1 (a) The concept of an absolute zero of temperature may be explained by reference to the behaviour of a gas.
Discuss **one** experiment that can be performed using a gas which would enable you to explain absolute zero and determine its value.
It is not necessary to give full details of the apparatus. Your answer should:

- include the quantities that are kept constant
- identify the measurements to be taken
- explain how the results may be used to find absolute zero
- justify why the value obtained is absolute zero.

The quality of your written communication will be assessed in your answer.

(6)

(b) (i) State **two** assumptions about the **movement** of molecules that are used when deriving the equation of state, $pV = \frac{1}{3} N m (c_{\mathrm{rms}})^2$ for an ideal gas.

1. ____

____

2. ____

____

(2)

(ii) Three molecules move at the speeds shown in the table below.

molecule	**speed / m s^{-1}**
1	2000
2	3000
3	7000

Calculate their mean square speed.

mean square speed ____________________ $m^2\ s^{-2}$

(1)

(c) The average molecular kinetic energy of an ideal gas is 6.6×10^{-21} J.
Calculate the temperature of the gas.

temperature ____________________ K

(2)

(Total 11 marks)

2 (a) Outline what is meant by an *ideal gas*.

____

____

____

____

(2)

(b) An ideal gas at a temperature of 22 °C is trapped in a metal cylinder of volume 0.20 m^3 at a pressure of 1.6×10^6 Pa.

(i) Calculate the number of moles of gas contained in the cylinder.

number of moles ____________________ mol

(2)

(ii) The gas has a molar mass of 4.3×10^{-2} kg mol^{-1}.

Calculate the density of the gas in the cylinder.

State an appropriate unit for your answer.

density ____________________ unit ___________

(3)

(iii) The cylinder is taken to high altitude where the temperature is −50 °C and the pressure is 3.6×10^4 Pa. A valve on the cylinder is opened to allow gas to escape.

Calculate the mass of gas remaining in the cylinder when it reaches equilibrium with its surroundings.

Give your answer to an appropriate number of significant figures.

mass ____________________ kg

(3)

(Total 10 marks)

3 An electrical heater is placed in an insulated container holding 100 g of ice at a temperature of –14 °C. The heater supplies energy at a rate of 98 joules per second.

(a) After an interval of 30 s, all the ice has reached a temperature of 0 °C. Calculate the specific heat capacity of ice.

answer = ______________________ J $kg^{-1}K^{-1}$

(2)

(b) Show that the final temperature of the water formed when the heater is left on for a further 500 s is about 40 °C.

specific heat capacity of water = 4200 J $kg^{-1}K^{-1}$

specific latent heat of fusion of water = 3.3×10^5 J kg^{-1}

(3)

(c) The whole procedure is repeated in an uninsulated container in a room at a temperature of 25 °C.

State and explain whether the final temperature of the water formed would be higher or lower than that calculated in part (b).

____

____

____

____

(2)

(Total 7 marks)

4

Figure 1

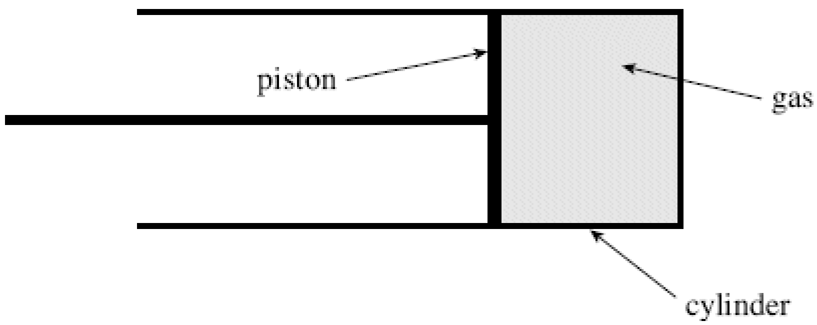
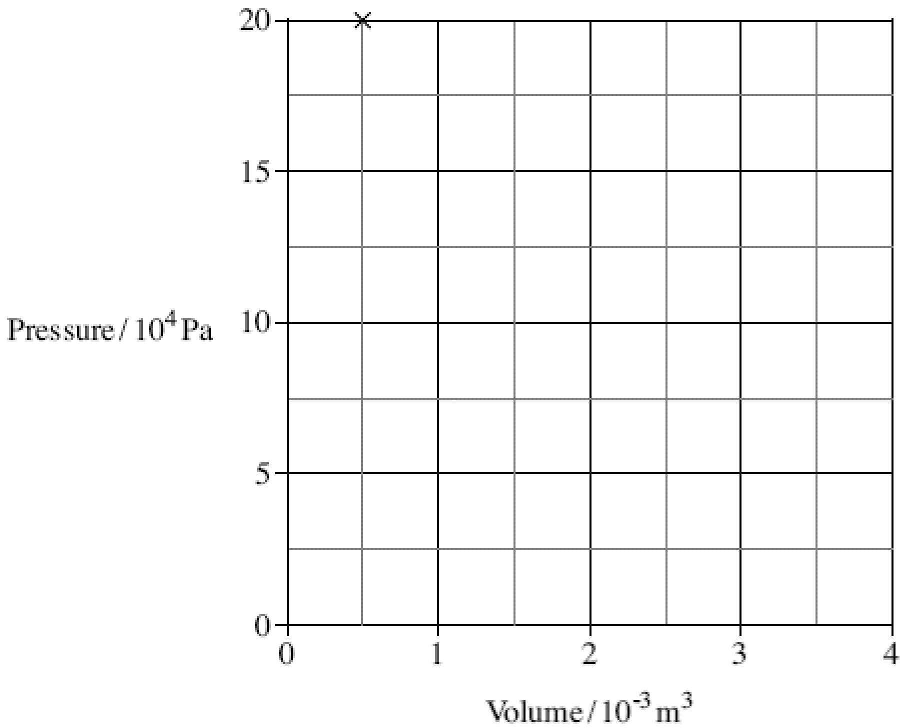


