14. Temperature

14.3 Specific heat capacity and specific latent heat

Paper 4

Question Paper

1 **(a)** Define specific heat capacity.

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..... [2]

(b) Two solid blocks X and Y are made from different metals. The blocks have different initial temperatures. Block Y is initially at room temperature.

The blocks are placed in direct thermal contact with each other at time $t = 0$. Fig. 2.1 shows the variation with t of the temperatures of the two blocks.

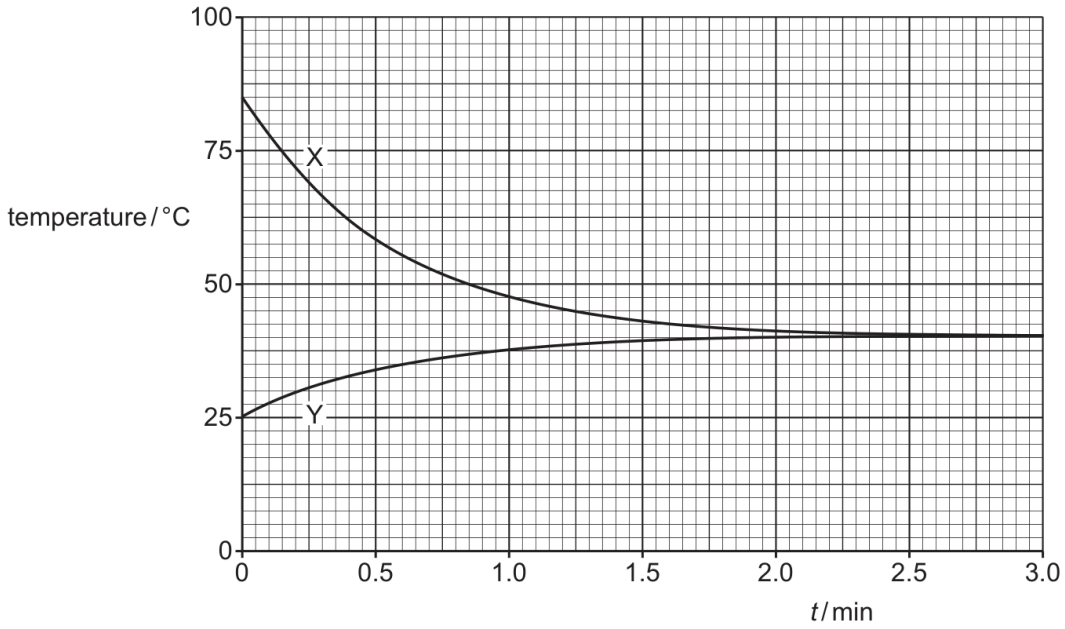


Fig. 2.1

(i) State **three** conclusions that may be drawn from Fig. 2.1. The conclusions may be qualitative or quantitative.

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2 .....

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3 .....

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[3]

(ii) The ratio $\frac{\text{mass of block Y}}{\text{mass of block X}}$ is equal to 1.3.

The metal in block Y has a specific heat capacity of 901 $J\,kg^{-1}\,K^{-1}$.

Determine the specific heat capacity of the metal in block X.

specific heat capacity = ... $J\,kg^{-1}\,K^{-1}$ [3]

2 **(a)** Define specific latent heat.

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..... [2]

(b) A dish containing $7.2 \times 10^{-5}\,m^3$ of a substance rests on a laboratory bench. The substance is initially a liquid of density $710\,kg\,m^{-3}$. Atmospheric pressure is $1.0 \times 10^5\,Pa$.

The liquid is heated at its boiling point so that it completely vaporises. The increase in the internal energy of the substance during this process is 17.6 kJ. The final volume of the vapour is $0.017\,m^3$.

(iii) Use your answer in **(b)(ii)** to determine a value for the specific latent heat of vaporisation L_V, in $kJ\,kg^{-1}$, of the substance.

L_V = ... $kJ\,kg^{-1}$ [2]

(c) The substance in **(b)** has a specific latent heat of fusion L_F.

Suggest and explain whether L_F is likely to be less than, the same as, or greater than the answer in **(b)(iii)**.

