TOPIC 11 Thermal Properties of Matter

11.1 Specific Heat Capacity

1 12 000 J of heat energy raises the temperature of a 2 kg block of a metal from 20 °C to 30 °C.

What is the specific heat capacity of the metal?

A 200 J/(kg °C)
B 300 J/(kg °C)
C 400 J/(kg °C)
D 600 J/(kg °C)
E 1200 J/(kg °C) J90/I/15

2 Heat energy is supplied at the same rate to 100 g of paraffin and 100 g of water in similar containers. The temperature of the paraffin rises faster.

This is because the paraffin

A is more dense than water.
B is less dense than water.
C evaporates less readily than water.
D has a smaller specific heat capacity than water.
E has a larger specific heat capacity than water.
J90/I/16; J98/I/14

3 It takes 2 minutes to raise the temperature of 1.7 kg of water by 40 °C using a 2.5 kW heater.

Assuming there are no heat losses, how long would it take to raise the temperature of 170 kg of water by the same amount using a 5.0 kW heater?

A 4 minutes
B 80 minutes
C 100 minutes
D 200 minutes
E 400 minutes N90/I/14

4 The specific heat capacity of copper is 400 J/ (kg K) . A 2 kg mass of copper is heated for 40 s by a heater which produces 100 J/s.

What is the rise in temperature?

A 5 K
B 10 K
C 20 K
D 50 K
E 80 K J91/I/17

5 When a heater provides 2000 J of energy to a liquid of mass 0.10 kg, the temperature rises by 5 K.

What is the specific heat capacity of the liquid?

A 40 J/(kg K)
B 1 000 J/(kg K)
C 4 000 J/(kg K)
D 4 200 J/(kg K)
E 100 000 J/(kg K) N92/I/15

6 In an electrical method for determining the specific heat capacity of a metal, the following readings were obtained.

mass of metal:	2 kg
supply voltage:	240V
current:	3 A
time for which heat supplied:	20 s
temperature rise of metal:	10 °C

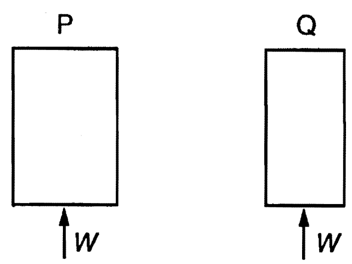
What is the specific heat capacity of the metal?

A $\frac{240 \times 3 \times 6}{2 \times 10 \times 20}$ J/kg °C
B $\frac{2 \times 10 \times 20}{240 \times 3 \times 60}$ J/kg °C
C $\frac{2 \times 10 \times 20}{240 \times 3}$ J/kg °C
D $\frac{2 \times 10}{240 \times 3 \times 20}$ J/kg °C
E $\frac{240 \times 3 \times 20}{2 \times 10}$ J/kg °C
J93/I/30

7 A 2 kg mass of copper is heated for 40 s by a heater which produces 100 J/s. The specific heat capacity of copper is 400 J/(kg K).
What is the rise in temperature?

A 5 K **C** 20 K
B 10 K **D** 50 K N95/I/15

8 The diagrams represent two blocks of copper, P and Q, each receiving the same amount of energy *W*. The mass of P is twice the mass of Q. The temperature rise of P is half the temperature rise of Q.



mass = 0.40 kg
temperature rise = 20.0 K

mass = 0.20 kg
temperature rise = 40.0 K

Which statement about P and Q is correct?

A The heat capacity of P is half the heat capacity of Q.
B The heat capacity of P is twice the heat capacity of Q.
C The specific heat capacity of P is half the specific heat capacity of Q.
D The specific heat capacity of P is twice the specific heat capacity of Q. N96/I/15

9 In a storage heater, heat is used to raise the temperature of a block of material which subsequently re-emits the heat as it cools down. In such a heater, what are the advantages of using a material which has *(a)* a high specific heat capacity, *(b)* a high density?

A liquid flows at the rate of 56 g (= 0.056 kg) per minute through a tube containing a heating element. If the heating element dissipates 6.3 W to the liquid and the liquid is uniformly heated, by how much will the temperature of the liquid rise as it passes through the tube? [The specific heat capacity of the liquid = 0.60 J/g K 600 J/kg K).]
N79/II/8

10 Calculate the quantity of heat required to heat the water for a bath, if it involves raising the temperature of 80 kg of water by 30 K. [The specific heat capacity of water 4200 J/kg K.]

How long would it take an electric heater rated at 4 kW to supply this quantity of energy? N80/I/4

11 An electric heating element immersed in a large beaker of water has a potential difference of 240 V applied across it. The current through the element is 10.0 A.

In 80.0 s the temperature of the beaker and water rises from 15.0 °C to 65.0 °C. Calculate the total heat capacity of the beaker and its contents, assume that no heat is lost from the beaker. N81/I/7

12 *(b)* (i) The heat capacity of a thermocouple is very small. Why is this an advantage when the thermocouple is used to measure a rapidly varying temperature?

(ii) Why, when heating a quantity of water, is it an advantage to use a saucepan with a small heat capacity. J84/II/8*(b)*

13 An electric heating coil supplies 50 W of power to a metal block of mass 0.60 kg and raises the temperature of the block from 10 °C to 35 °C in 90 s. Assuming that all the output from the heating coil is absorbed by the block, calculate a value of the specific heat capacity of the metal. N84/I/8

14 An engine is water cooled; given that the specific heat capacity of water is 4200 J/(kg K) and that the rise in temperature of the water is to be no more than 25 K as it passes through the engine, calculate the mass of cooling water which must flow through the engine per second if 6×10^5 J of heat is produced inside it every second.

State and explain one *advantage* and one *disadvantage* of using water rather than air as a cooling material. J86/II/7

15 A gas burner is used to heat 0.50 kg of water in a beaker. The temperature of the water rises from 15 °C to 60 °C in 60 seconds.

