WORKSHEET
Temperature
A Level Physics 9702

1 **(a)** State the reason why two objects that are at the same temperature are described as being in thermal equilibrium.

9702/MJ/23/41/Q3

....

.... [1]

(b) Fig. 3.1 shows the variations with temperature of the densities of mercury and of water between 0 °C and 100 °C.

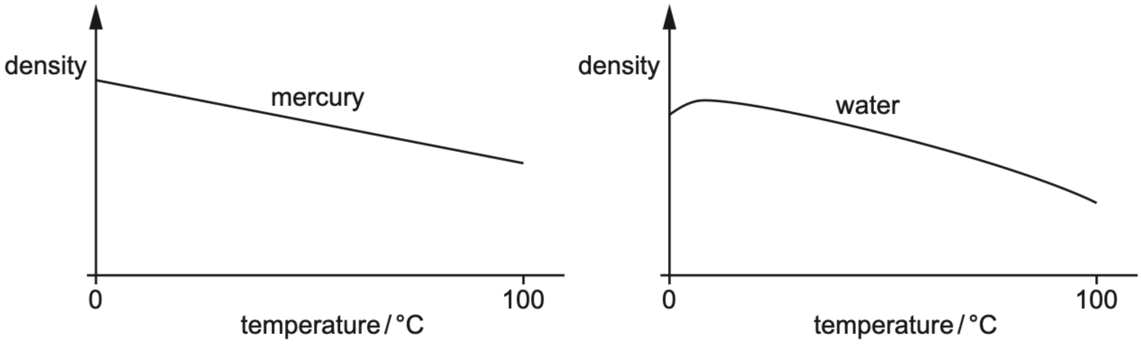

Fig. 3.1

Temperature may be measured using the variation with temperature of the density of a liquid.

Suggest why, for measuring temperature over this temperature range:

(i) mercury is a suitable liquid

....

.... [1]

(ii) water is not a suitable liquid.

....

....

.... [2]

(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.

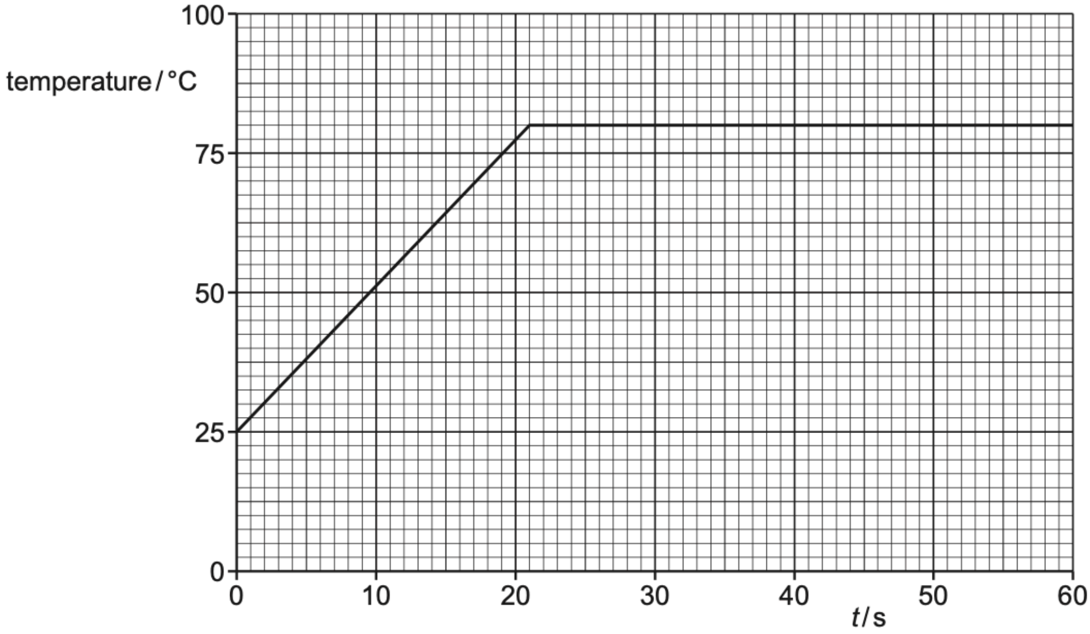

Fig. 3.2

(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]

