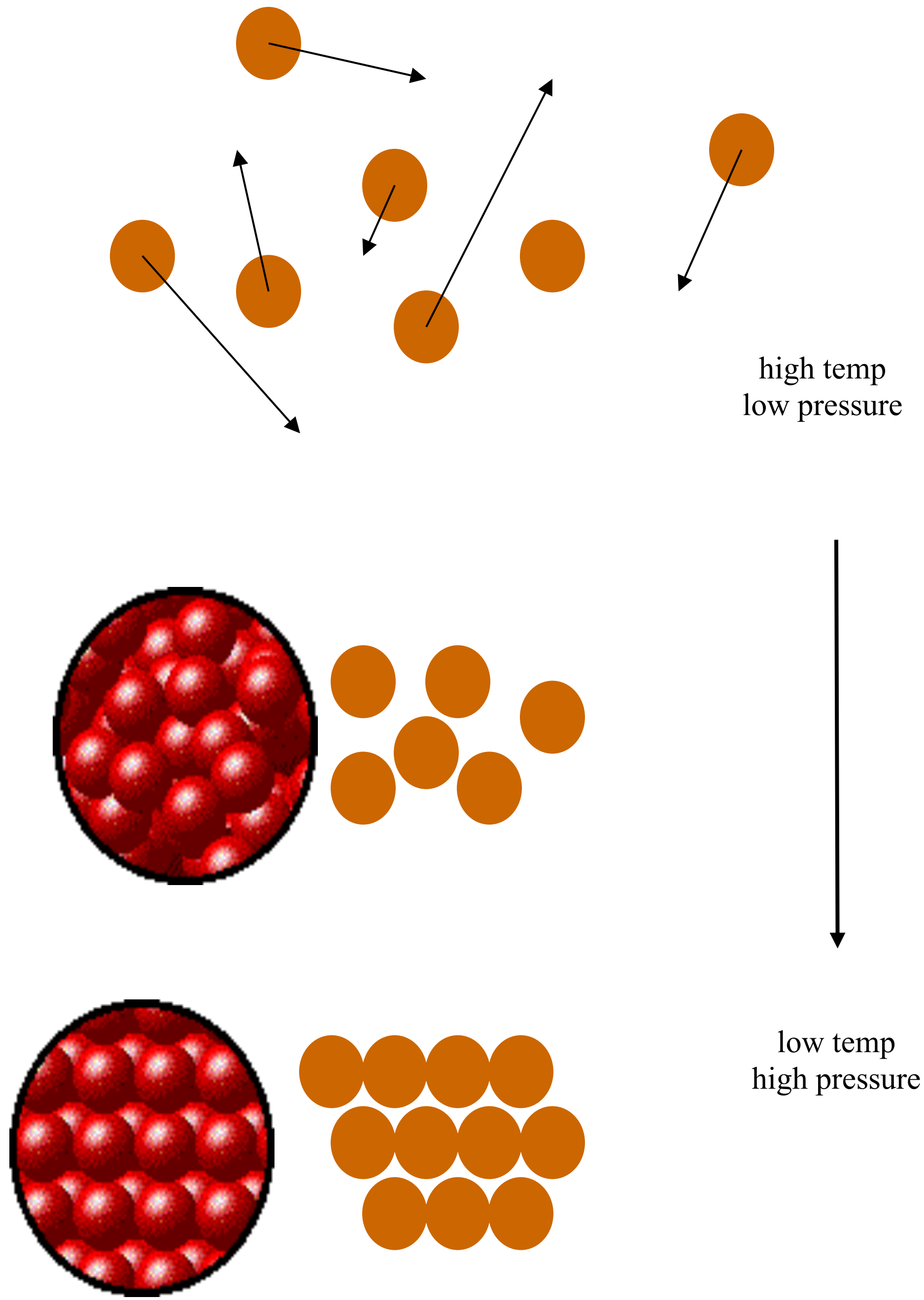


Phases of matter

Gas - very weak intermolecular forces, rapid random motion

Liquid - intermolecular forces bind closest neighbours

Solid - strong intermolecular forces



Latent Heat of fusion

When a solid melts, energy must be added to the solid. it extracts energy from its surroundings and hence the surroundings are cooled. When a liquid freezes energy is released into the surroundings. During this melting or freezing, the temperature remains constant! (This can be explained by considering that it takes energy to break the bonds holding the material together.)