Assuming that the specific heat capacity of water is 4200 J/(kg K), calculate the average rate at which heat is transferred to the water. [4]
J89/I/6

16 *(c)* When a corked boiling tube containing 50 g of water is allowed to cool in a steady draught, the temperature changes as shown in the table.

time/min	1.00	2.00	3.00	4.00	5.00
temperature/°C	66.5	54.5	45.2	38.0	32.8

(i) Plot a graph of temperature/°C (y-axis) against time/min (x-axis), starting your x-axis at time/min = 0.

(ii) Use your graph to determine the time taken for the water to cool from 60 °C to 35 °C.

(iii) Given that the specific heat capacity of water is 4.2 kJ/(kg K), calculate the energy lost by the water in cooling from 60 °C to 35 °C.

(iv) Use your graph to estimate the temperature of the water when timing began. Show clearly how you obtained your estimate. [8]
J94/II/10*(c)*

17 *(a)* A physics student wishes to measure the thermal energy from the Sun that falls on the surface of a lens. He sets up the experiment as shown in Fig. 10.1. Sunlight is converged by a lens on to a blackened piece of metal, which absorbs all of the incident energy. The lens transmits all of the energy that falls on it.

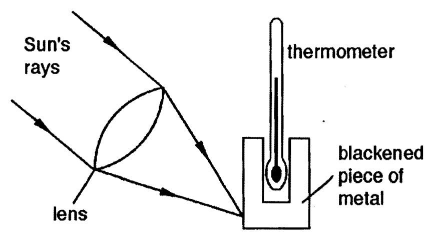


Fig. 10.1

The mass of the block of metal is 0.20 kg and its specific heat capacity is 390 J/(kg K). The reading on the thermometer increases by 2.1 K in one minute.

(i) Calculate the energy received by the block of metal in one minute.

(ii) Calculate the power received by the block of metal.

(iii) What other measurement does the student need to make in order to measure the thermal power from the Sun that falls on to a 1 cm^2 area of the surface of the lens? [7]
N98/II/10*(a)*

18 A water bath is kept warm by an electric heater placed inside the water, as shown in Fig. 1.1. The heater switches on when the temperature of the water is 40 °C or below, and switches off when the temperature reaches 45 °C.

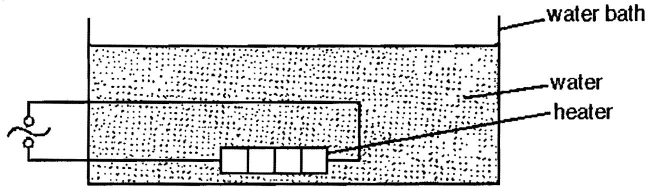


Fig. 1.1

(a) Energy from the heater warms all of the water in the tank by means of convection currents.

(i) Explain in detail how convection currents are formed.

(ii) Describe an experiment that you could perform to demonstrate a convection current in a liquid or in a gas. In your account, draw a diagram showing the convection current. [6]

(b) The variation with time of the temperature of the water in the tank is shown in Fig. 1.2.

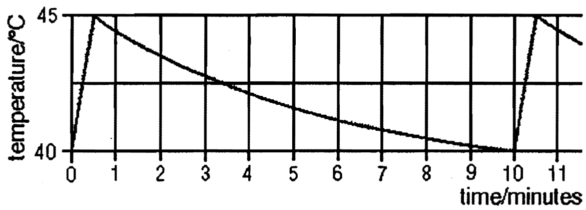


Fig. 1.2

The water bath contains 3.0 kg of water and the specific heat capacity of water is 4200 J/(kg °C).

(i) Show that the energy needed to warm the water from 40 °C to 45 °C is 63 000 J.

(ii) Show that the power of the heater is 2100 W. You may assume that all of the energy from the heater is used to raise the temperature of the water.

(iii) In every hour, the heater is on for 3 minutes. Calculate the amount of energy in kWh used by the heater in one hour. [7]

(c) Describe two ways by which the water cools down while the heater is switched off. [2]

J2000/II/11

11.2 Melting, Boiling and Evaporation
11.3 Specific Latent Heat

1 When water is heated steadily, its temperature will stop rising when the water starts to

A boil.
B condense.
C evaporate.
D freeze.
E melt.

J90/I/13

2 An immersion heater rated at 150 W is fitted into a large block of ice at 0 °C. The specific latent heat of fusion of ice is 300 J/g.

How long does it take to melt 10 g of ice?

A 2 s
B 5 s
C 20 s
D 150 s
E 4500 s

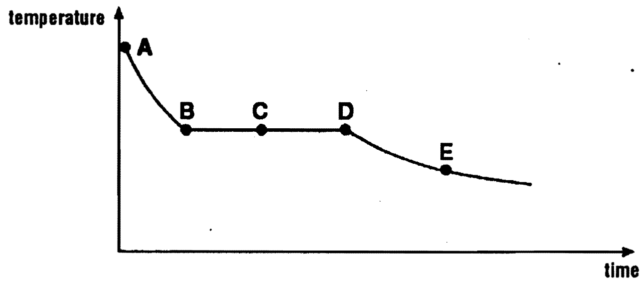
J90/I/17

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

A Water evaporates and causes cooling.
B Water is a good conductor of heat.
C Water prevents sunlight from reaching the skin.
D Water insulates them from the warm air.
E Water is colder than the air.

J91/I/13; N99/I/12

4 The graph shows how the temperature of some wax changes as it cools from liquid to solid.



At which labelled point would the wax be a mixture of solid and liquid?

J91/I/16

5 Hot water at 100 °C is added to 5 g of ice at 0 °C.

What is the minimum mass of hot water needed to melt the ice?

