1 (a) Lead has a specific heat capacity of 130 J kg^{-1} K^{-1}.

Explain what is meant by this statement.

____

____

____

____

(1)

(b) Lead of mass 0.75 kg is heated from 21 °C to its melting point and continues to be heated until it has all melted.

Calculate how much energy is supplied to the lead.
Give your answer to an appropriate number of significant figures.

melting point of lead = 327.5 °C
specific latent heat of fusion of lead = 23 000 J kg^{-1}

energy supplied ____________________ J

(3)

(Total 4 marks)

2 (a) ‘The pressure of an ideal gas is inversely proportional to its volume’, is an incomplete statement of Boyle’s law.

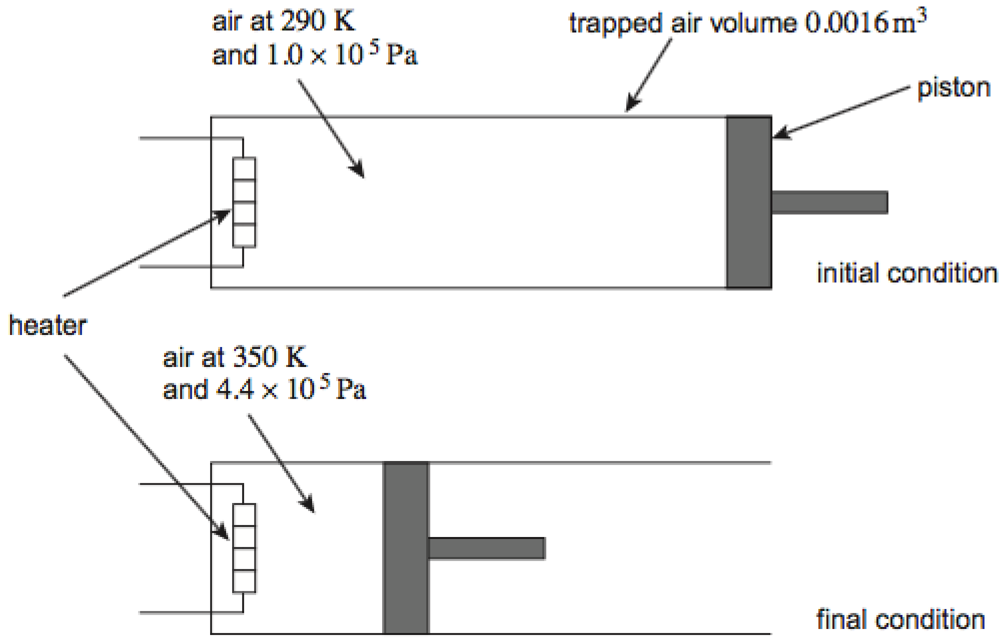
State **two** conditions necessary to complete the statement.

1. ____

2. ____

(2)

(b) A volume of 0.0016 m^3 of air at a pressure of 1.0×10^5 Pa and a temperature of 290 K is trapped in a cylinder. Under these conditions the volume of air occupied by 1.0 mol is 0.024 m^3. The air in the cylinder is heated and at the same time compressed slowly by a piston. The initial condition and final condition of the trapped air are shown in the diagram.



In the following calculations treat air as an ideal gas having a molar mass of 0.029 kg mol^{-1}.

(i) Calculate the final volume of the air trapped in the cylinder.

volume of air = ____________________ m^3

(2)

(ii) Calculate the number of moles of air in the cylinder.

number of moles = ____________________

(1)

(iii) Calculate the initial density of air trapped in the cylinder.

density = ____________________ kg m^{-3}

(2)

(c) State and explain what happens to the speed of molecules in a gas as the temperature increases.

____

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____

____

(2)

(Total 9 marks)

3 The pressure inside a bicycle tyre of volume 1.90×10^{-3} m^3 is 3.20×10^5 Pa when the temperature is 285 K.

(i) Calculate the number of moles of air in the tyre.

answer = ____________________ mol

(1)

(ii) After the bicycle has been ridden the temperature of the air in the tyre is 295 K. Calculate the new pressure in the tyre assuming the volume is unchanged. Give your answer to an appropriate number of significant figures.

answer = ____________________ Pa

(3)

(b) Describe **one** way in which the motion of the molecules of air inside the bicycle tyre is similar and **one** way in which it is different at the two temperatures.

similar ____

____

different ____

____

(2)

(Total 6 marks)

4 A female runner of mass 60 kg generates thermal energy at a rate of 800 W.

(a) Assuming that she loses no energy to the surroundings and that the average specific heat capacity of her body is 3900 J $kg^{-1}K^{-1}$, calculate

(i) the thermal energy generated in one minute,

____

____

(ii) the temperature rise of her body in one minute.

