Q1.

2 **(a)** On Fig. 2.1, place a tick (✓) against those changes where the internal energy of the body is increasing. [2]

water freezing at constant temperature	....
a stone falling under gravity in a vacuum	....
water evaporating at constant temperature	....
stretching a wire at constant temperature	....

Fig. 2.1

(b) A jeweller wishes to harden a sample of pure gold by mixing it with some silver so that the mixture contains 5.0% silver by weight. The jeweller melts some pure gold and then adds the correct weight of silver. The initial temperature of the silver is 27 °C. Use the data of Fig. 2.2 to calculate the initial temperature of the pure gold so that the final mixture is at the melting point of pure gold.

	gold	silver
melting point / K	1340	1240
specific heat capacity (solid or liquid) / $J\,kg^{-1}\,K^{-1}$	129	235
specific latent heat of fusion / $kJ\,kg^{-1}$	628	105

Fig. 2.2

temperature = ... K [5]

(c) Suggest a suitable thermometer for the measurement of the initial temperature of the gold in **(b)**.

.... [1]

Q2.

USE

6 The first law of thermodynamics may be expressed in the form

$$\Delta U = q + w,$$

where U is the internal energy of the system,
ΔU is the increase in internal energy,
q is the thermal energy supplied to the system,
w is the work done on the system.

Complete Fig. 6.1 for each of the processes shown. Write down the symbol '+' for an increase, the symbol '–' to indicate a decrease and the symbol '0' for no change, as appropriate.

	U	q	w
the compression of an ideal gas at constant temperature			
the heating of a solid with no expansion			
the melting of ice at 0 °C to give water at 0 °C (Note: ice is less dense than water)			

[6]

Fig. 6.1

Q3.

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

....

....

....[2]

(b) A mass of 24 g of ice at –15 °C is taken from a freezer and placed in a beaker containing 200 g of water at 28 °C. Data for ice and for water are given in Fig. 3.1.

	specific heat capacity / J kg^{-1} K^{-1}	specific latent heat of fusion / J kg^{-1}
ice	2.1×10^3	3.3×10^5
water	4.2×10^3	–

Fig. 3.1

(i) Calculate the quantity of thermal energy required to convert the ice at –15 °C to water at 0 °C.

energy = ... J [3]

(ii) Assuming that the beaker has negligible mass, calculate the final temperature of the water in the beaker.

temperature = ... °C [3]

Q4.

3 The electrical resistance of a thermistor is to be used to measure temperatures in the range 12 °C to 24 °C. Fig. 3.1 shows the variation with temperature, measured in degrees Celsius, of the resistance of the thermistor.