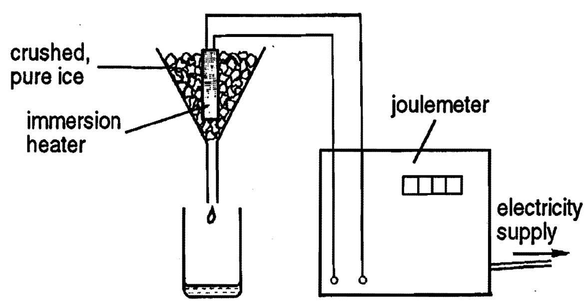
[Specific latent heat of fusion of ice is 336 J/g. Specific heat capacity of water is 4.2 J/(g K)].

A 0.8 g
B 4.0 g
C 16.8 g
D 70.6 g
E 400 g

N91/I/16

6 In the experiment shown in the diagram, the amount of electrical energy used to melt some ice is measured using a joulemeter.

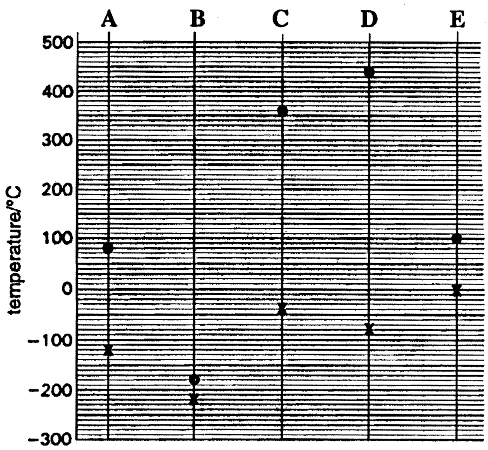
To find the specific latent heat of fusion of the ice, what must also be measured?



A the final temperature of the water
B the mass of water produced by melting ice
C the temperature change of the ice
D the time taken for the ice to melt
E the voltage of the electrical supply

N92/I/16

7 The diagram shows the melting points and boiling points of five substances. (× = melting point, o = boiling point.)



Which substance is a liquid at −10 °C and a gas at 150 °C?

J93/I/14

8 Aniline melts at −6 °C and boils at 184 °C.

At which temperature would aniline not be a liquid?

A −9 °C
B −3 °C
C 25 °C
D 100 °C
E 102 °C

N93/I/15

9 An ice-making machine extracts energy at a rate of 500 W.

The specific latent heat of fusion of ice is 300 kJ/kg.

How long does it take to freeze 2 kg of water at 0 °C?

A $\frac{2 \times 300}{500}$ s **C** $\frac{2 \times 300 \times 1000}{500}$ s
B $\frac{2 \times 500}{300}$ s **D** $\frac{2 \times 500}{300 \times 1000}$ s

J94/I/16

10 The table gives the melting points and boiling points of four elements.

Which element is a liquid at 1000 °C?

	element	*melting point/°C*	*boiling points/°C*
A	aluminium	660	2470
B	chlorine	−101	−35
C	iron	1540	2750
D	mercury	−39	357

N94/I/14

11 An immersion heater rated at 150 W is fitted into a large block of ice at 0 °C. The specific latent heat of fusion of the ice is 300 J/g.

How long does it take to melt 10 g of the ice?

A 2 s **C** 20 s
B 5 s **D** 150 s

N94/I/18

12 'As the temperature is raised, molecules gain energy and vibrate more vigorously about their fixed positions. Eventually they have enough energy to overcome the strong forces between them so that they can move past each other, although weaker forces still do not allow them complete freedom of movement.'

Which process is described in the above statement?

A conduction
B convection
C a solid melting
D a liquid boiling

J95/I/11

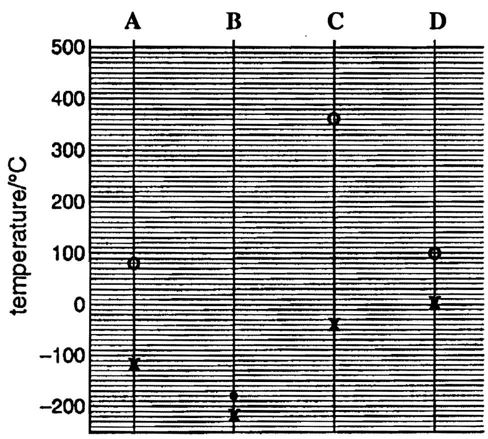
13 What is the name given to the amount of energy needed to turn 1 kg of water at 100 °C into steam?

A heat capacity
B latent heat
C specific heat capacity
D specific latent heat

J95/I/14

14 The diagram shows the melting points and boiling points of four substances. (× = melting point, o = boiling point.)

Which substance is a gas at 150 °C and a solid at −50 °C?



J96/I/16

15 What happens when a liquid is being heated at its boiling point?

A an increase in molecular size
B an increase in molecular spacing
C an increase in the average kinetic energy of the molecules
D an increase in the total number of molecules

J97/I/14

16 At which temperature, and where in a liquid, does evaporation occur?

	temperature	*where in a liquid*
A	any	point(s) of heating only
B	any	surface only
C	boiling point only	point(s) of heating only
D	boiling point only	surface only

N97/I/14

17 When a liquid evaporates rapidly, why does it cool?

A Air molecules remove heat by contact with the liquid surface.

B Energy is lost by convection currents.

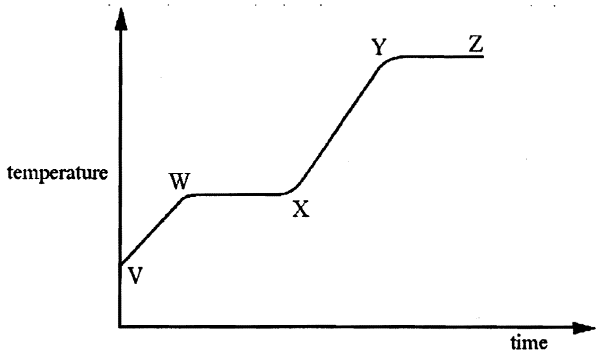
C Fewer molecules are left in the liquid.