Figure 1 shows a cylinder, fitted with a gas-tight piston, containing an ideal gas at a constant temperature of 290 K. When the pressure, p, in the cylinder is 20×10^4 Pa the volume, V, is 0.5×10^{-3} m^3.

Figure 2 shows this data plotted.

Figure 2



(a) By plotting two or three additional points draw a graph, on the axes given in **Figure 2**, to show the relationship between pressure and volume as the piston is slowly pulled out. The temperature of the gas remains constant.

(3)

(b) (i) Calculate the number of gas molecules in the cylinder.

answer = ______________________ molecules

(2)

(ii) Calculate the total kinetic energy of the gas molecules.

answer = ______________________ J

(3)

(c) State **four** assumptions made in the molecular kinetic theory model of an ideal gas.

(i) ____

____

(ii) ____

____

(iii) ____

____

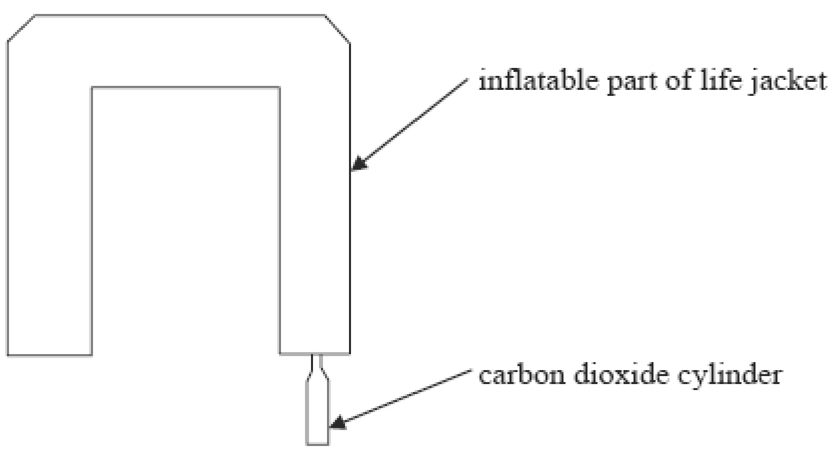
(iv) ____

____

(4)

(Total 12 marks)

5 A life jacket inflates using gas released from a small carbon dioxide cylinder. The arrangement is shown in the following figure**.**



(a) The cylinder initially contains 1.7×10^{23} molecules of carbon dioxide at a temperature of 12 °C and occupying a volume of 3.0×10^{-5} m^3.

(i) Calculate the initial pressure, in Pa, in the carbon dioxide cylinder.

(ii) When the life jacket inflates, the pressure falls to 1.9×10^5 Pa and the final temperature is the same as the initial temperature. Calculate the new volume of the gas.

(iii) Calculate the mean molecular kinetic energy, in J, of the carbon dioxide in the cylinder.

(6)

(b) (i) Explain, in terms of the kinetic theory model, why the pressure drops when the carbon dioxide is released into the life jacket.

____

____

____

____

____

____

(ii) Explain why the kinetic theory model would apply more accurately to the gas in the inflated life jacket compared with the gas in the small cylinder.

____

____

____

____

____

____

(6)

(c) Explain, in terms of the first law of thermodynamics, how the temperature of the gas in the system can be the same at the beginning and the end of the process.

____

____

____

____

____

____

(4)

(Total 16 marks)

6 A cola drink of mass 0.200 kg at a temperature of 3.0 °C is poured into a glass beaker. The beaker has a mass of 0.250 kg and is initially at a temperature of 30.0 °C.

specific heat capacity of glass = 840 J $kg^{-1}K^{-1}$
specific heat capacity of cola = 4190 J $kg^{-1}K^{-1}$

(i) Show that the final temperature, T_f, of the cola drink is about 8 °C when it reaches thermal equilibrium with the beaker.
Assume no heat is gained from or lost to the surroundings.