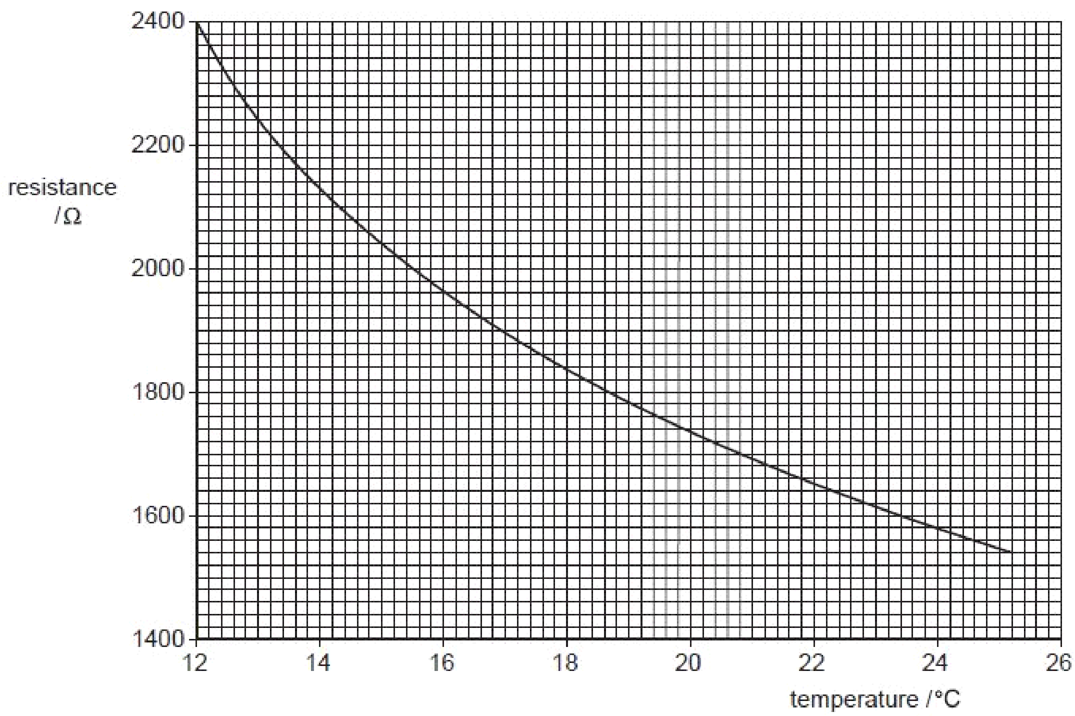


Fig. 3.1

(a) State and explain the feature of Fig. 3.1 which shows that the thermometer has a sensitivity that varies with temperature.

....

....

.... [2]

(b) At one particular temperature, the resistance of the thermistor is 2040 ± 20 Ω.

Determine this temperature, in kelvin, to an appropriate number of decimal places.

temperature = ... K [3]

Q5.

2 **(a)** Use the kinetic theory of matter to explain why melting requires energy but there is no change in temperature.

....

....

....

.... [3]

(b) Define *specific latent heat of fusion*.

....

....

.... [2]

(c) A block of ice at 0 °C has a hollow in its top surface, as illustrated in Fig. 2.1.

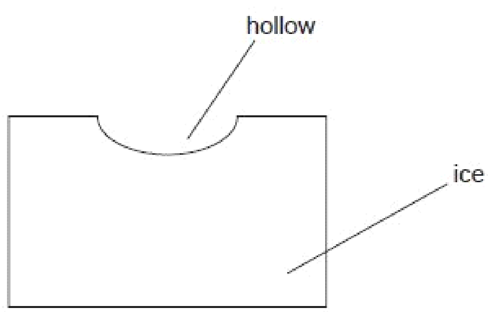


Fig. 2.1

A mass of 160 g of water at 100 °C is poured into the hollow. The water has specific heat capacity 4.20 kJ kg^{-1} K^{-1}. Some of the ice melts and the final mass of water in the hollow is 365 g.

(i) Assuming no heat gain from the atmosphere, calculate a value, in kJ kg^{-1}, for the specific latent heat of fusion of ice.

specific latent heat = ... kJ kg^{-1} [3]

(ii) In practice, heat is gained from the atmosphere during the experiment. This means that your answer to **(i)** is not the correct value for the specific latent heat.
State and explain whether your value in **(i)** is greater or smaller than the correct value.

....

....

.... [2]

Q6.

3 When a liquid is boiling, thermal energy must be supplied in order to maintain a constant temperature.

(a) State two processes for which thermal energy is required during boiling.

1. ....

....

2. ....

....

[2]

(b) A student carries out an experiment to determine the specific latent heat of vaporisation of a liquid.
Some liquid in a beaker is heated electrically as shown in Fig. 3.1.

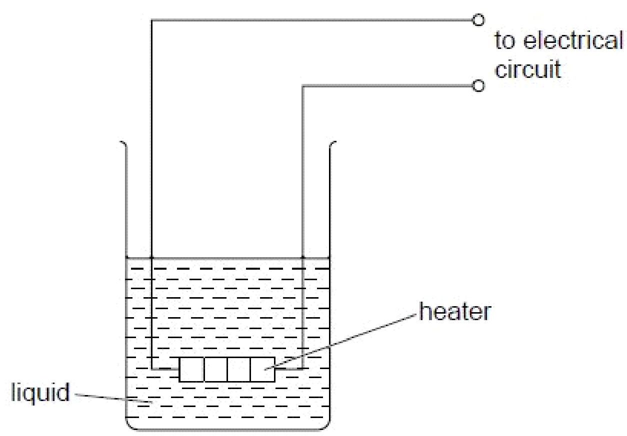


Fig. 3.1

Energy is supplied at a constant rate to the heater. When the liquid is boiling at a constant rate, the mass of liquid evaporated in 5.0 minutes is measured.
The power of the heater is then changed and the procedure is repeated.
Data for the two power ratings are given in Fig. 3.2.

power of heater /W	mass evaporated in 5.0 minutes /g
50.0 70.0	6.5 13.6

Fig. 3.2

(i) Suggest

1. how it may be checked that the liquid is boiling at a constant rate,

....

.... [1]

2. why the rate of evaporation is determined for two different power ratings.

....