[Total: 11]

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

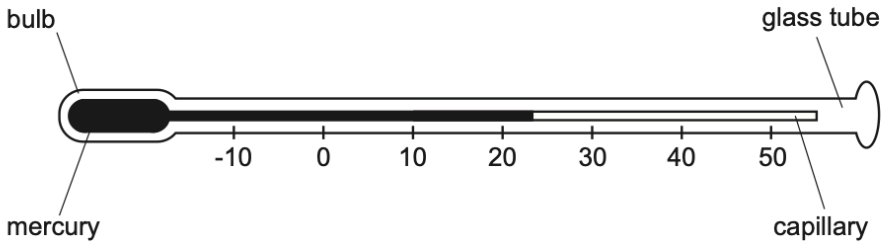

Fig. 2.1

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

(a) State **two** other physical properties of materials, apart from the density of a liquid, that can be used for measuring temperature.

1 ....

2 ....
[2]

(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.

....

.... [1]

(c) (i) Explain why the thermometer in Fig. 2.1 does **not** provide a direct measurement of thermodynamic temperature.

....

....

.... [2]

(ii) Thermodynamic temperature T may be determined by the behaviour of a type of substance for which T is proportional to the product of pressure and volume.

State the name of this type of substance.

.... [1]

[Total: 10]

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

....

....

.... [2]

(b) The specific latent heat of vaporisation of water at atmospheric pressure of 1.0×10^5 Pa is $2.3 \times 10^6\,\mathrm{J\,kg^{-1}}$. 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]

(ii) The mass of 1.0 mol of water is 18 g. Assume that water vapour can be considered to behave as an ideal gas.

Show that the volume of water vapour produced is $0.64\,\mathrm{m^3}$.

[3]

(iii) Assume that the initial volume of the liquid water is negligible compared with the volume of water vapour produced.

Determine the magnitude of the work done by the water in expanding against the atmosphere when it vaporises.

work done = ... J [2]

(iv) Use your answers in **(b)(i)** and **(b)(iii)** to determine the increase in internal energy of the water when it vaporises at 100 °C. Explain your reasoning.

increase in internal energy = ... J [2]

(c) Use the first law of thermodynamics to suggest, with a reason, how the specific latent heat of vaporisation of water at a pressure greater than atmospheric pressure compares with its value at atmospheric pressure.

....

....

.... [2]

[Total: 12]

4 **(a)** State what is meant by *specific latent heat*. 9702/ON/19/42/Q3

....

....

.... [2]

(b) A student uses the apparatus illustrated in Fig. 3.1 to determine a value for the specific latent heat of fusion of ice.

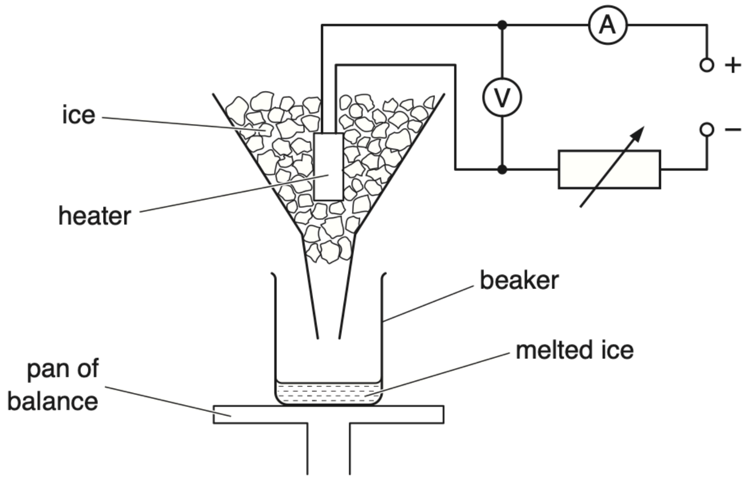

Fig. 3.1

The balance reading measures the mass of the beaker and the melted ice (water) in the beaker.

