Chapter 11 – Thermal Properties of Matter

Subject content

Content
- Internal energy
- Specific heat capacity
- Melting, boiling and evaporation
- Specific latent heat

Learning outcomes
(a) describe a rise in temperature of a body in terms of an increase in its internal energy (random thermal energy)
(b) define the terms heat capacity and specific heat capacity
(c) recall and apply the relationship thermal energy = mass × specific heat capacity × change in temperature to new situations or to solve related problems
(d) describe melting / solidification and boiling / condensation as processes of energy transfer without a change in temperature
(e) explain the difference between boiling and evaporation
(f) define the terms latent heat and specific latent heat
(g) recall and apply the relationship thermal energy = mass × specific latent heat to new situations or to solve related problems
(h) explain latent heat in terms of molecular behaviour
(i) sketch and interpret a cooling curve

Definitions

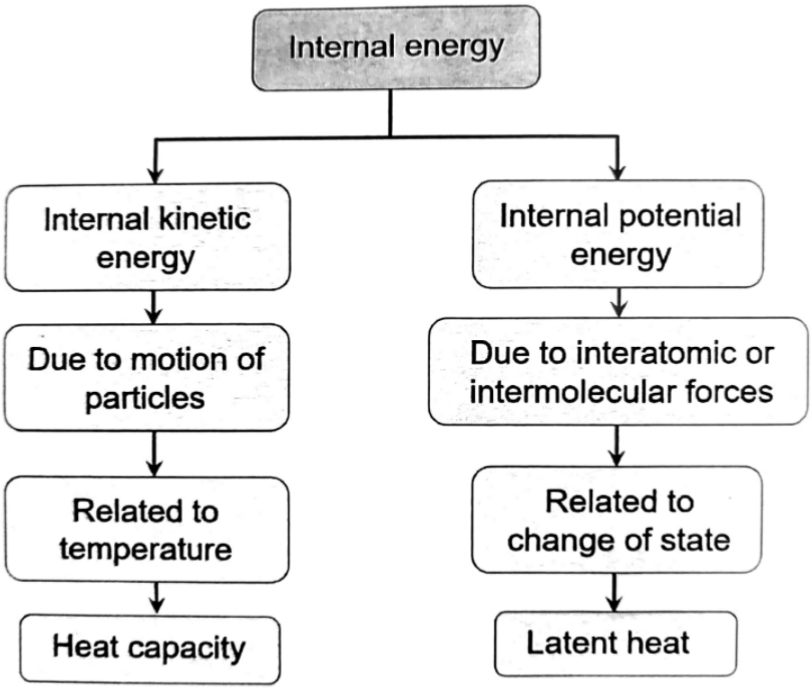
Term	Definition	SI unit
Internal energy	Sum of internal kinetic energy + internal potential energy of particles	
Heat capacity (C)	Amount of thermal energy required to raise the temperature of substance by 1 K / °C	$J\ K^{-1}$
Specific heat capacity (c)	… unit mass …	$J\ kg^{-1}\ K^{-1}$
Latent heat of fusion	Amount of thermal energy required for substance to change from solid → liquid state, without change in temperature	J
Specific latent heat of fusion	… unit mass …	$J\ kg^{-1}$
Latent heat of vaporisation	Amount of energy required for substance to change from liquid → gaseous state, without change in temperature	J
Specific latent heat of vaporisation	… unit mass …	$J\ kg^{-1}$

Formulae

Heat capacity	Latent heat	Power
$Q = mc\,\Delta\theta$	$Q = m\,l$	$Q = P \times t$

11.1 Heat Capacity and Specific Heat Capacity

Internal energy



Internal energy

Internal kinetic energy	**Internal potential energy**
Affected by motion of particles	Affected by intermolecular bonds b/w particles
Related to temperature (average kinetic energy of particles)	Related to change of state

Heat capacity

Heat capacity (unique for every substance)

$$C = \frac{Q}{\Delta\theta}$$

where Q = thermal energy required (in J)
$\Delta\theta$ = change in temperature (in K / °C)

1 J K^{-1} = 1 J required to raise temp by 1 K

Factors affecting:
1. **Mass** (great mass, high heat capacity)
2. **Material** (low for metal, high for water)

Specific heat capacity

Specific heat capacity

$$c = \frac{C}{m} = \frac{Q}{m\,\Delta\theta}$$

where Q = thermal energy required (in J)
$\Delta\theta$ = change in temperature (in K / °C)
m = mass of substance (in kg)

Commonly used variation:

$$Q = mc\,\Delta\theta$$

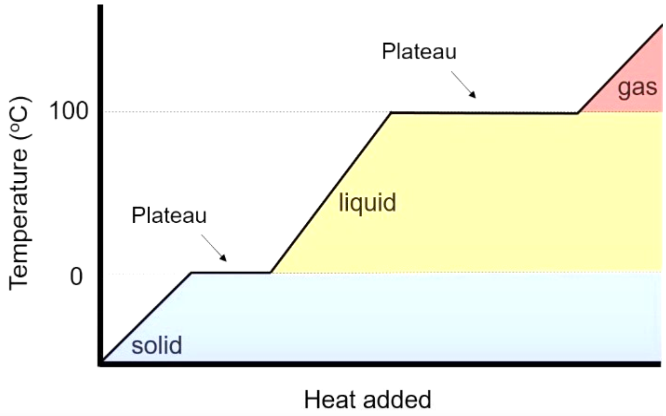
11.2 Latent Heat

Change of state

Change of state: temperature remains constant

- all heat energy supplied → overcome intermolecular forces → molecules move further apart → change state
- internal energy:

Kinetic energy	Potential energy
constant	increase



Formula

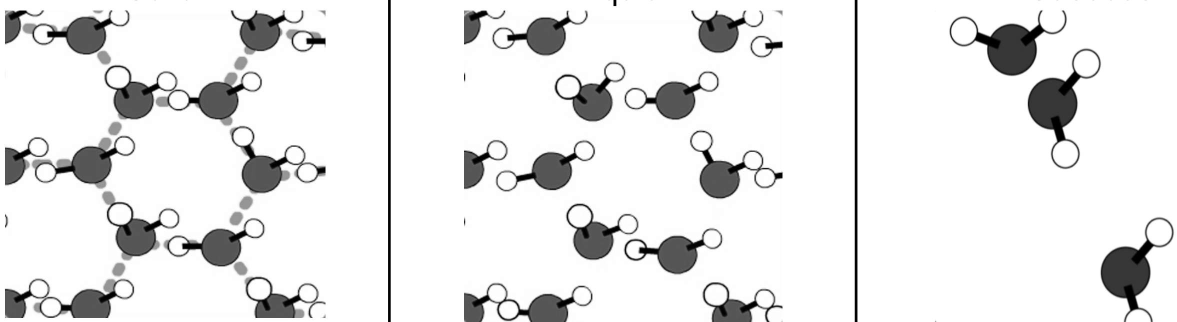
$$\boxed{Q = m\,l}$$

where Q = amount amount of energy supplied
m = mass of substance
l_f = specific latent heat of fusion
l_v = specific latent heat of vaporisation