(2)

(ii) The cola drink and beaker are cooled from T_f to a temperature of 3.0 °C by adding ice at a temperature of 0 °C.
Calculate the mass of ice added.
Assume no heat is gained from or lost to the surroundings.

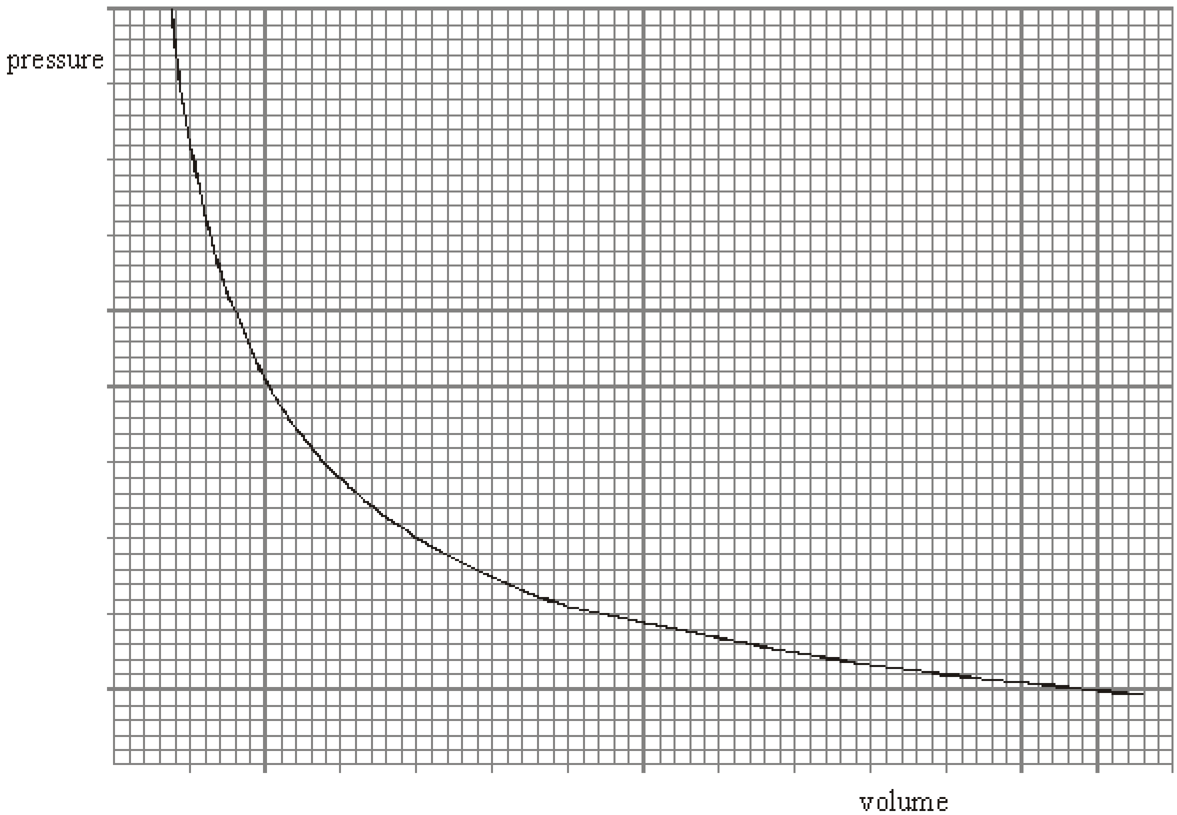
specific heat capacity of water = 4190 J kg^{-1} K^{-1}
specific latent heat of fusion of ice = 3.34×10^5 J kg^{-1}

mass ____________________ kg

(3)

(Total 5 marks)

7 The graph shows how the pressure of an ideal gas varies with its volume when the mass and temperature of the gas are constant.



(a) On the same axes, sketch **two** additional curves **A** and **B**, if the following changes are made.

(i) The same mass of gas at a lower constant temperature (label this **A**).

(ii) A greater mass of gas at the original constant temperature (label this **B**).

(2)

(b) A cylinder of volume 0.20 m^3 contains an ideal gas at a pressure of 130 kPa and a temperature of 290 K. Calculate

(i) the amount of gas, in moles, in the cylinder,

____

____

____

(ii) the average kinetic energy of a molecule of gas in the cylinder,

____

(iii) the average kinetic energy of the molecules in the cylinder.

(5)

(Total 7 marks)

8 A bicycle and its rider have a total mass of 95 kg. The bicycle is travelling along a horizontal road at a constant speed of 8.0 m s^{-1}.

(a) Calculate the kinetic energy of the bicycle and rider.