The heater is switched on and pieces of ice at 0 °C are added continuously to the funnel so that the heater is always surrounded by ice.

When water drips out of the funnel at a constant rate, the balance reading is noted at 2.0 minute intervals. After 10 minutes, the current in the heater is increased and the balance readings are taken for a further 12 minutes.

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

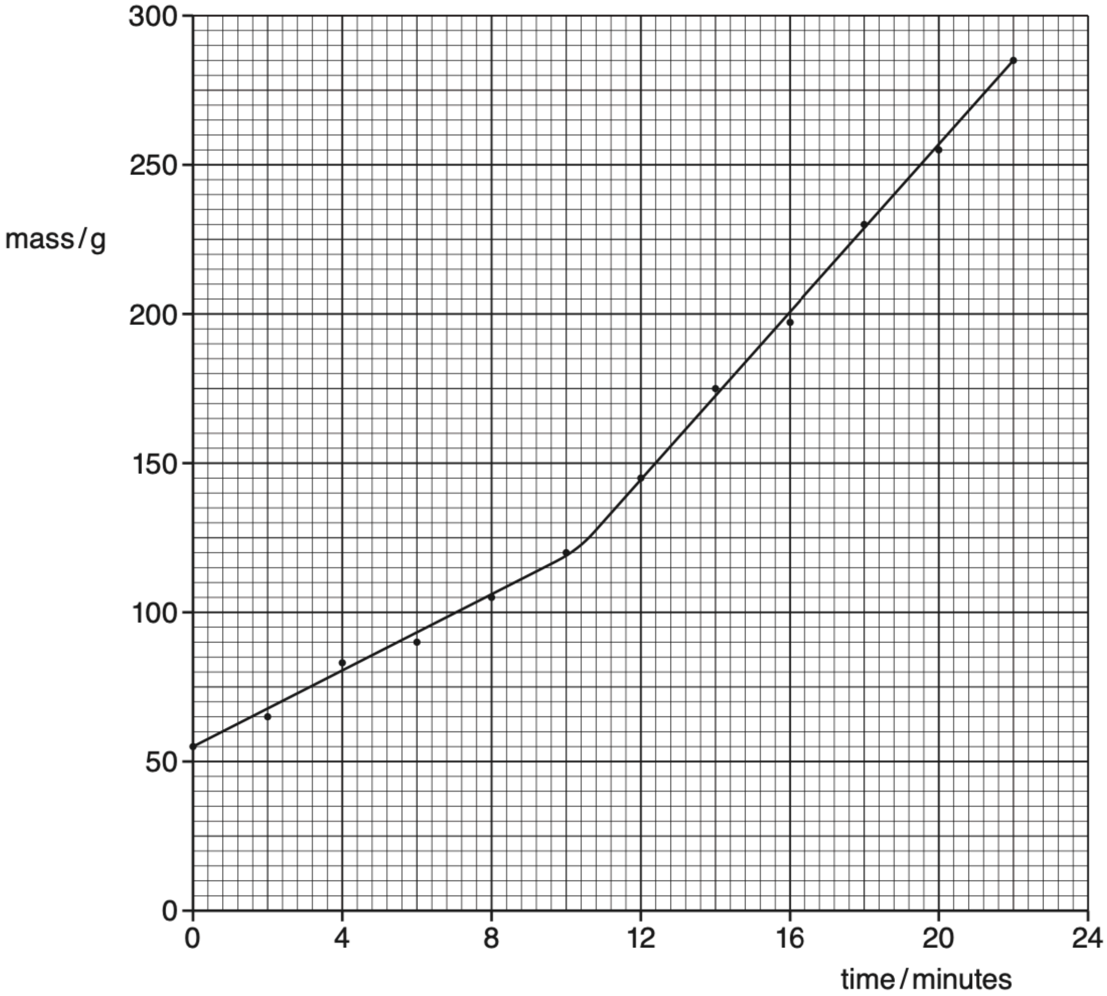

Fig. 3.2

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

(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]

(ii) Explain why, although the power of the heater is changed, the rate at which thermal energy is transferred from the surroundings to the ice is constant.