____

____

____

____

(3)

(b) In practice it is desirable for a runner to maintain a constant temperature. This may be achieved partly by the evaporation of sweat. The runner in part (a) loses energy at a rate of 500 Wby this process.

Calculate the mass of sweat evaporated in one minute.

specific latent heat of vaporisation of water = 2.3×10^6 J kg^{-1}

___

___

___

(3)

(c) Explain why, when she stops running, her temperature is likely to fall.

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___

___

___

___

(2)

(Total 8 marks)

5 Most cars manufactured in recent years have been fitted with air bags as a safety feature. In a collision the bag inflates automatically to protect the driver as air is released from a compressed air cylinder.

(a) Explain why the driver would be less seriously injured in a collision if the air bag inflates than he would be if unrestrained.

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___

(5)

(b) Why is the driver of a car fitted only with seat belts more likely to be injured than if an air bag was fitted? Ignore the different deceleration times and the difference in the materials used.

___

___

___

___

(2)

(c) With reference to pressure, volume and temperature, discuss what happens to the air as the bag inflates.

___

___

___

___

___

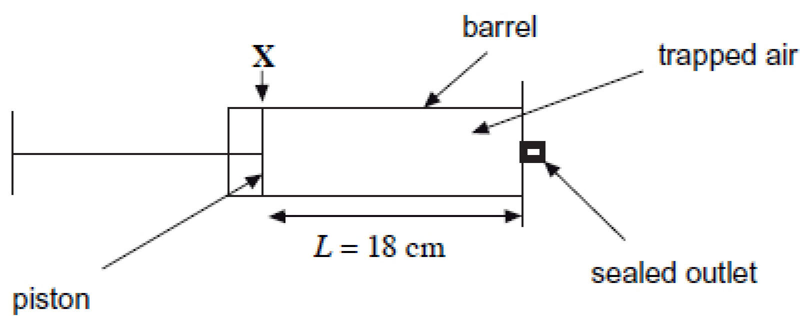
___

(3)

(Total 10 marks)

6 **Figure 1** shows the cross-section of a bicycle pump with a cylindrical barrel. The piston has been pulled to the position marked **X** and the outlet of the pump sealed.

Figure 1



The length L of the column of trapped air is 18 cm and the volume of the gas is 1.7×10^{-4} m^3 when the piston is at position **X**. Under these conditions the trapped air is at a pressure p of 1.01×10^5 Pa and its temperature is 19°C.

Assume the trapped air consists of identical molecules and behaves like an ideal gas in this question.

(a) (i) Calculate the internal diameter of the barrel.

diameter ____________________ m

(2)

(ii) Show that the number of air molecules in the column of trapped air is approximately 4×10^{21}.

(3)

(iii) The ratio $\dfrac{\text{total volume of the air molecules}}{\text{volume occupied by the column of trapped air}}$ equals 7.0×10^{-4}.

Calculate the volume of one air molecule.

volume ____________________ m^3

(2)

(iv) The ratio in part **(a)(iii)** is important in supporting assumptions made in the kinetic theory of ideal gases.

Explain how the value of the ratio supports **two** of the assumptions made in the kinetic theory of ideal gases.

____

____

____

____

____

____

(3)

(b) The mass of each air molecule is 4.7×10^{-26} kg.

Calculate the mean square speed of the molecules of trapped air when the length of the column of trapped air is 18.0 cm.
Give an appropriate unit for your answer.

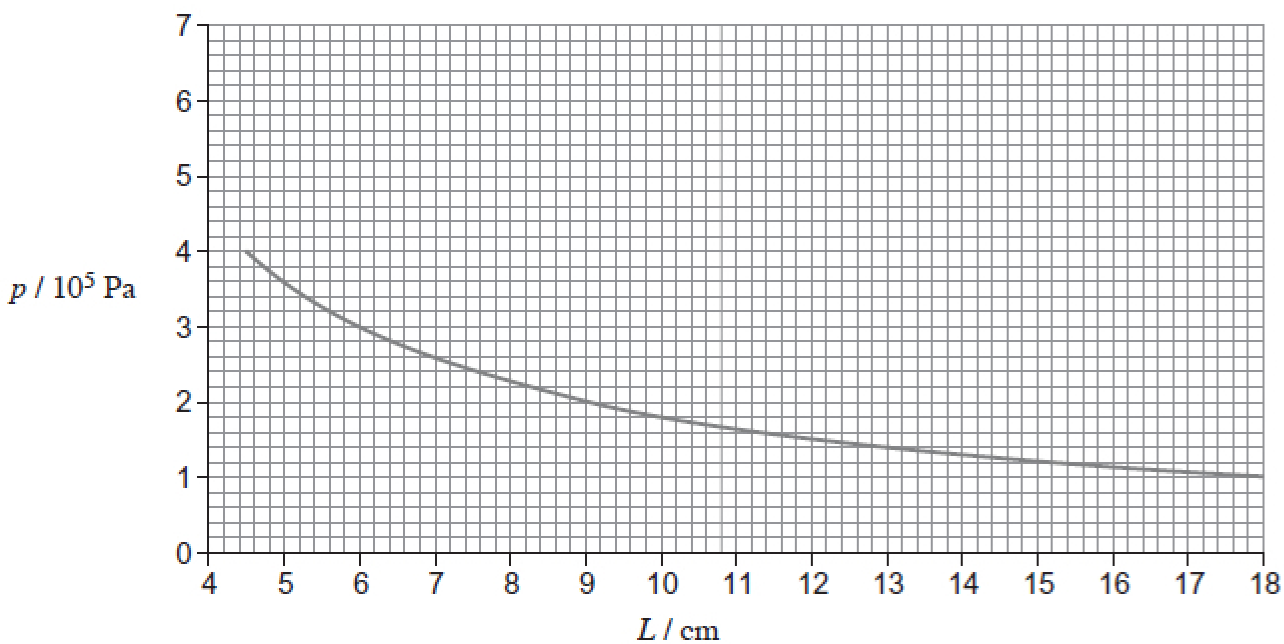
mean square speed ____________________ unit __________