The amount of thermal energy used to melt 1 kg of a material or the amount of thermal energy released to freeze 1 kg of a material is called its **latent heat of fusion (L_f)**.

Latent Heat of fusion

The amount of thermal energy it takes to melt a mass m of a material is

$$Q = mL_f$$

The **latent heat of fusion is measured in J/kg**.

Material	Latent Heat L_f
Mercury	11300 J/kg
Lead	24700 J/kg
Uranium	82800 J/kg
Copper	20500 J/kg
Water	334000 J/kg

Latent Heat of fusion

Exercise: If the latent heat of fusion of ice is 336 000 J/kg. What is the quantity of heat required to melt 400 g of ice at 0^oC?
(Ans. 134400 J)

Exercise: If 61500 J of heat is required to melt 3 kg of a certain material, what is the latent heat of fusion of that material?
(Ans. 20500 J/kg)

Latent Heat of Vaporization

When a liquid evaporates, energy must be added to the liquid. it extracts energy from its surroundings and hence the surroundings are cooled. When a gas condenses energy is released into the surroundings. During this evaporation or condensation, the temperature remains constant! (This can be explained by considering that it takes energy to break the bonds holding the material together.)

The amount of thermal energy used to evaporate 1 kg of a material or the amount of thermal energy released to condense 1 kg of a material is called its **latent heat of vaporization (L_v)**.

Latent Heat of Vaporization

The amount of thermal energy it takes to evaporate a mass m of a material is

$$Q = mL_v$$

The latent heat of vaporization is measured in J/kg.