....

.... [1]

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

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

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

rate = ... W [2]

[Total: 10]

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

....

....

.... [2]

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

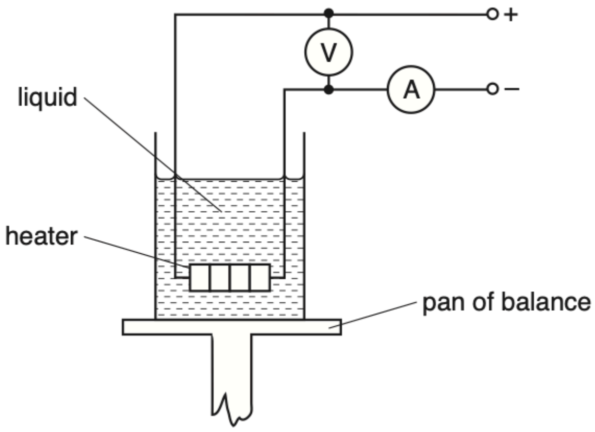

Fig. 3.1

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 after time 10 minutes	1.2 1.0	230 190

Fig. 3.2

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

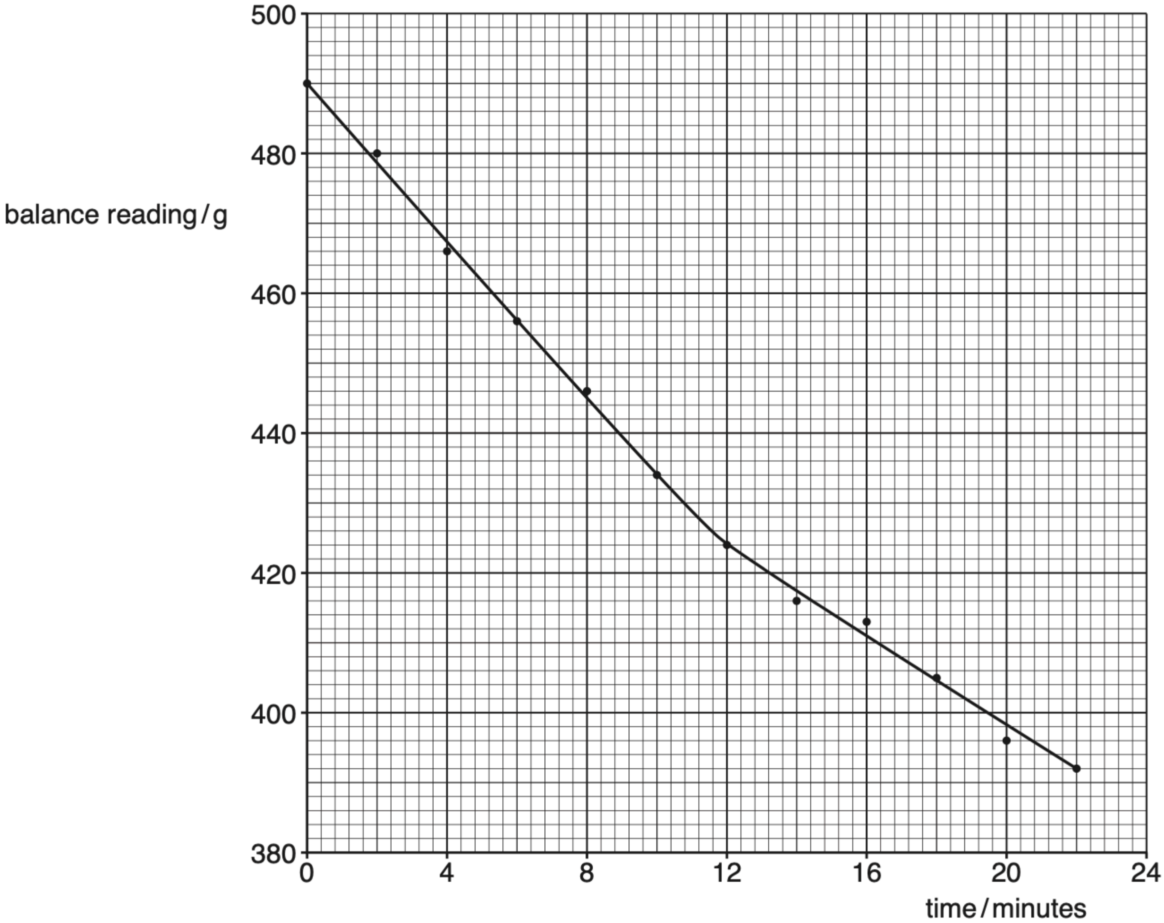

Fig. 3.3

(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]

(ii) Explain why, although the power of the heater is changed, the rate of loss of thermal energy to the surroundings may be assumed to be constant.

....

.... [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]

[Total: 10]

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

....

....

....[2]

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

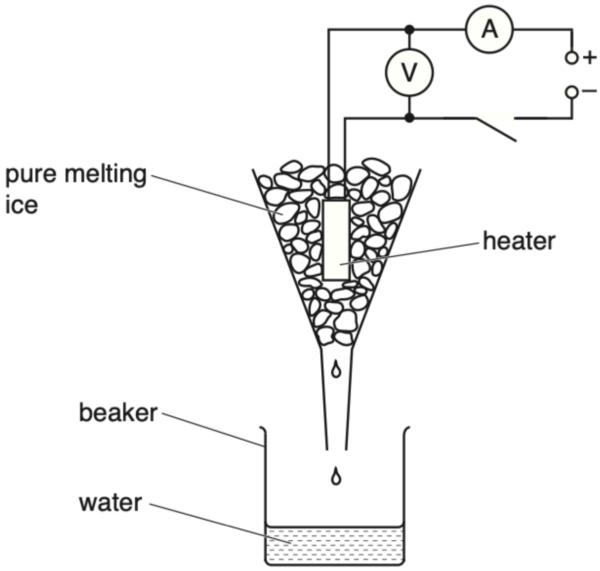

Fig. 3.1

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 $332\,\mathrm{J\,g^{-1}}$.

