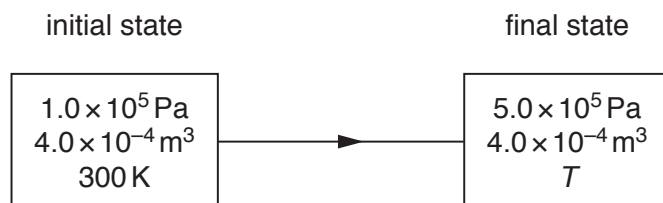


1. Question part 1/2 | 9702 Oct-Nov 2016 P4 V1 Q2

- 2 An ideal gas initially has pressure $1.0 \times 10^5 \text{ Pa}$, volume $4.0 \times 10^{-4} \text{ m}^3$ and temperature 300 K , as illustrated in Fig. 2.1.

**Fig. 2.1**

A change in energy of the gas of 240 J results in an increase of pressure to a final value of $5.0 \times 10^5 \text{ Pa}$ at constant volume.

The thermodynamic temperature becomes T .

(a) Calculate

- (i) the temperature T ,

$T = \dots\dots\dots \text{ K}$ [2]

- (ii) the amount of gas.

amount = $\dots\dots\dots \text{ mol}$ [2]

(b) The increase in internal energy ΔU of a system may be represented by the expression

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

(i) State what is meant by the symbol

1. $+q$,

.....
2. $+w$.

.....
- [2]

(ii) State, for the gas in **(a)**, the value of

1. ΔU ,

$\Delta U =$ J
2. $+q$,

$+q =$ J
3. $+w$.

$+w =$ J
- [3]

[Total: 9]

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

.....

.....

.....[2]

(b) Explain, by reference to work done and heating, whether the internal energy of the following increases, decreases or remains constant:

(i) the gas in a toy balloon when the balloon bursts suddenly,

.....

.....

.....

.....[3]

(ii) ice melting at constant temperature and at atmospheric pressure to form water that is more dense than the ice.

.....

.....

.....

.....[3]

[Total: 8]

3. Question part 1/2 | 9702 Feb-March 2017 P4 V2 Q2

2 (a) The first law of thermodynamics can be represented by the expression

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

State what is meant by the symbols in the expression.

+ ΔU

+ q

+ w

[2]

(b) A fixed mass of an ideal gas undergoes a cycle ABCA of changes, as shown in Fig. 2.1.

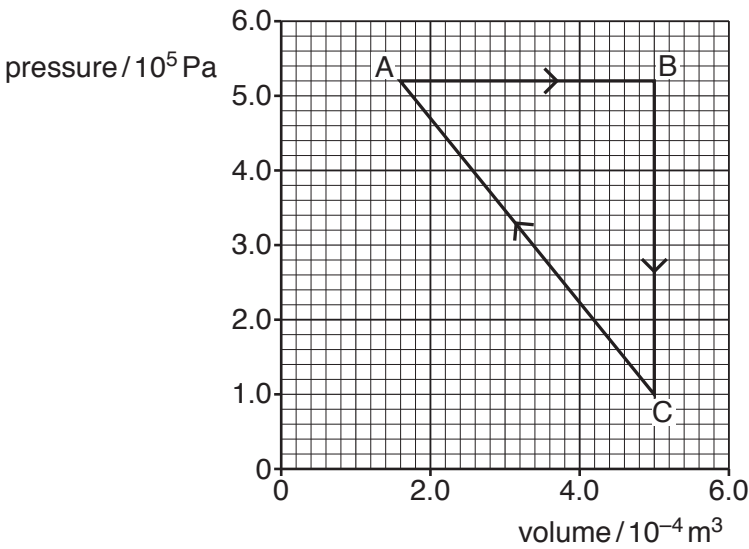


Fig. 2.1

(i) During the change from A to B, the energy supplied to the gas by heating is 442 J.

Use the first law of thermodynamics to show that the internal energy of the gas increases by 265 J.

[2]

(ii) During the change from B to C, the internal energy of the gas decreases by 313 J.

By considering molecular energy, state and explain qualitatively the change, if any, in the temperature of the gas.

.....

.....

.....

.....

.....[3]

(iii) For the change from C to A, use the data in (b)(i) and (b)(ii) to calculate the change in internal energy.

change in internal energy = ... J [1]

(iv) The temperature of the gas at point A is 227 °C. Calculate the number of molecules in the fixed mass of the gas.

number = ...[2]

[Total: 10]

4. Question part 1/2 | 9702 Oct-Nov 2017 P4 V2 Q2

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

.....

.....

.....[2]

(b) A beaker of boiling water is placed on the pan of a balance, as illustrated in Fig. 2.1.

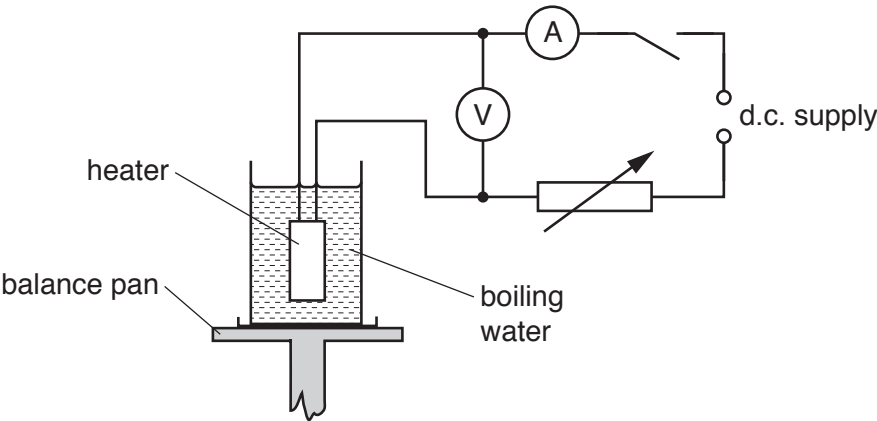


Fig. 2.1

The water is maintained at its boiling point by means of a heater.
The change M in the balance reading in 300 s is determined for two different input powers to the heater.
The results are shown in Fig. 2.2.

voltmeter reading / V	ammeter reading / A	M/g
11.5	5.2	5.0
14.2	6.4	9.1

Fig. 2.2

(i) Energy is supplied continuously by the heater.
State where, in this experiment,

1. external work is done,

.....

.....

2. internal energy increases. Explain your answer.

.....

.....

.....

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4. Question part 2/2 | 9702 Oct-Nov 2017 P4 V2 Q2

(ii) Use data in Fig. 2.2 to determine the specific latent heat of vaporisation of water.

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

[Total: 8]

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

.....

.....

.....

.....[2]

(ii) Explain why, for an ideal gas, the change in internal energy is directly proportional to the change in thermodynamic temperature of the gas.

.....

.....

.....

.....

.....[3]

(b) A cylinder of volume $1.8 \times 10^4\text{cm}^3$ contains helium gas at pressure $6.4 \times 10^6\text{Pa}$ and temperature 25°C .
Helium gas may be considered to be an ideal gas consisting of single atoms.

Calculate the number of helium atoms in the cylinder.

number = ...[3]

[Total: 8]

6. Question part 1/2 | 9702 May-June 2018 P4 V1 Q12

- 12** An X-ray beam is used to produce an image of a model of a thumb.
A parallel beam of X-ray radiation of intensity I_0 is incident on the model, as illustrated in Fig. 12.1.

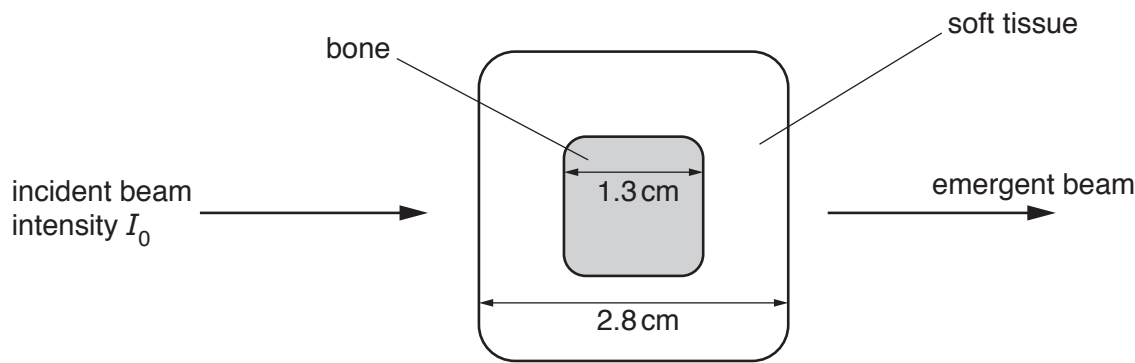


Fig. 12.1

Data for the attenuation (absorption) coefficient μ in bone and in soft tissue are shown in Fig. 12.2.