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..... [3]

3 **(c)** A beaker contains a liquid of mass 120 g. The liquid is supplied with thermal energy at a rate of 810 W. The beaker has a mass of 42 g and a specific heat capacity of 0.84 $J g^{-1} K^{-1}$. The beaker and the liquid are in thermal equilibrium with each other at all times and are insulated from the surroundings.

Fig. 3.2 shows the variation with time *t* of the temperature of the liquid.

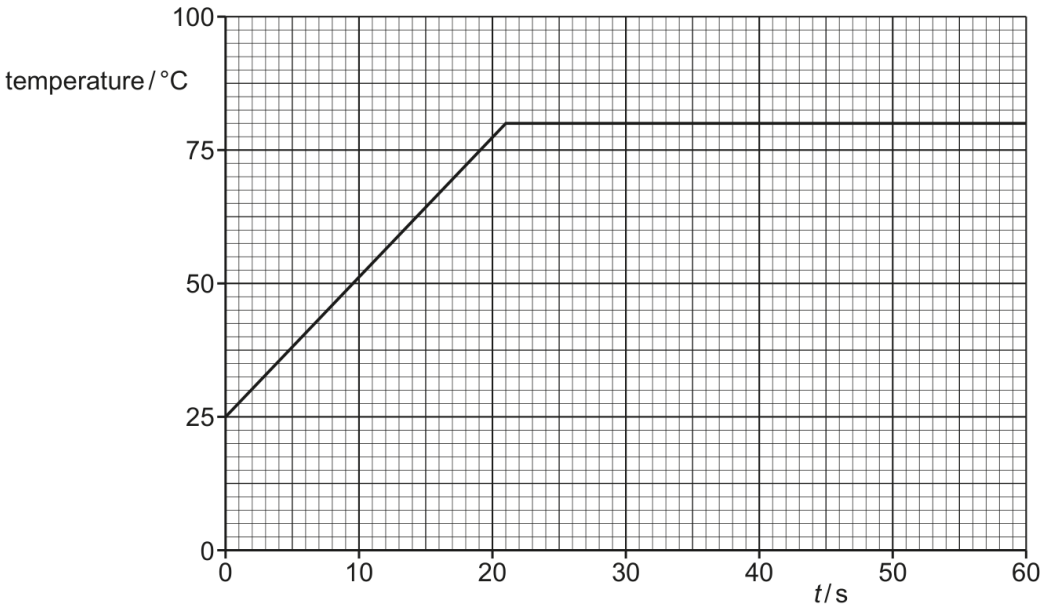


Fig. 3.2

(i) State the boiling temperature, in °C, of the liquid.

temperature = ... °C [1]

(ii) Determine the specific heat capacity, in $J g^{-1} K^{-1}$, of the liquid.

specific heat capacity = ... $J g^{-1} K^{-1}$ [4]

(d) The experiment in **(c)** is repeated using water instead of the liquid in **(c)**. The mass of liquid used, the power supplied, and the initial temperature are all unchanged.
The specific heat capacity of water is approximately twice that of the liquid in **(c)**.
The boiling temperature of water is 100 °C.

On Fig. 3.2, sketch the variation with time t of the temperature of the water between $t = 0$ and $t = 60$ s. Numerical calculations are not required. [2]

4 **(a)** Define specific heat capacity.

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..... [2]

(b) An ideal gas of mass 0.35 kg is heated at a constant pressure of 2.0×10^5 Pa so that its internal energy increases by 7600 J. During this process, the volume of the gas increases from 0.038 m^3 to 0.063 m^3 and the temperature increases by 56 °C.

(iv) Calculate the specific heat capacity of the gas for this process. Give a unit with your answer.

specific heat capacity = ... unit ..... [2]

5 **(a)** Define specific latent heat of vaporisation.

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..... [2]

(b) The specific latent heat of vaporisation of water at atmospheric pressure of 1.0×10^5 Pa is $2.3 \times 10^6\,\text{J kg}^{-1}$. A mass of 0.37 kg of liquid water at 100 °C is provided with the thermal energy needed to vaporise all of the water at atmospheric pressure.