Latent heat of fusion & vaporisation

Melting	Boiling
Melting point: specific temp where melting takes place in pure substance	**Boiling point**: specific temp where boiling takes place in pure substance
Latent heat of **fusion**	Latent heat of **vaporisation**

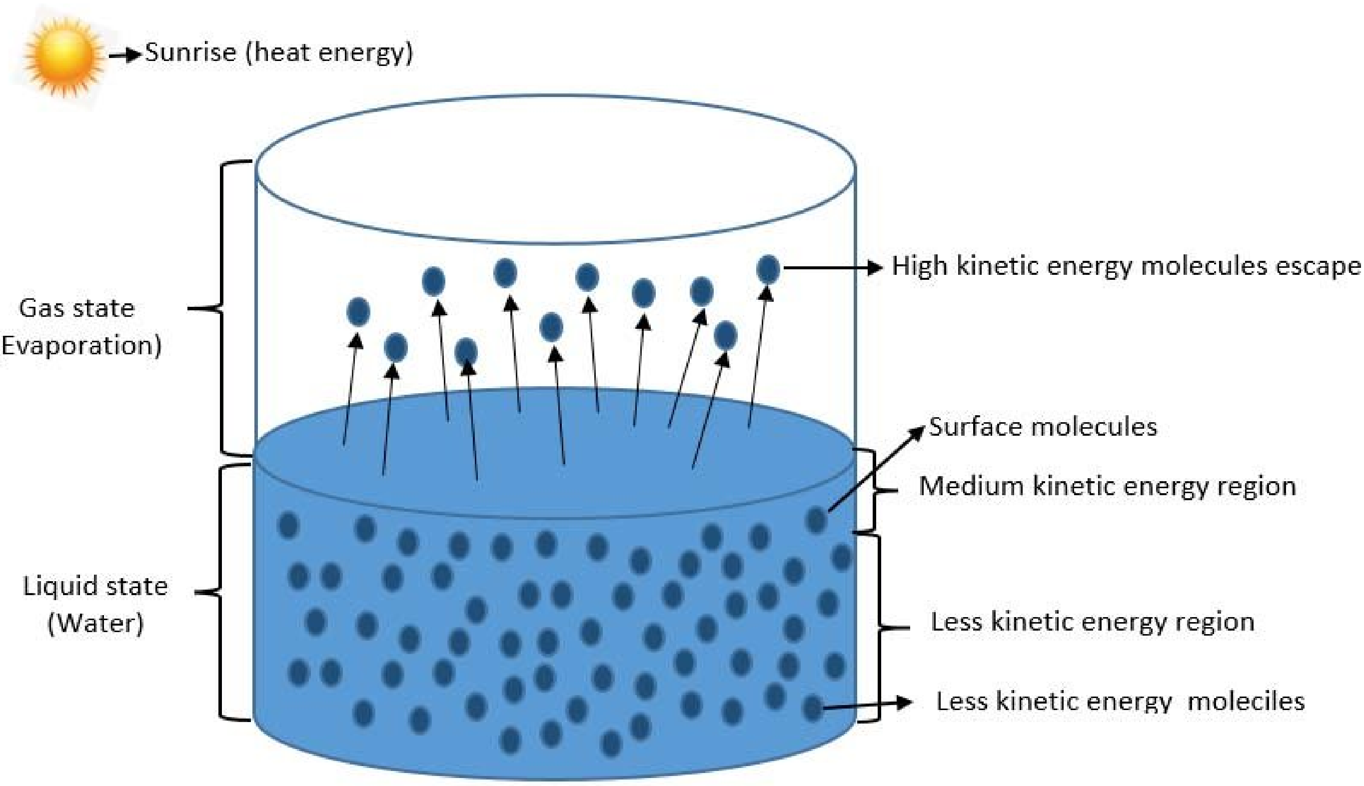
Solid:	Liquid:	Gaseous:



11.3 Evaporation

Occurrence

1. Latent heat of vaporisation → <u>break intermolecular bonds</u> b/w water mol
2. Water mol with <u>greater KE</u>: escape from liquid
   Water mol with <u>lower KE</u>: left in liquid
3. <u>Average KE</u> of remaining water mol in liquid decrease → temp decrease



Factors affecting rate of evaporation:

1. **Temperature**
2. **Humidity of surrounding air**
3. **Movement of air**
4. **Atmospheric pressure**
5. **Surface area of liquid**
6. **Boiling point of liquid**

Applications of evaporation (absorb latent heat from body)

1. Perspiration evaporate from skin → cooler
2. Use water to sponge person having fever → reduce temp
3. Refrigerator use coolant with low boiling point → remove heat via evaporation + condensation

Differences b/w boiling & evaporation:

Aspect	**Boiling**	**Evaporation**
1. Temperature of occurrence	particular	any (b/w *mp* & *bp*)
2. Speed	fast	slow
3. Take place in liquid	throughout	surface
4. Bubbles in liquid	yes	no
5. Temperature during process	constant	decrease
6. Supply of thermal energy	External energy source	Surroundings

<u>Typical questions</u>

Multiple choice questions

1 The specific heat capacity of copper is 400 J / (kg °C).
A 2 kg mass of copper is heated for 40 s by a 100 W heater.
What is the maximum possible rise in temperature? (N2011/P1/Q18)

A 5°C
B 10°C
C 20°C
D 50°C

2 Which changes of state occur as a result of the removal of thermal energy? (N2016/P1/Q20)

A boiling and melting
B boiling and solidification
C condensation and melting
D condensation and solidification

3 Different amounts of energy are supplied to copper blocks of different masses.
Which block experiences the greatest temperature change? (N2017/P1/Q17)

	mass of block / kg	energy supplied / J
A	0.10	150
B	0.25	380
C	0.45	600
D	0.80	1300