.... [1]

(ii) Calculate the specific latent heat of vaporisation of the liquid.

specific latent heat of vaporisation = ... $J\,g^{-1}$ [3]

For Examiner's Use

Q7.

3 **(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.

Exa

(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]

Q8.

4 **(a)** The first law of thermodynamics may be expressed in the form

$$\Delta U = q + w.$$

Explain the symbols in this expression.

+ ΔU ....

+ q ....

+ w .... [3]

(b) **(i)** State what is meant by *specific latent heat*.

....

....

....

.... [3]

(ii) Use the first law of thermodynamics to explain why the specific latent heat of vaporisation is greater than the specific latent heat of fusion for a particular substance.

....

....

....

.... [3]

For Examiner's Use

Q9.

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

Exa

....

....

.... [2]

(b) The heater in an electric kettle has a power of 2.40 kW.
When the water in the kettle is boiling at a steady rate, the mass of water evaporated in 2.0 minutes is 106 g.
The specific latent heat of vaporisation of water is 2260 J g^{-1}.

Calculate the rate of loss of thermal energy to the surroundings of the kettle during the boiling process.

rate of loss = ... W [3]

Q10.

3 **(a)** State what is meant by the *internal energy* of a system.

For Examin Use

....

....

....[2]

(b) State and explain qualitatively the change, if any, in the internal energy of the following systems:

(i) a lump of ice at 0 °C melts to form liquid water at 0 °C,

....

....

....

....[3]

(ii) a cylinder containing gas at constant volume is in sunlight so that its temperature rises from 25 °C to 35 °C.

....

....

....

....[3]

Q11.

1 A kettle is rated as 2.3 kW. A mass of 750 g of water at 20 °C is poured into the kettle. When the kettle is switched on, it takes 2.0 minutes for the water to start boiling. In a further 7.0 minutes, one half of the mass of water is boiled away.

(a) Estimate, for this water,

(i) the specific heat capacity,

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

(ii) the specific latent heat of vaporisation.

specific latent heat = ... $J\,kg^{-1}$
[5]

(b) State **one** assumption made in your calculations, and explain whether this will lead to an overestimation or an underestimation of the value for the specific latent heat.

....

....

....[2]

Q12.

3 The volume of some air, assumed to be an ideal gas, in the cylinder of a car engine is $540\,cm^3$ at a pressure of $1.1 \times 10^5\,Pa$ and a temperature of 27 °C. The air is suddenly compressed, so that no thermal energy enters or leaves the gas, to a volume of $30\,cm^3$. The pressure rises to $6.5 \times 10^6\,Pa$.

(a) Determine the temperature of the gas after the compression.

temperature = ... K [3]

(b) **(i)** State and explain the first law of thermodynamics.

....

....

....

.... [2]

(ii) Use the law to explain why the temperature of the air changed during the compression.

....

....

....

....

....[4]

Q13.

7 The e.m.f. generated in a thermocouple thermometer may be used for the measurement of temperature.

Fig. 7.1 shows the variation with temperature *T* of the e.m.f. *E*.

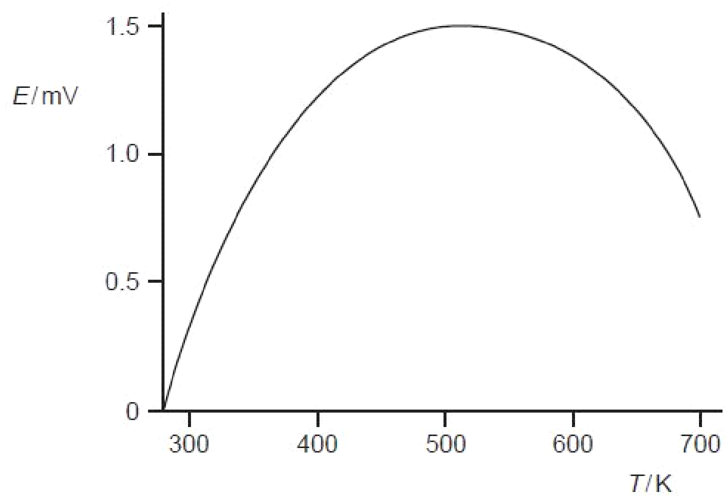


Fig. 7.1

(a) By reference to Fig. 7.1, state two disadvantages of using this thermocouple when the e.m.f. is about 1.0 mV.

1. ....

2. ....[2]

(b) An alternative to the thermocouple thermometer is the resistance thermometer.

State two advantages that a thermocouple thermometer has over a resistance thermometer.