(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]

[Total: 7]

7 **(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.

....

....

....

....

....[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.

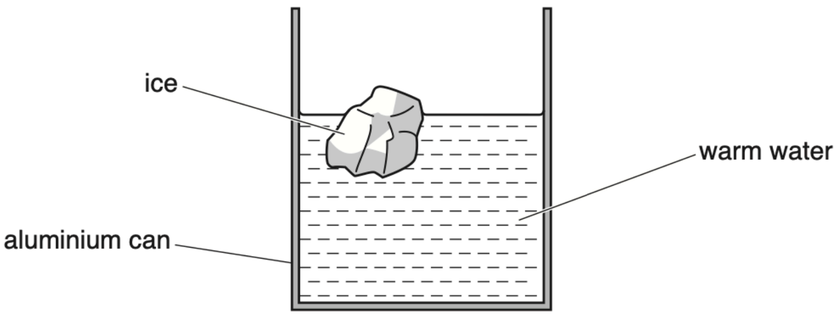

Fig. 3.1

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]

[Total: 7]

8 **(a)** State

(i) what may be deduced from the difference in the temperatures of two objects,

....

.... [1]

(ii) the basic principle by which temperature is measured.

....

.... [1]

(b) By reference to your answer in **(a)(ii)**, explain why two thermometers may not give the same temperature reading for an object.

....

....

.... [2]

(c) A block of aluminium of mass 670 g is heated at a constant rate of 95 W for 6.0 minutes.
The specific heat capacity of aluminium is $910\,\mathrm{J\,kg^{-1}\,K^{-1}}$.
The initial temperature of the block is 24 °C.

(i) Assuming that no thermal energy is lost to the surroundings, show that the final temperature of the block is 80 °C.

[3]

(ii) In practice, there are energy losses to the surroundings.
The actual variation with time t of the temperature θ of the block is shown in Fig. 1.1.