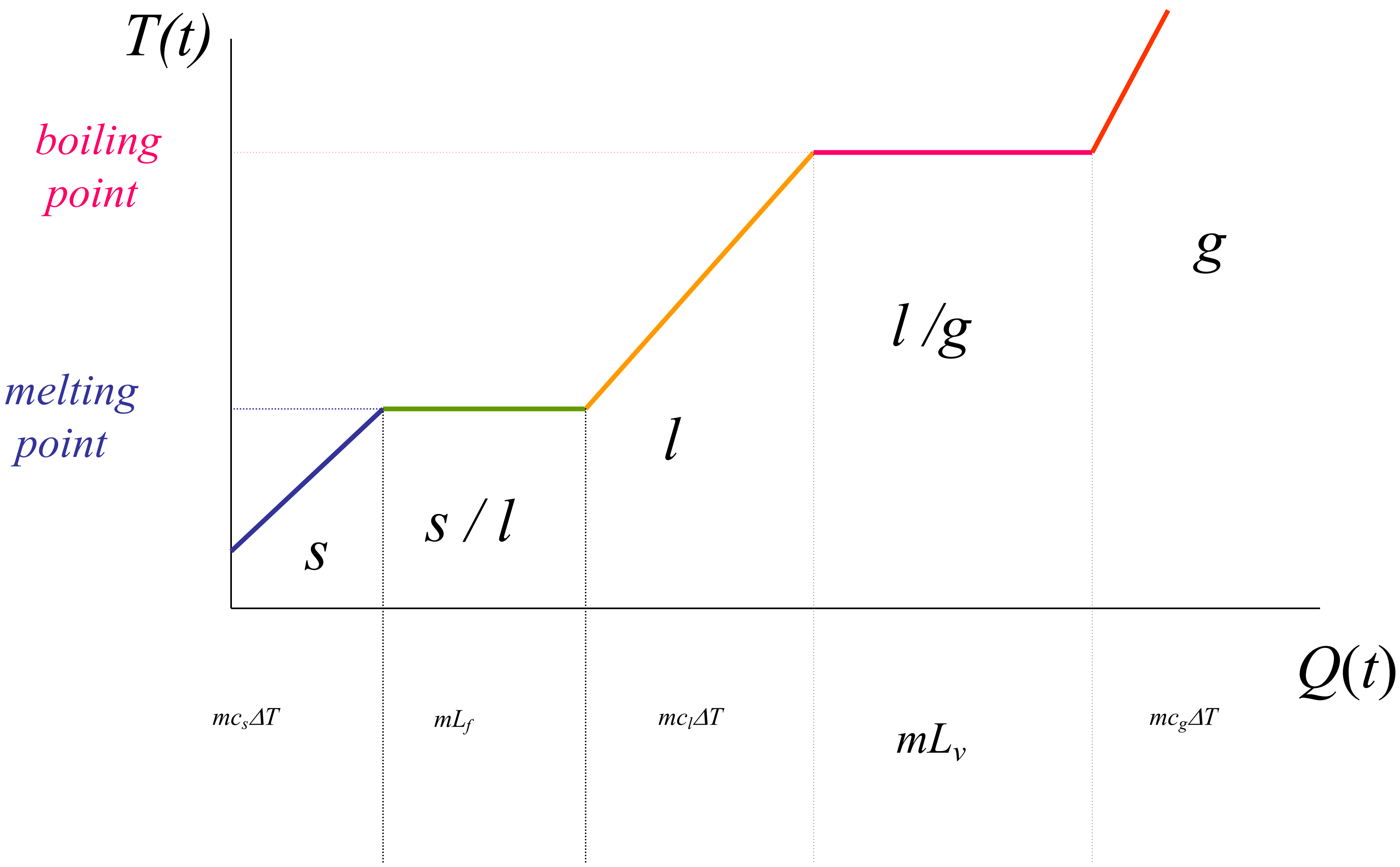
Substance	Latent Heat Vaporization J/kg
Alcohol, ethyl	85500
Ammonia	136900
Carbon dioxide	57400
Helium	2100
Hydrogen	45500
Lead	87100
Methane	51000
Nitrogen	20000
Oxygen	21300
Water	2256000

Latent Heat of Vaporization

Exercise: If the latent heat of vaporization of alcohol is 85500 J/kg. What is the quantity of heat required to evaporate 750 g of alcohol at its boiling point?
(Ans. 64125 J)

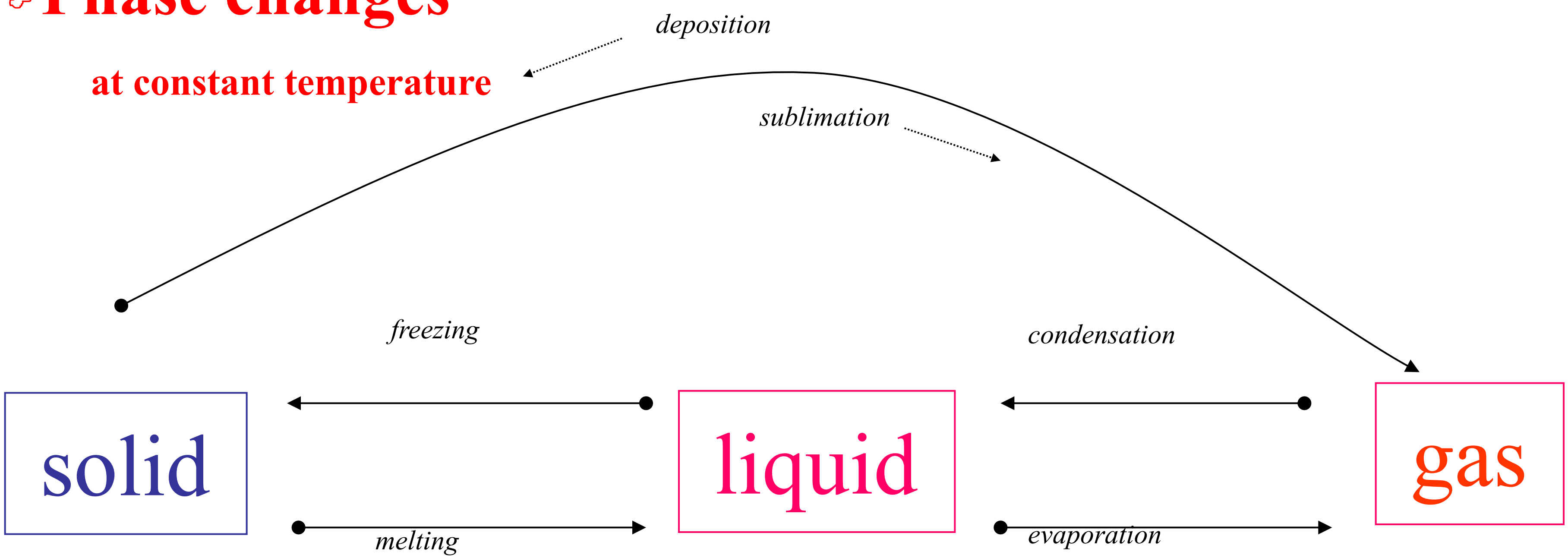
Exercise: If 7896000 J of heat is required to evaporate a glass of water, How much water was in the glass given that the latent heat of vaporization of water is 2256 kJ/kg?
(Ans. 3.5 kg)

