Chapter 15

Temperature, Heat & Expansion

Objectives

1) What is ‘temperature’?
2) What is ‘heat’?
3) Specific Heat Capacity of a substance
4) Thermal Expansion
5) Thermal Expansion of Water

What is Temperature?

What is Temperature?

The quantity that indicates warmth of a substance with respect to some standard is called **temperature.**

Atoms and molecules in matter have kinetic energy due to random motion (linear, rotational, vibrational)

The average translational KE produces warmth.

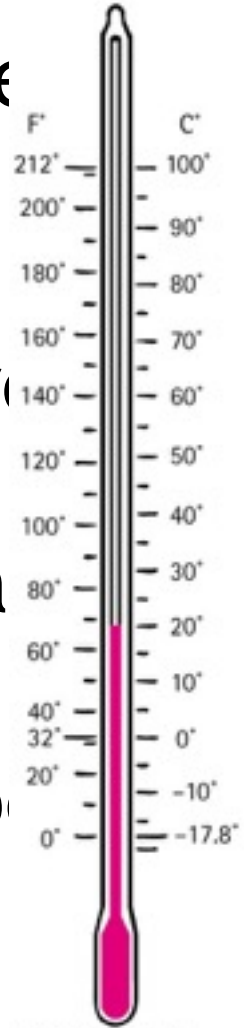
Temperature

Temperature is measured by a thermomete

- Measures temperature by expansion or contraction of a liquid (mercury or color alcohol)
- Reading occurs when the thermometer a

the object reach thermal equilibrium

(having the same average kinetic energy p particle)



Temperature Scales

- Celsius scale named after Anders Celsius

  0°C for freezing point of water to 100°C for boiling point of water

- Fahrenheit scale named after G. D. Fahrenheit

  32°F for freezing point of water to 212°F for boiling point of water

- Kelvin scale named after Lord Kelvin

  273 K for freezing point of water to 373 K for boiling point of water

  0 K = absolute zero (-273^0C)

  At 0 K, substance has no kinetic energy.

Conversion

Celsius to Fahrenheit

$$(^{\circ}C \times {}^{9}/_{5}) + 32 = {}^{\circ}F$$

Fahrenheit to Celsius

$$(^{\circ}F - 32) \times {}^{5}/_{9} = {}^{\circ}C$$

Celsius to Kelvin

$$(^{\circ}C + 273) = K$$

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

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

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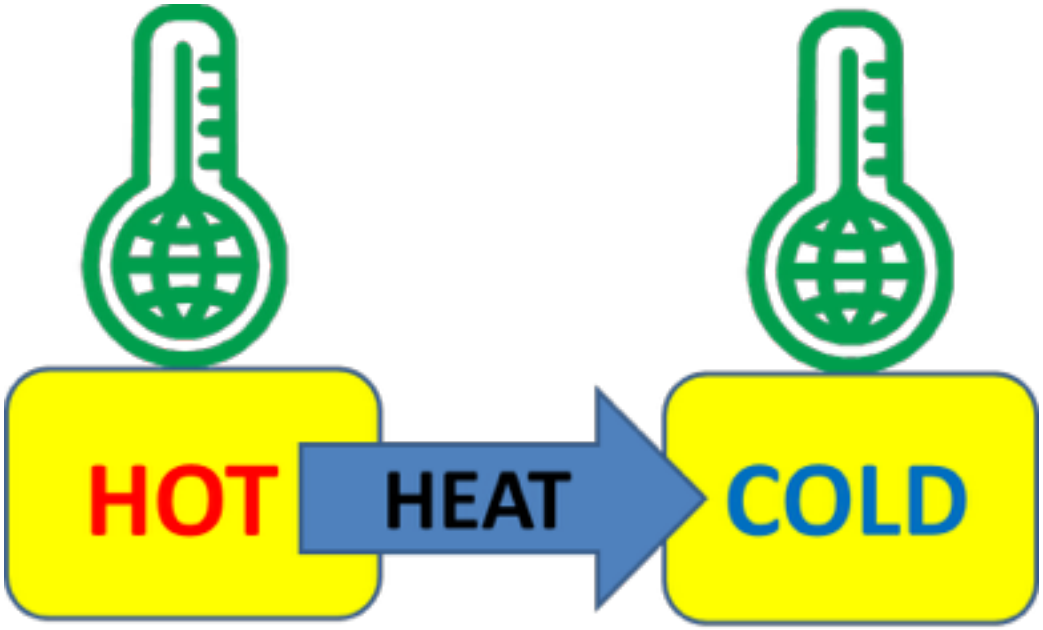
Heat (Q)