(i) Calculate the thermal energy q supplied to the water.

q = ... J [1]

6 Fig. 2.1 shows a laboratory thermometer that is calibrated to measure temperature in degrees Celsius.

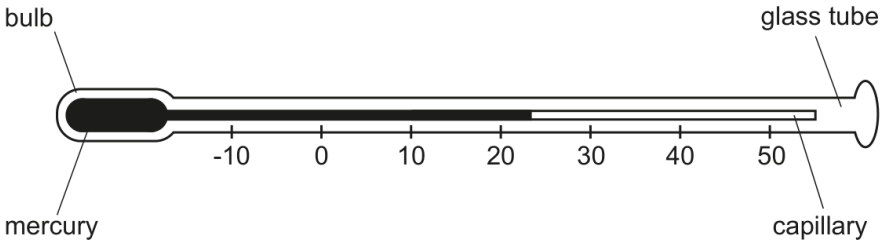


Fig. 2.1

The thermometer makes use of the fact that the density of mercury varies with temperature.

(b) The thermometer is initially at 23.0 °C, as shown in Fig. 2.1. It is used to measure the temperature of an insulated beaker of water that is at 37.4 °C. The bulb of the thermometer is inserted into the water, and the water is stirred until the reading on the thermometer becomes steady.

The mass of water in the beaker is 18.7 g.
The mass of mercury in the thermometer is 6.94 g.
The specific heat capacity of water is 4.18 J g^{-1} K^{-1}.
The specific heat capacity of mercury is 0.140 J g^{-1} K^{-1}.
The glass of the thermometer and the beaker containing the water can be considered to have negligible heat capacity.

(i) Calculate, to three significant figures, the final steady temperature indicated by the thermometer in the water.

temperature = ... °C [4]

(ii) Suggest **one** change that could be made to the design of the thermometer that would enable it to give a more accurate measurement of temperature.

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..... [1]

7 **(a)** Define specific heat capacity.

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..... [2]

(b) A fixed mass of water in a beaker is at atmospheric pressure.

(i) The initial temperature of the water is 0 °C.

The water is supplied with thermal energy E, so that its temperature increases to 8 °C. There is no net change in the volume of the water.

(ii) The water is now heated so that its temperature increases by a further 8 °C to a final temperature of 16 °C. This process causes the volume of the water to increase so that work W is done.
Assume that the change in internal energy is the same as in **(b)(i)**.

(c) Use the information in **(b)** to suggest, with a reason, how the average specific heat capacity of water between 8 °C and 16 °C compares with its average value between 0 °C and 8 °C.

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..... [1]

8 **(a)** Define *specific heat capacity*.

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..... [2]

(b) A sealed container of fixed volume V contains N molecules, each of mass m, of an ideal gas at pressure p.

(ii) Show that the mean translational kinetic energy E_K of a molecule of the gas is given by

$$E_K = \frac{3}{2}kT.$$

(c) The gas in **(b)** is supplied with thermal energy Q.

(i) Explain, with reference to the first law of thermodynamics, why the increase in internal energy of the gas is Q.

(ii) Use the expression in **(b)(ii)** and the information in **(c)(i)** to show that the specific heat capacity c of the gas is given by

$$c = \frac{3k}{2m}.$$

[2]

9 **(a)** State what is meant by *specific latent heat*.

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..... [2]

(b) A student determines the specific latent heat of vaporisation of a liquid using the apparatus illustrated in Fig. 3.1.

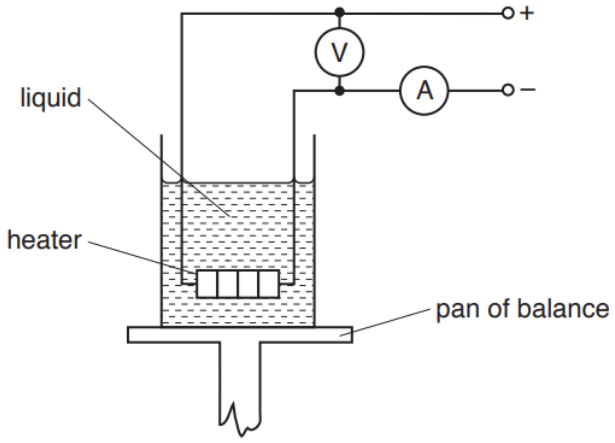


Fig. 3.1

The heater is switched on. When the liquid is boiling at a constant rate, the balance reading is noted at 2.0 minute intervals.

