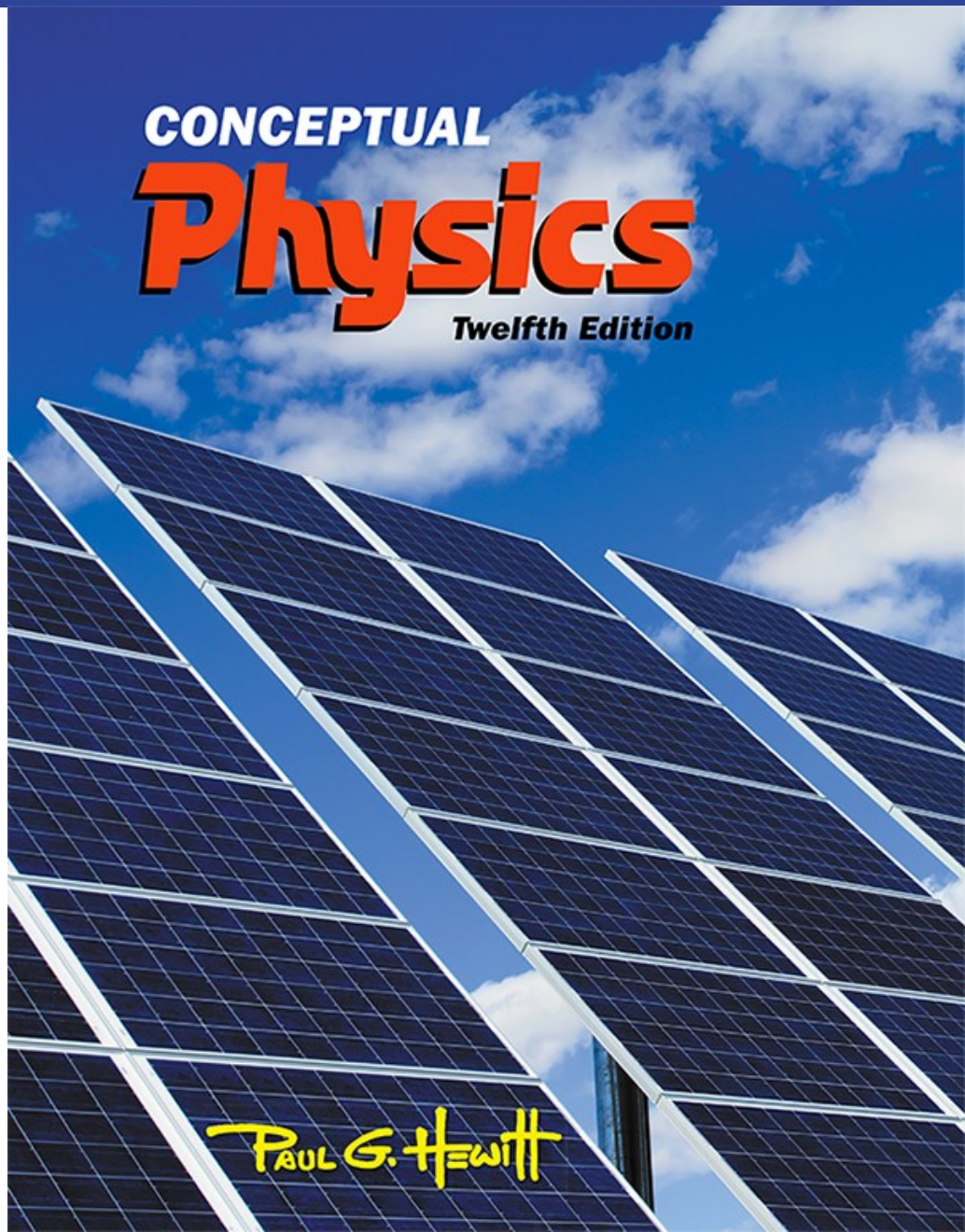
Lecture Outline

Chapter 15: Temperature, Heat, and Expansion



This lecture will help you understand:

- Temperature
- Heat
- Specific Heat Capacity
- Thermal Expansion

Temperature

- Temperature
  - A number that corresponds to the warmth or coldness of an object
  - Measured by a thermometer
  - Is a per-particle property
  - No upper limit
  - Definite limit on lower end

Temperature, Continued

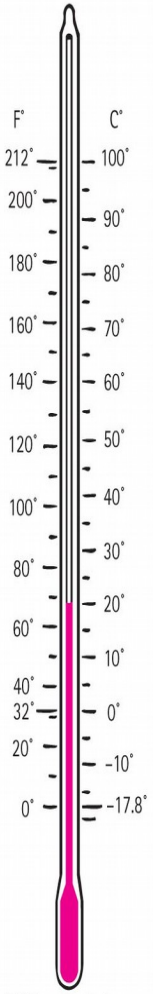
- Temperature is proportional to the average translational kinetic energy per particle in a substance.
  - Gas—how fast the gas particles are bouncing to and fro
  - Liquid—how fast particles slide and jiggle past one another
  - Solid—how fast particles move as they vibrate and jiggle in place

Temperature, Continued-1

- Thermometer
  - Measures temperature by expansion or contraction of a liquid (mercury or colored alcohol)
  - Reading occurs when the thermometer and the object reach thermal equilibrium (having the same average kinetic energy per particle)
  - Infrared thermometers operate by sensing IR radiation

Temperature, Continued-2

- Temperature scale
  - Celsius scale named after Anders Celsius (1701–1744).
    - 0°C for freezing point of water to 100°C for boiling point of water
  - Fahrenheit scale named after G. D. Fahrenheit (1686–1736).
    - 32°F for freezing point of water to 212°F for boiling point of water
  - Kelvin scale named after Lord Kelvin (1824–1907).
    - 273 K for freezing point of water to 373 K for boiling point of water
    - 0 at absolute zero; same size degrees as Celsius scale
    - kelvins, rather than degrees, are used



Temperature
CHECK YOUR NEIGHBOR

There is twice as much molecular kinetic energy in 2 liters of boiling water as in 1 liter of boiling water. Which will be the same for both?

A. Temperature
B. Thermal energy
C. Both A and B.
D. Neither A nor B.

Temperature
CHECK YOUR ANSWER

There is twice as much molecular kinetic energy in 2 liters of boiling water as in 1 liter of boiling water. Which will be the same for both?

A. Temperature

Explanation:

Average kinetic energy of molecules is the same, which means temperature is the same for both.

Temperature
CHECK YOUR NEIGHBOR

To say that body A has a higher temperature than body B is to say that body A has more

A. internal energy.
B. mass.
C. kinetic energy per particle.
D. potential energy.

Temperature
CHECK YOUR ANSWER

To say that body A has a higher temperature than body B is to say that body A has more

C. kinetic energy per particle.

Heat

- Heat
  - Internal energy transferred from one thing to another due to a temperature difference
  - Internal energy in transit
- Flow of internal energy
  - From a high-temperature substance to a low-temperature substance until thermal equilibrium is reached
  - Internal energy never flows unassisted from a low-temperature to a high-temperature substance

Heat
CHECK YOUR NEIGHBOR

If a red-hot thumbtack is immersed in warm water, the direction of heat flow will be from the

A. warm water to the red-hot thumbtack.
B. red-hot thumbtack to the warm water.
C. There will be no heat flow.
D. Not enough information.