- Heat is NOT temperature.
- Heat is Internal energy transferred from one thing to another due to a temperature difference.
- It is internal energy in transit. (Once transferred, the energy ceases to be heat)

- Heat flows from a high-temperature substance to a low-temperature substance until thermal equilibrium is reached.

- How much heat flows will depend <u>both on the temp. difference and on the amount of material</u>.



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.

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Quantity of Heat

Heat is internal energy in transit.

So, what is the unit of heat?

Quantity of Heat

- Heat is measured in joules or calories
- 4.18 joules = 1 calorie

- 4.18 joules of heat are required to change the temperature of 1 gram of water by 1 Celsius degree

More water → more heat needed to change the temperature

Heat unit for labeling food

Energy ratings of foods and fuels are determined from energy released when they are burned.

Calorie, is the common unit for food. (with a capital C)

1 Calorie = 1 kilocalorie or 1000 calories

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.

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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

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Specific Heat Capacity (c)

- 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, c is the resistance of a substance to a change in temperature.

- Higher c → harder to change the temperature

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.

Which one has higher specific heat capacity? Iron pot or silver pot?

Specific Heat Capacity

- Water = 4186 J/kg ^{0}C
- Iron = 448 J/kg ^{0}C
- Silver = 234 J/kg ^{0}C
- Glass = 837 J/kg ^{0}C
- Copper = 387 J/kg ^{0}C

Specific Heat Capacity

Energy Q needed to raise the temperature of a system of mass *m* by ΔT :

$$Q = mc\,\Delta T$$

Example:

How much energy is required to raise the temperature of 0.5 kg of water by 3.0 ^{0}C ?

C_{water} = 4186 J/kg ^{0}C

$$Q = mc\,\Delta T$$

Q = (0.5 kg) (4186 J/kg ^{0}C) (3.0 ^{0}C)

= **6.28 x 10^3 J**

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.

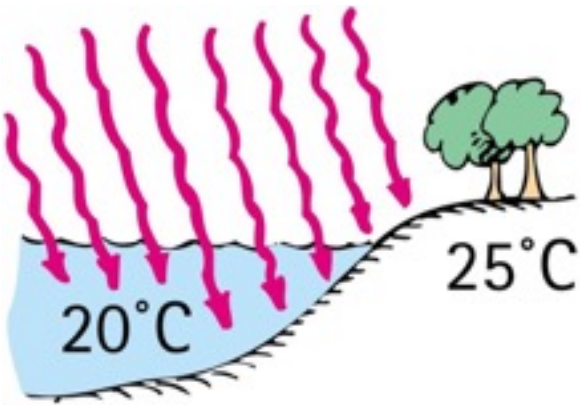
1 gram of iron requires 1/8 as much energy for the same temperature increase.

Therefore, water absorbs more heat than iron for the same change in temperature. Water has a higher specific heat .

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.

Hint: which one needs a longer time to heat up?



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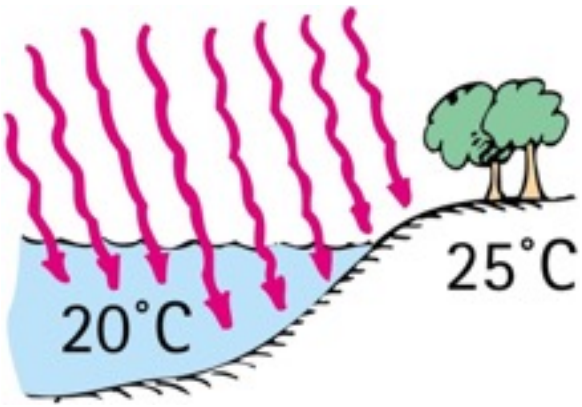


Thermal Expansion

- Due to rise in temperature of a substance, molecules jiggle faster and move farther apart.
- Most substances expand when heated and contract when cooled.