After 10 minutes, the current in the heater is reduced and the balance readings are taken for a further 12 minutes.

The readings of the ammeter and of the voltmeter are given in Fig. 3.2.

	ammeter reading /A	voltmeter reading /V
from time 0 to time 10 minutes	1.2	230
after time 10 minutes	1.0	190

Fig. 3.2

The variation with time of the balance reading is shown in Fig. 3.3.

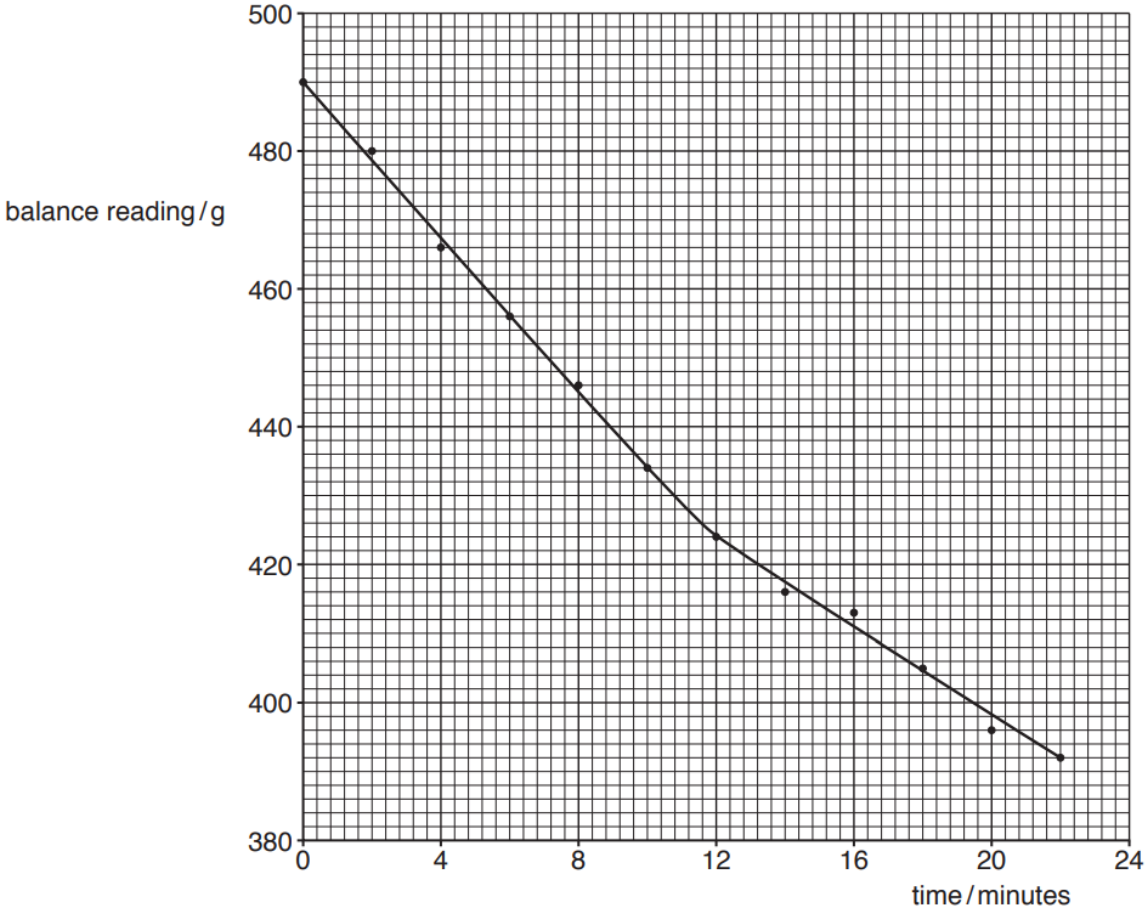


Fig. 3.3

(i) From time 0 to time 10.0 minutes, the mass of liquid evaporated is 56 g.