Heat
CHECK YOUR ANSWER

If a red-hot thumbtack is immersed in warm water, the direction of heat flow will be from the

B. red-hot thumbtack to the warm water.

Quantity of Heat

- Quantity of heat
  - Measured in joules or calories
  - 4.18 joules of heat are required to change the temperature of 1 gram of water by 1 Celsius degree
  - 4.18 joules = 1 calorie

Quantity of Heat, Continued

- Energy ratings of foods and fuels are determined from energy released when they are burned.
- Unit of energy, the Calorie, is common for foods.
- Heat unit for labeling food
  - kilocalorie or 1000 calories called a Calorie
  - heat needed to change the temperature of 1 kg of water by 1°C

Quantity of Heat
CHECK YOUR NEIGHBOR

The same quantity of heat is added to different amounts of water in two equal-size containers. The temperature of the smaller amount of water

A. decreases more.
B. increases more.
C. does not change.
D. Not enough information.

Quantity of Heat
CHECK YOUR ANSWER

The same quantity of heat is added to different amounts of water in two equal-size containers. The temperature of the smaller amount of water

B. increases more.

Quantity of Heat
CHECK YOUR NEIGHBOR, Continued

You heat a half-cup of tea and its temperature rises by 4°C. How much will the temperature rise if you add the same amount of heat to a full cup of tea?

A. 0°C
B. 2°C
C. 4°C
D. 8°C

Quantity of Heat
CHECK YOUR ANSWER, Continued

You heat a half-cup of tea and its temperature rises by 4°C. How much will the temperature rise if you add the same amount of heat to a full cup of tea?

B. 2°C

Specific Heat Capacity

- Specific heat capacity
  - Defined as the quantity of heat required to change the temperature of a unit mass of the substance by 1 degree Celsius
  - Like thermal inertia—resistance of a substance to a change in temperature

Specific Heat Capacity, Continued

- Different substances have different thermal capacities for storing energy.
- Example:
  - Takes about 2 minutes to raise the temperature of an iron pot of water to boiling temperature
  - Takes less than 1 minute to raise the temperature of the same quantity of water in a silver pot to boiling temperature

Specific Heat Capacity, Continued-1

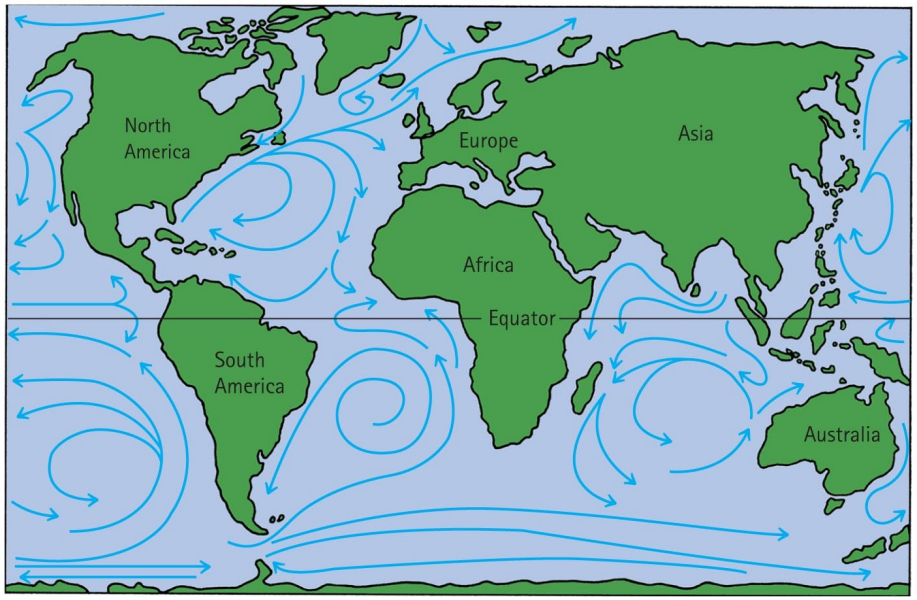
- Equal masses of different materials required different quantities of heat to change their temperatures by a specified number of degrees.
  - 1 gram of water requires 1 calorie of energy to raise the temperature 1 degree Celsius.
  - 1 gram of iron requires 1/8 as much energy for the same temperature increase. Therefore, water absorbs more heat than iron for the same change in temperature. Water has a higher specific heat.