D Some of the most energetic molecules leave the liquid.

N98/I/11

18 Some ice is placed in a beaker and is heated until the beaker contains boiling water.

The graph shows the temperature of the beaker and its contents during the experiment.



Between which two points on the graph does the beaker contain a mixture of solid and liquid?

A V and W **C** X and Y
B W and X **D** Y and Z N98/I/14

19 Water left in a beaker evaporates.

What happens during the evaporation?

A High energy molecules escape and the water gains thermal energy from the surroundings.

B High energy molecules escape and the water loses thermal energy to the surroundings.

C Low energy molecules escape and the water loses thermal energy to the surroundings.

D Low energy molecules escape and the water gains thermal energy from the surroundings. J99/I/11

20 A swimmer comes out of the water on a windy day.

He may feel colder before he dries himself than afterwards. Why is this?

A The water is cooled down by the swimmer.

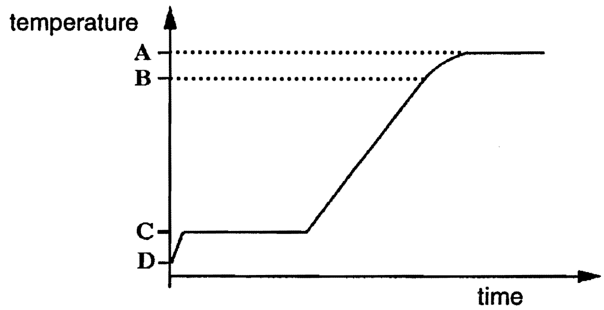
B The water on his skin is colder than the air.

C The water prevents warm air reaching his skin.

D The wind evaporates the water, cooling his skin.

J2000/I/12

21 Some ice cubes are taken from a deep-freeze and placed in a metal container. The container is heated at a steady rate and temperature/time readings are taken. The results are recorded on a graph.



Which temperature corresponds to 0 °C? N2000/I/12

22 A vacuum flask contains water at 15 °C, with a thermometer and an electric heater immersed in the water. 20 g (= 0.020 kg) of dried ice at 0 °C is added to the water, the heater is connected to a power supply and switched on. The heater gives an output of 24 J/s.

(a) How much heat is required to melt the ice?

[Specific latent heat of fusion of ice = 336 J/g (= 336 000 J /kg).]

(b) How much heat is required to raise the temperature of this melted ice to 15 °C?

[Specific heat capacity of water = 4.2 J/g K (= 4200 J/kg K).]

(c) For how long must the heater be used before the thermometer begins to rise above 15 °C, assuming there is no heat exchange between the vacuum flask and the surroundings, and the contents of the flask are thoroughly mixed?

(d) Why would the value for the time be different if the ice had not been dried before it was added?

(e) Why is it not necessary to know either the heat capacity of the vacuum flask or the initial mass of water it contained in order to calculate the time to reach 15 °C?

J79/II/2

23 A jet of steam at 100 °C is directed for a short time on to a large block of ice at 0 °C. Some of the steam condenses to form water and some ice is melted. The condensed steam forms 0.40 kg of water at 0 °C. Calculate the heat given out by this mass of steam in changing to water without change in temperature.

[Take the specific latent heat of vaporization of water as 2200 kJ/kg.]

Calculate the heat given out by this water as it cools to the temperature of the ice. [Take the specific heat capacity of water as 4.2 kJ /kg K.] J80/I/5

24 Answer each part of this question in terms of the *kinetic theory of matter.*

(a) A sample of liquid at its boiling point is to be converted to vapour at the same temperature. Why must heat energy be supplied to bring about this change?

(b) When all the liquid has been converted into vapour at the boiling point, the vapour fills a container at atmospheric pressure. Explain why the volume of the vapour is much greater than the original volume of the liquid?

(c) Why does the vapour exert a pressure on its container?

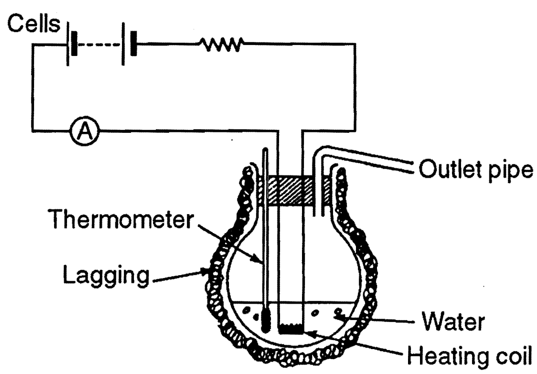
(d) If the temperature of the container is raised, why does the pressure of the vapour inside the container rise? (Assume that the volume of the container does not change.)

J80/II/2

25 A small heater, rated at 24 W, is embedded in a large block of ice at 0 °C. After the heater has been switched on for 672 s it is found that 48 g (0.048 kg) of ice has been melted into water at 0 °C.

Calculate the specific latent heat of ice. N80/I/5

26 The diagram shows an experimental arrangement which can be used to determine the specific latent heat of vaporisation of water at its normal boiling point. The thermometer is to check the boiling point of the liquid.



(a) Describe how you would obtain the mass of water evaporated in a certain time. You may show on the diagram any additional apparatus you would use.

(b) The outlet pipe becomes blocked so that the pressure inside the flask rises. How will the reading of the thermometer shown in the diagram change? State briefly a reason for you answer.

(d) In a particular experiment 9.0 g (0.0090 kg) of water is evaporated when a current of 2.0 A is passed through the heating coil for 630 s. The resistance of the heating coil is 8.0 U. Calculate the specific latent heat of vaporisation of water, assuming that no heat escapes from the flask.

N80/II/2(*a, b* & *d*)

27 Using your knowledge of the simple kinetic theory, explain why it is necessary to supply energy

(a) to change ice into water at the same temperature,

(b) to raise the temperature of water.