	μ/cm^{-1}
bone	3.0
soft tissue	0.90

Fig. 12.2

- (a) Calculate, in terms of the incident intensity I_0 of the X-ray beam, the intensity of the beam after passing through
- (i) a thickness of 2.8 cm of soft tissue,

intensity = ... I_0 [2]

(ii) the bone and soft tissue, as shown in Fig. 12.1.

intensity = ... I_0 [2]

(b) (i) State what is meant by the *contrast* of an X-ray image.

.....

.....

.....[2]

(ii) By reference to your answers in (a), suggest whether the X-ray image of the model has good contrast.

.....

.....

.....[1]

[Total: 7]

3 (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.

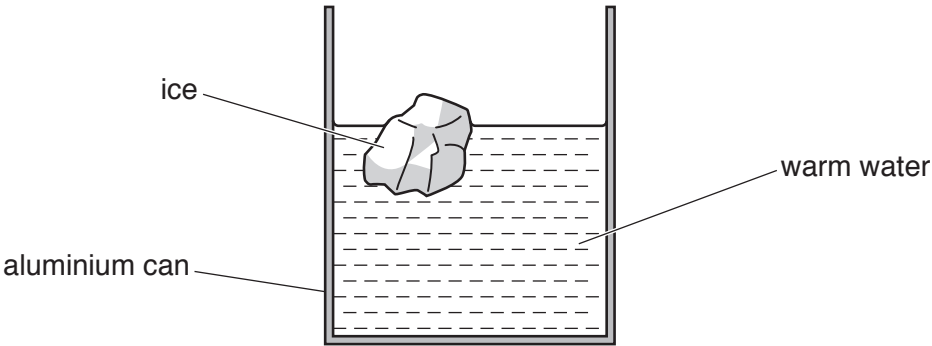


Fig. 3.1

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.

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

Fig. 3.2

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7. Question part 2/2 | 9702 May-June 2018 P4 V2 Q3

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 $2.3 \times 10^4 \text{ J}$,

[2]

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

$L = \dots\dots\dots \text{ J g}^{-1}$ [2]

[Total: 7]

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

.....

.....

.....

.....[2]

- (b) An ideal gas undergoes a cycle of changes as shown in Fig. 2.1.

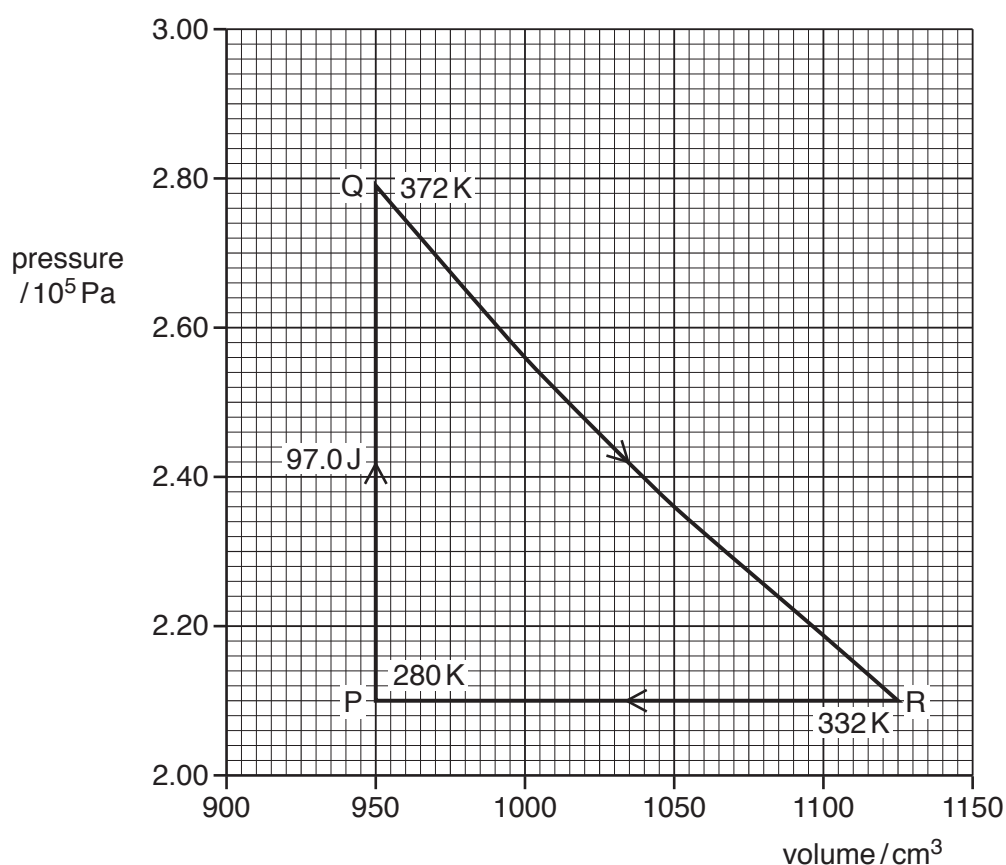


Fig. 2.1

At point P, the gas has volume 950 cm^3 , pressure $2.10 \times 10^5 \text{ Pa}$ and temperature 280 K .

The gas is heated at constant volume and 97.0 J of thermal energy is transferred to the gas. Its pressure and temperature change so that the gas is at point Q on Fig. 2.1.

The gas then undergoes the change from point Q to point R and then from point R back to point P, as shown on Fig. 2.1.

Some energy changes that take place during the cycle PQRP are shown in Fig. 2.2.

	change $P \rightarrow Q$	change $Q \rightarrow R$	change $R \rightarrow P$
thermal energy transferred to gas/J	+97.0	0	.....
work done on gas/J	.....	-42.5	+37.0
increase in internal energy of gas/J	.....	.....	.....

Fig. 2.2

(i) State the total change in internal energy of the gas during the complete cycle PQRP. Explain your answer.

.....
.....
.....[2]

(ii) On Fig. 2.2, complete the energy changes for the gas during

- 1. the change $P \rightarrow Q$,
- 2. the change $Q \rightarrow R$,
- 3. the change $R \rightarrow P$.

[5]

[Total: 9]

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

.....

.....

.....

.....[2]

- (b) An ideal gas undergoes a cycle of changes as shown in Fig. 2.1.