Specific Heat Capacity, Continued-2

- The high specific heat capacity of water
  - has higher capacity for storing energy than almost any other substance.
  - involves various ways that energy can be absorbed.
    - increases the jiggling motion of molecules, which raises the temperature
    - increases the amount of internal vibration or rotation within the molecules, which becomes potential energy and doesn't raise temperature
    - water molecules can absorb energy without increasing translational kinetic energy

Specific Heat Capacity, Continued-3

- Specific heat affects climate
  - For Europeans, the Atlantic Ocean current carries warm water northeast from the Caribbean regions and retains much of its internal energy long enough to reach the North Atlantic Ocean. Energy released is carried by westerly winds over the European continent.



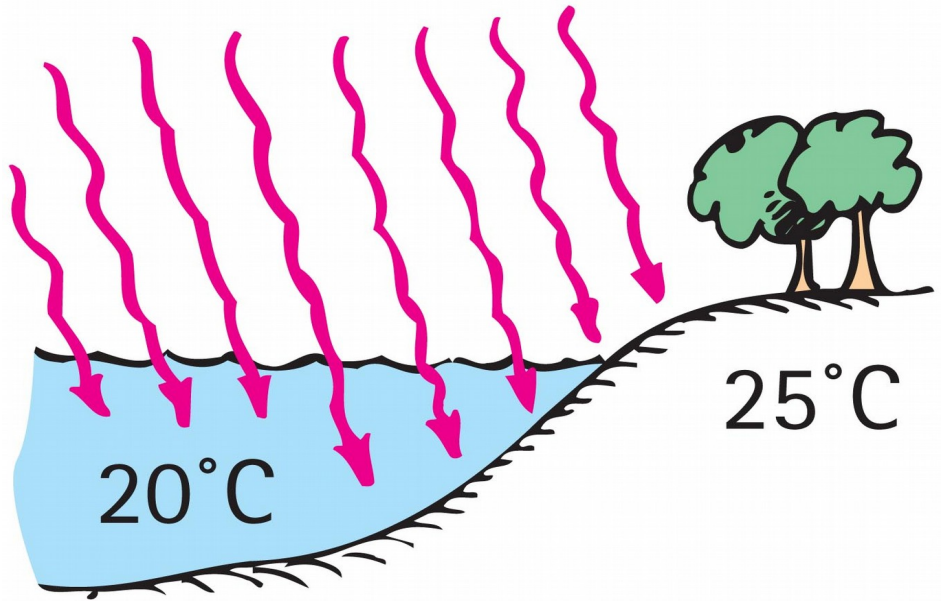
Specific Heat Capacity, Continued-4

- Specific heat affects climate (continued)
  - In the United States, winds in North America are mostly westerly. On the West Coast, air moves from the Pacific Ocean to the land. In winter months, the ocean water is warmer than the air. Air blows over the warm water and then moves over the coastal regions. This produces a warm climate.
  - On the East Coast, air moves from the land to the Atlantic Ocean. Land with lower specific heat capacity gets hot in the summer and cool in the winter.

Specific Heat Capacity
CHECK YOUR NEIGHBOR

Which has the higher specific heat capacity, water or land?

A. Water
B. Land
C. Both of the above are the same.
D. None of the above.



Specific Heat Capacity
CHECK YOUR ANSWER

Which has the higher specific heat capacity, water or land?