A glass containing 0.30 kg of water at 0 °C with 0.20 kg of ice floating in it, is brought into a warm room. The water is stirred continuously. It is observed that after 300 s all the ice has melted and the temperature of all of the water has risen to 15.0 °C.

Calculate

(i) the total amount of heat absorbed by the contents of the glass,

(ii) the average *rate* at which the contents of the glass absorbed heat.

(The specific heat capacity of water is 4200 J/kg K and specific latent heat of ice is 336000 J/kg.) N81/II/8

28 A heater supplying energy at a constant rate of 500 W is completely immersed in a large block of ice at 0 °C. In 1320 s, 2.0 kg of water at 0 °C are produced. Calculate a value for the specific latent heat of fusion of ice.

J82/I/6

29 An electric kettle is fitted with a 2 kW heater. When the water in the kettle reaches boiling-point, the heater in the kettle continues to operate. Assuming that all the heat from the heating element is then used to vaporise the boiling water, calculate the mass of steam given off in one minute. [Take the specific latent heat of vaporisation of water to be 2250 kJ/ kg.]

When all the steam produced in one minute is condensed, the mass obtained in one minute is considerably less than that expected from this calculation. Why is this? N82/I/7

30 A block of ice, mass 6.0 kg, is placed inside a bag to keep the contents cold and the bag is closed. The contents of the bag, including the ice, are initially at 0 °C and heat enters the bag at the rate of 250 W. Calculate the time until the temperature inside the bag rises above 0 °C, assuming that the temperature throughout the bag is always uniform.

[The specific latent heat of ice is 3.3×10^5 J/kg.]

Why would this time be less if the bag had been open to the air and not carefully sealed? J83/II/3

31 Describe briefly an experiment to demonstrate that evaporation produces cooling.

Indicate how kinetic theory offers an explanation of

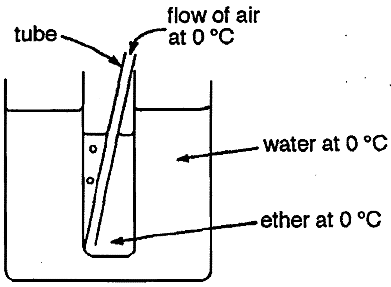
(a) the cooling effect produced by evaporation of a liquid,

(b) the fact that the heat needed to produce rapid evaporation of a liquid causes no rise in the temperature of the liquid.

The temperature of 2.5 kg of water is raised from 20 °C to 100 °C by passing steam at 100 °C through it. Find the mass of steam that must condense to produce this rise in temperature, taking the specific heat capacity of water as 4.2×10^3 J/(kg K) and the specific latent heat of steam as 2.0×10^6 J/kg.

[Ignore heat losses.] J83/II/9

32 In terms of kinetic theory distinguish between the liquid state and gaseous state of a simple substance.



In the arrangement shown, the ether evaporates. Assuming that the tube and the air, ether and water all stay at 0 °C, calculate the mass of ice formed around the tube when 11 g of ether have evaporated. (Ignore any heat gained from the surroundings.)

[Specific latent heat of vaporisation of ether = 400 J/g. Specific latent heat of fusion of ice = 330 J/g.] N83/II/8

33 A mixture of 1 kg of water and 1 kg of ice, both initially at 0 °C, is used to keep some medical supplies cool. Calculate the heat that the mixture absorbs in reaching a temperature of 10 °C. [The specific latent heat of ice is 336 000 J/kg and the specific heat capacity of water is 4200 J/kg K).] J84/I/8

34 In an experiment to determine the specific latent heat of vaporisation of water, a current of 2.1 A was passed through a heating element immersed in an open container of water. The voltage across the heater was 240 V. Once steady boiling was achieved, it was found that the mass of water in the container decreased by 0.12 kg in 10.0 minutes.

Calculate a value for the specific latent heat of vaporisation of water.

State *one* reason why, in this experiment, it would be better to use a vacuum flask to contain the water rather than a copper container. J85/I/5

35 In an experiment to determine the rate of heat production by a bunsen burner, a beaker of water is heated. It is found that the temperature of 1.5 kg of water rises from 15 °C to 70 °C in 500 s. The specific heat capacity of water is 4200 J/(kg K) and the heat capacity of the beaker itself is 50 J/K.

Calculate a value for the rate of production of heat by the bunsen burner.

Using this value, estimate the rate at which the water in the beaker will turn to steam once the temperature reaches 100 °C.

[Take the specific latent heat of steam as 2250 kJ/kg.]
J84/II/8*(c)*

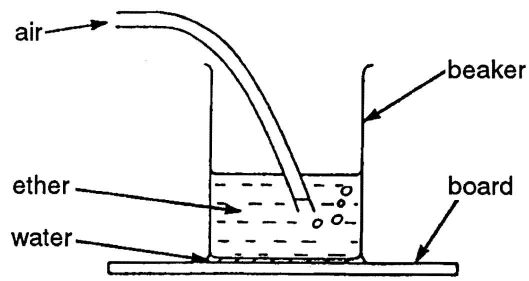
36 A glass contains 0.40 kg of water at 15 °C which is to be cooled to 0 °C by the addition of ice cubes. Neglecting the heat capacity of the glass, calculate the heat which must be removed from the water to bring about the cooling. [Specific heat capacity of water is 4200 J/(kg K)]

Calculate the mass of ice at 0 °C which must be added to the water. (The specific latent heat of fusion of ice is 3.4×10^5 J/kg.) N85/I/7

37 2.0 kg of ice is placed in a vacuum flask, both ice and flask being at 0 °C. It is found that exactly 14 hours elapse before the contents of the flask are entirely water at 0 °C. Given that the specific latent heat of fusion of ice is 3.4×10^5 J/kg calculate the average *rate* at which the contents gain heat from the surroundings.