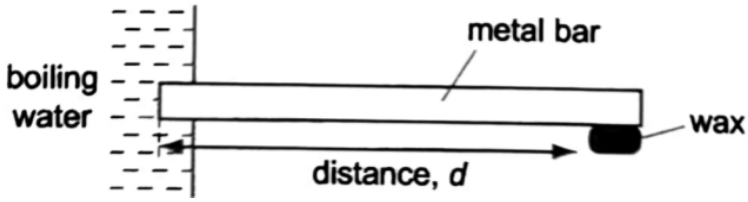
4 The temperature of a gas is increased.
Which property of the gas **must** also increase? (N2019/P1/Q18)

A volume
B pressure
C density
D internal energy

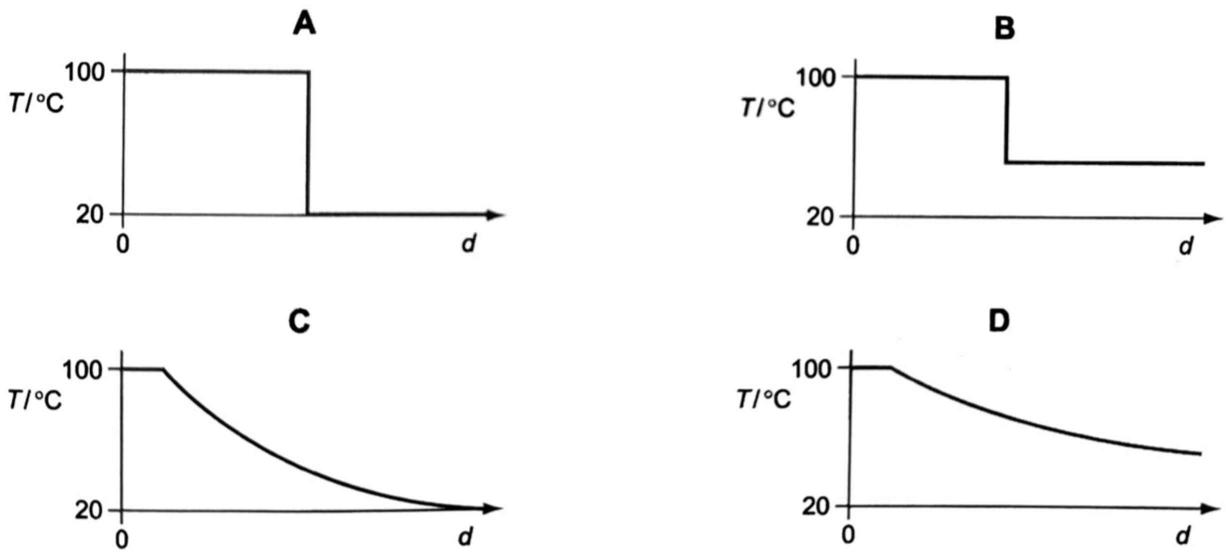
5 A block of copper is at room temperature.
Which row describes a smaller block of copper at the same temperature? (N2019/P1/Q19)

	internal energy	heat capacity	specific heat capacity
A	less	less	same
B	less	same	less
C	same	less	same
D	same	same	same

6 A piece of solid wax is attached at one end of a metal rod at room temperature (20°C). The other end of the rod is placed in boiling water.



After some minutes, the wax starts to melt.
Which graph shows how the temperature *T* of the rod varies with the distance *d* along the rod at this time? (N2012/P1/Q17)



7 Which statement about boiling and evaporation is correct? (N2013/P1/Q23)

A Boiling only occurs at the surface of a liquid.
B Bubbles of air are produced throughout the liquid during boiling.
C Evaporation is not affected by the surface area of the liquid.
D Evaporation occurs at any temperature.

8 In an experiment, 1700 J of thermal energy (heat) is supplied to 8.0 g of ice at 0°C.
Assume that water from the melted ice stays at 0°C.
The specific latent heat of fusion of ice is 340 J / g.
How much ice remains? (N2013/P1/Q24)

A 0
B 3.0 g
C 5.0 g
D 7.8 g

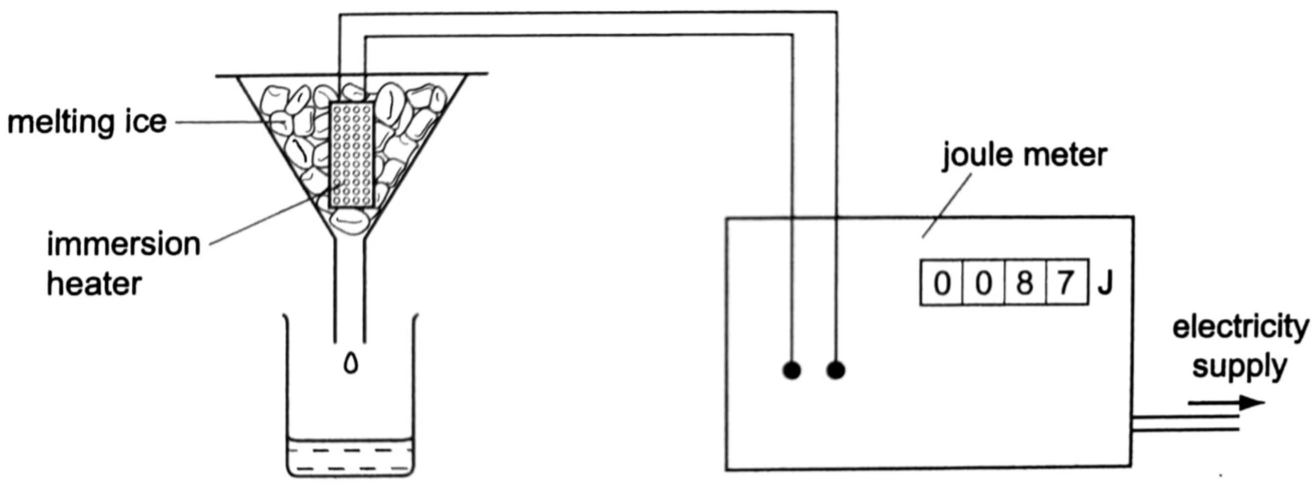
9 Which statement describes the boiling of water? (N2014/P1/Q19)

A It occurs at a fixed temperature and only on the surface.
B It occurs at a fixed temperature and throughout the liquid.
C It occurs at any temperature and only on the surface.
D It occurs at any temperature and throughout the liquid.

10 The bulb of a thermometer is wrapped in a tube of cotton fabric. The fabric is dipped into water at room temperature and left for some time. The thermometer wrapped in wet fabric is then removed and evaporation takes place.
What happens to the thermometer reading? (N2014/P1/Q20)

A It falls.
B It remains unchanged.
C It rises.
D It rises and then falls.

