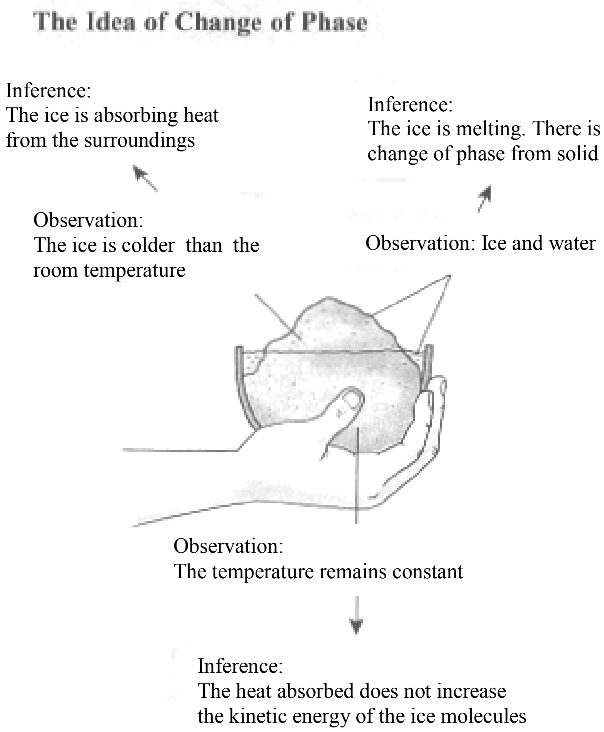
Specific Latent Heat
Change of Phase



Latent Heat

The heat absorbed or given out at constant temperature during change of phase is known as latent heat.

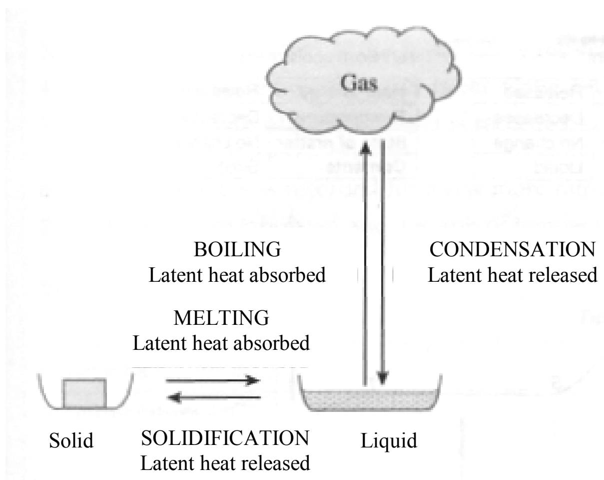


Figure 4.29

The four main changes of phase: melting, boiling, condensation and solidification are summarised in Figure 4.29.