(4)

(c) The piston is pushed slowly inwards until the length L of the column of trapped air is 4.5 cm.

Figure 2 shows how the pressure p of the trapped air varies as L is changed during this process.

Figure 2



(i) Use data from **Figure 2** to show that p is inversely proportional to L.

(3)

(ii) Name the physical property of the gas which must remain constant for p to be inversely proportional to L.

____

(1)

(d) Explain how the relationship between p and L shown in **Figure 2** can be predicted using the kinetic theory for an ideal gas.

____

____

____

____

____

____

____

____

(4)

(Total 22 marks)

7 (a) Define the Avogadro constant.

____

____

____

(1)

(b) (i) Calculate the mean kinetic energy of krypton atoms in a sample of gas at a temperature of 22 °C.

mean kinetic energy ____________________ J

(1)

(ii) Calculate the mean-square speed, $(c_{rms})^2$, of krypton atoms in a sample of gas at a temperature of 22 °C.
State an appropriate unit for your answer.

mass of 1 mole of krypton = 0.084 kg

mean-square speed____________________ unit ___________

(3)

(c) A sample of gas consists of a mixture of krypton and argon atoms.
The mass of a krypton atom is greater than that of an argon atom.
State and explain how the mean-square speed of krypton atoms in the gas compares with that of the argon atoms at the same temperature.

___

___

___

___

___

(2)

(Total 7 marks)

8 (a) Define the specific latent heat of vaporisation of water.

___

___

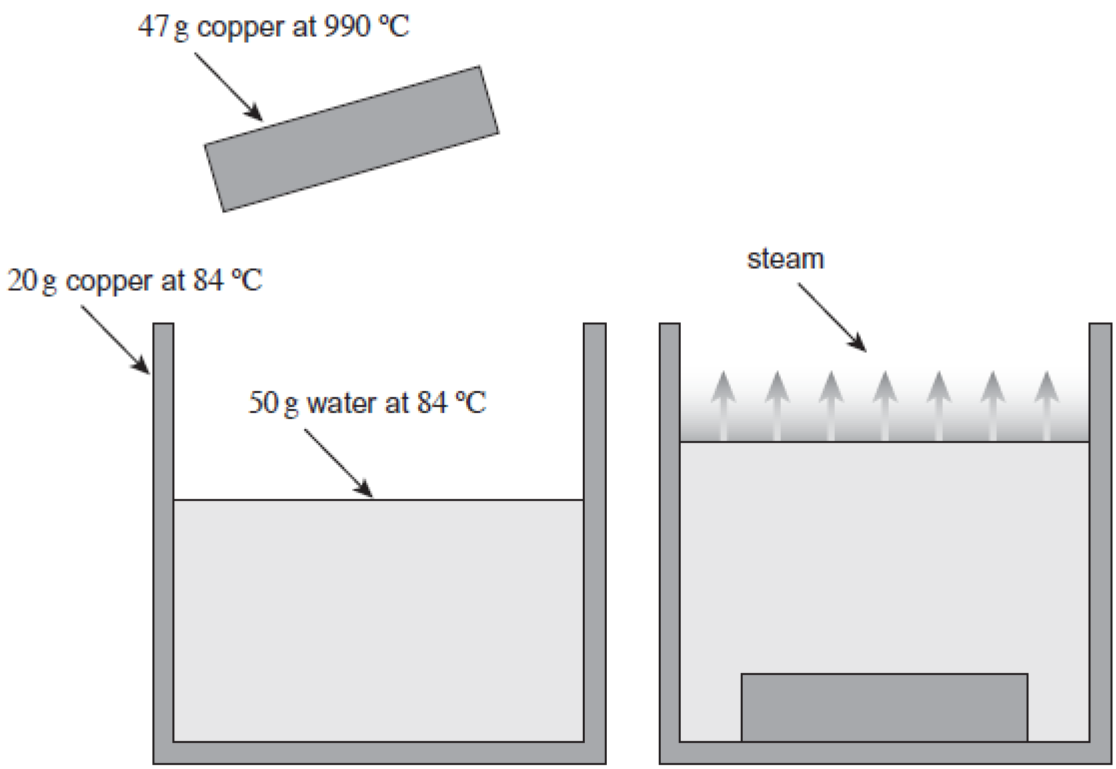
___

___

(2)