Thermal Expansion

Examples:

- Warming metal lids on glass jars under hot water loosens the lid by more expansion of the lid than the jar.
- 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.

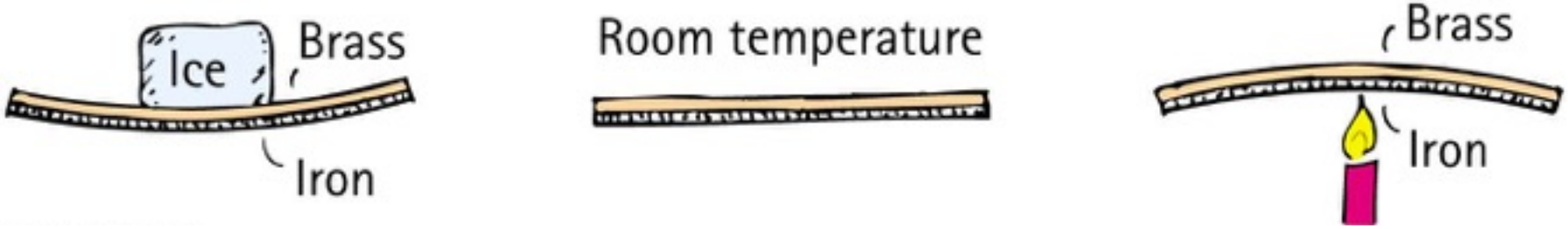
Thermal Expansion

- 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.



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.

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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

Increases in expansion are greater in liquids than in solids.

Example:

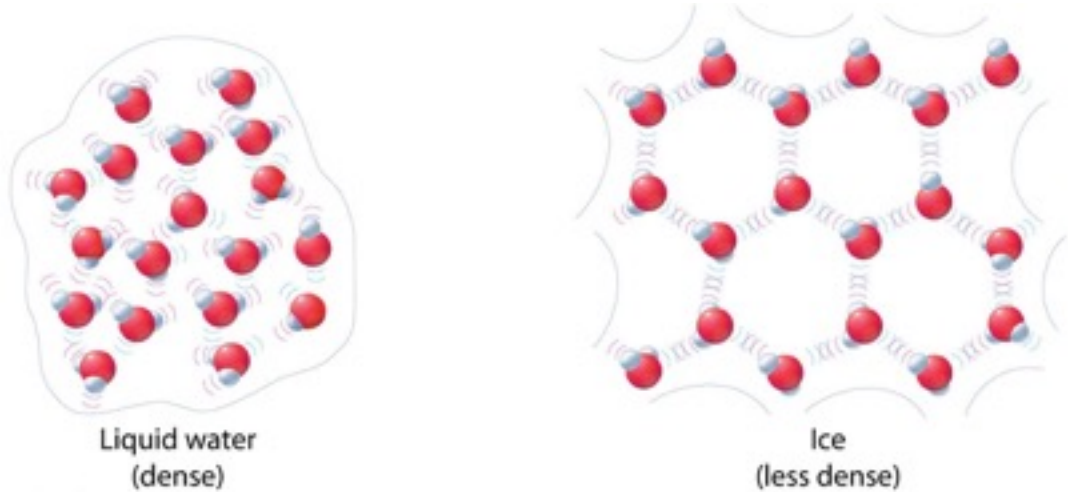
Overflow of gasoline from a car's tank on a hot day.

Reason: Gasoline underground is cool, but when placed in the car's tank, it warms and expands.

