LESSON 4.3 – Understanding specific latent heat, I

What does the word “latent heat” mean?

Latent heat means hidden heat. This heat energy changes the state of a substance (phase change). The heat cannot be ‘seen’ because there is no rise in temperature of the substance.

Phase Change

When a phase change has occurred, latent heat is absorbed or released.

**Latent heat and kinetic theory**

In a solid, the molecules are linked to the neighbours by forces of attraction. As the solid is heated, the molecules vibrate more strongly. When the solid reaches its melting point, the vibrations have become so strong that the links begin to give way. Extra energy is needed to overcome these forces and separate the molecules. This is called the latent heat of fusion. No temperature rise occurs during this process, because the latent heat of fusion is used to overcome the intermolecular binding forces. The average translational kinetic energy does not change, so the temperature remains constant.

In a liquid, the molecules are free enough to slide around and change neighbours, but they are still almost as close to each other as in a solid. The links are weaker but still effective. As the liquid is heated further, the kinetic energy of the molecules increases more. At the boiling point, the molecules break free from each other and become a gas. Energy is needed to overcome the remaining links. This is called the latent heat of vaporisation. No temperature rise occurs during this process, because the latent heat of vaporisation is used to overcome the intermolecular binding forces. The average translational kinetic energy does not change, so the temperature remains constant.

**The Heating and Cooling Curve (Naphthalene)**

**Heating curve**

Melting point = 80°C  Boiling point = 218°C
AB = Solid  ,  BC = solid + liquid  ,  CD = liquid
DE = liquid + gas   ,  EF = gas
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At AB, CD dan EF :
The heat supplied increases the kinetic energy of naphthalene. So the temperature rises because the temperature is a measure of the average kinetic energy of molecules in a substance.

At BC, DE :
At t₁ and t₂ phase change has occurred. The latent heat is absorbed to provide the energy to overcome the binding forces between the molecules. The energy absorbed does not increase the kinetic energy of the molecules, so the temperature remains constant.

**Cooling curve**

Freezing point = 80°C
Condensation point = 218°C

AB = Gas  BC = Gas + Liquid  CD = Liquid  DE = Liquid + Solid  EF = Solid

Pada AB, CD dan EF :
Heat is released to the surroundings and the kinetic energy of the molecules decreases, resulting in a fall in the temperature of the naphthalene because the temperature is a measure of the average kinetic energy of molecules in a substance.

Pada BC, DE :
At t₁ and t₂ phase change has occurred. The latent heat is released to the surroundings as the molecules become more closely packed. The energy released does not decrease the kinetic energy of the molecules, so the temperature remains constant.

**Definition and the S.I unit of Specific Latent Heat
d\(l\)**

The specific latent heat of fusion, \(l_f\) :
Is the quantity of heat energy required to change 1 kg of a substance from the solid state to the liquid state, without a change in temperature.

The specific latent heat of Vaporisation, \(l_v\) :
Is the quantity of heat energy required to change 1 kg of a substance from the liquid state to the gaseous state, without a change in temperature.

The S.I. unit of \(l_f\) and \(l_v\) is J kg\(^{-1}\)

**The relationship between \(m, l\) and \(Q\)**

\[ Q = m l \]

Where,
- \(Q\) = the heat energy transferred to the substance
- \(m\) = the mass of the substance
- \(l\) = the specific latent heat of the substance

**Example 1**

What is the quantity of heat required to melt 2.0 kg ice at 0 °C.
(The specific latent heat of fusion of ice = \(3.34 \times 10^5\) J kg\(^{-1}\))

**Solution**
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**Example 2**

How much energy has to be removed from 4.0 kg of water at 20°C to produce a block of ice at 0°C. (The specific heat capacity of water = 4.2 x 10³ J kg⁻¹°C⁻¹. The specific latent heat of fusion of ice = 3.34 x 10⁵ J kg⁻¹)

**Solution**

**Example 3**

Calculate the heat required to convert 4 kg of ice at -15°C into steam at 100°C. (Specific heat capacity of ice = 2.1 x 10³ J kg⁻¹°C⁻¹. Specific heat capacity of water = 4.2 x 10³ J kg⁻¹°C⁻¹. Latent heat of fusion of ice = 3.34 x 10⁵ J kg⁻¹ and Latent heat of vaporisation of water = 2.26 x 10⁶ J kg⁻¹)

**Solution**
Precautions

(1) The immersion heater must be fully immersed in the ice cubes to avoid or reduce heat loss.