(2)

(b) The brakes are applied until the bicycle and rider come to rest. During braking, 60% of the kinetic energy of the bicycle and rider is converted to thermal energy in the brake blocks. The brake blocks have a total mass of 0.12 kg and the material from which they are made has a specific heat capacity of 1200 J kg^{-1} K^{-1}.

(i) Calculate the maximum rise in temperature of the brake blocks.

(ii) State an assumption you have made in part (b)(i).

(4)

(Total 6 marks)

9 (a) A student immerses a 2.0 kW electric heater in an insulated beaker of water. The heater is switched on and after 120 s the water reaches boiling point.

The table below gives data collected during the experiment.

initial mass of beaker	25 g
initial mass of beaker and water	750 g
initial temperature of water	20 °C
final temperature of water	100 °C

Calculate the specific heat capacity of water if the thermal capacity of the beaker is negligible.

___

___

___

(4)

(b) The student in part (a) continues to heat the water so that it boils for 105 s. When the mass of the beaker and water is measured again, it is found that it has decreased by 94 g.

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

___

___

(ii) State **two** assumptions made in your calculation.

___

___

(4)

(Total 8 marks)

10 A fixed mass of an ideal gas initially has a volume V and an absolute temperature T. Its initial pressure could be doubled by changing its volume and temperature to

A $V/2$ and $4T$

B $V/4$ and $T/2$

C $2V$ and $T/4$

D $4V$ and $2T$

(Total 1 mark)

11 A car of mass M travelling at speed V comes to rest using its brakes. Energy is dissipated in the brake discs of total mass m and specific heat capacity c. The rise in temperature of the brake discs can be estimated from

A $\dfrac{mV^2}{2Mc}$

B $\dfrac{2MV^2}{mc}$

C $\dfrac{MV^2}{2mc}$

D $\dfrac{2mc}{MV^2}$

(Total 1 mark)

12 Which one of the following is **not** an assumption about the properties of particles in the simple kinetic theory?

A $< c^2 >$ is the average speed of the particles

B The forces between the particles are negligible except when particles collide

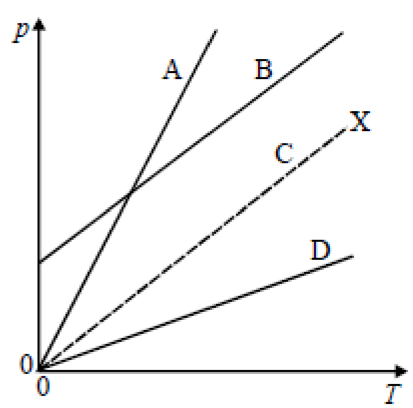
C The time spent by particles in collision is negligible compared with the time spent between collisions

D The volume of the particles is negligible compared to the volume of the container

(Total 1 mark)

13 In the diagram the dashed line **X** shows the variation of pressure, p, with absolute temperature, T, for 1 mol of an ideal gas in a container of fixed volume.

Which line, **A**, **B**, **C** or **D** shows the variation for 2 mol of the gas in the same container?



(Total 1 mark)

14 A raindrop of mass m falls to the ground at its terminal speed v. The specific heat capacity of water is c and the acceleration of free fall is g. Given that 25% of the energy is retained in the raindrop when it strikes the ground, what is the rise in temperature of the raindrop?

A $\frac{mv^2}{8c}$

B $\frac{v^2}{4mc}$

C $\frac{mg}{4c}$

D $\frac{v^2}{8c}$

(Total 1 mark)

Mark schemes

1 (a) The mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC).

High Level − Good to Excellent
An experiment with results and interpretation must be given leading to the measurement of absolute zero. The student refers to 5 or 6 points given below. However each individual point must stand alone and be clear.*The information presented as a whole should be well organised using appropriate specialist vocabulary. There should only be one or two spelling or grammatical errors for this mark.*

6 clear points = 6 marks

5 clear points = 5 marks

5-6

Intermediate Level − Modest to Adequate
An experiment must be given and appropriate measurements must be suggested. For 3 marks the type of results expected must be given. 4 marks can only be obtained if the method of obtaining absolute zero is given.*The grammar and spelling may have a few shortcomings but the ideas must be clear.*

4 clear points = 4 marks

3 clear points = 3 marks

3-4

Low Level − Poor to Limited
One mark may be given for any of the six points given below. For 2 marks an experiment must be chosen and some appropriate results suggested even if the details are vague. Any 2 of the six points can be given to get the marks.
There may be many grammatical and spelling errors and the information may be poorly organised.

2 clear points = 2 marks

Any one point = 1 mark

1-2

The description expected in a competent answer should include:
1. Constant mass of gas (may come from the experiment if it is clear that the gas is trapped) and constant volume (or constant pressure).

For (point 1) amount / quantity / moles of gas is acceptable.

2. Record pressure (or volume) for a range of temperatures.(the experiment must involve changing the temperature with pressure or volume being the dependent variable).