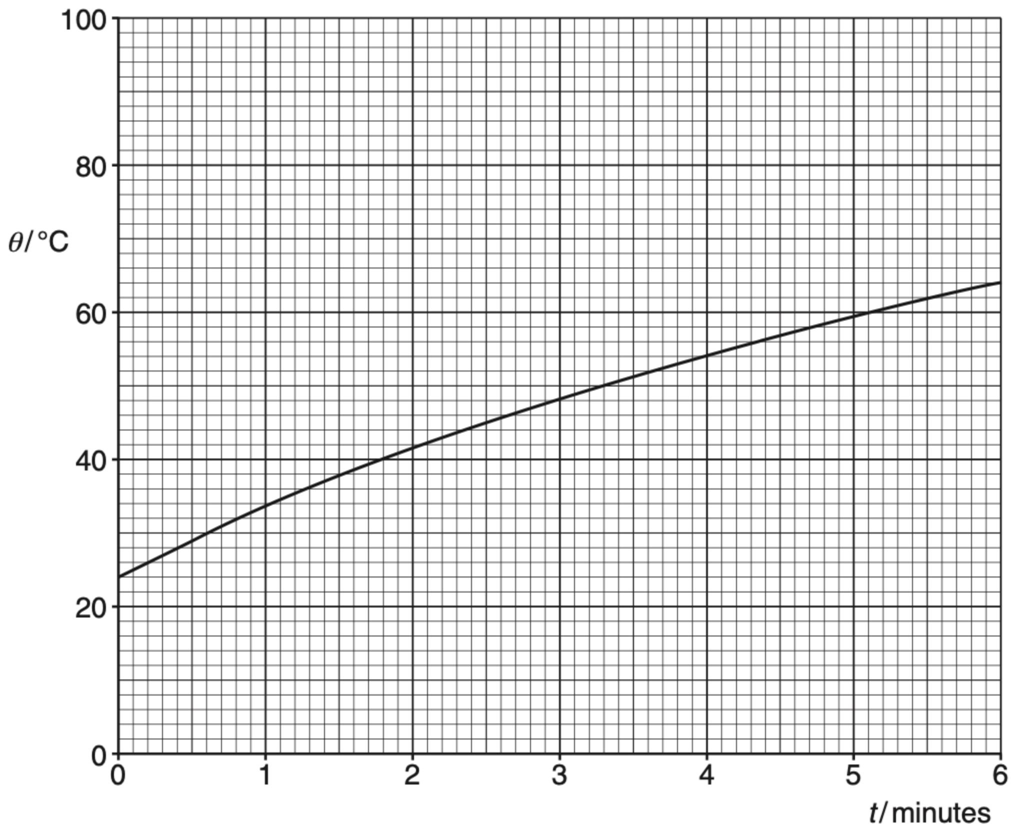

Fig. 1.1

1. Use the information in **(i)** to draw, on Fig. 1.1, a line to represent the temperature of the block, assuming no energy losses to the surroundings. [1]

2. Using Fig. 1.1, calculate the total energy loss to the surroundings during the heating process.

energy loss = ... J [2]

[Total: 10]

9 **(a)** The resistance of a thermistor at 0 °C is 3840 Ω. At 100 °C the resistance is 190 Ω. When the thermistor is placed in water at a particular constant temperature, its resistance is 2300 Ω.

(i) Assuming that the resistance of the thermistor varies linearly with temperature, calculate the temperature of the water.

temperature = ... °C [2]

(ii) The temperature of the water, as measured on the thermodynamic scale of temperature, is 286 K.

By reference to what is meant by the thermodynamic scale of temperature, comment on your answer in **(i)**.

....

....

....

.... [3]

(b) A polystyrene cup contains a mass of 95 g of water at 28 °C.

A cube of ice of mass 12 g is put into the water. Initially, the ice is at 0 °C. The water, of specific heat capacity $4.2 \times 10^3\,\mathrm{J\,kg^{-1}\,K^{-1}}$, is stirred until all the ice melts.

Assuming that the cup has negligible mass and that there is no heat exchange with the atmosphere, calculate the final temperature of the water.