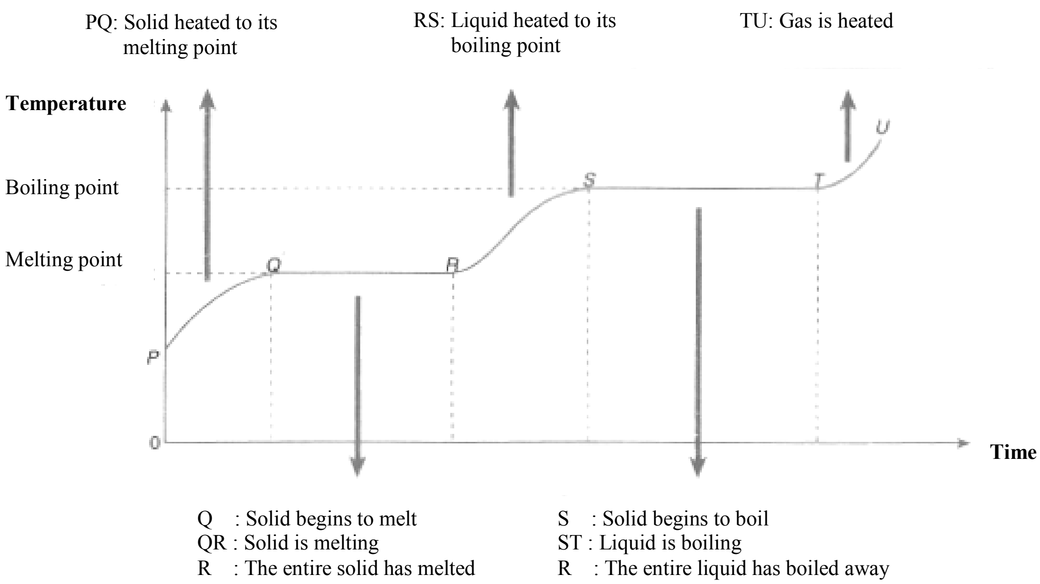


Figure 4.30 The heating curve

Figure 4.30 shows the heating curve when a substance in a solid state is heated uniformly and undergoes a change of phase from solid to liquid to gas.

Figure 4.31 shows the cooling curve when a substance in a gaseous state cools down and undergoes a change of phase from gas to liquid to solid.

There are three common characteristics in the four processes of change of phase:

(a) A substance undergoes a change of phase at a particular temperature.
(b) Heat energy is transferred during change of phase.
(c) During change of phase the temperature remains even though there is transfer of heat.

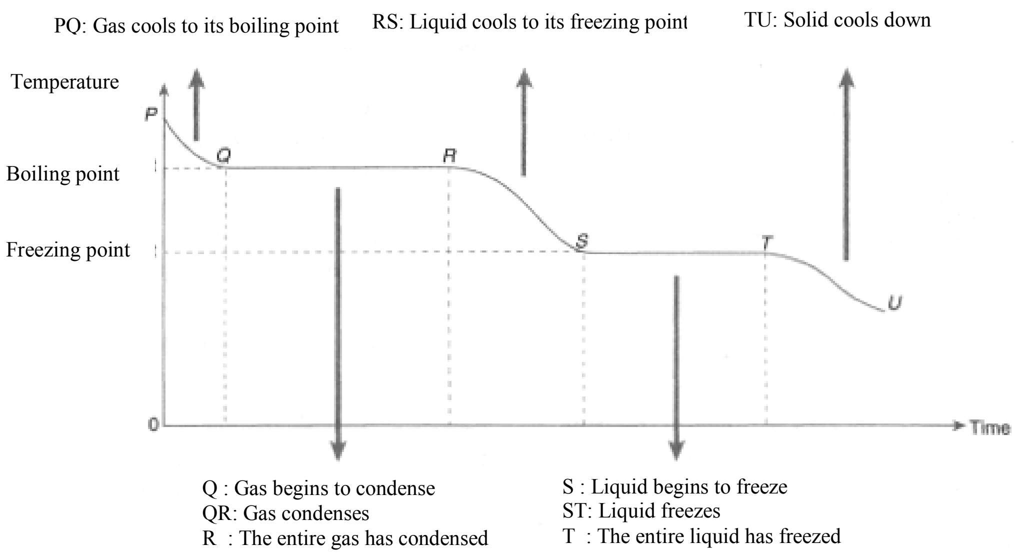


Figure 4.31 *The cooling curve*

Latent Heat of Fusion

The heat absorbed by melting solid is known as the latent heat of fusion.

For a liquid to solidify at its freezing point latent heat of fusion has to be removed from it.

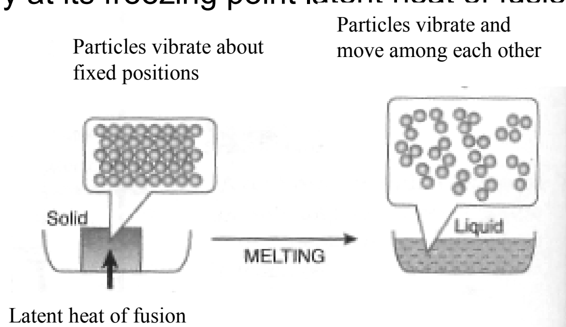


Figure 4.36 *Transition from a solid to liquid*

Latent Heat of Vaporisation

When a liquid boils, the heat absorbed is used to

(a) Completely break the bonds between the particles,

(b) Do work against atmospheric pressure when the gaseous vapour expands into the atmosphere.

The heat absorbed during boiling is known as the latent heat of vaporisation.

When vapour condenses back into the liquid phase, latent heat of vaporisation is released.