For (point 2) no specific details of the apparatus are needed. Also the temperature recording may not be explicitly stated eg. record the pressure at different temperatures is condoned.

3. How the temperature is maintained / changed / controlled. (The gas must be heated uniformly by a temperature bath or oven − so not an electric fire or lamp).

4. Describe or show a graph of pressure against temperature (or volume against temperature) that is linear. The linear relationship may come from a diagram / graph or a reference to the Pressure Law or Charles' Law line of best fit is continued on implies a linear graph).

5. Use the results in a graph of pressure against temperature (or volume against temperature) which can be extrapolated to lower temperatures which has zero pressure (or volume) at absolute zero, which is at 0 K or −273 °C (a reference to crossing the temperature axis implies zero pressure or volume).

For (points 4 and 5) the graphs referred to can use a different variable to pressure or volume but its relationship to V or P must be explicit.

In (point 5) the graph can be described or drawn.

6. Absolute zero is obtained using any gas (provided it is ideal or not at high pressures or close to liquification)
Or Absolute temperature is the temperature at which the volume (or pressure or mean kinetic energy of molecules) is zero / or when the particles are not moving.

Discount any points that are vague or unclear

(Second part of point 6) must be stated not just implied from a graph.

(b) (i)
- The motion of molecules is random.
- Collisions between molecules (or molecules and the wall of the container) are elastic.
- The time taken for a collision is negligible (compared to the time between collisions).
- Newtonian mechanics apply (or the motion is non-relativistic).
- The effect of gravity is ignored or molecules move in straight lines (at constant speed) between collisions.

✓✓ any two

If more than 2 answers are given each wrong statement cancels a correct mark.

2

(ii) **Escalate if the numbers used are 4000, 5000 and 6000 giving 25666666 or similar.**

mean square speed
(= $(2000^2 + 3000^2 + 7000^2) / 3 =$
20.7×10^6)
$= 2.1 \times 10^7$ ($m^2\ s^{-2}$)

Common correct answers

20.7×10^6

21×10^6

2.07×10^7

2.1×10^7

20 700 000

21 000 000.

***Possible escalation**.*

1

(c) **Escalate if the question and answer line requires a volume instead of a temperature.**

(using meanKE = $3RT / 2N_A$)
$T = 2N_A \times \text{meanKE} / 3R$
$= 2 \times 6.02 \times 10^{23} \times 6.6 \times 10^{-21} / 3 \times 8.31$ ✓
= 320 (K) ✓ (318.8 K)
Or
(meanKE = $3kT / 2$)
$T = 2 \times \text{meanKE} / 3k$
$= 2 \times 6.6 \times 10^{-21} / 3 \times 1.38 \times 10^{-23}$ ✓
= 320 (K) ✓ (318.8 K)

First mark for substitution into an equation.

Second mark for answer

***Possible escalation**.*

Answer only can gain 2 marks.

2

[11]

2 (a) molecules have negligible volume
collisions are elastic
the gas cannot be liquified
there are no interactions between molecules (except during collisions)
the gas obeys the (ideal) gas law / obeys Boyles law etc.
at all temperatures/pressures
any two lines ✓ ✓

a gas laws may be given as a formula

2

(b) (i) $n\ (= PV / RT) = 1.60 \times 10^6 \times 0.200 / (8.31 \times (273 + 22))$ ✓
= 130 or 131 mol ✓ (130.5 mol)

2

(ii) mass = 130.5 × 0.043 = 5.6 (kg) ✓
(5.61kg)

allow ecf from bi

density (= mass / volume) = 5.61 / 0.200 = 28 ✓ (28.1 kg m^{-3})
kg m^{-3} ✓

a numerical answer without working can gain the first two marks

3

(iii) *($V_2 = P_1 V_1 T_2 / P_2 T_1$)*
$V_2 = 1.6 \times 10^6 \times .200 \times (273 - 50) / 3.6 \times 10^4 \times (273 + 22)$ or 6.7(2) (m^3) ✓

allow ecf from bii

[reminder must see bii]
look out for

mass remaining = 5.61 × 0.20 / 6.72 = 0.17 (kg) ✓ (0.167 kg)
or
$n = (PV / RT = 3.6 \times 10^4 \times 0.200 / (8.31 \times (273 - 50)) = 3.88(5)$ (mol) ✓

mass remaining = $3.885 \times 4.3 \times 10^{-2} = 0.17$ (kg) ✓
2 sig figs ✓

any 2 sf answer gets the mark

3

[10]

3 (a) (use of $\Delta Q = m\,c\,\Delta T$)

$30 \times 98 = 0.100 \times c \times 14$ ✓

$c = 2100$ (J kg^{-1} K^{-1}) ✓

2

(b) (use of $\Delta Q = m\,l + m\,c\,\Delta T$)