A. Water

Explanation:

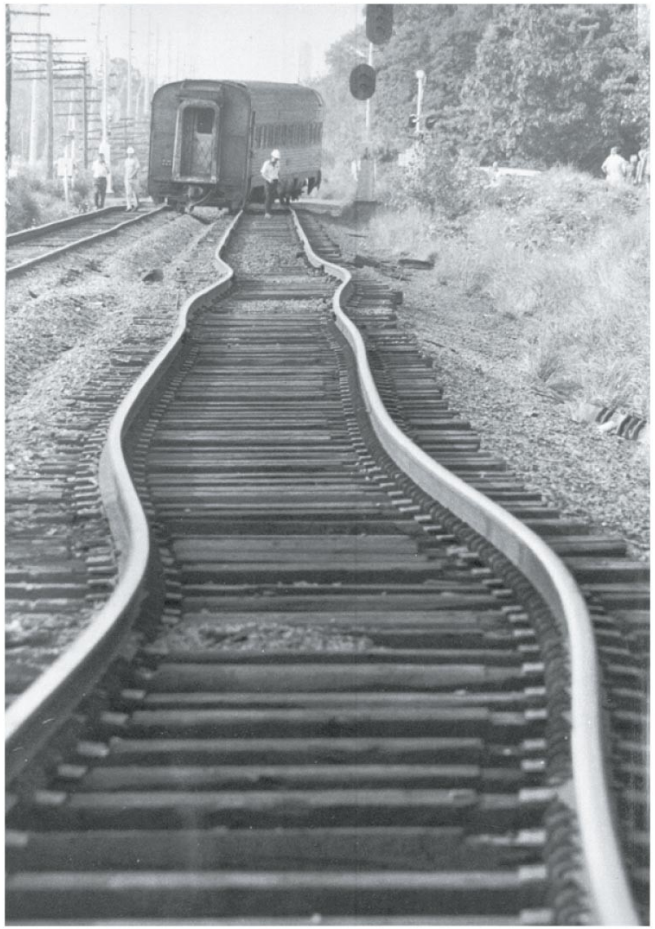
A substance with small temperature changes for large heat changes has a high specific heat capacity. Water takes much longer to heat up in the sunshine than does land. This difference is a major influence on climate.

Thermal Expansion

- Thermal expansion
  - Due to rise in temperature of a substance, molecules jiggle faster and move farther apart.
  - Most substances expand when heated and contract when cooled.
    - Railroad tracks laid on winter days expand and can buckle in hot summer.
    - Warming metal lids on glass jars under hot water loosens the lid by more expansion of the lid than the jar.

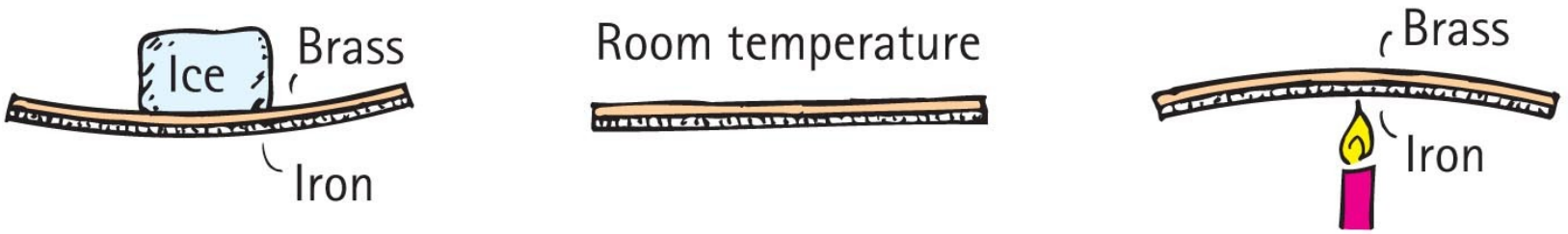
Thermal Expansion, Continued

- Thermal expansion (continued)
  - Plays a role in construction and devices.
  - Example:
    - Use of reinforcing steel with the same rate of expansion as concrete—expansion joints on bridges.
    - Gaps on concrete roadways and sidewalks allow for concrete expansion in the summer and contraction in the winter.