11 In the experiment shown, the amount of electrical energy used to melt some ice is measured using a joule meter.



To find the specific latent heat of fusion of the ice, what must also be measured?
(N2015/P1/Q20)

A the mass of ice melted by the heater
B the temperature change of the ice
C the time taken for the ice to melt
D the voltage of the electricity supply

12 A liquid is heated in a vessel that is open to the atmosphere.
Which statement describes two properties of boiling that are different from the properties of evaporation? (N2017/P1/Q18)

A Boiling occurs at a specific temperature and throughout the liquid.
B Boiling occurs at a specific temperature but only on the surface of the liquid.
C Boiling occurs at all temperatures and throughout the liquid.
D Boiling occurs at all temperatures but only at the surface of the liquid.

13 Equal masses of oil and water are heated to 90°C and then allowed to cool.
Which statement explains why the oil cools faster than the water? (N2019/P1/Q22)

A Oil has a higher boiling point than water.
B Oil has a lower melting point than water.
C Oil has a lower specific latent heat than water.
D Oil has a lower specific heat capacity than water.

14 Which of the following is not a factor affecting the rate of evaporation?

A The surface area
B The temperature of the liquid
C The movement of air above the liquid surface
D The volume of the liquid being evaporated

15 When a liquid boils, bubbles rise from the bottom of the liquid to the surface which then burst. These bubbles are

A gas that has escaped from the liquid state
B vacuum that has formed
C air from the atmosphere
D trapped air inside the liquid

Structured questions

1 David wants to boil a kettle of water. Given that the specific heat capacity of water is 4200 J kg^{-1} K^{-1} and the power of the kettle is 2 kW, calculate the time required to boil 3 litres of water from 30°C to 100°C.

$Q = mc\,\Delta\theta = 3\ (4200)\ (100 - 30)$

$t = \frac{E}{P} = \frac{3\ (4200)\ (70)}{2000} =$ <u>**441 s**</u>

2 John is preparing to bathe his baby brother in a bathtub. The bathtub now contains 30 kg of water at 25°C. The optimal temperature for the baby to bathe is 40°C. To heat up the water in the bathtub, John boiled a kettle of water to 90°C. What is the mass of hot water should John pour into the bathtub to heat the water to 40°C? (Assume no heat is lost to the surroundings.)

Both temperatures reach equilibrium at 40°C.
By the <u>Law of Conservation of Energy</u>,
Heat loss by hot water = heat gain by cold water
mc (90°C - 40°C) = 30*c* (40°C - 25°C)
50 *m* = 450
m = <u>**9 kg**</u>

3 Explain why putting a layer of perfume on the skin produces a cooling effect.

- <u>Perfume usually contains alcohol (which has low specific heat capacity) and evaporates easily.</u>
- <u>As evaporation removes heat from the skin, the skin feels cool.</u>

4 Explain the difference between *heat capacity* and *specific heat capacity*. [1]
(N2013/P2/Q5a)

<u>Heat capacity refers to the amount of thermal energy required to raise the temperature of a substance by 1°C;</u>
<u>specific heat capacity refers to the amount of thermal energy required to raise the temperature of 1 kg of the substance by 1°C (heat capacity per unit mass).</u>

5 (N2014/P2A/Q5)

(a) The energy of a liquid decreases as it turns into a solid at the melting point. Explain, using ideas about molecules, why this decrease occurs. [1]

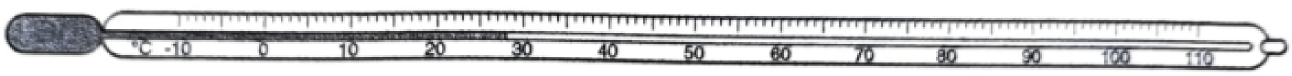
<u>During solidification, intermolecular bonds are formed. This forming of bonds decreases the potential energy of the molecules.</u>

(Note: There is no change in the kinetic energy of the molecules, as there is no change in temperature during solidification)

(b) An ice-cube tray is filled with 400 g of water at 20°C. It is placed in the freezer compartment of a refrigerator and the water becomes ice at 0°C.
The specific heat capacity of water is 4.2 J (g °C) and the specific latent heat of fusion of water is 330 J / g.
Calculate the total energy that is removed from the water. [3]

Total energy removed
= Energy removed when cooling liquid from 20°C to 0°C +
Energy removed when liquid freezes
= $mc\,\Delta\theta + ml_f$
= (400)(4.2)(20) + (400)(330)
= 33600 + 132000 = **<u>165600 J</u>**

6 The figure below shows a liquid-in-glass thermometer.

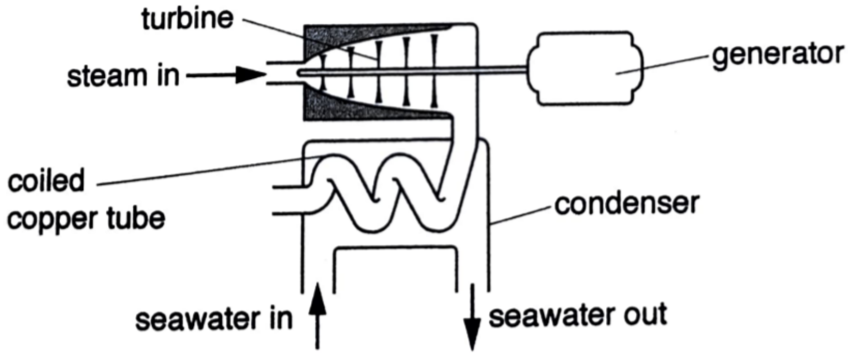


The thermometer has a heat capacity of 2.5 J/°C and initially reads 20°C. The thermometer is placed in a small mass of water which is initially at a temperature of 85°C. The final temperature of the water and the thermometer is 80°C.
The specific heat capacity of water is 4.2 J / (g °C).
Calculate the mass of water, assuming that there is no loss or gain of heat to the surroundings. [3]
(N2015/P2A/Q5)

Gain in thermal energy by the thermometer
= $C\,\Delta\theta$ = (2.5)(80 – 20) = 150 J
Loss in thermal energy by the water = Gain in thermal energy by thermometer = 150 J
(No loss or gain of heat to the surroundings)

To find mass of water:
$m = \frac{Q}{c\,\Delta\theta} = \frac{150}{(4.2)(85-80)}$ = 7.14 g

7 The figure below shows steam from a boiler passing through a turbine connected to a generator.



Steam passes through the turbine and condenses in the condenser. The internal energy of the seawater rises. (N2016/P2A/Q4)

(a) State what is meant by *condensation*. [1]

Condensation is a change in the state of a substance from gaseous to liquid state, without a change in temperature.