$500 \times 98 = 0.100 \times 3.3 \times 10^5$ ✓ $+ 0.100 \times 4200 \times \Delta T$ ✓

(ΔT = 38 °C)

T = 38°C ✓

3

(c) the temperature would be higher ✓

as the ice/water spends more time below 25°C

or heat travels in the direction from hot to cold

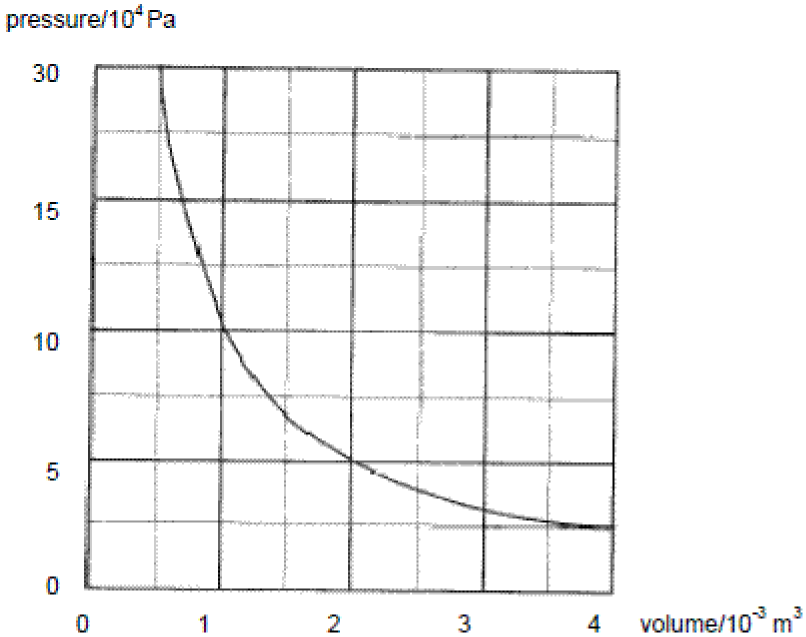
or ice/water first gains heat then loses heat

any **one** line ✓

2

[7]

4 (a)



3

curve with decreasing negative gradient that passes through the given point which does not touch the x axis **(1)**

designated points	
pressure/10^4 Pa	volume/10^{-3} m^3
10	1.0
5.0	2.0
4.0	2.5
2.5	4.0

2 of the designated points **(1)(1)** (one mark each)

(b) (i) $N = PV/kT = 5 \times 10^4 \times 2 \times 10^{-3}/1.38 \times 10^{-23} \times 290$ **(1)**

[or alternative use of $PV = nRT$
$5 \times 10^4 \times 2.0 \times 10^{-3}/8.31 \times 290 = 0.0415$ moles]
$= 2.50 \times 10^{22}$ molecules **(1)**

2

(ii) (mean) kinetic energy of a molecule

$= \frac{3}{2}kT = \frac{3}{2} \times 1.38 \times 10^{-23} \times 290$ **(1)** (= 6.00×10^{-21} J)

(total kinetic energy = mean kinetic energy × *N*)

= $6.00 \times 10^{-21} \times 2.50 \times 10^{22}$ **(1)**

= 150 (J) **(1)**

3

(c) all molecules/atoms are identical

molecules/atoms are in random motion

Newtonian mechanics apply

gas contains a large number of molecules

the volume of gas molecules is negligible (compared to the volume occupied by the gas) or reference to point masses

no force act between molecules except during collisions or the speed/velocity is constant between collisions or motion is in a straight line between collisions

collisions are elastic or **kinetic** energy is conserved

and of negligible duration

any 4 ***(1)(1)(1)(1)***

max 4

[12]

5 (a) (i) $PV = NkT$ **(1)**

223×10^5 Pa **(1)**

2

(ii) pV = const or repeat calculation from (i) **(1)**

3.5×10^{-3} m^3 **(1)**

2

(iii) kinetic energy = 3/2 kT **(1)**

$5.9(0) \times 10^{-21}$ J **(1)**

2

(b) (i) volume increase **(1)**
time between collisions increases **(1)**
speed constant as temp constant **(1)**
rate of change of momentum decreases **(1)**

max 3

(ii) volume smaller in cylinder **(1)**

molecules occupy significantly greater proportion of the volume **(1)**

molecules closer so intermolecular forces greater **(1)**

3

(c) internal energy stays the same **(1)**

gas does work in expanding so *W* is negative **(1)**

gas must be heated to make *U* positive **(1)**

U and *W* equal and opposite **(1)**

4

[16]

6 (i) (heat supplied by glass = heat gained by cola)
(use of $m_g c_g \Delta T_g = m_c c_c \Delta T_c$)