The specific latent heat of fusion of ice is $3.3 \times 10^5\,\mathrm{J\,kg^{-1}}$.

temperature = ... °C [4]

1 estion	Answer	Marks
3(a)	no <u>net</u> thermal energy is transferred (between them)	**B1**
(b)(i)	variation (of density with temperature) is linear **or** each temperature has a unique value of density	**B1**
(b)(ii)	• variation (of density with temperature) is not linear • region where the density does not vary with temperature • different temperatures have the same density *Any two points, 1 mark each*	**B2**
(c)(i)	boiling point = 80 °C	**A1**
(c)(ii)	$Q = Pt$ **and** $t = 21$ s (thermal energy supplied = 810 × 21 = 17000 J)	**C1**
	$c = Q / m\Delta\theta$	**C1**
	thermal energy absorbed by beaker = 42 × 0.84 × (80 – 25) (= 1940 J)	**C1**
	s.h.c. of liquid = [(810 × 21) – (42 × 0.84 × (80 – 25))] / [120 × (80 – 25)] = 2.3 J g^{-1} K^{-1}	**A1**
3(d)	sketch: straight diagonal line from 25 °C to 100 °C **and** then horizontal at 100 °C	**B1**
	straight diagonal line starting at 25 °C with gradient approximately half that of the original line	**B1**

2 estion	Answer	Marks
2(a)	• resistance of a metal • volume of a gas at constant pressure • e.m.f. of a thermocouple *Any two points, 1 mark each*	**B2**
(b)(i)	$Q = mc\Delta T$	**C1**
	evidence of realisation that Q lost by water = Q gained by mercury	**C1**
	18.7 × 4.18 × (37.4 – T) = 6.94 × 0.140 × (T – 23.0)	**C1**
	T = 37.2 °C	**A1**
(b)(ii)	use a liquid with a lower (specific) heat capacity (than mercury) **or** use a smaller mass of mercury	**B1**
(c)(i)	depends on properties of a real substance	**B1**
	0 °C is not absolute zero	**B1**
(c)(ii)	ideal gas	**B1**

3 Question	Answer	Marks
3(a)	(thermal) energy per unit mass	B1
	energy to change state between liquid and gas at constant temperature	B1
(b)(i)	$q = mL = 0.37 \times 2.3 \times 10^6$ $= 8.5 \times 10^5$ J	A1
(b)(ii)	$pV = nRT$ **and** $T = 373$ K	C1
	$n = 370 / 18$	C1
	$V = [(370 / 18) \times 8.31 \times 373] / (1.0 \times 10^5) = 0.64$ m^3	A1
(b)(iii)	$w = p\Delta V$	C1
	$= 1.0 \times 10^5 \times 0.64$ $= 6.4 \times 10^4$ J	A1
(b)(iv)	(water does work against atmosphere so) work done on water is negative	B1
	increase in internal energy = $(8.5 - 0.64) \times 10^5 = 7.9 \times 10^5$ J	A1
3(c)	valid reasoning of how work done by water is affected	M1
	correct use of first law to draw conclusion about effect on specific latent heat that is consistent with work done	A1

4 Question	Answer	Marks
3(a)	(thermal) energy per unit mass (to change state)	B1
	change of state without any change of temperature	B1
3(b)(i)	140 g	A1
3(b)(ii)	temperature difference (between apparatus and surroundings) does not change	B1
(b)(iii)	$VIt = mL$	C1
	$(\{15.1 \times 3.6\} + R) \times 600 = 140 \times L$ **or** $(\{7.3 \times 1.8\} + R) \times 600 = 65 \times L$	C1
	$41.22 \times 600 = 75 \times L$	C1
	$L = 330$ J g^{-1}	A1
(b)(iv)	$15.1 \times 3.6 \times 600 = (140 \times 330) - H$ **or** $7.3 \times 1.8 \times 600 = (65 \times 330) - H$	C1
	$H = 13600$ rate of gain = 13600 / 600 = 23 W	A1