Suggest a reason why the rate of gain of heat gradually decreases *after* all the ice has melted. J86/I/5

38 The diagram shows a beaker containing ether which stands on a wooden board; there is a thin film of water between the board and the base of the beaker. Air is then blown through the tube so that it bubbles out from the immersed end. This causes the ether to evaporate more rapidly.



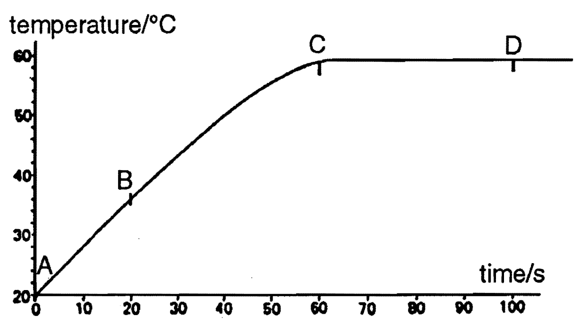
Explain why the water between the board and the base of the beaker freezes. N86/I/5

39 In terms of the kinetic theory (i.e. in terms of the motion of molecules) explain briefly

(a) why the evaporation of a liquid causes it to be cooled,

(b) why the rate of evaporation of a liquid increases when it is heated. J87/I/4

40 *(a)* In an experiment to measure the heat capacity of a quantity of liquid an electric immersion heater was used to supply 120 W of power to the liquid. The liquid was stirred thoroughly during the experiment, and readings of temperature were taken at regular intervals of time after the heater was switched on. The graph shown was plotted from the results obtained as the temperature rose from room temperature, 20 °C (A) to boiling point 60 °C (C).



(i) Use the portion AB of the graph to calculate a value of the heat capacity of the sample of liquid. Explain why the actual heat capacity of the liquid will be *smaller* than the value you have calculated.

(ii) Explain why it was good practice to stir the liquid during the experiment.

(iii) During the time represented by the part CD of the graph the liquid was boiling.

Calculate a value for the specific latent heat of vaporisation of the liquid, given that 0.0090 kg of the liquid evaporated in 45 s after the liquid started to boil.

Why would the use of a more powerful heater during this part of the experiment enable a more accurate value to be obtained? J87/II/8*(a)*

41 A mass of 0.15 kg of water at 0 °C is placed in a vessel of negligible heat capacity. An electric heater with an output of 24 W is placed in the water and switched on. When the temperature of the water reaches 12 °C the heater is switched off. Assuming that the specific heat capacity is 4200J/(kg K), calculate the time for which the heater has been switched on. [4]

An ice-cube of mass 0.025 kg is added to 0.15 kg of water at 0 °C in the same vessel and the heater switched on. Assuming that all the ice is at 0 °C, calculate how much longer it will take for the water to reach 12 °C than it did when the ice-cube was not present. Assume that the specific latent heat of fusion of ice is 340 000 J/kg. [5]

If this procedure were to be used to measure the specific latent heat of fusion of ice, state and explain the special steps and precautions you would take to obtain a more accurate result. Do **not** refer to any points considered in the earlier part of the question. [4] N87/II/8

42 A 100 g packet of frozen peas at 0 °C is taken from the cold compartment of a refrigerator; after 20 min, the ice has completely melted and produced 5 g of water.

(a) Assuming that the peas and the water are still at 0 °C, calculate the rate at which heat has been gained from the surroundings to melt the ice. Assume that the specific latent heat of melting ice is 340 J/g. [2]

(b) (i) Suggest why the rate of gain of heat might have been larger than the value you have calculated. [1]

(ii) If the peas and water are left for several more minutes, the rate of gain of heat decreases. Suggest why this is so. [1] N88/I/6

43 Thermal energy is supplied at a constant rate to the water in the pan shown in Fig. 1. The graph shows the temperature recorded by the thermometer at different times.

(a) Explain why the temperature remains constant after a few minutes. [1]

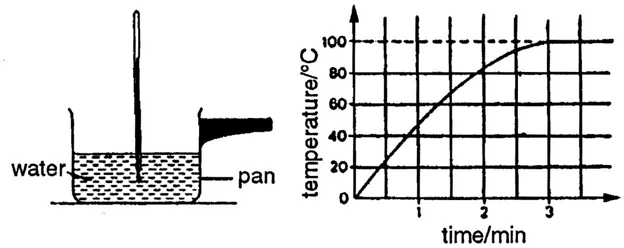


Fig. 1 N89/I/4*(a)*

44 *(a)* What is meant by the term *latent heat of fusion of a solid*? [2]

(b) Thermal energy is supplied to a melting solid at a constant rate of 2000 W. Calculate the mass of the solid changed to liquid in 2.0 minutes. Assume that the specific latent heat of fusion of the solid is 95 000 J/kg and that heat exchange with the surroundings may be neglected. [2]

N89/I/5

45 A small quantity of crushed ice was allowed to warm up from a temperature of –2 °C. The graph in Fig. 2 shows how the temperature of the ice varied with time.

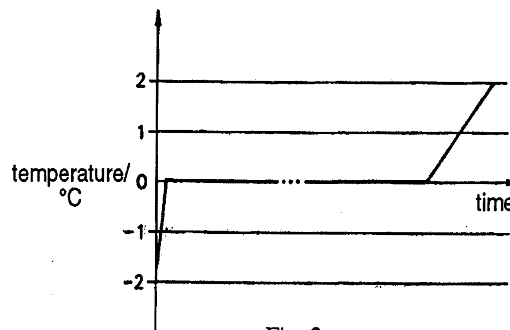


Fig. 2

(a) Explain why, after an initial rise to 0 °C, the temperature remained constant for a long time. [3]

(b) Suggest why the slope of the graph between –2 °C and 0 °C is greater than that between 0 °C and +2 °C. [1]

N90/II/3

46 *(b)* Explain what is meant by each of the statements

(i) the specific heat capacity of water is 4.2 kJ/(kg K),

(ii) the specific latent heat of ice at 0 °C is 334 kJ/kg. [4]

(c) Calculate the change in internal energy when 1.0 kg of water

(i) cools from 30.0 °C to 5.0 °C,

(ii) warms from 0.0 °C to 5.0 °C. [3]

(d) Calculate how much ice at a temperature of 0.0 °C would be needed to cool 1.00 kg of water from 30.0 °C to 5.0 °C. [4]

J92/II/10

47 The label on an electric kettle is marked '240V, 3 kW'.

One such kettle contains 1.7 kg of water at 20 °C.