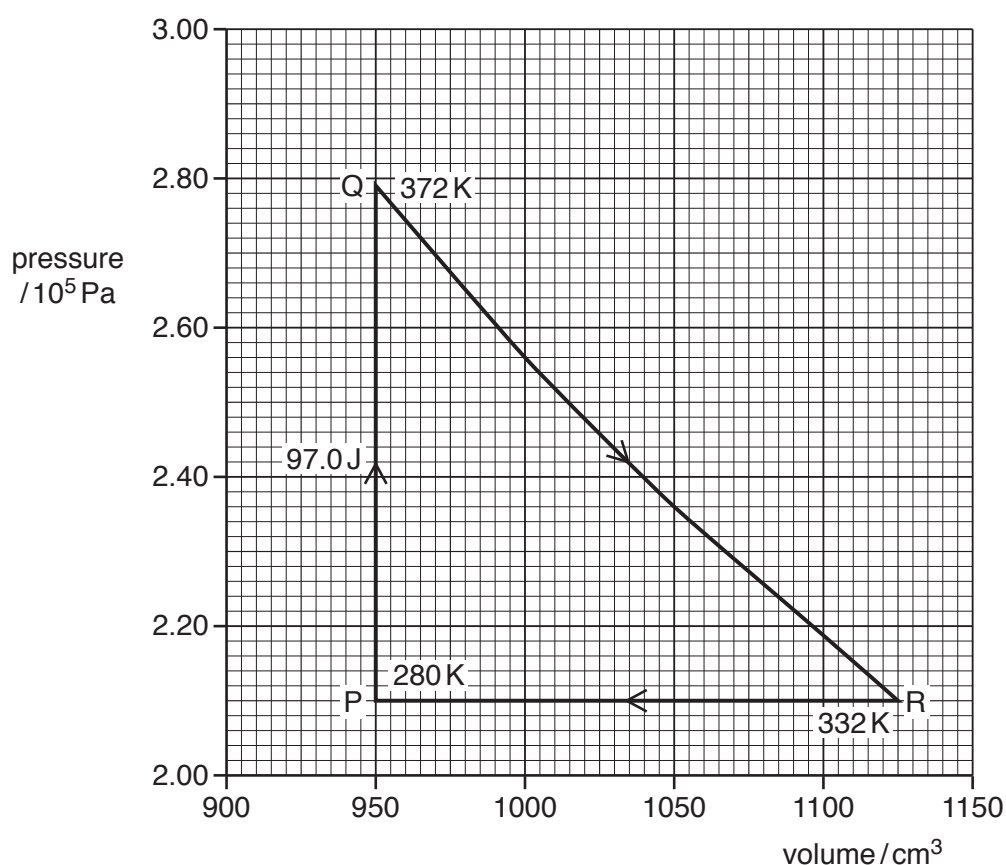


Fig. 2.1

At point P, the gas has volume 950 cm^3 , pressure $2.10 \times 10^5 \text{ Pa}$ and temperature 280 K .

The gas is heated at constant volume and 97.0 J of thermal energy is transferred to the gas. Its pressure and temperature change so that the gas is at point Q on Fig. 2.1.

The gas then undergoes the change from point Q to point R and then from point R back to point P, as shown on Fig. 2.1.

Some energy changes that take place during the cycle PQRP are shown in Fig. 2.2.

	change $P \rightarrow Q$	change $Q \rightarrow R$	change $R \rightarrow P$
thermal energy transferred to gas/J	+97.0	0	.....
work done on gas/J	.....	-42.5	+37.0
increase in internal energy of gas/J	.....	.....	.....

Fig. 2.2

(i) State the total change in internal energy of the gas during the complete cycle PQRP. Explain your answer.

.....

.....

.....[2]

(ii) On Fig. 2.2, complete the energy changes for the gas during

- 1. the change $P \rightarrow Q$,
- 2. the change $Q \rightarrow R$,
- 3. the change $R \rightarrow P$.

[5]

[Total: 9]

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10. Question part 1/3 | 9702 May-June 2019 P4 V2 Q2

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

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

- (i)** State, for a system, what is meant by:

1. $+q$

.....
.....

2. $+w$.

.....
.....

[2]

- (ii)** State what is represented by a negative value of ΔU .

.....
.....

[1]

(b) An ideal gas, sealed in a container, undergoes the cycle of changes shown in Fig. 2.1.

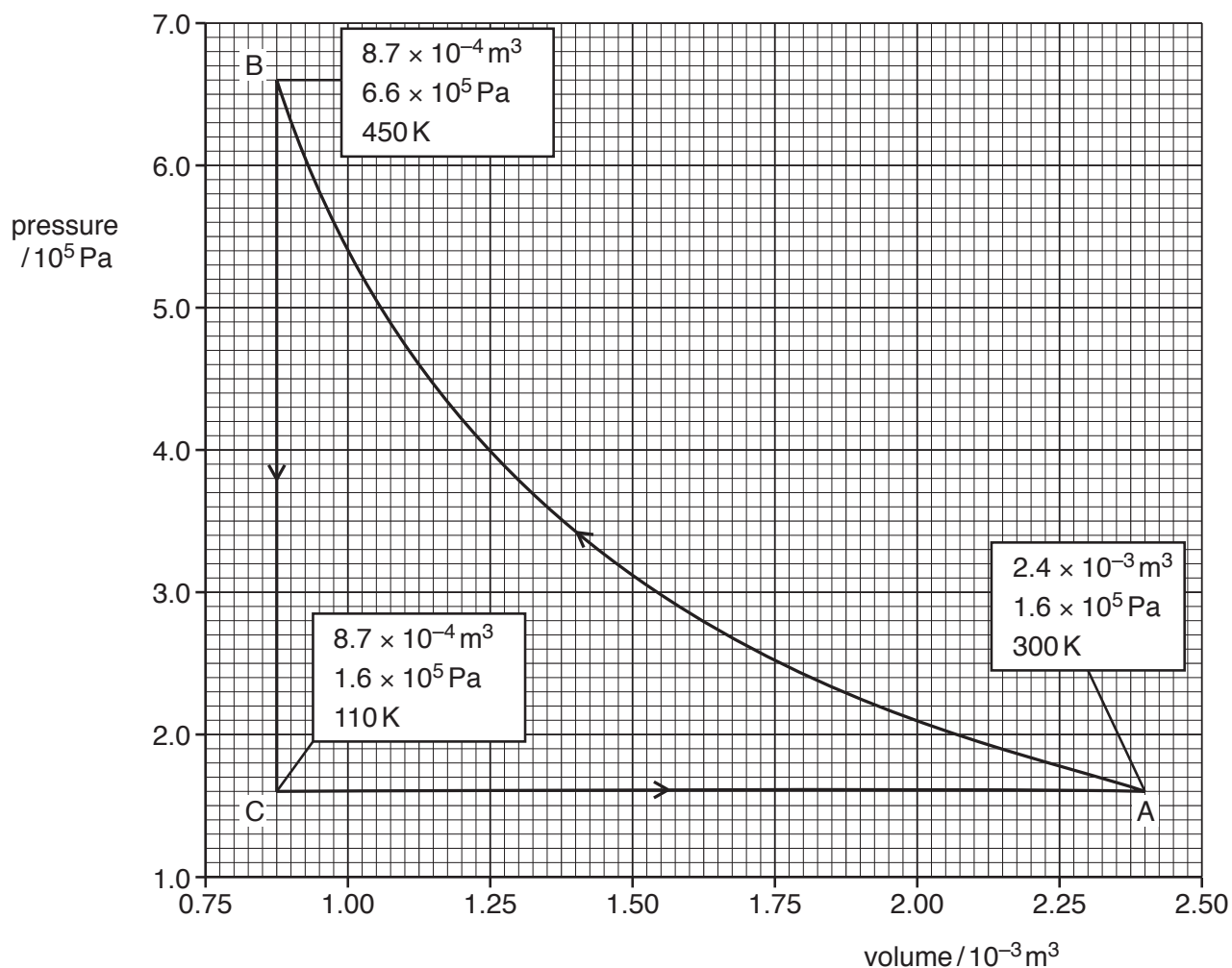


Fig. 2.1

At point A, the gas has volume $2.4 \times 10^{-3} \text{ m}^3$, pressure $1.6 \times 10^5 \text{ Pa}$ and temperature 300 K .

The gas is compressed suddenly so that no thermal energy enters or leaves the gas during the compression. The amount of work done is 480 J so that, at point B, the gas has volume $8.7 \times 10^{-4} \text{ m}^3$, pressure $6.6 \times 10^5 \text{ Pa}$ and temperature 450 K .

The gas is now cooled at constant volume so that, between points B and C, 1100 J of thermal energy is transferred. At point C, the gas has pressure $1.6 \times 10^5 \text{ Pa}$ and temperature 110 K .

Finally, the gas is returned to point A.

10. Question part 3/3 | 9702 May-June 2019 P4 V2 Q2

- (i) State and explain the total change in internal energy of the gas for one complete cycle ABCA.

.....
.....
.....[2]

- (ii) Calculate the external work done on the gas during the expansion from point C to point A.

work done = ... J [2]

- (iii) Complete Fig. 2.2 for the changes from:

- 1. point A to point B
- 2. point B to point C
- 3. point C to point A.

change	+q/J	+w/J	$\Delta U/J$
A → B			
B → C			
C → A			

Fig. 2.2

[4]

[Total: 11]

11. Question part 1/3 | 9702 Oct-Nov 2019 P4 V3 Q3

3 (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.