1st mark for RHS or LHS of substituted equation

$0.250 \times 840 \times (30.0 - T_f) = 0.200 \times 4190 \times (T_f - 3.0)$ ✓

2nd mark for 8.4°C

$(210 \times 30 - 210\, t_f = 838\, T_f - 838 \times 3)$

$T_f = 8.4(1)$ (°C) ✓

Alternatives:

8°C is substituted into equation (on either side shown will get mark) ✓

resulting in 4620J~4190J ✓

or

8°C substituted into LHS ✓ *(produces ΔT = 5.5°C and hence)*

= 8.5°C ~ 8°C ✓

8°C substituted into RHS ✓

(produces ΔT = 20°C and hence)

= 10°C ~ 8°C ✓

2

(ii) (heat gained by ice = heat lost by glass + heat lost by cola)

NB correct answer does not necessarily get full marks

(heat gained by ice = $mc\Delta T + ml$)
heat gained by ice = $m \times 4190 \times 3.0 + m \times 3.34 \times 10^5$ ✓
(heat gained by ice = $m \times 346600$)

3rd mark is only given if the previous 2 marks are awarded

heat lost by glass + heat lost by cola
= 0.250 × 840 × (8.41 – 3.0) + 0.200 × 4190 × (8.41 – 3.0) ✓
(= 5670 J)

(especially look for $m \times 4190 \times 3.0$)

the first two marks are given for the formation of the substituted equation not the calculated values

m (=5670 / 346600) = 0.016 (kg) ✓

if 8°C is used the final answer is 0.015 kg

or (using cola returning to its original temperature)
(heat supplied by glass = heat gained by ice)
(heat gained by glass = 0.250 × 840 × (30.0 – 3.0))
heat gained by glass = 5670 (J) ✓
(heat used by ice = $mc\Delta T + ml$)
heat used by ice = $m(4190 \times 3.0 + 3.34 \times 10^5)$ ✓ (= $m(346600)$)

m (=5670 / 346600) = 0.016 (kg) ✓

3

[5]

7 (a) (i) curve A below original, curve B above original **(1)**

(ii) both curves correct shape **(1)**

2

(b) (i) (use of $pV = nRT$ gives) $130 \times 10^3 \times 0.20 = n \times 8.31 \times 290$ **(1)**

n = 11 (mol) **(1)** (10.8 mol)

(ii) (use of $E_k = \frac{3}{2}kT$ gives) $E_k = \frac{3}{2} \times 1.38 \times 10^{-23} \times 290$ **(1)**

$= 6.0 \times 10^{-21}$ J **(1)**

(iii) (no. of molecules) $N = 6.02 \times 10^{23} \times 10.8$ (= 6.5×10^{24})
total k.e. = $6.5 \times 10^{24} \times 6.0 \times 10^{-21} = 3.9 \times 10^4$ J **(1)**
(allow C.E. for value of n and E_k from (i) and (ii))
(use of n = 11 (mol) gives total k.e. = 3.9 (7) × 10^4 J)

5

[7]

8 (a) (use of $E_k = ½mv^2$ gives) $E_k = \frac{1}{2} \times 95 \times 8.0^2$ **(1)**

$= 3040$ J **(1)**

2

(b) (i) $\Delta Q = 0.60 \times 3040 = 1824$ (J) **(1)**
(allow C.E. for E_k from (a))
(use of $\Delta Q = mc\,\Delta\theta$ gives) $1824 = 0.12 \times 1200\,\Delta\theta$ **(1)**
$\Delta\theta = 13$ K **(1)** **(**12.7 K)
(allow C.E. for ΔQ)

(ii) no heat is lost to the surroundings **(1)**

4

[6]

9 (a) (use of $mc\Delta\theta = Pt$ gives)

$0.725 \times c \times (100 - 20)$ **(1)** $= 2000 \times 120$ **(1)**

$c = 41\ 00$ **(1)** J kg^{-1} **(1)** (4140 J kg^{-1})

4
QWC 2

(b) (i) (use of $mL = Pt$ gives) $94 \times 10^{-3}\,L = 2000 \times 105$ **(1)**
$L = 2.2 \times 10^6$ J kg^{-1} **(1)**

(ii) no evaporation (before water heated to boiling point)
no heat lost (to the surroundings)
heater 100% efficient any two **(1)** **(1)**

4

[8]

10 B

[1]

11 C

[1]

12 A

[1]

13 A

[1]

14 D

[1]