5

Question	Answer	Marks
3(a)	(thermal) energy per (unit) mass (to change state)	B1
	(heat transfer during) change of state at constant temperature	B1
3(b)(i)	32 g	A1
3(b)(ii)	temperature difference (between liquid and surroundings) does not change	B1
3(b)(iii)	$VIt = mL$	C1
	$230 \times 1.2 \times 60 \times 10 = (56 \times L) + H$ **or** $190 \times 1.0 \times 60 \times 10 = (32 \times L) + H$	C1
	$86 \times 600 = (56 - 32) \times L$	C1
	or	
	$230 \times 1.2 = (56 \times L) / (60 \times 10) + P$ **or** $190 \times 1.0 = (32 \times L) / (60 \times 10) + P$	(C1)
	$276 - 190 = (24 \times L) / 600$	(C1)
	$L = 2200\ \text{J g}^{-1}$	A1

6

Question	Answer	Marks
3(a)	(thermal) energy per unit mass (to cause change of state)	B1
	(energy transfer during) change of state between solid and liquid at constant temperature	B1
3(b)(i)	Any one from: • rate of increase in mass (of beaker and water) is constant • level of water rises at a constant rate • volume of water (in beaker) increases at a constant rate • constant time between drops • constant rate of dripping	B1
3(b)(ii)	(electrical power supplied =) 12.8×4.60 (= 58.9 W)	C1
	(rate of transfer to ice =) $[(185.0 - 121.5) \times 332] / [5.00 \times 60]$ (= 70.3 W)	C1
	1. rate = 70.3 W	A1
	2. rate = 70.3 – 58.9 = 11.4 W	A1

7

Question	Answer	Marks
3(a)	(during melting,) bonds between atoms/molecules are broken	B1
	potential energy of atoms/molecules is increased	B1
	no/little work done so required input of energy is thermal	B1
3(b)(i)	$(\Delta Q =)\ mc\Delta\theta$	C1
	loss = $(160 \times 0.910 \times 15) + (330 \times 4.18 \times 15)$ $= 2.3 \times 10^4\ \text{J}$	A1
3(b)(ii)	$2.3 \times 10^4 = (48 \times 2.10 \times 18) + 48L + (48 \times 4.18 \times 23)$	C1
	$48L = 1.66 \times 10^4$ $L = 350\ \text{J g}^{-1}$	A1

8

Question	Answer	Marks
(a)(i)	direction or rate of transfer of (thermal) energy **or** (if different,) not in thermal equilibrium/energy is transferred	**B1**
(a)(ii)	uses a property (of a substance) that changes with temperature	**B1**
1(b)	• temperature scale assumes linear change of property with temperature • physical properties may not vary linearly with temperature • agrees only at fixed points *Any 2 points.*	**B2**
(c)(i)	$Pt = mc(\Delta)\theta$	**C1**
	$95 \times 6 \times 60 = 0.670 \times 910 \times \Delta\theta$	**M1**
	$\Delta\theta = 56\,°C$ so final temperature = 56 + 24 = 80 °C	**A1**
	or	
	$95 \times 6 \times 60 = 0.67 \times 910 \times (\theta - 24)$	**(M1)**
	so final temperature or $\theta = 80$ °C	**(A1)**

9

(a) **(i)** 1 deg C corresponds to (3840 – 190) / 100 Ω — C1
for resistance 2300 Ω, temperature is 100 × (2300 – 3840) / (190 – 3840)
temperature is 42 °C — A1 [2]

(ii) *either* 286 K ≡ 13 °C *or* 42 °C ≡ 315 K — B1
thermodynamic scale does not depend on the property of a substance — M1
so change in resistance (of thermistor) with temperature is non-linear — A1 [3]

(b) heat gained by ice in melting = $0.012 \times 3.3 \times 10^5$ J — C1
= 3960 J
heat lost by water = $0.095 \times 4.2 \times 10^3 \times (28 - \theta)$ — C1
$3960 + (0.012 \times 4.2 \times 10^3 \times \theta) = 0.095 \times 4.2 \times 10^3 \times (28 - \theta)$ — C1
θ = 16°C — A1 [4]
(answer 18°C – melted ice omitted – allow max 2 marks)
(use of (θ – T) then allow max 1 mark)