Thermal Expansion of Water

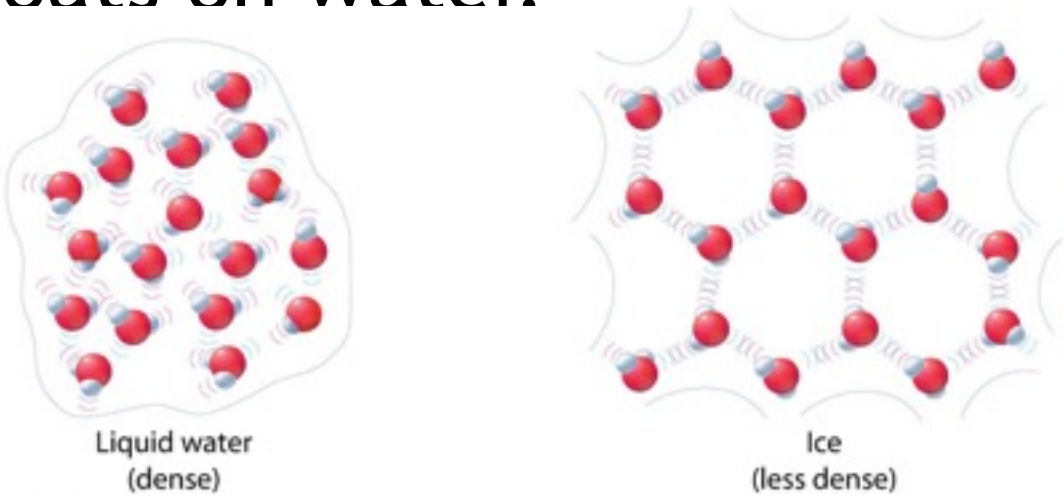
Water, like most other substances, expands when heated.

But, it doesn't expand in the temperature range between 0°c and 4 °C.



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.