Thermal Expansion, Continued-1

- Thermal expansion (continued)
  - Different substances expand at different rates.
- Example:
  - When the temperature of a bimetallic strip of brass and iron is increased, greater expansion occurs for the brass strip, which bends to turn a pointer, to regulate a valve, or to close a switch.
- Bimetallic strips are used in heaters, oven thermometers, refrigerators, and electric toasters.



Thermal Expansion
CHECK YOUR NEIGHBOR

When stringing telephone lines between poles in the summer, it is advisable to allow the lines to

A. sag.
B. be taut.
C. be close to the ground.
D. allow ample space for birds.

Thermal Expansion
CHECK YOUR ANSWER

When stringing telephone lines between poles in the summer, it is advisable to allow the lines to

A. sag.

Explanation:

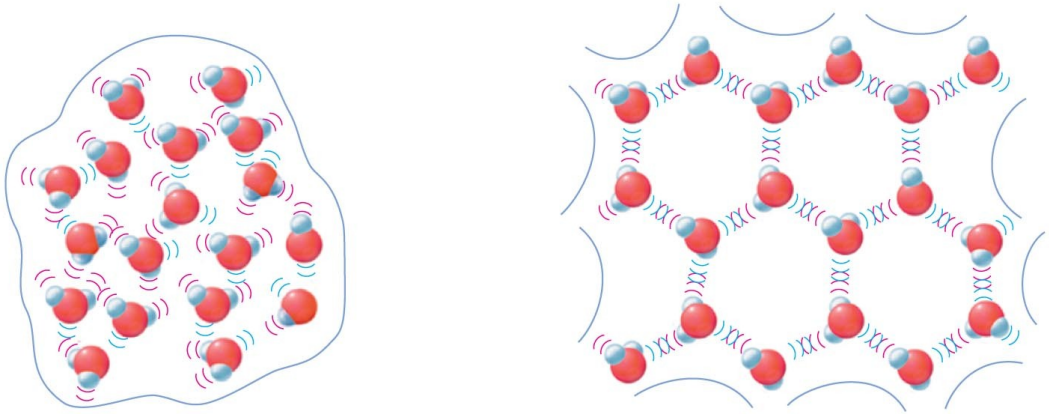
Telephone lines are longer in a warmer summer and shorter in a cold winter. Hence, they sag more on hot summer days than in winter. If the lines are not strung with enough sag in summer, they might contract too much and snap during the winter—especially when carrying ice.

Thermal Expansion, Continued-2

- Increases in expansion are greater in liquids than in solids.
  - Example: Overflow of gasoline from a car’s tank on a hot day
  - Reason: Gasoline underground is cool, but when placed in the car's tank, it warms and expands.

Thermal Expansion, Continued-3

- Expansion of water
  - When water becomes ice, it expands. Ice has open-structured crystals resulting from strong bonds at certain angles that increase its volume. This make ice less dense than water.



Liquid water
(dense)