1. ....

....

2. ....

....[2]

Q14.

3 **(a)** State the first law of thermodynamics in terms of the increase in internal energy ΔU, the heating q of the system and the work w done on the system.

....

.... [1]

(b) The volume occupied by 1.00 mol of liquid water at 100 °C is $1.87 \times 10^{-5}\,m^3$. When the water is vaporised at an atmospheric pressure of 1.03×10^5 Pa, the water vapour has a volume of $2.96 \times 10^{-2}\,m^3$.
The latent heat required to vaporise 1.00 mol of water at 100 °C and 1.03×10^5 Pa is 4.05×10^4 J.
Determine, for this change of state,

(i) the work w done on the system,

w = ... J [2]

(ii) the heating q of the system,

q = ... J [1]

(iii) the increase in internal energy ΔU of the system.

ΔU = ... J [1]

(c) Using your answer to **(b)(iii)**, estimate the binding energy per molecule in liquid water.

energy = ... J [2]

Q15.

2 A mercury-in-glass thermometer is to be used to measure the temperature of some oil.

The oil has mass 32.0 g and specific heat capacity 1.40 $J\,g^{-1}K^{-1}$. The actual temperature of the oil is 54.0 °C.

The bulb of the thermometer has mass 12.0 g and an average specific heat capacity of 0.180 $J\,g^{-1}K^{-1}$. Before immersing the bulb in the oil, the thermometer reads 19.0 °C.

The thermometer bulb is placed in the oil and the steady reading on the thermometer is taken.

(a) Determine

(i) the steady temperature recorded on the thermometer,

temperature = ... °C [3]

(ii) the ratio

$$\frac{\text{change in temperature of oil}}{\text{initial temperature of oil}}.$$

ratio = ... [1]

(b) Suggest, with an explanation, a type of thermometer that would be likely to give a smaller value for the ratio calculated in **(a)(ii)**.

....

....

.... [2]

(c) The mercury-in-glass thermometer is used to measure the boiling point of a liquid. Suggest why the measured value of the boiling point will **not** be affected by the thermal energy absorbed by the thermometer bulb.

....

....

....

.... [2]

Q16.

For Examiner Use

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

....

....

.... [2]

(b) Some crushed ice at 0 °C is placed in a funnel together with an electric heater, as shown in Fig. 2.1.

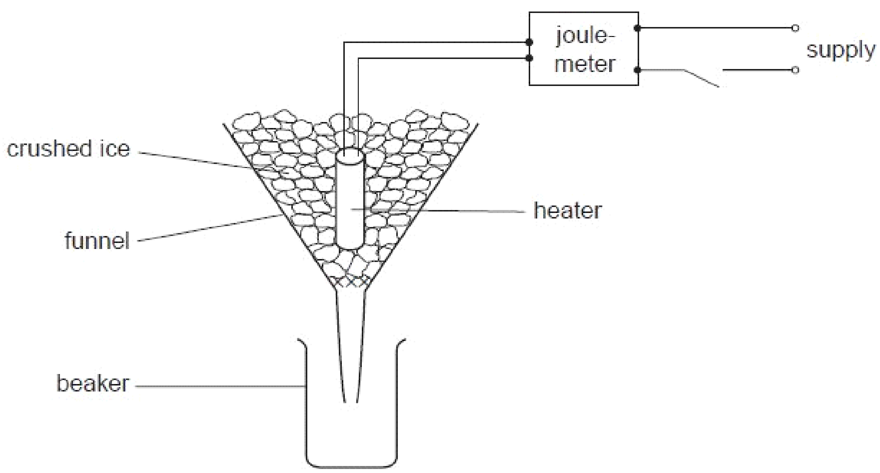


Fig. 2.1

The mass of water collected in the beaker in a measured interval of time is determined with the heater switched off. The mass is then found with the heater switched on. The energy supplied to the heater is also measured.
For both measurements of the mass, water is not collected until melting occurs at a constant rate.
The data shown in Fig. 2.2 are obtained.

	mass of water / g	energy supplied to heater / J	time interval / min
heater switched off	16.6	0	10.0
heater switched on	64.7	18000	5.0

Fig. 2.2

(i) State why the mass of water is determined with the heater switched off.

....

.... [1]

(ii) Suggest how it can be determined that the ice is melting at a constant rate.

For Examiner Use

....

.... [1]

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

latent heat = ... $kJ\ kg^{-1}$ [3]

Q17.