Discussions

The value of the specific latent heat of fusion of ice, $l_f$, determined in the experiment is larger than the standard value of $l_f$. This is because the experimental value of the mass of ice melted, $m$, less than the expected $m$ due to some heat loss to the surroundings. The smaller the mass $m$, the greater the specific latent heat of fusion of ice, $l_f$,

$$l_f = \frac{P_t}{m}$$

To determine the latent heat of vaporisation of water

The electrical power of the heater is recorded = $P$

The electric heater is switched on the heat the water to its boiling point.
When the water starts to boil at a steady rate, the stopwatch is started and the reading on the balance is recorded = $m_1$
After a time, $t$, the reading on the electronic balance is recorded again = $m_2$
Calculate the mass of water evaporated, $m = m_1 - m_2$
Calculate the heat supplied by the heater = $P_t$
Calculate the heat absorbed by the water during vaporisation = $m_l$
On the assumption that there is no heat loss to surroundings, $P_t = m_l$

$$l_v = \frac{P_t}{m}$$

Example 4

A 800 W electric heater is used to boil water. What is the time required to reduce the mass of water by 4 kg after the water has reached its boiling point?

[$\text{Specific latent heat of vaporization of water} = 2.26 \times 10^6 \text{ J kg}^{-1}$]

Solution
Example 5

0.5 kg of a solid is heated by a 100 W heater. The graph shows how the temperature substance varies with time.

![Temperature vs Time Graph]

Calculate the specific latent heat of fusion of the solid.

Solution

Applications of Specific Latent Heat in Everyday Life

1. When we are engaged in strenuous activities, sweating cools our bodies. The sweat evaporates and the bodies heat is removed as the latent heat of vaporisation. Thus our bodies temperature is decreased.

2. Drinks can be cooled by adding in several cubes of ice. When the ice is melting, the latent heat of fusion is absorbed from the drinks. The temperature of the drinks is lowered.

3. Food can be cooked by using steam. Food such as cakes, eggs, fish, buns and others receive a large amount of energy when the latent heat of vaporization of steam released from condensing steam.

1. Latent heat is "hidden" because
   A. cannot be measured
   B. does not actually exist
   C. is a form of internal kinetic energy
   D. cannot be seen in the form of a temperature rise

2. A substance changes from a liquid state to a solid state. This process is called
   A. fusion
   B. sublimation
   C. vaporization
   D. solidification

3. A liquid naphthalene begin to solidify. Which of the following is true?
   A. Temperature decreases
   B. Temperature increases
   C. Heat is absorbed
   D. Heat is released

4. The latent heat is released when
   A. liquid changes to steam
   B. solid changes to steam
   C. steam change to liquid

5. The graph shows the heating curve of a substance.

![Temperature vs Time Graph]

At which stage is the substance in a solid and liquid state at the same time?
6 The graph shows the cooling curve of a substance.

Which of the following is true?

A At section WX the average kinetic energy of the substance molecules decreases
B At section XY heat is not released
C At section YZ the substance exits in the solid and liquid states

7 The diagram shows a process in which water is changed to steam.

The heat absorbed during the process is called

A specific heat capacity of vapour
B specific heat capacity of liquid
C latent heat of vaporisation
D latent heat of fusion

8 When the hot steam condenses to water,

A the density of the steam decreases
B the latent heat is absorbed from the surroundings
D the kinetic energy of the molecules are remain constant
D the distance of separation between molecules increase

9 Aniline melts at -6°C and boils at 184°C. At which temperature would aniline not be a liquid?

A -10°C  B -4°C
C 78°C  D 156°C

10 The table gives the melting points and the boiling points of four elements. Which element is liquid at 1000°C?

<table>
<thead>
<tr>
<th>Element</th>
<th>Melting point /°C</th>
<th>Boiling point /°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Aluminium</td>
<td>660</td>
</tr>
<tr>
<td>B</td>
<td>Chlorine</td>
<td>-101</td>
</tr>
<tr>
<td>C</td>
<td>iron</td>
<td>1540</td>
</tr>
<tr>
<td>D</td>
<td>Mercury</td>
<td>-39</td>
</tr>
</tbody>
</table>

11 The specific latent heat of fusion of ice is the quantity of energy required to

A change 1 kg of ice from ice to water with 1°C rise in temperature
B change 1 kg of ice from water to steam without a change in temperature
C change 1 kg of ice from water to steam with 1°C rise in temperature
D change 1 kg of ice from ice to water without a change in temperature

12 0.4 kg of water at 100°C. What is the quantity of heat required to change the water to steam at 100°C?

\[ \text{Specific latent heat of vaporisation of water} = 2.3 \times 10^6 \text{ J kg}^{-1} \]

A \(9.2 \times 10^2\) J  B \(9.2 \times 10^5\) J
C \(9.2 \times 10^6\) J  D \(9.2 \times 10^8\) J
E \(9.2 \times 10^{10}\) J

13 What is the quantity of heat released to change 0.3 kg of water at 0°C to ice at 0°C?

\[ \text{specific latent heat of fusion of ice} = 3.3 \times 10^5 \text{ J kg}^{-1} \]

A \(9.9 \times 10^2\) J  B \(9.9 \times 10^4\) J
C \(9.9 \times 10^6\) J  D \(9.9 \times 10^8\) J
E \(9.9 \times 10^{10}\) J

14 What is the quantity of heat required to change 0.02 kg of ice at 0°C to water at 40°C?

\[ \text{specific heat capacity of water} = 4.2 \times 10^3 \text{ J kg}^{-1} \text{°C}^{-1} \]
\[ \text{specific latent heat of fusion of ice} = 3.34 \times 10^5 \text{ J kg}^{-1} \]

A \(9.9 \times 10^2\) J  B \(9.9 \times 10^4\) J
C \(9.9 \times 10^6\) J  D \(9.9 \times 10^8\) J
E \(9.9 \times 10^{10}\) J
Understanding thermal latent heat

15 The melt naphthalene of mass 0.01 kg at 90°C is cooled until it has solidified at 80°C. What is the quantity of heat released?