Specific Latent Heat

The specific latent heat of a substance is the amount of heat required to change the phase of 1 kg of the substance at a constant temperature.

Specific latent heat,

$$l = \frac{Q}{m}$$

where, Q = latent heat absorbed or released by the substance,

m = mass of the substance,

with unit in J kg^{-1}.

The latent heat absorbed or released when a substance of mass m changes from one phase to another is given by:

$$Q = ml$$

The specific latent heat of fusion of a substance is defined as the amount of heat required to change 1 kg of the substance from a solid to liquid phase without a change in temperature.

The specific latent heat of vaporisation of a substance is defined as the amount of heat required to change 1 kg of the substance from a liquid to gaseous phase without a change in temperature.

If heat is supplied electrically to change the phase of a substance, the equation Q = ml can be written as:

Where, P = power of the heater, unit in W, t= time the heater is on, unit in seconds.

The specific latent heat of fusion of a substance is usually smaller than the specific latent heat of vaporisation.

This is due to the extra work done against atmospheric pressure during change of phase from liquid to gas.

Examples:

1 An electric kettle contains 3.4 kg of water.

(a) Calculate the amount of heat required to boil away all the water after the boiling point has been reached.

(b) If the power of the heater is 2.4 kW, what is the time taken?
[Specific latent heat of vaporisation of water = 2.26×10^6 J kg^{-1}]

Answer:

(a) Mass of water, m = 3.4 kg

Q = ml

Q= $3.4 \times 2.26 \times 10^6$J

Q= 7.684×10^6J

(b) Q = ml, Pt = ml

$3000 \times t = 3.4 \times 2.26 \times 10^6$

Therefore t= $2.56 \times IO^3$ s

2 Water of mass 0.36 kg at 25°C is put into the freezer compartment of a refrigerator. Calculate the amount of heat that must be removed to change the water completely into ice.
[Specific heat capacity, c = 4200 J kg^{-1} $°C^{-1}$; Specific latent heat of fusion, l=3.36 x $l0^5$ J $kg^{-1]}$

Answer:
The change from water to ice can be illustrated in the following diagram.

0.36 kg, water, 25°C

↓ mcϴ

0.36 kg, water, 0°C $\xrightarrow{ml}$ 0.36 kg, ice, 0°C

Total heat removed,
Q = mcϴ + ml
Q = (0.36 x 4200 x 25) + (0.36 x 3.36 x $l0^5$)
Q = 158 760J

3 How much heat must be supplied to 2.0 kg of water at 28°C to change it to steam at 100°C?
[Specific heat capacity, c = 4200 J $kg^{-1}°C^{-1}$; Specific latent heat of vaporisation, l = 2.26 x 10^6 J kg']

Answer:

2.0 kg, water, 100°C $\xrightarrow{ml}$ 2.0 kg, steam, 100°C

↑mcϴ

2.0 kg, water, 28°C

Heat supplied,
Q = mcϴ + ml
= 2.0 x 4200 x (100 - 28) + 2.0 x 2.26 x 10^6 = 5.12 x 10^6 J

Short Note
- The four main changes of phase are melting, boiling, condensation and solidification.
- The heat absorbed or released at constant temperature during a change of phase is known as latent heal.
- During the change of phase between solid and liquid, the heat is known as heat of fusion.
- For change of phase between liquid and gas, the heat is known as latent heat of vaporisation.

- The specific latent heat of fusion, l of a substance is defined as the amount of heat required to change 1 kg of the substance from the solid to liquid phase without a change in temperature.
- The specific latent heat of vaporisation, 1 of a substance is defined as the amount of heat required to change 1 kg of the substance from the liquid to gaseous phase without a change in temperature.
- Latent heat is given by Q = ml.