4 **(a)** Write down an equation to represent the first law of thermodynamics in terms of the heating q of a system, the work w done on the system and the increase ΔU in the internal energy.

.... [1]

(b) The pressure of an ideal gas is decreased at constant temperature.
Explain what change, if any, occurs in the internal energy of the gas.

....

....

....

.... [3]

For Examiner's Use

Q18.

3 **(a)** A student states, quite wrongly, that temperature measures the amount of thermal energy (heat) in a body.

State and explain two observations that show why this statement is incorrect.

1. ....

....

....

2. ....

....

....

[4]

For Examiner's Use

(b) A thermometer and an electrical heater are inserted into holes in an aluminium block of mass 960 g, as shown in Fig. 3.1.

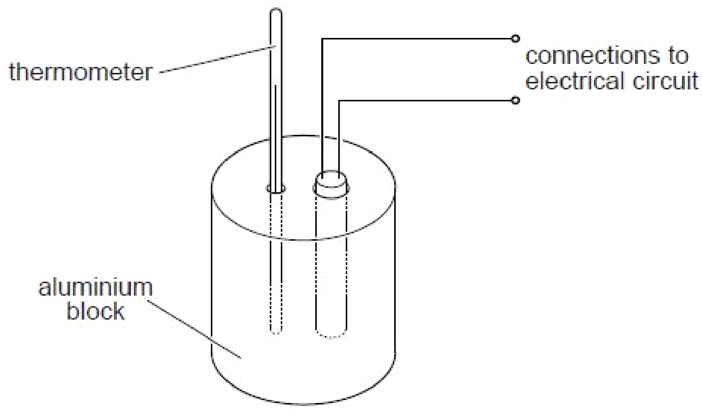


Fig. 3.1

The power rating of the heater is 54 W.

For Examiner's Use

The heater is switched on and readings of the temperature of the block are taken at regular time intervals. When the block reaches a constant temperature, the heater is switched off and then further temperature readings are taken. The variation with time t of the temperature θ of the block is shown in Fig. 3.2.

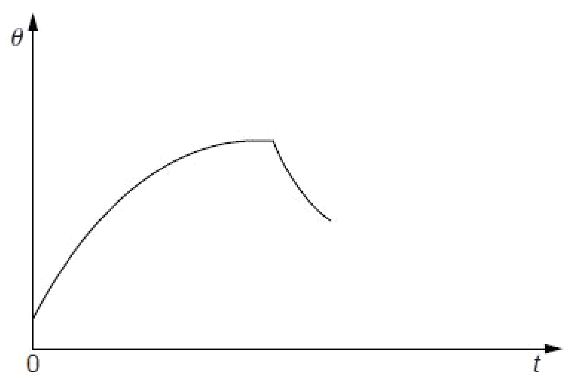


Fig. 3.2

(i) Suggest why the rate of rise of temperature of the block decreases to zero.

....

....

.... [2]

(ii) After the heater has been switched off, the maximum rate of fall of temperature is 3.7 K per minute.

Estimate the specific heat capacity of aluminium.

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

Q19.

2 (a) State what is meant by the *internal energy* of a gas.

For Examiner's Use

....

....

.... [2]

(b) The first law of thermodynamics may be represented by the equation

$$\Delta U = q + w.$$

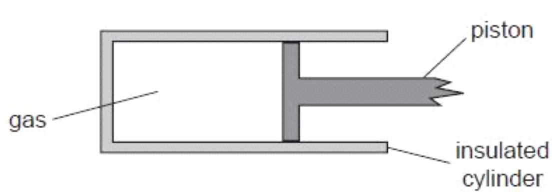
State what is meant by each of the following symbols.

$+\Delta U$ ....

$+q$ ....

$+w$ .... [3]

(c) An amount of 0.18 mol of an ideal gas is held in an insulated cylinder fitted with a piston, as shown in Fig. 2.1.



Atmospheric pressure is 1.0×10^5 Pa.

The volume of the gas is suddenly increased from $1.8 \times 10^3 \, cm^3$ to $2.1 \times 10^3 \, cm^3$.

For the expansion of the gas,

(i) calculate the work done by the gas and hence show that the internal energy changes by 30 J,

[3]

(ii) determine the temperature change of the gas and state whether the change is an increase or a decrease.

For Examiner's Use

change = ... K

....

[3]

Q20.

2 (a) A resistance thermometer and a thermocouple thermometer are both used at the same time to measure the temperature of a water bath.

For Examiner's Use

Explain why, although both thermometers have been calibrated correctly and are at equilibrium, they may record different temperatures.