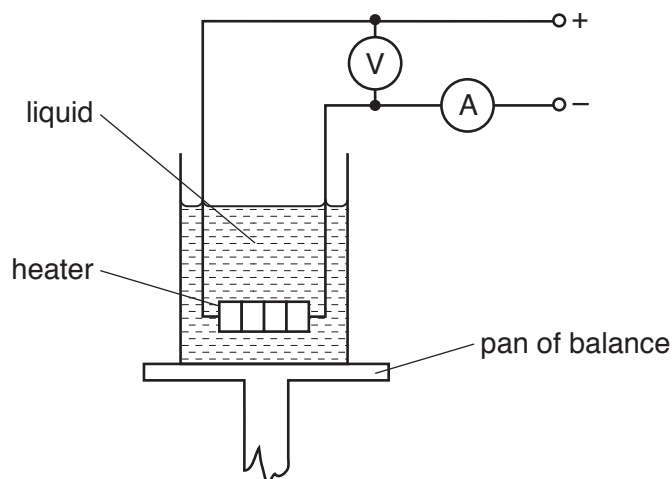


Fig. 3.1

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	1.2	230
after time 10 minutes	1.0	190

Fig. 3.2

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

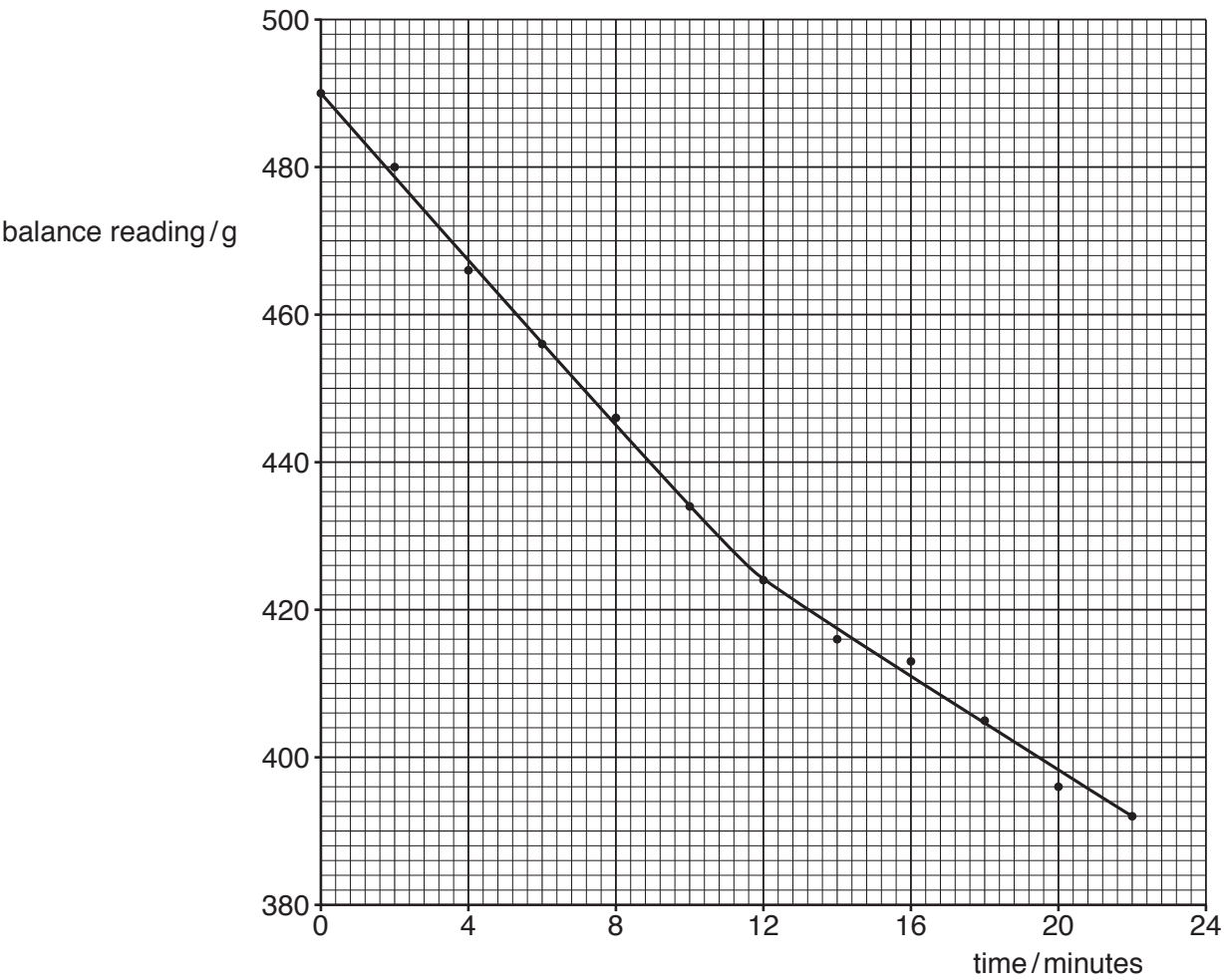


Fig. 3.3

11. Question part 3/3 | 9702 Oct-Nov 2019 P4 V3 Q3

- (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.

$L = \dots\dots\dots \text{Jg}^{-1}$ [4]

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

rate = ... W [2]

[Total: 10]

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

.....

.....

.....

..... [2]

(b) By reference to intermolecular forces, explain why the change in internal energy of an ideal gas is equal to the change in total kinetic energy of its molecules.

.....

.....

..... [2]

(c) State and explain the change, if any, in the internal energy of a solid metal ball as it falls under gravity in a vacuum.

.....

.....

.....

..... [3]

[Total: 7]

13. Question | 9702 May-June 2020 P4 V2 Q3

3 By reference to the first law of thermodynamics, state and explain the change, if any, in the internal energy of:

(a) a lump of solid lead as it melts at constant temperature

.....

.....

.....

.....

..... [3]

(b) some gas in a toy balloon when the balloon bursts and no thermal energy enters or leaves the gas.

.....

.....

.....

.....

..... [3]

[Total: 6]

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

.....

.....

.....

..... [2]

(b) By reference to intermolecular forces, explain why the change in internal energy of an ideal gas is equal to the change in total kinetic energy of its molecules.

.....

.....

..... [2]

(c) State and explain the change, if any, in the internal energy of a solid metal ball as it falls under gravity in a vacuum.

.....

.....

.....

..... [3]

[Total: 7]

15. Question part 1/2 | 9702 Oct-Nov 2020 P4 V1 Q2

- 2 (a) The first law of thermodynamics may be expressed as

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

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

State the meaning of:

$+q$

.....

$+w$

.....

[2]

- (b) The variation with pressure p of the volume V of a fixed mass of an ideal gas is shown in Fig. 2.1.