Assessment

Objective Question

1. A piece of ice of mass 2 kg at a temperature of 0°C is heated until it becomes water at 10^{o}C. If the specific heat capacity of water is 4 200 J kg^{-1}°C^{-1} and the specific latent heat of fusion of ice is 3.36 x 10^5 Jkg^{-1} what is the energy supplied?
   A 6.60 x 10^3 J
   B 7.48 x 10^3 J
   C 8.40 x 10^5 J
   D 7.56 x 10^5 J
   E 7.56 x 10^6 J

2. In an experiment, Azmi uses an electric heater to heat 1.0 kg of ice at 0°C until it becomes water at 60°C. Calculate the electrical energy used in the experiment. [Specific heat capacity of water = 4.2 x 10^{3}J kg^{-1} °C^{-1}, specific latent heat of fusion of ice = 3.34 x 10^5 J kg^{-1}]
   A 2.12 x 10^5 J
   B 4.68 x I0^5 J
   C 5.86 x 10^5 J
   D 7.54 x 10^5 J
   E 8.68 x 10^5 J

3. A piece of ice is added to 200 g of water at 30°C. When all the ice has melted, the temperature of the water becomes 20°C. What is the mass of the ice?
   [Specific heat capacity of water = 4 200 J kg^{-1} °C^{-1}, specific latent heat of fusion of ice=3.36X 10^{5}J kg^{-1}]
   A 18.3 g B 20.1 g
   C 25.0 g D 50.5 g
   E 65.5 g

4. On a hot day, a student added 80g of ice into 250 g of orange squash at a temperature of 28°C. What is the final temperature of the orange squash?
   [Specific heat capacity of the orange squash = 4 200 J kg^{-1} °C^{-1}, specific latent heat of fusion of ice = 3.36 x 10^5 J kg^{-1}]
   A 2.4°C B 2.5°C
   C 2.8°C D 25 °C
   E 28 °C

5. 1.2 kg of water at a temperature of 28°C is put into the freezer of a refrigerator of 1200 W. How long does it take for all the water to completely freeze to ice?
   [Specific heat capacity of water = 4 200 J kg^{-1} °C^{-1} specific latent heat of fusion of ice = 3.30 x 10^5 J kg^{-1}]
   A 108.0 s B 117.6 s
   C 216.7 s D 344.5 s
   E 453.6s

Structure Questions:

1. The following are statements on wax that in the process of solidifying. Mark '/' for statements which are true and 'X' for statements which are false.
   (a) [ ] The temperature of the wax is constant.

(b) [ ] The wax is giving out heat.
(c) [ ] The average kinetic energy of the molecules is decreasing.
(d) [ ] The motion of the molecules changes from moving freely to vibrating about fixed positions.

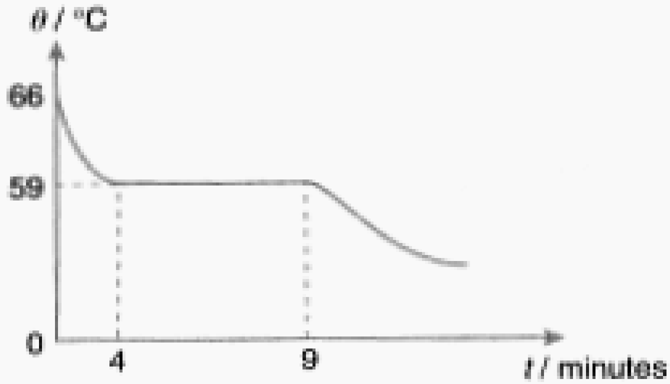


Figure 4.42

2. **Figure 4.42** shows how the temperature of a substance changes with time when it changes phase from a liquid to solid.

(a) What is the melting point of the substance?

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(b) Explain why the temperature remains constant during solidification though heat is being released to the surroundings.

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____.

(c) The mass of the substance is 0.05 kg and heat is lost to the surroundings at an average rate of 25 J s^{-1}. Calculate the specific latent heat of fusion of the substance. An ice cube is taken out of the freezer compartment of a refrigerator. Explain why the surface of the ice is initially dry but becomes wet a short while later.

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____.

Marking Scheme

Objective:

1	2	3	4	5
D	C	C	A	E

Structure:

1. (a) /
   (b) /
   (c) X
   (d) /

2. (a) 59°C

   (b) The average kinetic energy of the molecules does not change. Heat energy is released when the molecules move closer together.

   (c) Specific latent heat of fusion of the substance

   $$Q = ml$$
   $$25\ (5 \times 60) = 0.05 \times l$$

   Therefore $l = 150\ 000\ Jkg^{-1}$

   The initial temperature of the ice is less than its melting point. Therefore the ice remains as a dry solid for a short period of time. When the ice quickly absorbs heat from the surroundings, the surface of the ice starts to melt.