(b) The steam is not in contact with the seawater.
Explain how condensation of the steam causes the internal energy of the seawater to rise, and state the effect on the molecules of the seawater. [3]

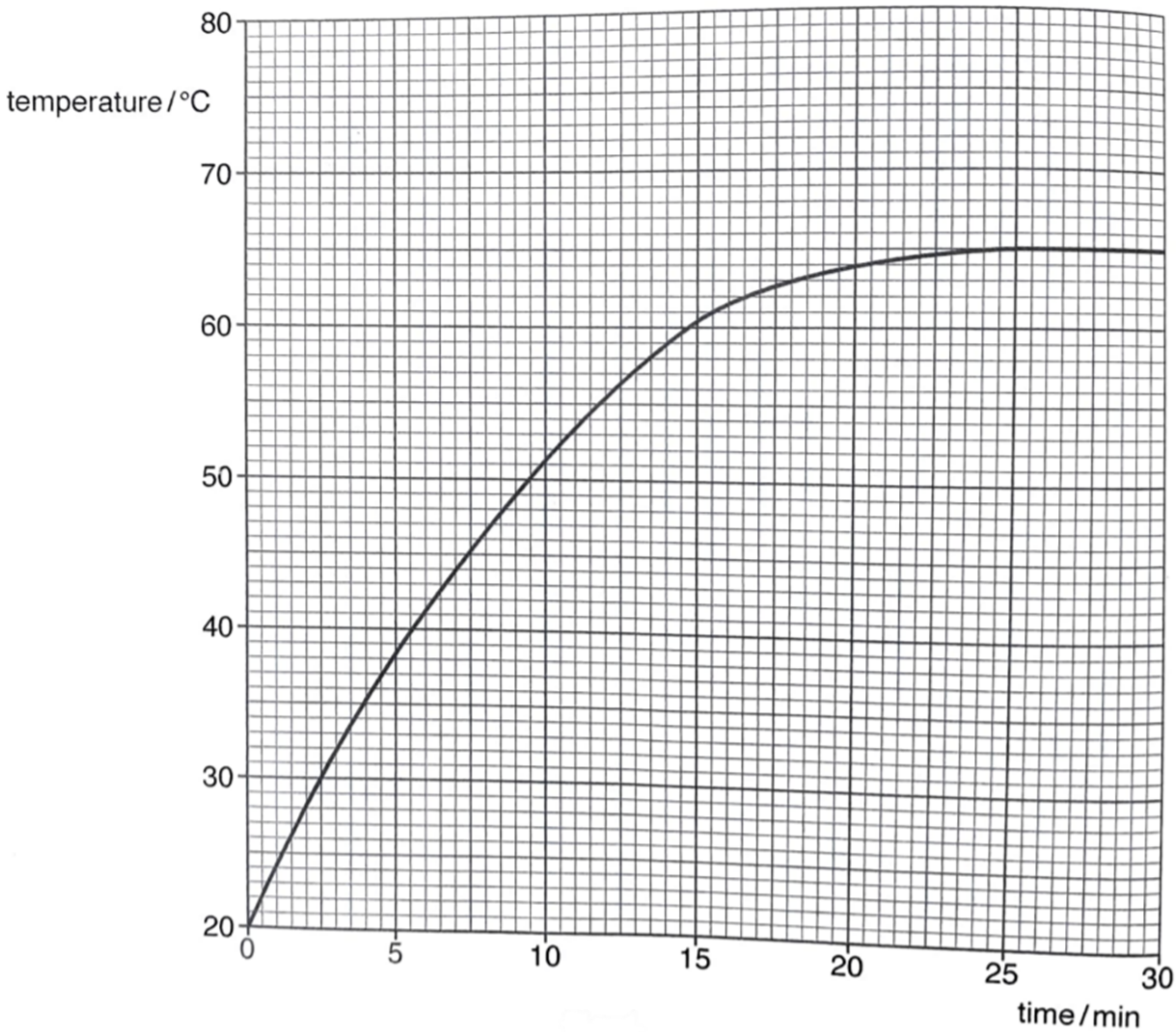
- Latent heat of vaporisation is released during the condensation of steam.
- The thermal energy from the steam is conducted through the copper tube to the seawater.
- The average kinetic energy of the seawater molecules rises, thus internal energy increases, causing seawater molecules to move faster.

(c) The seawater enters the condenser at a temperature of 28°C, and leaves at a temperature of 49°C. At a certain time, 220 MJ of thermal energy passes into the seawater.
The specific heat capacity of seawater is 399 J / (kg °C).
Calculate the mass of seawater that enters the condenser at this time. Give your answer to an appropriate number of significant figures. [3]

$Q = mc\,\Delta\theta$

$m = \dfrac{Q}{c\,\Delta\theta} = \dfrac{220 \times 10^6}{(3900)(49-28)}$ = 2690 kg

8 A small electrical heater is used to heat water in a plastic cup, without a lid.
The figure below shows how the temperature varies for 30 minutes after the heater is switched on.



(N2017/P2B/Q11b EITHER)

(a) Determine the initial rate of rise in temperature, giving your answer in °C / min. [1]

Initial temperature = $\dfrac{30-20}{2.5}$ = **<u>4 °C / min</u>**

(b) The heater provides a constant amount of energy per minute to the water.
The mass of water in the cup is 50 g. The specific heat capacity of water is 4.2 J / (g °C).
Using your answer to **(a)**, calculate the energy supplied to the water per minute. [2]

For a 4°C increase in temperature in 1 minute, amount of thermal energy supplied:
$Q = mc\,\Delta\theta$ = (50)(4.2)(4) = **<u>540 J</u>**

(c) After 25 minutes, the temperature has stopped rising, even through heat is still supplied at the same rate to the water.
Explain why. [2]

- As temperature of the water increases, the rate of heat loss from the cup to the surroundings increases as well (since the temperature difference between the water and the surroundings is increased).
- After 25 minutes, the rate of heat supplied is equal to the rate of heat loss, and hence the temperature stays the same.