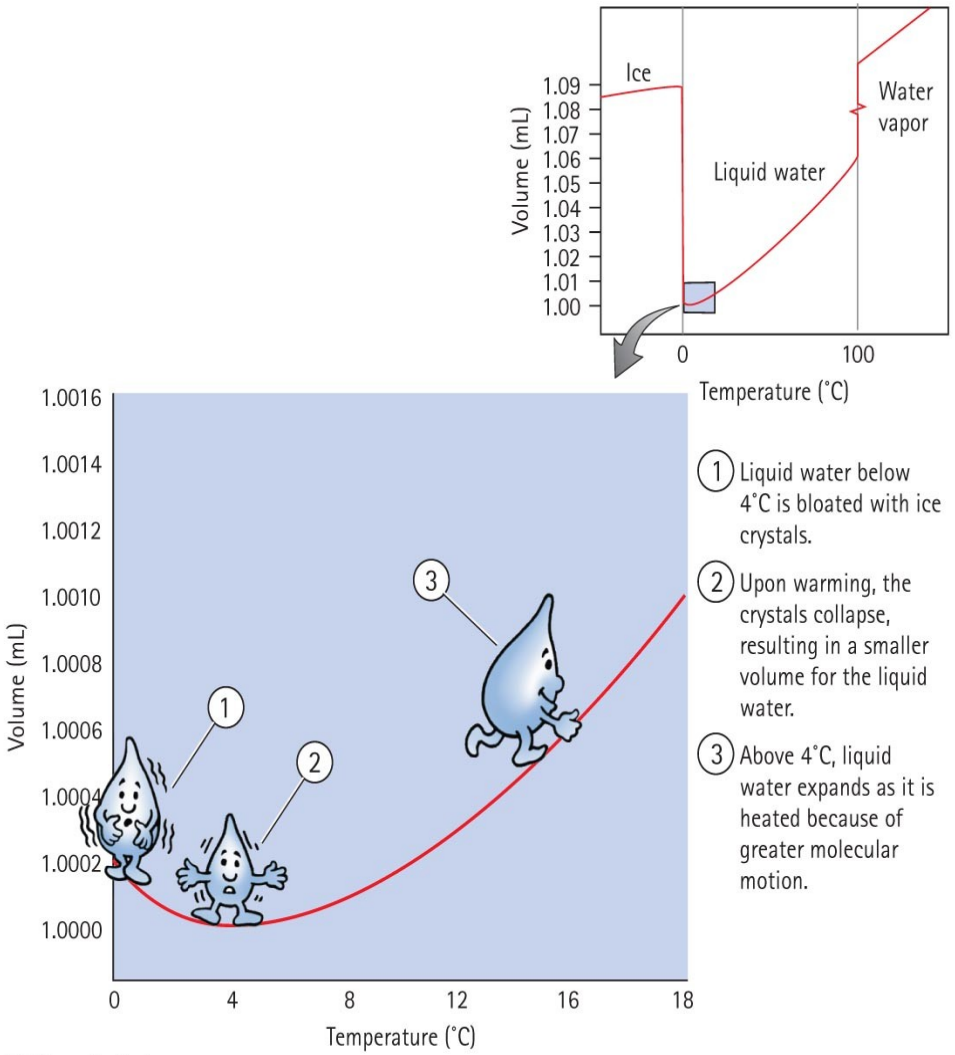
Ice
(less dense)

Thermal Expansion, Continued-4

- Thermal expansion of water
  - As temperature of water at 0°C increases, more of the remaining ice crystals collapse. The melting of these ice crystals further decrease the volume of the water. Two opposite processes occur at the same time—contraction and expansion. Volume decreases as ice crystals collapse, while volume increases due to greater molecular motion. The collapsing effect dominates until the temperature reaches 4°C. After that, expansion overrides contraction because most of the ice crystals have melted.

Thermal Expansion, Continued-5

- Volume changes for a 1-gram sample of water.



Thermal Expansion, Continued-6

- Thermal expansion of water
  - When ice freezes to become solid ice, its volume increases tremendously. As solid ice cools further, it contracts. Density of ice at any temperature is much lower than the density of water, which is why ice floats on water.

Thermal Expansion
CHECK YOUR NEIGHBOR, Continued

When a sample of 0°C water is heated, it first

A. expands.
B. contracts.
C. remains unchanged.
D. Not enough information.

Thermal Expansion
CHECK YOUR ANSWER, Continued

When a sample of 0°C water is heated, it first

B. contracts.

Explanation:

Water continues to contract until it reaches a temperature of 4°C. With further increase in temperature beyond 4°C, water then expands.

Thermal Expansion
CHECK YOUR NEIGHBOR, Continued-1

When a sample of 4°C water is cooled, it

A. expands.
B. contracts.
C. remains unchanged.
D. Not enough information.

Thermal Expansion
CHECK YOUR ANSWER, Continued-1

When a sample of 4°C water is cooled, it

A. expands.

Explanation:

Parts of the water will crystallize and occupy more space.