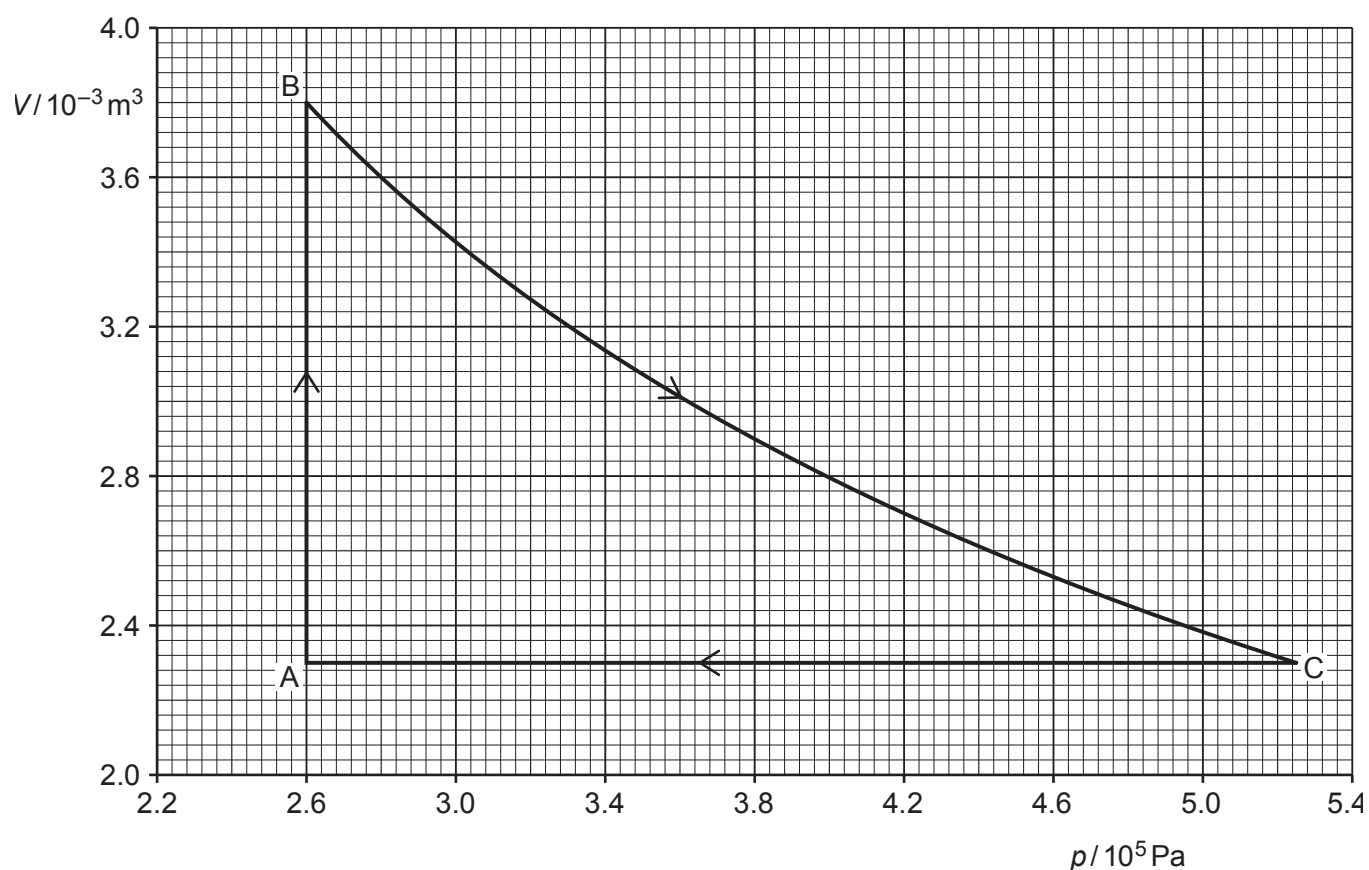


Fig. 2.1

The gas undergoes a cycle of changes A to B to C to A.

During the change A to B, the volume of the gas increases from $2.3 \times 10^{-3} \text{ m}^3$ to $3.8 \times 10^{-3} \text{ m}^3$.

(i) Show that the magnitude of the work done during the change A to B is 390 J.

[1]

(ii) State and explain the total change, if any, in the internal energy of the gas during one complete cycle.

.....

.....

..... [2]

(c) During the change A to B, 1370 J of thermal energy is transferred to the gas.

During the change B to C, no thermal energy enters or leaves the gas. The work done on the gas during this change is 550 J.

Use these data and the information in (b) to complete Table 2.1.

Table 2.1

change	q/J	w/J	$\Delta U/\text{J}$
A to B			
B to C			
C to A			

[4]

[Total: 9]

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

.....

 [2]

- (b) The atoms of an ideal gas occupy a container of volume $2.30 \times 10^{-3} \text{ m}^3$ at pressure $2.60 \times 10^5 \text{ Pa}$ and temperature 180 K , as illustrated in Fig. 2.1.

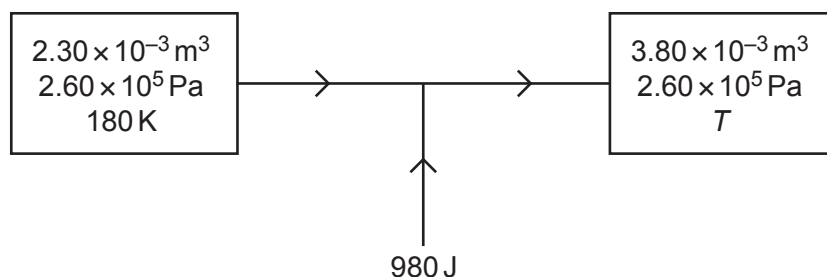


Fig. 2.1

The gas is heated at constant pressure so that its volume becomes $3.80 \times 10^{-3} \text{ m}^3$ at a temperature T .

For the fixed mass of gas, calculate:

- (i) the amount of substance, in mol

amount = ... mol [2]

- (ii) the temperature T , in K.

$T = \dots\dots\dots \text{ K}$ [2]

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16. Question part 2/2 | 9702 Oct-Nov 2020 P4 V2 Q2

(c) During the change in (b), the thermal energy supplied to the gas is 980 J.

(i) Determine the work done on the gas during this change. Explain your working.

work done = ... J [3]

(ii) Determine the change ΔU in internal energy of the gas.

$\Delta U =$ J [1]

[Total: 10]

- 2 (a) The first law of thermodynamics may be expressed as

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

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

State the meaning of:

$+q$

.....

$+w$

.....

[2]

- (b) The variation with pressure p of the volume V of a fixed mass of an ideal gas is shown in Fig. 2.1.