Use Fig. 3.3 to determine the mass of liquid evaporated from time 12.0 minutes to time 22.0 minutes.

mass = ... g [1]

(iii) Determine a value for the specific latent heat of vaporisation L of the liquid.

L = ... $J g^{-1}$ [4]

(iv) Calculate the rate at which thermal energy is transferred to the surroundings.

rate = ... W [2]

10 (a) State what is meant by *specific latent heat*.

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..... [2]

The variation with time of the balance reading is shown in Fig. 3.2.

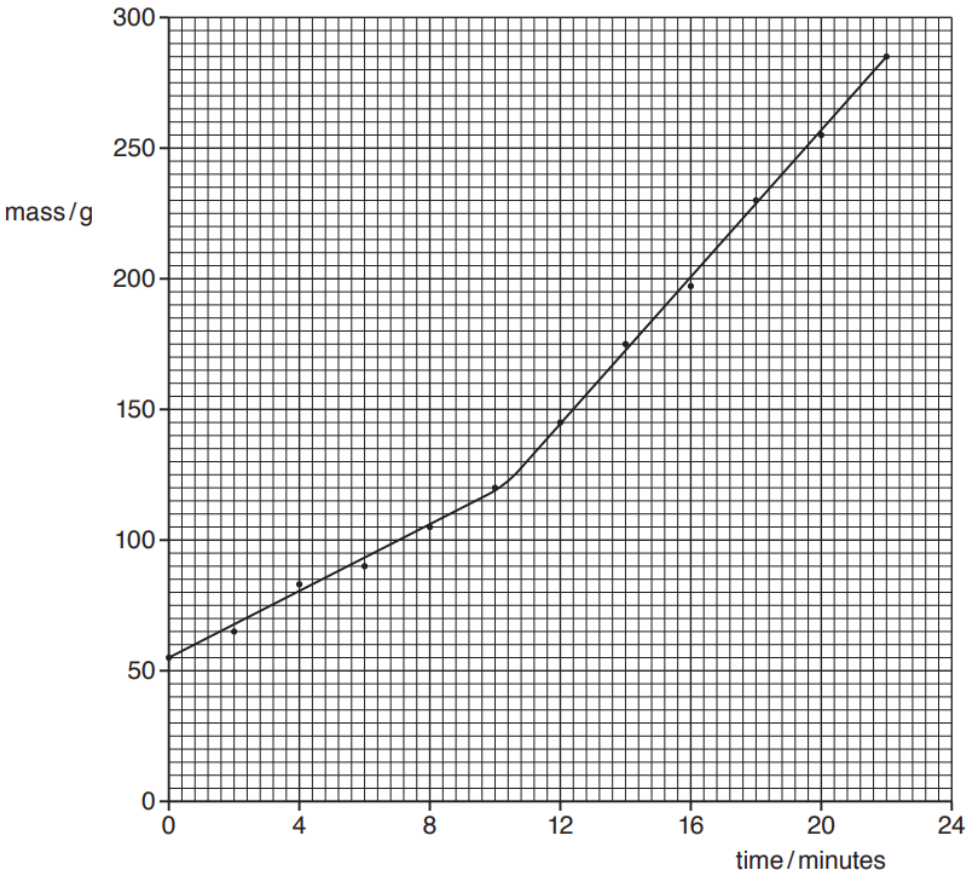


Fig. 3.2

The readings of the ammeter and of the voltmeter are shown in Fig. 3.3.

	ammeter reading /A	voltmeter reading /V
from time 0 to time 10 minutes after time 10 minutes	1.8 3.6	7.3 15.1

Fig. 3.3

(b) (i) From time 0 to time 10.0 minutes, 65 g of ice is melted.

Use Fig. 3.2 to determine the mass of ice melted from time 12.0 minutes to time 22.0 minutes.

mass = ... g [1]

(iii) Determine a value for the specific latent heat of fusion L of ice.