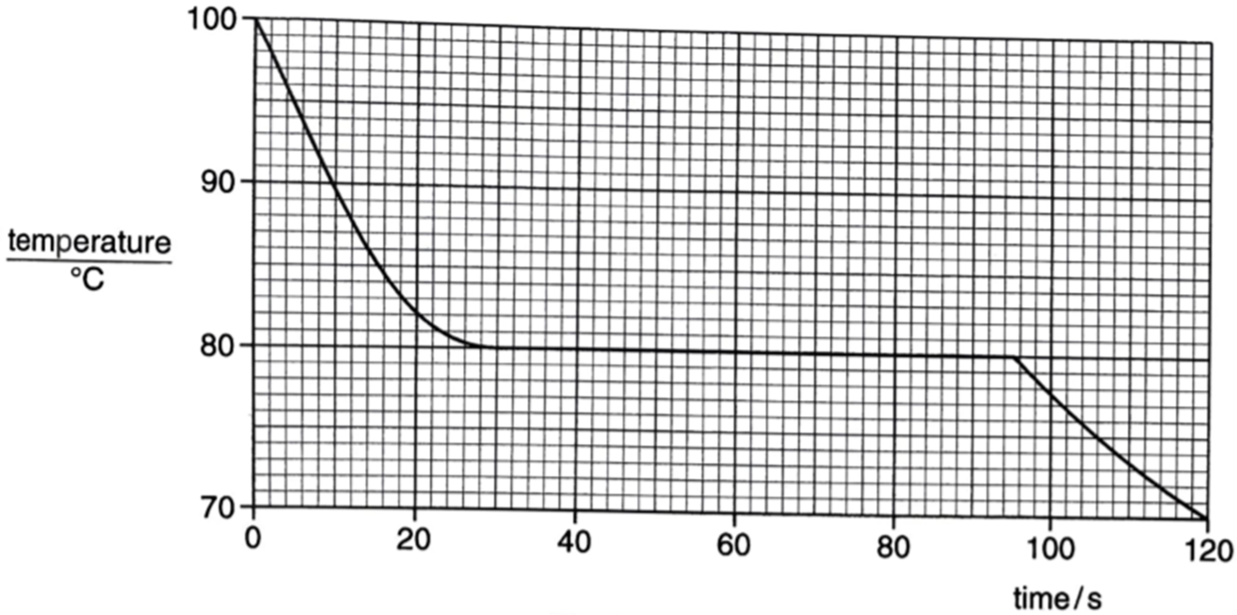
(Note: Water boils at 100°C, so it is not yet boiling.)

(d) The experiment is repeated using the same amount of water in the same plastic cup but with a lid.

1. On the figure above, sketch a line to show the new variation of temperature with time after the heater is switched on. [2]
2. Explain why your line is different from the line in the initial experiment. [1]

- With a lid, there would be less heat loss by evaporation.
- As such, the rate of increase of temperature of the water would be increased (steeper graph). In addition, the temperature will continue to rise beyond 65°C.

9 A liquid, at a temperature of 100°C, is placed in a test-tube. The sample is allowed to cool for 120s in a laboratory where the temperature is 20°C.
The figure below shows the cooling curve obtained.



(N2012/P2A/Q5)

(a) State why the sample is losing thermal energy (heat) throughout the experiment. [1]

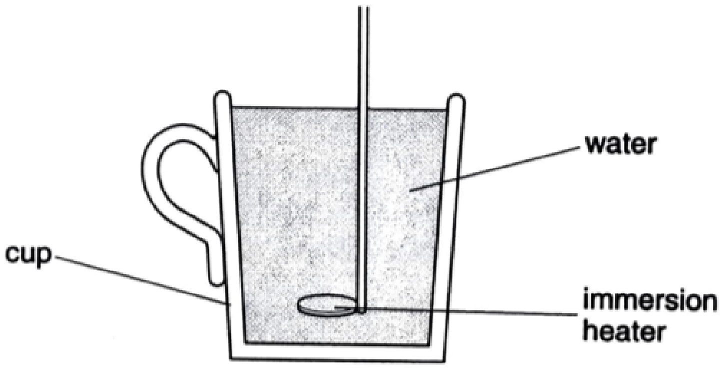
- <u>The temperature of a sample is higher than room temperature (20°C),</u>
- <u>thus there is a net transfer of thermal energy from the sample to the room.</u>

(b) Explain why the temperature of the sample is constant for some of the time, even though thermal energy (heat) is lost to the laboratory. [2]

- <u>During freezing, the intermolecular bonds are being formed.</u>
- <u>Only the potential energy of the molecules decreases. There is no change in the kinetic energy of the molecules.</u>

(c) A test-tube containing an identical sample of the liquid at 100°C is placed in a beaker of water that is kept a temperature of 90°C.
On the figure above, sketch the cooling curve obtained. [1]

10 The figure below shows an electric immersion heater being used to heat water in a cup.



The cup contains 0.20 kg of water at a temperature of 20°C.
The heat capacity of the cup is 80 J/°C.
The specific heat capacity of water is 4200 J/(kg °C).

Some water evaporates as the temperature rises. Explain, in terms of molecular behaviour, why energy is needed for this evaporation. [1]

(N2013/P2A/Q5)

<u>Energy is required to break the intermolecular forces in a liquid (water), in order for the molecule to now move freely as a gas (water vapour).</u>

11 The marathon is a long-distance race of about 42 km. Water on the skin of a marathon runner evaporates as he runs. (N2018/P2B/Q9)

(a) State two differences between *evaporation* and *boiling*. [2]

- Evaporation takes place at any temperature; boiling occurs at boiling point.
- Bubbles are seen during boiling, but not during evaporation.

(b) Data relevant to the marathon is given in the box.

mass of marathon runner: 70 kg time taken by runner to complete the marathon: 3.5 hours average body temperature before starting the marathon: 37°C body temperature above which overheating may cause serious damage: 40°C average production of thermal energy in one hour by the runner: 3.2×10^6 J average loss of energy in one hour by evaporation from the skin: 2.3×10^6 J average specific heat capacity of the human body: 3500 J / (kg °C) latent heat of vaporisation of water at body temperature: 2.4×10^6 J/kg

The level of dehydration of a human body is measured by the percentage loss of body mass caused by evaporation. The table below shows three levels of dehydration.

level of dehydration	percentage of body mass lost by evaporation of water
mild dehydration	< 3%
moderate dehydration	3 – 5%
severe dehydration	> 5%

(N2018/P2B/Q9)

(i) Calculate the mass of water lost by evaporation from the skin of the runner in one hour. [2]