Simple model for heating a substance at a constant rate



Phase changes

at constant temperature



$$Q = \pm m L_f$$

At melting point: L_f *latent heat of fusion or heat of fusion*

$$Q = \pm m L_V$$

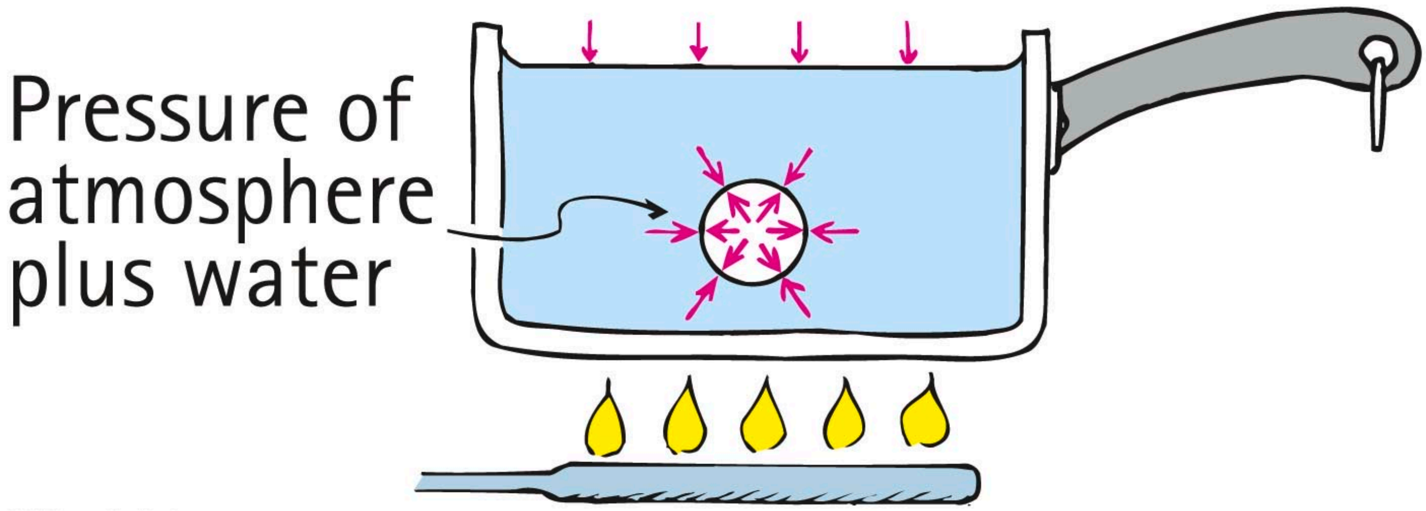
At boiling point: L_V *latent heat of vaporization or heat of vaporization*