- Specific heat capacity of naphthalene = $2.1 \times 10^3$ J kg$^{-1}$ °C$^{-1}$
- Specific latent heat of fusion of naphthalene = $1.7 \times 10^5$ J kg$^{-1}$

Options:
A 210 J  
B 1490 J  
C 1700 J  
D 1910 J  
E 2400 J  

16 A 2000 W electric heater is used to change 2 kg of water at 100°C to steam. What is the time taken to change the water to steam?

- Specific latent heat of vaporisation of water = $2.26 \times 10^6$ J kg$^{-1}$

Options:
A 590 s  
B 1540 s  
C 2260 s  
D 3280 s  
E 4070 s  

17 A 500 W electric heater is used to heat 0.1 kg of a liquid to its boiling point. The liquid is allowed to boil in 3 minutes again until the mass of liquid becomes 0.06 kg. What is the specific latent heat of vaporisation of the liquid?

Options:
A $4.75 \times 10^6$ J kg$^{-1}$  
B $3.85 \times 10^6$ J kg$^{-1}$  
C $2.25 \times 10^6$ J kg$^{-1}$  
D $1.15 \times 10^6$ J kg$^{-1}$  
E $1.45 \times 10^6$ J kg$^{-1}$  

18 A solid is heated by an electrical heater. Which one of the following graph shows the solid have the large specific heat capacity and the large specific latent heat?

19 Why do people feel cool if they do not dry themselves after swimming in the sea?

Options:
A Water evaporates and causes cooling  
B Water insulates them from the warm air  
C Water is good conductor of heat  
D Water is colder than the air
20 A steam burn is more damaging than a burn from boiling water at the same temperature. It is because

A the water boils and released heat to surroundings
B the steam has a higher temperature than the boiling water
C the heat released from condensing steam.

21 At a picnic, why would wrapping a bottle in a wet cloth be a better method of cooling than placing the bottle in a bucket of cold water?

A The temperature of wet cloth is lower than cold water
B Wet cloth has the large specific latent heat than cold water
C Wet cloth reached the thermal equilibrium more faster than cold water
D The water from wet cloth absorbed the specific latent heat from the bottle to evaporate

22 Figure (a) shows an arrangement of the apparatus to determine the specific latent heat of fusion of ice. At the beginning, beaker A contains 0.24 kg of ice. The taken to melt the ice is recorded.

(b) In this experiment, the readings of voltmeter and ammeter are 12.0 V and 4.0 A respectively. All of the ice is melted in 30 minutes. Determine the specific latent heat of fusion of ice.

(c) Figure (b) shows another arrangement of the apparatus to determine the specific latent heat of fusion of ice.

Figure (b)

(i) State one advantage used the arrangement of the apparatus in Figure (b) compared to arrangement of the apparatus in Figure (a).

(ii) When the arrangement of the apparatus in Figure (b) is used, the observation showed that the value of the specific latent heat of fusion of ice determined in the experiment is larger than the standard value of . Explain why it happen and suggest a method to improve the situation.
A solid substance of mass 0.1 kg is heated using 200 W heater. A graph showing in variation of temperature with time is shown in Figure below.

(a) Based on the graph, what are the states of matter between point
   (i) WX……………………………………
   (ii) XY……………………………………
   (iii) YZ……………………………………

(b) Using kinetic theory of matter, explain why
   (i) at section XY, the temperature remains constant?
   (ii) at section YZ, the temperature increases

(c) Using the graph, determine
   (i) the melting point of the substance?
   (ii) the specific latent heat of fusion of the substance.

24 (a) Sweating is one of the ways our body maintains the body temperature of about 37°C. Sweat is largely made up of water and it comes from sweat glands as shown in the following figure.

   When sweat evaporates, it takes heat away from our body.
   (i) What is meant by evaporation?
   (ii) Using kinetic theory of matter, explain how evaporation takes away heat from our body.
(b) State two environmental factors that affect the rate of evaporation of sweat.

1. ........................................

2. ........................................

(c) While playing badminton, 0.05 kg of sweat was evaporated from Ahmad's body. Calculate the quantity of heat lost from his body due to the evaporation. The latent heat of vaporization of sweat is $2.3 \times 10^6$ J kg$^{-1}$. 