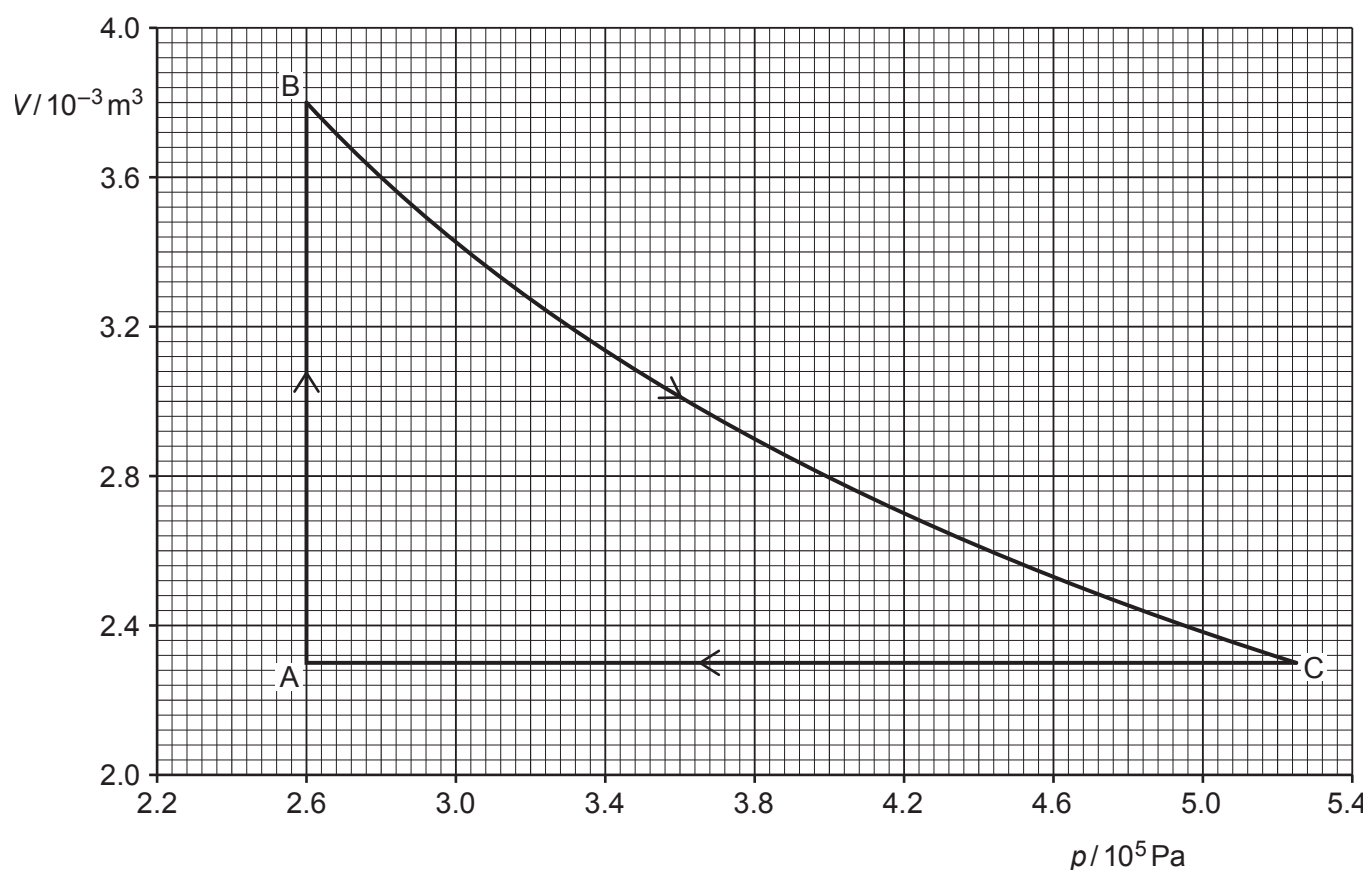


Fig. 2.1

The gas undergoes a cycle of changes A to B to C to A.

During the change A to B, the volume of the gas increases from $2.3 \times 10^{-3} \text{ m}^3$ to $3.8 \times 10^{-3} \text{ m}^3$.

(i) Show that the magnitude of the work done during the change A to B is 390 J.

[1]

(ii) State and explain the total change, if any, in the internal energy of the gas during one complete cycle.

.....

.....

..... [2]

(c) During the change A to B, 1370 J of thermal energy is transferred to the gas.

During the change B to C, no thermal energy enters or leaves the gas. The work done on the gas during this change is 550 J.

Use these data and the information in (b) to complete Table 2.1.

Table 2.1

change	q/J	w/J	$\Delta U/\text{J}$
A to B			
B to C			
C to A			

[4]

[Total: 9]

3 (a) Define *specific heat capacity*.

.....
.....
..... [2]

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

(i) State an expression, in terms of V , N , p and the Boltzmann constant k , for the thermodynamic temperature T of the gas.

..... [1]

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

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

[2]

(iii) Explain why the internal energy of the gas is equal to the total kinetic energy of the molecules.

.....
.....
..... [2]

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

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

.....
.....
..... [2]

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

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

[2]

- (d) The container in (b) is now replaced with one that does not have a fixed volume. Instead, the gas is able to expand, so that the pressure of the gas remains constant as thermal energy is supplied.

Suggest, with a reason, how the specific heat capacity of the gas would now compare with the value in (c)(ii).

.....

.....

.....

..... [2]

[Total: 13]

3 (a) Define *specific heat capacity*.

.....
.....
..... [2]

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

(i) State an expression, in terms of V , N , p and the Boltzmann constant k , for the thermodynamic temperature T of the gas.

..... [1]

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

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

[2]

(iii) Explain why the internal energy of the gas is equal to the total kinetic energy of the molecules.

.....
.....
..... [2]

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

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

.....
.....
..... [2]

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

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

[2]

(d) The container in (b) is now replaced with one that does not have a fixed volume. Instead, the gas is able to expand, so that the pressure of the gas remains constant as thermal energy is supplied.

Suggest, with a reason, how the specific heat capacity of the gas would now compare with the value in (c)(ii).

.....

.....

.....

..... [2]

[Total: 13]

2 A fixed mass of an ideal gas has a volume V and a pressure p .

The gas undergoes a cycle of changes, X to Y to Z to X, as shown in Fig. 2.1.

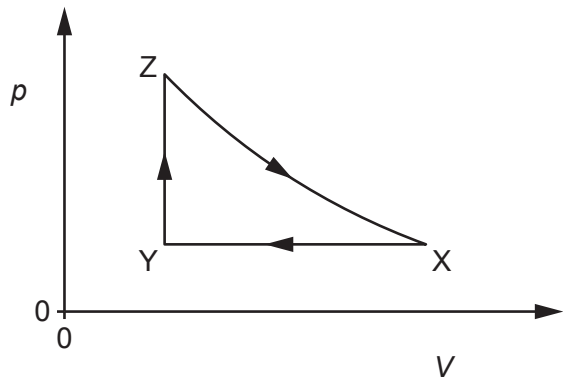


Fig. 2.1

Table 2.1 shows data for p , V and temperature T for the gas at points X, Y and Z.

Table 2.1

	$p/10^5\text{ Pa}$	$V/10^{-3}\text{ m}^3$	T/K
X	1.5	4.2	540
Y			230
Z	5.1		782

(a) State the change in internal energy ΔU for one complete cycle, XYZX.

$\Delta U = \dots\dots\dots \text{ J [1]}$

(b) Calculate the amount n of gas.

$n = \dots\dots\dots \text{ mol [2]}$

- (c) Complete Table 2.1.
Use the space below for any working.

[2]

- (d) (i) The first law of thermodynamics for a system may be represented by the equation

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

State, with reference to the system, what is meant by:

- ΔU :
 q :
 W : [3]

- (ii) Explain how the first law of thermodynamics applies to the change Z to X.

.....
.....
.....
..... [2]

[Total: 10]

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21. Question part 1/2 | 9702 May-June 2022 P4 V2 Q3

- 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 $2.3 \times 10^6 \text{ J kg}^{-1}$. A mass of 0.37 kg of liquid water at 100°C is provided with the thermal energy needed to vaporise all of the water at atmospheric pressure.

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

$q = \dots\dots\dots \text{ J}$ [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 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 = $\dots\dots\dots \text{ J}$ [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]

2 (a) Define specific heat capacity.

.....

.....

..... [2]

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

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

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

Use the first law of thermodynamics to complete Table 2.1 for this process.

Table 2.1

work done on water	thermal energy supplied to water	increase in internal energy of water
	+ E	

[2]

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

Use the first law of thermodynamics to complete Table 2.2 for this process.

Table 2.2

work done on water	thermal energy supplied to water	increase in internal energy of water

[2]

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

.....

..... [1]

[Total: 7]

3 (a) State the first law of thermodynamics. Identify the meaning of any symbols that you use.

.....

.....

..... [2]

(b) The state of an ideal gas is continuously changed according to the cycle ABCDA shown in Fig. 3.1.

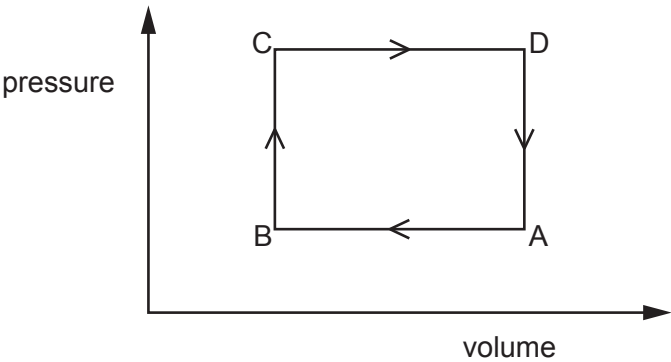


Fig. 3.1

(i) Complete Table 3.1 for the changes A to B and B to C by placing two ticks (✓) in each row.

Table 3.1

change	change in internal energy			work done on gas		
	decrease	no change	increase	negative	zero	positive
A to B						
B to C						

[4]

(ii) Use the first law of thermodynamics to describe and explain the energy transfers associated with one complete cycle ABCDA.

.....

.....

.....

.....

..... [3]

[Total: 9]

2 (a) Define specific heat capacity.

.....

.....

..... [2]

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

(i) Show that the magnitude of the work done on the gas is 5000J.

[1]

(ii) Explain whether the work done on the gas is positive or negative.

.....

.....

..... [2]

(iii) Determine the magnitude of the thermal energy q transferred to the gas.

$q = \dots\dots\dots \text{ J [2]}$

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

specific heat capacity = $\dots\dots\dots$ unit $\dots\dots\dots$ [2]

- (c) The gas in (b) is now heated at constant volume rather than at constant pressure. The increase in internal energy of the gas is the same as in (b).