$Q > 0$ energy *absorbed* by substance during phase change

$Q < 0$ energy *released* by substance during phase change

Boiling

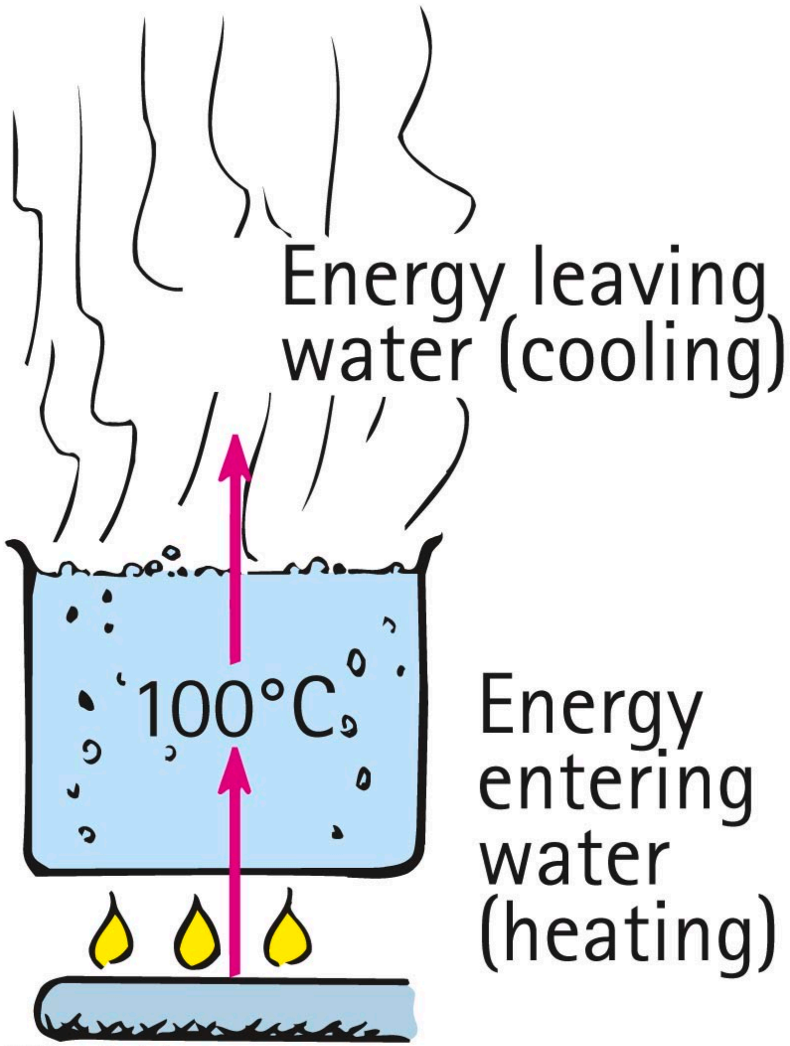
- Boiling process
  - Rapid evaporation occurs beneath the surface of a liquid



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.

Pressure Cooker

- The tight lid of a pressure cooker holds pressurized vapor above the water surface, which inhibits boiling.
- In this way, the boiling point of water is greater than 100ºC.

Boiling
CHECK YOUR NEIGHBOR

When a liquid is brought to a boil, the boiling process tends to

A. resist a further change of phase.

B. heat the liquid.

C. cool the liquid.

D. radiate energy from the system.

Boiling
CHECK YOUR ANSWER

When a liquid is brought to a boil, the boiling process tends to

A. resist a further change of phase.

B. heat the liquid.

C. cool the liquid.

D. radiate energy from the system.

Example

How much energy is needed to convert 23.0 grams of ice at -10.0 °C into water at 20 °C?

C (water) = 4200 J/kg.C

C (ice) = 2108 J/kg.C

Lf (ice) = 334000 J/kg

Ans. = 10098.84 J