$Q = ml_v$

$m = \frac{Q}{l_v} = \frac{2.3 \times 10^6}{2.4 \times 10^6} =$ **0.958 kg**

(ii) Assume that the runner only losses energy by evaporation from his skin. Calculate the rise in temperature of his body in one hour of the race. [3]

Energy gained by body
= $(3.2 \times 10^6) - (2.3 \times 10^6)$
= 0.9×10^6 J

$\Delta\theta = \frac{Q}{mc} = \frac{0.9 \times 10^6}{(70)(3500)}$ = **<u>3.67 °C</u>**

(iii) Using your answer to **(b)(ii)**, show that evaporation from his skin is not sufficient, on its own, to prevent overheating during the race. [1]

<u>The increase in body temperature of 3.67°C on average body temperature of 37°C will result in a body temperature of 40.67°C, which could cause serious damage to the body, and hence, evaporation is not sufficient.</u>

(iv) One other mechanism for evaporation occurs in breathing. Water is vaporised in the lungs and is then exhaled.
Assume that there is no increase in the runner's body temperature during the race.
Calculate the mass of water vapour that the runner exhales during the **whole** race. [2]

If there is no increase in body temperature, all thermal energy produced is lost.
Amount of thermal energy lost through vaporisation through exhalation:
$(3.2 \times 10^6) - (2.3 \times 10^6) = 0.9 \times 10^6$ J
In 3.5 hours, amount of thermal energy loss = $(0.9 \times 10^6) \times 3.5 = 3.15 \times 10^6$ J

$m = \frac{Q}{l_v} = \frac{3.15 \times 10^6}{2.4 \times 10^6}$ = 1.3125 kg = **<u>1.31 kg</u>** (3 s.f.)

(v) Assume that the runner does not drink any water during the race.
Using your answer to **(b)(i)** and **(b)(iv)**, determine the level of dehydration of the runner at the end of the race. [2]

Total mass of water lost = 1.31 + (0.958 × 3.5) = 4.184 kg

Percentage of body mass lost by evaporation of water = $\frac{4.184}{70} \times 100\%$ = 5.98%

As such, the runner suffers from **<u>severe dehydration</u>**.

12 Microwave radiation is a type of electromagnetic radiation that is used in a microwave oven.
The input power of a microwave oven is 850 W.
A beaker in the oven contains water at its boiling point. The energy absorbed by the water is 45% of the input energy supplied to the oven.
The specific latent heat of vaporisation of water is 2.3×10^6 J/kg.
Calculate the mass of water that turns to steam in 120 s. [3]
(N2019/P2B/Q10b)

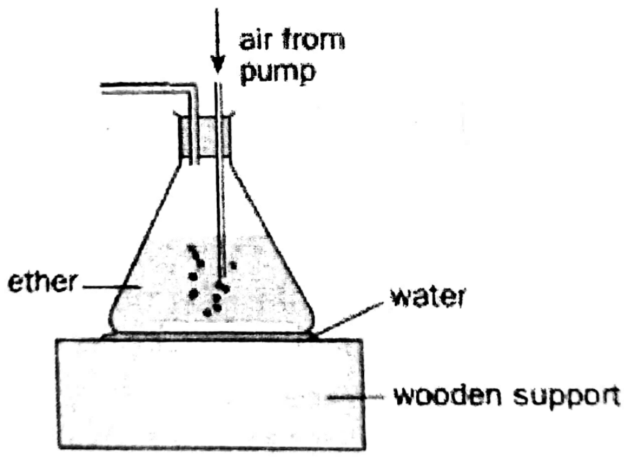
Total energy absorbed by water in 120 s

$= \frac{45}{100} \times 850 \times 120 = 45900$ J

$Q = ml_v$

$m = \frac{Q}{l_v} = \frac{45900}{2.3 \times 10^6}$ = **0.0200 kg** (3.s.f.)

13 The figure below shows an experiment that investigates the evaporation of ether. Ether is a volatile liquid, i.e. has a high evaporation rate.



After air is pumped into the ether for some time, the film of water freezes. Explain this phenomenon.

- As air is pumped in, the rate of evaporation of ether increases (surface area of ether, movement of air within ether, air above saturated with ether vapour is forced out).
- As latent heat is required for evaporation and the temperature of the remaining ether drops, thermal energy is transferred from the film of water to the ether.
- Hence, the temperature of the film of water drops and the water freezes when the temperature reached 0°C.

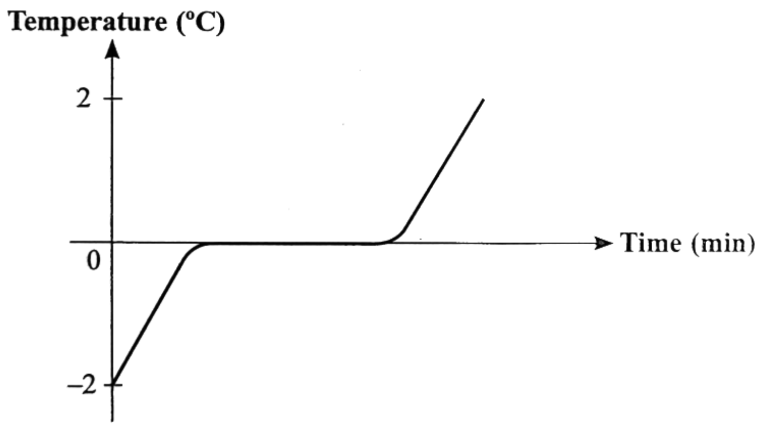
14 The latent heat of fusion is always less than the latent heat of vaporisation. Explain in terms of molecular behaviour.

More thermal energy is needed to break the intermolecular forces completely to allow molecules to move freely in the vapour (gas) state. The latent heat of fusion, on the other hand, requires less thermal energy to break the intermolecular forces in a solid as there are still attractive forces between the molecules in the liquid state.

15 What is the difference between kinetic energy and internal kinetic energy?

- Internal kinetic energy refers to the movement, vibration, and/or rotation of particles in an object. The random motion of the particles gives rise to the internal kinetic energy of the object. When we heat up the object, the particles move, vibrate and rotate faster, gaining more internal kinetic energy and thermal energy.
- Kinetic energy of an object depends on the movement of the object itself. It is not present in an object that is at rest but internal kinetic energy is.

16 A small quantity of crushed ice is warmed up from a temperature of – 2°C. The diagram below shows the graph of temperature against time plotted.



(a) Explain why, after the initial rise to 0°C, the temperature remains constant for a long time.