Use the first law of thermodynamics to explain whether the specific heat capacity of the gas for this process is less than, the same as, or greater than the answer in (b)(iv).

.....

.....

.....

.....

..... [3]

[Total: 12]

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

.....

.....

..... [2]

(b) Use the first law of thermodynamics to explain what happens to the internal energy:

(i) of a spring when it is stretched at constant temperature within its elastic limit

.....

.....

.....

.....

..... [3]

(ii) of a sample of water when it evaporates from a rain puddle on a hot day.

.....

.....

.....

.....

..... [3]

[Total: 8]

2 (a) Define specific heat capacity.

.....

.....

..... [2]

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

(i) Show that the magnitude of the work done on the gas is 5000J.

[1]

(ii) Explain whether the work done on the gas is positive or negative.

.....

.....

..... [2]

(iii) Determine the magnitude of the thermal energy q transferred to the gas.

$q = \dots\dots\dots \text{ J [2]}$

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

specific heat capacity = $\dots\dots\dots$ unit $\dots\dots\dots$ [2]

- (c) The gas in (b) is now heated at constant volume rather than at constant pressure. The increase in internal energy of the gas is the same as in (b).

Use the first law of thermodynamics to explain whether the specific heat capacity of the gas for this process is less than, the same as, or greater than the answer in (b)(iv).

.....

.....

.....

.....

..... [3]

[Total: 12]

2 (a) By referring to both kinetic energy and potential energy, explain what is meant by the internal energy of an ideal gas.

.....

.....

.....

..... [2]

(b) A fixed mass of an ideal gas at a temperature of 20 °C is sealed in a cylinder by a piston, as shown in Fig. 2.1.

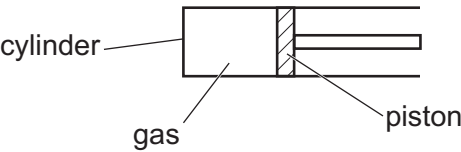


Fig. 2.1

The initial volume of the gas is $1.24 \times 10^{-4} \text{ m}^3$.
Thermal energy is supplied to the gas and its volume increases by $5.20 \times 10^{-5} \text{ m}^3$.

(i) The piston is freely moving so that the gas is always at atmospheric pressure.
Atmospheric pressure is $1.01 \times 10^5 \text{ Pa}$.
Calculate the work done by the gas.

work done by gas = ... J [2]

(ii) Calculate the final thermodynamic temperature T of the gas.

$T = \dots\dots\dots$ K [2]

(iii) The mass of the gas is 16 g. For this expansion, there is a net transfer of 960 J of thermal energy to the gas.

Calculate the specific heat capacity c of the gas at this pressure.

$c = \dots\dots\dots$ J kg⁻¹ K⁻¹ [2]

(c) The gas in (b) is allowed to return to its starting temperature. The piston is now fixed in position.

Thermal energy is supplied to increase the temperature to the same final temperature as in (b).

Use the first law of thermodynamics to suggest and explain how the specific heat capacity of the gas for this situation compares with the value in (b)(iii).

.....
.....
.....
..... [3]

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

.....

.....

..... [2]

(b) With reference to molecular kinetic and potential energies, describe and explain how the internal energy of the system changes when:

(i) a gas is heated at constant volume so that its temperature increases

.....

.....

.....

.....

..... [3]

(ii) a wire is stretched within its elastic limit at constant temperature.

.....

.....

.....

.....

..... [3]

[Total: 8]

3 (a) Define specific latent heat.

.....

.....

..... [2]

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

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

(i) Show that the magnitude of the work done on the substance when it vaporises is 1.7 kJ .

[2]

(ii) Use the information in (b)(i) to calculate the thermal energy Q , in kJ , supplied to the substance to cause it to vaporise.

$Q = \dots\dots\dots \text{ kJ} \quad [2]$

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

$L_V = \dots\dots\dots \text{ kJ kg}^{-1} \quad [2]$

29. Question part 2/2 | 9702 Oct-Nov 2024 P4 V2 Q3



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

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

.....

.....

.....

.....

..... [3]

[Total: 11]

30. Question | 9702 May-June 2025 P4 V1 Q4

4 (a) (i) State what is meant by the internal energy of a system.

.....

.....

..... [2]

(ii) Explain why the internal energy of an ideal gas is directly proportional to the thermodynamic temperature of the gas.

.....

.....

.....

..... [2]

(b) A sample of an ideal gas at thermodynamic temperature T has internal energy U .

The gas is compressed so that its temperature increases to $3T$.
During this compression, work W is done on the gas.

The gas is then cooled at constant volume so that its temperature decreases to $2T$.

Complete Table 4.1 to show, in terms of some or all of W , T and U , the work done on the gas, the thermal energy supplied to the gas and the increase in internal energy of the gas for each of the two processes.

Table 4.1

	work done on gas	thermal energy supplied to gas	increase in internal energy of gas
compression	$+W$		
cooling			

[4]

[Total: 8]

31. Question part 1/2 | 9702 May-June 2025 P4 V2 Q3

3 (a) Define specific heat capacity.

.....

.....

..... [2]

(b) A block of aluminium has a volume of $3.612 \times 10^{-3} \text{ m}^3$ at a temperature of 0°C .

Aluminium has a density of $2.700 \times 10^3 \text{ kg m}^{-3}$ at 0°C .
It has a density of $2.620 \times 10^3 \text{ kg m}^{-3}$ at 500°C .

The block is heated so that its temperature increases from 0°C to 500°C at an atmospheric pressure of $1.01 \times 10^5 \text{ Pa}$.
The increase in internal energy of the block is 4.38 MJ .

(i) Calculate the mass of the block.

mass = ... kg [2]

(ii) Show that the volume of the block at a temperature of 500°C is $3.722 \times 10^{-3} \text{ m}^3$.

[1]

(iii) Use the information in (b)(ii) to determine the magnitude of the work done on the block when its temperature is raised from 0°C to 500°C .

work done = ... J [2]

31. Question part 2/2 | 9702 May-June 2025 P4 V2 Q3



(iv) Explain whether the work done on the block is positive or negative.

.....

.....

..... [2]

(v) Use the first law of thermodynamics to determine, to three significant figures, a value for the specific heat capacity of aluminium. Explain your reasoning. Give a unit with your answer.

specific heat capacity = ... unit [3]

(c) Without further calculation, suggest with a reason how doubling the pressure in (b) is likely to affect the answer in (b)(v).

.....

.....

..... [1]

[Total: 13]

32. Question | 9702 May-June 2025 P4 V3 Q4

4 (a) (i) State what is meant by the internal energy of a system.

.....

.....

..... [2]

(ii) Explain why the internal energy of an ideal gas is directly proportional to the thermodynamic temperature of the gas.

.....

.....

.....

..... [2]

(b) A sample of an ideal gas at thermodynamic temperature T has internal energy U .

The gas is compressed so that its temperature increases to $3T$.
During this compression, work W is done on the gas.

The gas is then cooled at constant volume so that its temperature decreases to $2T$.

Complete Table 4.1 to show, in terms of some or all of W , T and U , the work done on the gas, the thermal energy supplied to the gas and the increase in internal energy of the gas for each of the two processes.

Table 4.1

	work done on gas	thermal energy supplied to gas	increase in internal energy of gas
compression	$+W$		
cooling			

[4]

[Total: 8]

33. Question | 9702 Oct-Nov 2025 P4 V1 Q2

2 (a) State **two** ways in which the first law of thermodynamics describes that the internal energy of a system may be changed.

1

.....

2

.....

[2]

(b) (i) Use the first law of thermodynamics to explain why a bicycle pump gets hot when it is used to pump up a tyre quickly.

.....

.....

.....

.....

..... [3]

(ii) With reference to molecular energies, explain why the temperature of water remains at 100 °C when it vaporises in a kettle, even though it is being heated.

.....

.....

.....

.....