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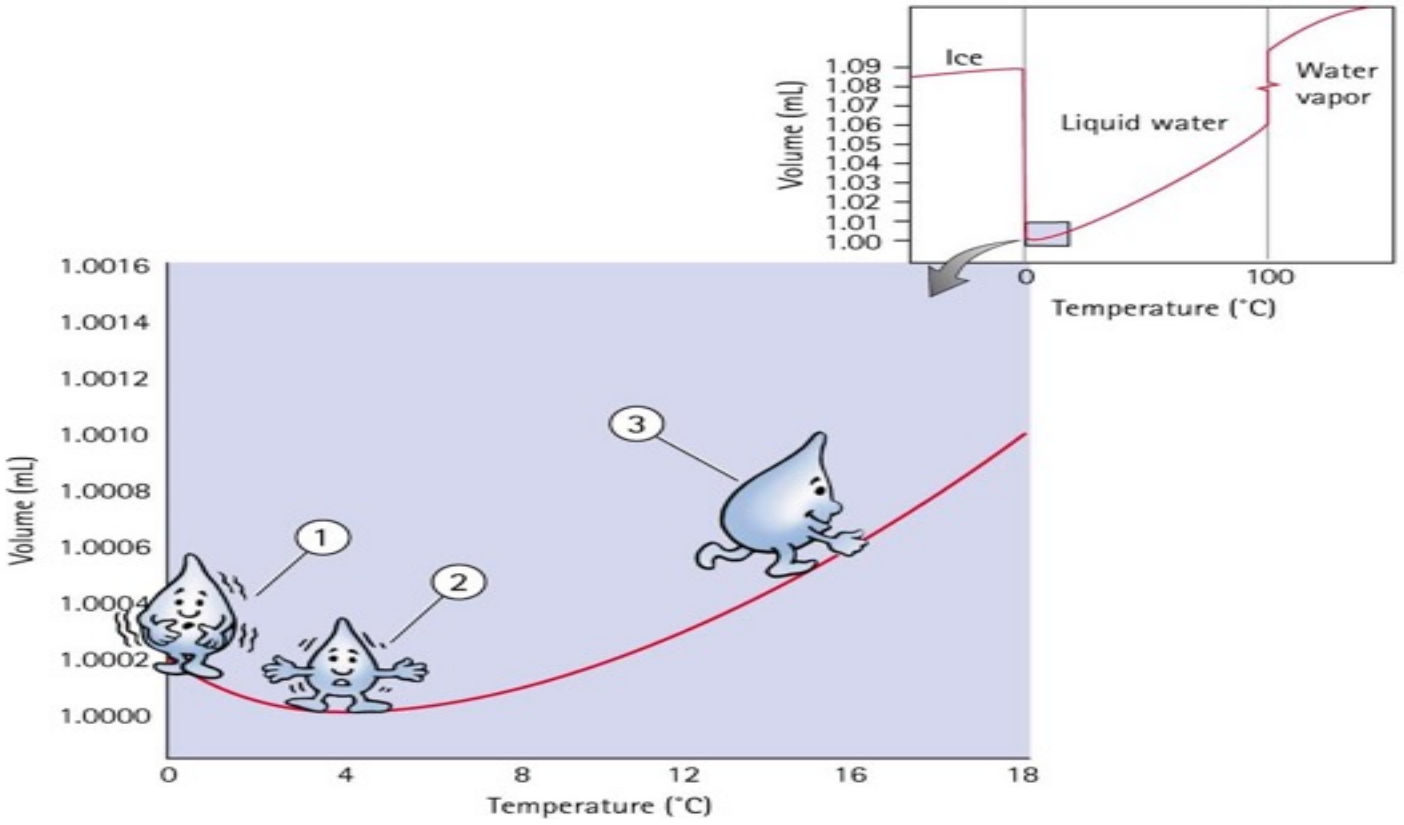
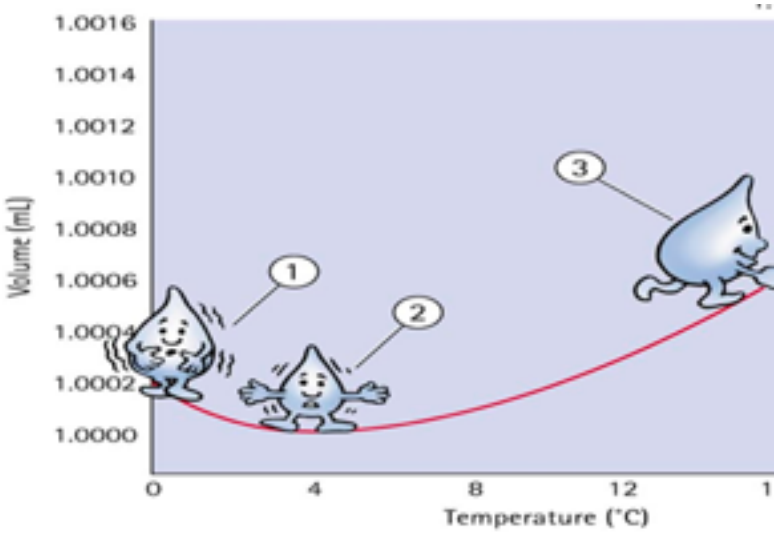


1. Liquid water below 4°C is bloated with ice crystals.
2. Upon warming, the crystals collapse, resulting in a smaller volume for the liquid water.
3. Above 4°C, liquid water expands as it is heated because of greater molecular motion.