Examiner reports

1 As in previous questions students found explanations difficult but this time they also found some of the calculations difficult. In part (a), the Quality of Written Communication question, it was surprising to come across so many students who appeared to have no knowledge of any experiment concerning gases. This became apparent when their potential experiment was considered. Some thought it feasible to measure the speed of molecules as the temperature was reduced. Others thought that the temperature would reduce uniformly as the pressure was reduced, even reaching absolute zero. A few latched onto an equation such as specific heat that involved temperature and thought they could substitute measured data when the temperature was equal to zero. These students were not an isolated few. Almost a third tackled the experiment in a way that would not work or be impossible to perform. Even students who used a workable idea thought that the experiment could be continued and actually reach absolute zero. The more able students did find this a straightforward task and gave the necessary details in a logical manner but the majority of students did not give their description in a clear fashion and their answers seemed to change direction many times. A very simple error made by many was to quote the temperature of absolute zero as −273 K. The question about assumptions, part (b)(i) was not read carefully by a number of students. In particular they did not respond to the emboldened 'movement' in the question. So many answers given were from the usual list of assumptions but they were not given credit here. An example being, 'molecules have negligible volume'. Even the stronger students sometimes got caught out in this way. As in previous exams some students mistakenly thought that random motion and Brownian motion are one and the same. The calculation of (b)(ii) was not done well by a majority of students. Not because of poor arithmetic but because students did not understand the processing of the term 'mean square speed'. Some students also had difficulties in part (c) with substituting data into the kinetic ideal gas equation. A large number of students squared the number given in the question for the mean square speed before making the substitution.

2 A majority of candidates referred to obeying a gas law in answer to part (a). A second marking point was often missed out, wrong or vague. This is illustrated in the two answers that follow: 'It has properties of a gas such as Brownian Motion', and 'The gas obeys the assumptions of the kinetic theory'.

Parts (b)(i)+(ii) were done well by most. Only a few did not convert the temperature to Kelvin before performing a calculation. Again very few did not know the unit for density.

In part (b)(iii) more than half the candidates could perform the calculation but a significant number of those did not quote the answer to 2 significant figures. Of those missing out on the calculation many did score the first mark but then went wrong by using the wrong density or by not finding the proportion of the gas still in the container.

3 Most candidates performed well in part (a).

In part (b) the less able candidates tended to score only one mark because they could not form the energy balance equation when both changes of temperature and changes of state were taking place.

Part (c) caught a majority of candidates out. Even grade A students were tempted to roll out the usual answer, 'the temperature would be less because heat is lost to the surroundings'. This statement scored no marks.

4 Part (a) proved difficult for less able candidates. Some drew straight lines and others tried to force the curve to intercept the volume axis. The less able candidates sometimes marked correct points on the grid but did not draw a line. It seemed that some less able candidates followed the wrong order in tackling this part. They drew the curve before they marked points on the grid. As a result the points were just randomly placed on the curve they had drawn.

Part (b) (i) was done well by most. Candidates who used the alternative equation $PV = nRT$ often stopped when they had found the number of moles of gas. Part (b) (ii) was much more discriminating with less than 50% of candidates obtaining the correct answer. Many candidates did not have a clue whereas others could find the mean kinetic energy but then did not follow this up by finding the total kinetic energy.

Although part (c) looks like a basic question it did discriminate well. It was only the more able candidates who scored full marks. Many did not know what the question was getting at and guessed. Sometimes these candidates did score the mark associated with molecules moving in random motion. In other cases candidates did not complete their statements fully. For example, stating 'atoms travel in straight lines', rather than, 'atoms travel in straight lines between collisions'.

6 Candidates found (i) quite difficult for a number of reasons. Some started correctly by equating heat supplied to glass equals heat gained by cola but then they could not make the final temperature the subject of the resulting equation. Others substituted the temperature the wrong way round and used $(3 - T_f)$, which was negative and fudged the arithmetic. As in a previous question candidates did not explain their approach which made it difficult to award partial marks. It was interesting to see some candidates who jumped in too quickly and made an initial mess of the calculation fared better on additional pages when they thought more carefully over the problem.

Part (ii) was also very discriminating. Only the best candidates scored full marks. Good candidates who just missed full marks usually forgot about the 3 degree rise in temperature of the ice after it had melted. Most other candidates were aware of the $mc\Delta T$ and ml equations but then made all manner of different errors.

7 Candidates found this question quite demanding and although in part (a) most were able to draw the two graphs correctly, the answers were spoilt due to a lack of care in the sketches.

The calculations in part (b) were more discriminating and arithmetic errors were common. The correction to part (b) (iii) did not seem to cause problems, although only the more able candidates were able to come up with a correct response. A significant proportion of candidates answered the question correctly but then lost the final mark due to a significant figure penalty.

8 The last question in the paper was generally done well and candidates across the ability range were able to perform the various calculations successfully. A minority were confused by the need to use only 60% of the kinetic energy, but because marks were awarded for consequential errors, this did not prove to be too much of a penalty.

9 A large number of candidates found this question difficult. Many seemed aware of the correct equation in part (a) but made mistakes such as using power instead of energy, converting temperatures to Kelvin and using an incorrect value for the mass of water.

The latent heat calculation in part (b) produced even fewer correct responses. Many candidates included a change of temperature in their calculations or used an incorrect value for the mass of steam. Part b(ii) realised better answers although stating only one assumption was quite common.