It takes 3.5 minutes to raise the temperature of the water to 100 °C.

It takes a further 3.5 minutes to boil away 0.23 kg of the water.

The specific heat capacity of water is 4.2 kJ/(kg K).

The specific latent heat of vaporisation of water at 100 °C is 2.3 MJ/kg.

(a) State the meaning of '240 V, 3 kW'. [2]

(b) Calculate

(i) the energy output of the electric element in the kettle in 3.5 minutes,

(ii) the energy required to raise the temperature of 1.7 kg of water from 20 °C to 100 °C,

(iii) the energy required to boil away 0.23 kg of water at 100 °C. [6]

(c) Estimate the unused power (i.e. average rate of energy 'loss')

(i) during the first 3.5 minutes,

(ii) during the second 3.5 minutes. [4]

(d) Suggest why the two rates of 'loss' are different. As part of your answer, consider possible energy changes in the body of the kettle. [3]

N93/II/9

48 Use the molecular theory of matter to explain briefly why

(a) a gas exerts a pressure on the walls of its container, [3]

(b) energy is required to evaporate a liquid. [2]

J94/II/5

49 Lemonade can be cooled by adding lumps of ice to it. A student discovers that 70 g of ice at a temperature of 0.0 °C cools 0.30 kg of lemonade from 28 °C to 7 °C.

The latent heat of fusion of ice is 0.33 MJ/kg.

The specific heat capacity of water is 4.2 kJ/(kg K).

Determine

(a) the energy gained by the ice in melting,

(b) the energy gained by the *melted ice*,

(c) the energy lost by the lemonade,

(d) a value for the specific heat capacity of the lemonade.

energy gained by ice in melting = ...

energy gained by melted ice = ...

energy lost by lemonade = ...

specific heat capacity of lemonade = ... [7]

J95/II/7

50 A heater **H** of resistance 4.0 Ω is connected in series with a 12 V battery, a switch and a rheostat **R**. The rheostat resistance may be varied between 0 and 20 Ω.

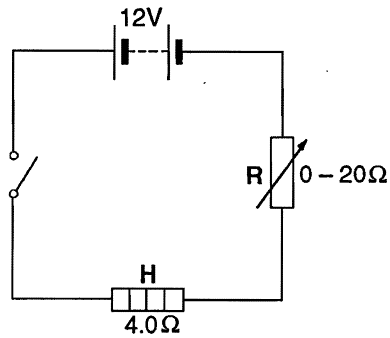


Fig. 3

**(a)* Calculate the minimum and maximum values of

(i) the current in the circuit,

(ii) the voltage across **H**,

(iii) the power developed in **H**. [5]

(b) Draw a diagram of the circuit shown in Fig. 3, modified to include an ammeter and voltmeter for measuring the current in and the voltage across **H**. [2]

(c) Explain what is meant by the statements

(i) the specific heat capacity of water is 4.2 kJ/(kg K),

(ii) the specific latent heat of vaporisation of water at 100 °C is 2.3 MJ/kg. [4]

(d) The apparatus shown in Fig. 3 is used to heat some water.

Calculate, neglecting any energy loss, the minimum time required

(i) to raise the temperature of 0.20 kg of water by 80 K (80 °C),

(ii) to vaporise 0.020 kg of water at 100 °C. [4]

N97/II/10

51

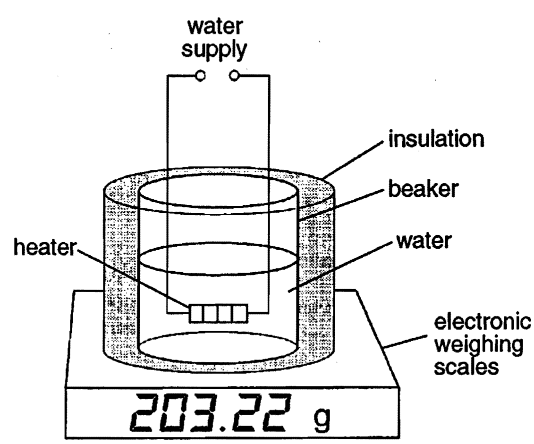


Fig. 4

Fig. 4 shows the apparatus used by a student to measure the specific latent heat of vaporisation of water. A heater is placed into a beaker of water which stands on top of electronic weighing scales so that the mass of the beaker and water may be measured.

In this question, you may assume that there is no heat lost to the atmosphere.

(a) Define what is meant by the *specific latent heat of vaporisation of* water. [3]

(b) As soon as the water is boiling, the student notes down the reading on the scales and starts a timer. Every 100 seconds the student notes down the reading on the scales. The results obtained are shown in the table.

time/s	0	100	200	300	400
reading on scale/g	203.22	201.62	199.79	198.26	196.50

(i) Draw up a table to show the total mass of water evaporated after 100 s, 200 s, 300 s and 400 s. That is, from 0 to 100 s, 0 to 200 s and so on.