....

....

.... [2]

(b) State

(i) in what way the absolute scale of temperature differs from other temperature scales,

....

.... [1]

(ii) what is meant by the absolute zero of temperature.

....

.... [1]

(c) The temperature of a water bath increases from 50.00 °C to 80.00 °C.
Determine, in kelvin and to an appropriate number of significant figures,

(i) the temperature 50.00 °C,

temperature = ... K [1]

(ii) the change in temperature of the water bath.

temperature change = ... K [1]

Q21.

3 **(a)** Two metal spheres are in thermal equilibrium.
State and explain what is meant by *thermal equilibrium*.

....

....

.... [2]

(b) An electric water heater contains a tube through which water flows at a constant rate. The water in the tube passes over a heating coil, as shown in Fig. 3.1.

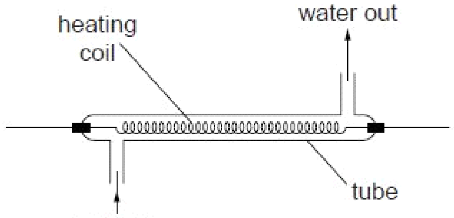


Fig. 3.1

The water flows into the tube at a temperature of 18 °C. When the power of the heater is 3.8 kW, the temperature of the water at the outlet is 42 °C.
The specific heat capacity of water is 4.2 J g^{-1} K^{-1}.

(i) Use the data to calculate the flow rate, in g s^{-1}, of water through the tube.

flow rate = ... g s^{-1} [3]

(ii) State and explain whether your answer in **(i)** is likely to be an overestimate or an underestimate of the flow rate.

....

....

.... [2]

Q22.

3 The volume of 1.00 kg of water in the liquid state at 100 °C is $1.00 \times 10^{-3}\,m^3$. The volume of 1.00 kg of water vapour at 100 °C and atmospheric pressure 1.01×10^5 Pa is $1.69\,m^3$.

(a) Show that the work done against the atmosphere when 1.00 kg of liquid water becomes water vapour is 1.71×10^5 J.

[2]

(b) **(i)** The first law of thermodynamics may be given by the expression

$$\Delta U = +q + w$$

where ΔU is the increase in internal energy of the system.

State what is meant by

1. $+q$,

.... [1]

2. $+w$.

.... [1]

(ii) The specific latent heat of vaporisation of water at 100 °C is $2.26 \times 10^6\,J\,kg^{-1}$.

A mass of 1.00 kg of liquid water becomes water vapour at 100 °C.

Determine, using your answer in **(a)**, the increase in internal energy of this mass of water during vaporisation.

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

Q23.

3 A microwave cooker uses electromagnetic waves of frequency 2450 MHz.
The microwaves warm the food in the cooker by causing water molecules in the food to oscillate with a large amplitude at the frequency of the microwaves.

(a) State the name given to this phenomenon.

.... [1]

(b) The effective microwave power of the cooker is 750 W.
The temperature of a mass of 280 g of water rises from 25 °C to 98 °C in a time of 2.0 minutes.

Calculate a value for the specific heat capacity of the water.

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

(c) The value of the specific heat capacity determined from the data in **(b)** is greater than the accepted value.
A student gives as the reason for this difference: 'heat lost to the surroundings'.

Suggest, in more detail than that given by the student, a possible reason for the difference.

....

.... [1]

Q24.

3 A fixed mass of gas has an initial volume of $5.00 \times 10^{-4}\,m^3$ at a pressure of $2.40 \times 10^5\,Pa$ and a temperature of 288 K. It is heated at constant pressure so that, in its final state, the volume is $14.5 \times 10^{-4}\,m^3$ at a temperature of 835 K, as illustrated in Fig. 3.1.

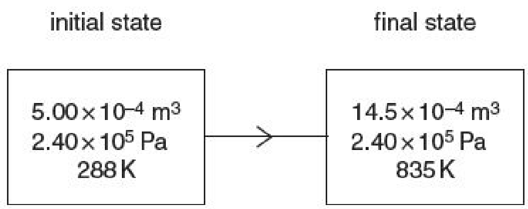


Fig. 3.1

(a) Show that these two states provide evidence that the gas behaves as an ideal gas.

[3]

(b) The total thermal energy supplied to the gas for this change is 569 J.

Determine

(i) the external work done,

work done = ... J [2]

(ii) the change in internal energy of the gas. State whether the change is an increase or a decrease in internal energy.

change in internal energy = ... J

.... [2]