..... [3]

[Total: 8]

34. Question part 1/2 | 9702 Oct-Nov 2025 P4 V2 Q4

4 A cylinder contains a fixed mass of an ideal gas at pressure $2Y$ and volume $6X$.

The gas undergoes a sequence of changes from its initial state A, through states B, C and D, then finally back to its initial state A, as shown in Fig. 4.1.

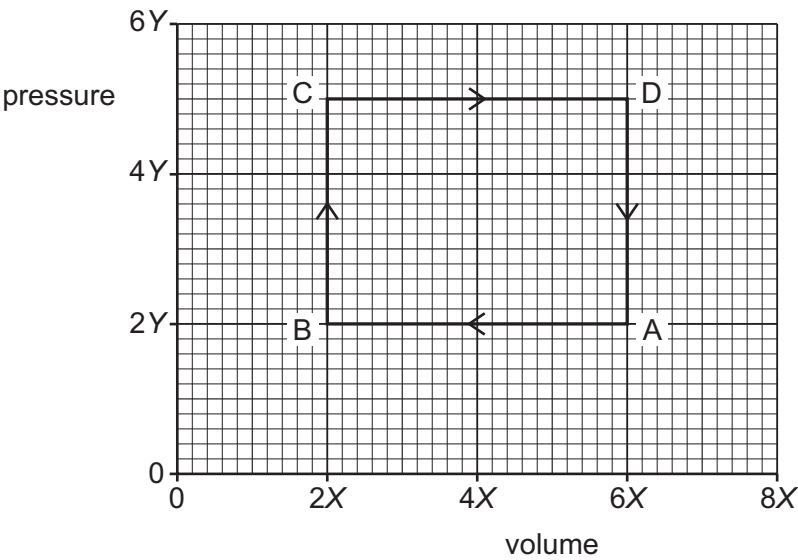


Fig. 4.1

Fig. 4.2 shows the variation with time of the internal energy of the gas.

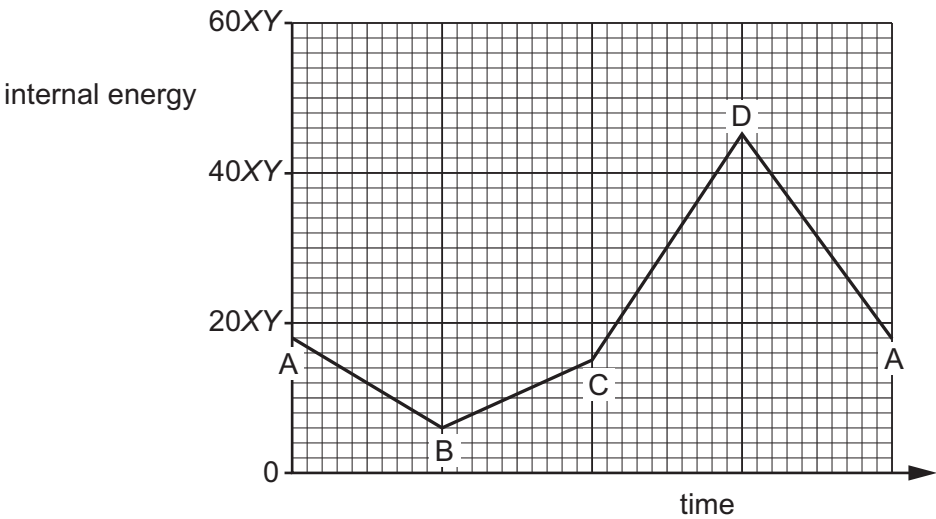


Fig. 4.2

(a) State the first law of thermodynamics.

.....
.....
..... [2]

34. Question part 2/2 | 9702 Oct-Nov 2025 P4 V2 Q4



- (b) (i)** Use Fig. 4.1 and Fig. 4.2 to determine the general expression for the internal energy U of the gas when it has pressure p and volume V .

$$U = \dots\dots\dots [1]$$

- (ii)** An ideal gas at thermodynamic temperature T contains N molecules.

Use your answer in **(b)(i)** and the equation of state for an ideal gas to deduce an expression for U in terms of N and T . Identify any other symbols you use.

$$U = \dots\dots\dots [2]$$

- (c)** Determine expressions, in terms of X and Y , for the work W done on the gas during:

- (i)** change AB

$$W = \dots\dots\dots [1]$$

- (ii)** change CD.

$$W = \dots\dots\dots [1]$$

- (d)** Use your answers in **(c)** and the first law of thermodynamics to determine an expression, in terms of X and Y , for the net thermal energy Q supplied to the gas during one full cycle ABCDA. Explain your reasoning.

$$Q = \dots\dots\dots [3]$$

[Total: 10]

35. Question | 9702 Oct-Nov 2025 P4 V3 Q2

2 (a) State **two** ways in which the first law of thermodynamics describes that the internal energy of a system may be changed.

1

.....

2

.....

[2]

(b) (i) Use the first law of thermodynamics to explain why a bicycle pump gets hot when it is used to pump up a tyre quickly.

.....

.....

.....

.....

..... [3]

(ii) With reference to molecular energies, explain why the temperature of water remains at 100 °C when it vaporises in a kettle, even though it is being heated.

.....

.....

.....

.....

..... [3]

[Total: 8]

36. Question part 1/2 | 9702 Oct-Nov 2025 P4 V4 Q3

- 3 (a) With reference to molecular kinetic energy and molecular potential energy, explain what is meant by the internal energy of an ideal gas.

.....

.....

..... [2]

- (b) A sample of an ideal gas is initially in state A, at a pressure of $2.0 \times 10^5 \text{ Pa}$ and with a volume of 0.016 m^3 , as shown in Fig. 3.1.

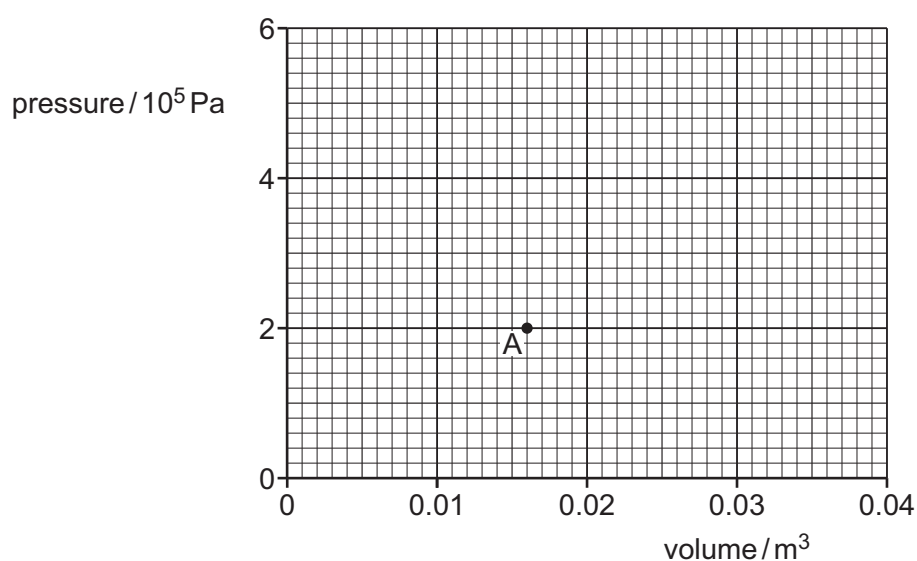


Fig. 3.1

In state A, the temperature of the gas is 400 K.

The gas undergoes two successive changes X and Y.

In change X, it is heated at constant volume to a pressure of $4.0 \times 10^5 \text{ Pa}$. At the end of change X, the gas is in state B.

In change Y, it is then allowed to expand at constant temperature back to its original pressure. At the end of change Y, the gas is in state C.

9702 Physics Paper 4 - Thermodynamics

Topical questions | 36 questions

36. Question part 2/2 | 9702 Oct-Nov 2025 P4 V4 Q3



- (i) Determine the internal energy of the gas in state A.

internal energy = ... J [2]

- (ii) Determine the temperature of the gas in state B.

temperature = ... K [1]

- (iii) Determine the volume of the gas in state C.

volume = ... m³ [1]

- (iv) On Fig. 3.1, draw two lines, one to represent change X and one to represent change Y.
Label your lines X and Y respectively. [3]

[Total: 9]