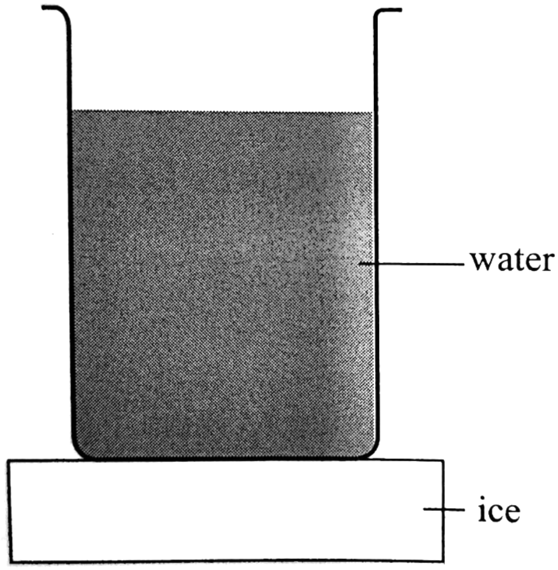
This is due to the melting of the ice.

- At 0°C, the molecules absorb energy to overcome the intermolecular forces and they move further apart from one another.
- As a result, there is no corresponding increase in the temperature at this stage as the kinetic energy of the molecules remains the same.
- Thus, the thermal energy absorbed is used to change ice (solid state) into water (liquid state).

(b) Suggest why the slope of the graph between – 2°C and 0°C is greater than that between 0°C and 2°C.

The specific heat capacity of ice is less than that of water. Hence, the rate of rise in temperature is greater for ice than that for water.

17 The diagram below shows a tall cylinder filled with water. The bottom of the cylinder rests on a block of ice at 0°C.



Explain, with reasons, whether the temperature of the water in the cylinder is higher at the top, constant throughout or higher at the bottom. Assume that the cylinder has been placed in the same position for a long time, room temperature is steady at about 30°C and there are no draughts.

- The temperature of the water in the cylinder is higher at the top. The temperature of water at the bottom of the cylinder decreases due to the loss of energy to the ice. There is a larger decrease in the temperature of water at the bottom of the cylinder compared to the top.
- In addition, as the density of cold water at the bottom of the cylinder is higher than that at the top, convection currents cannot take place.

18 A mercury-in-glass thermometer is used to determine the temperature of a hot environment. Explain, in terms of the changes involving the particles of the glass in the bulb of the thermometer, how energy is transferred from a hot environment to the cooler mercury.

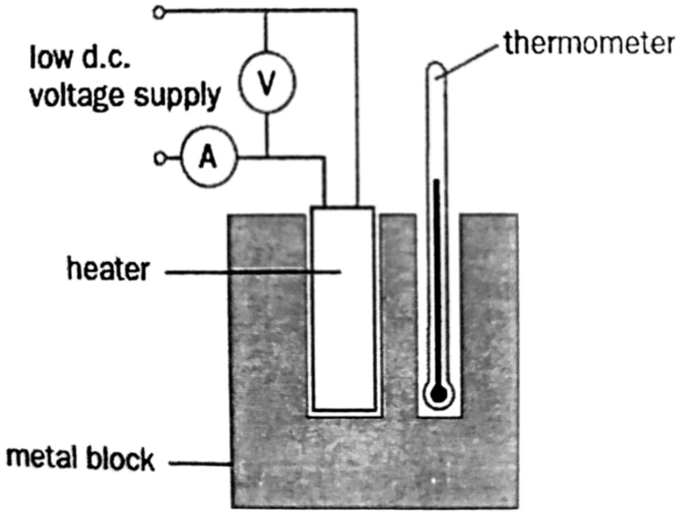
- The particles of the glass in the outer wall (which is in contact with the hot environment) gain energy from the hot environment. The particles vibrate more and collide with the neighbouring particles of glass. The energy is then transferred to the less energetic neighbouring particles of the glass.
- The process is repeated until the energy is transferred to the particles of mercury which are in contact with the particles of glass in the inner wall. Hence, energy is transferred from the hot environment to the cooler mercury through conduction.

19 20 g of ice at – 10°C is placed into a cup of hot water of mass 60 g at 90°C in order to reduce the temperature of the water. Assuming no heat is lost to the surroundings, calculate the final temperature of the water when thermal equilibrium is achieved. Take specific latent heat of fusion of ice, l_f = 334 kJ/kg, specific heat capacity of ice, c_{ice} = 2.05 kJ kg^{-1} $°C^{-1}$, and specific heat capacity of water, c_{water} = 4.18 kJ kg^{-1} $°C^{-1}$.

Given:
- mass of ice / melted ice, m_{ice} = 0.02 kg
- initial temperature of ice, θ_{ice} = – 10°C
- mass of water, m_{water} = 0.06 kg
- initial temperature of water, θ_{water} = 90°C
- melting point of water = 0°C

Let the final temperature of water be θ
Since no heat is lost to the surroundings,
Heat released by water = heat absorbed by ice
$m_{water}\, c_{water}\, (\theta_{water} - \theta) = m_{ice}\, l_f + m_{ice}\, c_{ice}\, (0 - \theta_{ice}) + m_{ice}\, c_{water}\, (\theta - 0)$
$0.06 \times 4180 \times (90 - \theta) = 0.02 \times 334000 + 0.02 \times 2050 \times [0 - (-10)] + 0.02 \times 4180 \times (\theta - 0)$
θ = 46.3 °C (3 s.f.)

20 An experiment is carried out to determine the specific heat capacity of an unknown metal, using a 1 kg block of metal. The heater is switched on for 500 s. The temperature reading increased by 50°C.



State why it is not advisable to take the thermometer reading immediately after switching off the current.

<u>There is insufficient time for heat to be distributed evenly throughout the metal block, thus the temperature will not reach a steady and accurate value.</u>

21 Mandy wants to drink a cold drink.

(a) She removes a 0.200 kg glass that has a temperature of 30.0°C. Into it, she pours 0.100 kg of Green Tea (mostly water), which comes out of a refrigerator with a temperature of 5.0 °C. Assuming that there is no external heat loss, what will be the final temperature of the glass of Green Tea? (specific heat capacity of glass = 840 J °C^{-1}; specific heat capacity of water = 4200 J kg^{-1} °C^{-1})

(b) Mandy does not feel that her drink is cold enough, so she throws an ice cube whose temperature is – 3.0°C. What is the mass of the ice cube if her drink (and glass) are now cooled to 1.0°C? (specific heat capacity of ice = 2100 J kg^{-1} °C^{-1}; specific latent heat of fusion = 336 kJ kg^{-1})