L = ... $J\,g^{-1}$ [4]

(iv) Calculate the rate at which thermal energy is transferred from the surroundings to the ice.

rate = ... W [2]

11 **(a)** During melting, a solid becomes liquid with little or no change in volume.

Use kinetic theory to explain why, during the melting process, thermal energy is required although there is no change in temperature.

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.....[3]

(b) An aluminium can of mass 160 g contains a mass of 330 g of warm water at a temperature of 38 °C, as illustrated in Fig. 3.1.

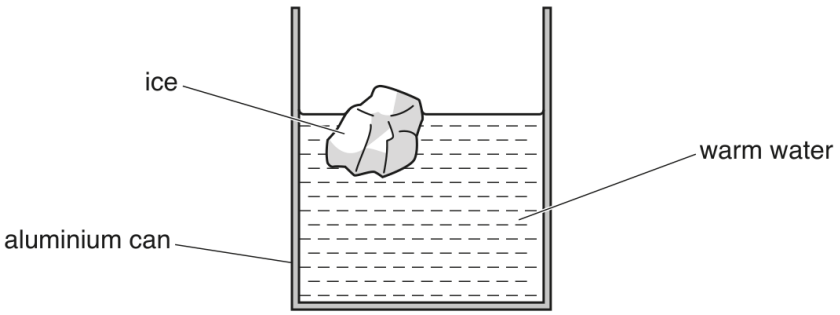


Fig. 3.1

A mass of 48 g of ice at –18 °C is taken from a freezer and put in to the water. The ice melts and the final temperature of the can and its contents is 23 °C.

Data for the specific heat capacity c of aluminium, ice and water are given in Fig. 3.2.

	c / J g^{-1} K^{-1}
aluminium	0.910
ice	2.10
water	4.18

Fig. 3.2

Assuming no exchange of thermal energy with the surroundings,

(i) show that the loss in thermal energy of the can and the warm water is 2.3×10^4 J,

[2]

(ii) use the information in **(i)** to calculate a value L for the specific latent heat of fusion of ice.

L = ... $J\,g^{-1}$ [2]

12 **(a)** Define *specific latent heat of fusion*.

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.....[2]

(b) A student sets up the apparatus shown in Fig. 3.1 in order to investigate the melting of ice.

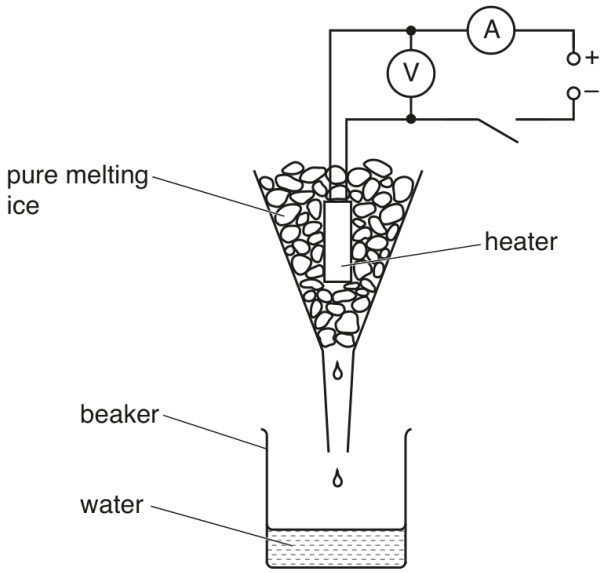


Fig. 3.1

The heater is switched on.
When the pure ice is melting at a constant rate, the data shown in Fig. 3.2 are collected.

voltmeter reading /V	ammeter reading /A	initial mass of beaker plus water/g	final mass of beaker plus water/g	time of collection /minutes
12.8	4.60	121.5	185.0	5.00

Fig. 3.2

The specific latent heat of fusion of ice is $332\,J\,g^{-1}$.

(i) State what is observed by the student that shows that the ice is melting at a constant rate.

.....

.....[1]

(ii) Use the data in Fig. 3.2 to determine the rate at which

1. thermal energy is transferred to the melting ice,

rate = ... W

2. thermal energy is gained from the surroundings.

rate = ... W
[4]