(ii) The heater supplies energy at the rate of 38 J/s. Add to your table values showing the energy provided by the heater in 100 s, 200 s, 300 s and 400 s. That is, from 0 to 100 s, 0 to 200 s and so on. [2]

(c) Plot a graph of energy supplied (y-axis) against mass of water evaporated (x-axis).
Start your axes at (0, 0). [4]

(d) Determine the gradient of your graph. How is the specific latent heat of vaporisation of water related to this gradient? [3]

(e) The voltage of the power supply connected to the heater is doubled. Describe and explain the effect this has on the readings obtained, and on the final result. [3]
J99/II/9

52 A small quantity of solid wax in a test-tube is heated slowly. Fig. 5 shows the variation with time of the temperature of the wax.

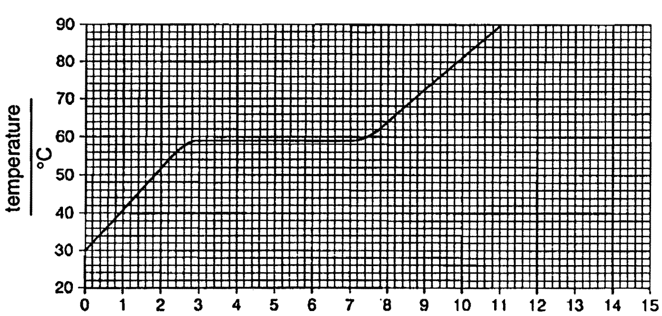


Fig. 5

(a) (i) State what is meant by the *melting point* of a substance.

(ii) Determine the melting point of the wax in the experiment.

melting point = ... [3]

(b) In a second experiment, twice the amount of wax is used, and exactly the same amount of heat energy every second is passed into the wax as in the first experiment. The initial temperature of the wax is also 30 °C.

On Fig. 5, draw the variation with time of the temperature of the wax in this second experiment. You may assume that the heat needed to warm up the test-tube itself is negligible. [2]
N99/II/8

53 A person running in a race generates, on average, 800 J of heat energy every second. Half of this heat energy is lost from the body by the evaporation of water.

(a) Explain in terms of molecules, how the loss of water by evaporation cools the body. [2]

(b) Calculate the mass of water evaporated from the body in a 2 hour race. The specific latent heat of vaporisation of water is 2.25×10^6 J/kg. [3]
J2000/II/4

54 Fig. 6 shows steam passing into a jug to warm up some cold water. In this question, you may ignore any heating of the atmosphere.

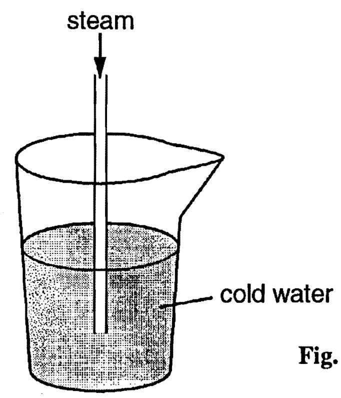


Fig. 6

Pure steam enters at 100 °C and the jug initially contains 500 g of water at 20 °C. Eventually, the water in the jug reaches a temperature of 100 °C. The specific heat capacity of water is 4.20 J/(g°C) and the specific latent heat of vaporisation of water is 2250 J/g.

(a) State what is meant by the *specific latent heat of vaporisation* of water. [2]

(b) Explain why the mass of water in the jug increases. [1]

(c) Calculate the energy needed to warm 500 g of water from 20 °C to 100 °C.

energy = ... [2]

(d) Calculate the final mass of water in the jug, when its temperature has reached 100 °C.

mass = ... [2] N2000/II/5

ANSWERS

11.1 Specific Heat Capacity

1. **D** 2. **D** 3. **C** 4. **A** 5. **C**
6. **E** 7. **A** 8. **B**
9. 11.2 °C
10. 1.008×10^7 J ; 2520 s
11. 3840 JK^{-1}
13. 300 J/Kg K
14. 5.7 kg
15. 1575 J/s
16. *(c)* (ii) 2.9 min (iii) 5250 J (iv) 77 °C
17. *(a)* (i) 164 J (ii) 2.73 W
18. *(b)* (iii) 0.105 kWh.

11.2 Melting, Boiling and Evaporation

11.3 Specific Latent Heat

1. **A** 2. **C** 3. **A** 4. **C** 5. **B**
6. **B** 7. **A** 8. **A** 9. **C** 10. **A**
11. **C** 12. **C** 13. **D** 14. **D** 15. **B**
16. **B** 17. **D** 18. **B** 19. **A** 20. **D**
21. **C**
22. *(a)* 6720 J *(b)* 1260 J *(c)* 332.5 s
23. 880 kJ ; 168 kJ
25. 336×10^3 J/kg
26. *(d)* 2240 kJ/kg
27. (i) 98 700 J (ii) 329 W
28. 330 kJ/kg
29. 0.0533 kg
30. 7920 s
31. 0.42 kg
32. 13.3 g
33. 420 kJ
34. 2.52×10^6 J/kg
36. 25 200 J ; 0.074 kg
37. 13.49 J/s
40. *(a)* (i) 150 J/K (iii) 600 000 J/kg
41. 315 s ; 407 s
42. *(a)* 85 J/min
44. *(b)* 2.526 kg
46. *(c)* (i) 105 kJ (ii) 21.0 kJ *(d)* 0.296 kg
47. *(b)* (i) 630 kJ (ii) 571.2 kJ (iii) 529 kJ
    (c) (i) 58.8 kJ (ii) 101 kJ
49. *(a)* 23 100 J *(b)* 2058 J
    (c) 25 158 J *(d)* 3993 J/kg K
50. *(a)* (i) 0.5 A ; 3 A (ii) 2 V ; 12 V
    (iii) 1 W ; 36 W
    (d) (i) 1870 s (ii) 1280 s
51. *(b)* (i) (ii)

time/s	0	100	200	300	400
mass of water evaporated/g	0	1.60	3.43	4.96	6.72
energy provided/J	0	3800	7600	11400	15200

52. *(a)* (ii) 59°C
53. *(b)* 1.28 kg
54. *(c)* 1.68×10^5 J *(d)* 74.7 g