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

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



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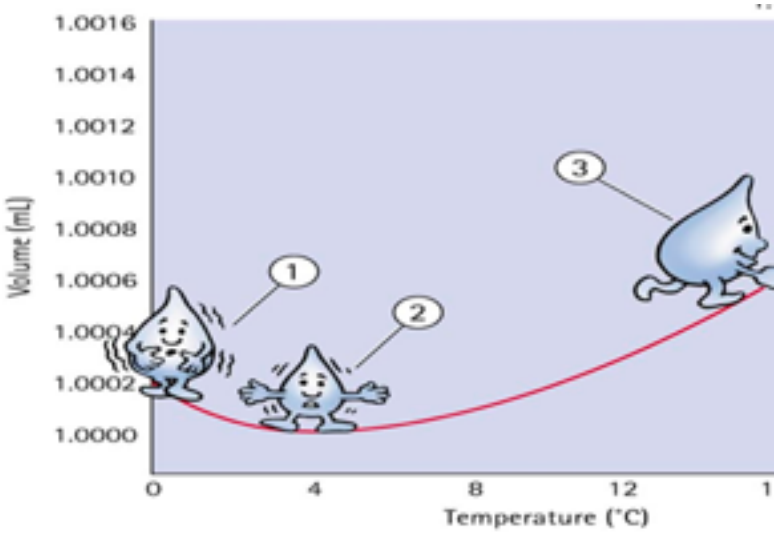
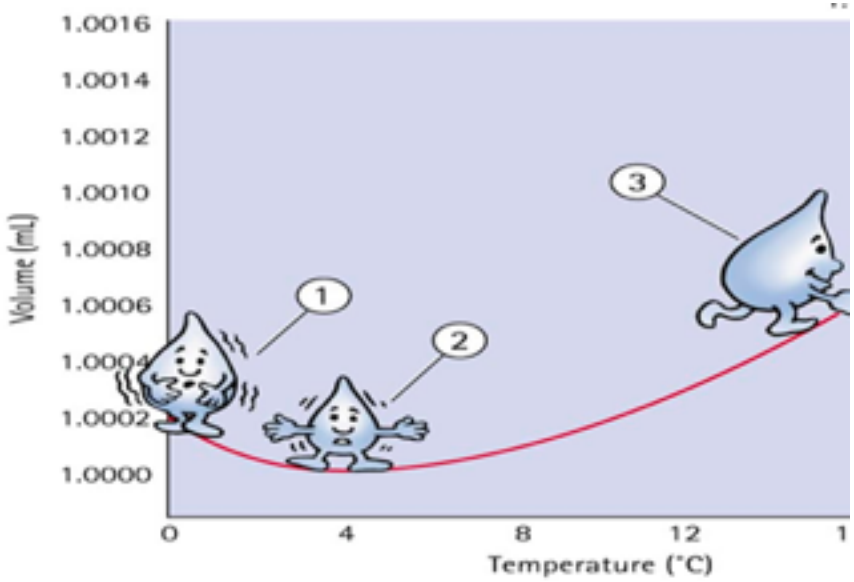
Explanation:

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



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

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



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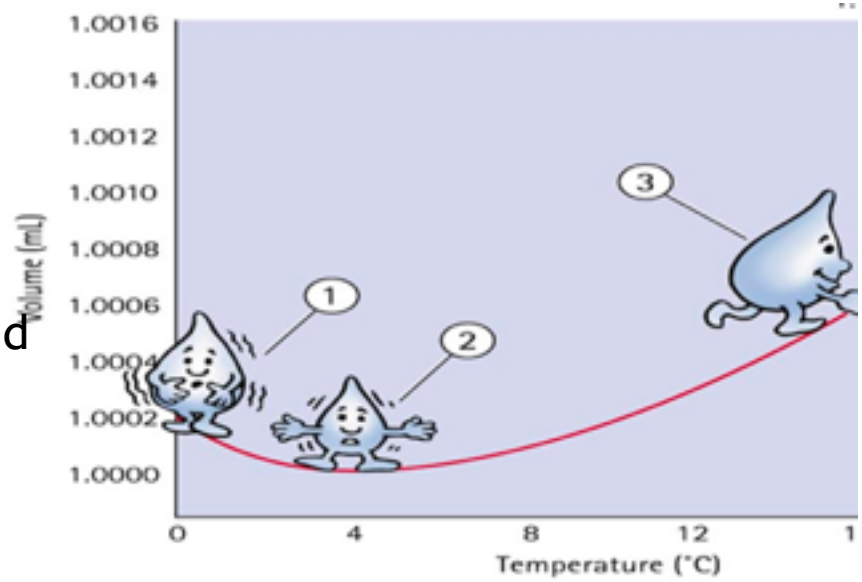
Explanation:

Parts of the water will crystallize and occupy more space.



Homework

- Read Chapter 15 in detail.
- Do Exercises 2, 5, 7, 42, 45

Homework due : July 02