(b) An insulated copper can of mass 20 g contains 50 g of water both at a temperature of 84 °C. A block of copper of mass 47 g at a temperature of 990 °C is lowered into the water as shown in the figure below. As a result, the temperature of the can and its contents reaches 100 °C and some of the water turns to steam.

specific heat capacity of copper = 390 $\mathrm{J\,kg^{-1}\,K^{-1}}$
specific heat capacity of water = 4200 $\mathrm{J\,kg^{-1}\,K^{-1}}$
specific latent heat of vaporisation of water = 2.3×10^6 $\mathrm{J\,kg^{-1}}$



Before placement

After placement

(i) Calculate how much thermal energy is transferred from the copper block as it cools to 100 °C.
Give your answer to an appropriate number of significant figures.

thermal energy transferred ____________________ J

(2)

(ii) Calculate how much of this thermal energy is available to make steam.
Assume no heat is lost to the surroundings.

available thermal energy ____________________ J

(2)

(iii) Calculate the maximum mass of steam that may be produced.

mass ____________________ kg

(1)

(Total 7 marks)

9 A liquid flows continuously through a chamber that contains an electric heater. When the steady state is reached, the liquid leaving the chamber is at a higher temperature than the liquid entering the chamber. The difference in temperature is Δt.

Which of the following will increase Δt with no other change?

A	Increasing the volume flow rate of the liquid	☐
B	Changing the liquid to one with a lower specific heat capacity	☐
C	Using a heating element with a higher resistance	☐
D	Changing the liquid to one that has a higher density	☐

(Total 1 mark)

10 The temperature of a hot liquid in a container falls at a rate of 2 K per minute just before it begins to solidify. The temperature then remains steady for 20 minutes by which time all the liquid has all solidified.

What is the quantity $\frac{\text{Specific heat capacity of the liquid}}{\text{Specific latent heat of fusion}}$?

A $\frac{1}{40}\,\mathrm{K}^{-1}$ ⬭

B $\frac{1}{10}\,\mathrm{K}^{-1}$ ⬭

C 10 K^{-1} ⬭

D 40 K^{-1} ⬭

(Total 1 mark)

11 A fixed mass of gas occupies a volume V. The temperature of the gas increases so that the root mean square velocity of the gas molecules is doubled.
What will the new volume be if the pressure remains constant?

A $\frac{V}{2}$ ⬭

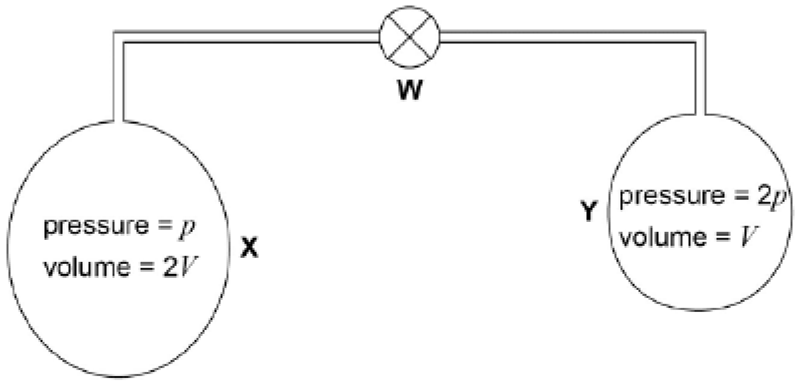
B $\frac{V}{\sqrt{2}}$ ⬭

C $2V$ ⬭

D $4V$ ⬭

(Total 1 mark)

12 $\mathbf{X}$ and $\mathbf{Y}$ are two gas bottles that are connected by a tube that has negligible volume compared with the volume of each bottle.



Initially the valve $\mathbf{W}$ is closed.

$\mathbf{X}$ has a volume $2V$ and contains hydrogen at a pressure of p.
$\mathbf{Y}$ has a volume V and contains hydrogen at a pressure of $2p$.
$\mathbf{X}$ and $\mathbf{Y}$ are both initially at the same temperature.

$\mathbf{W}$ is now opened. Assuming that there is no change in temperature, what is the new gas pressure?

A $\frac{2}{3}p$ ☐

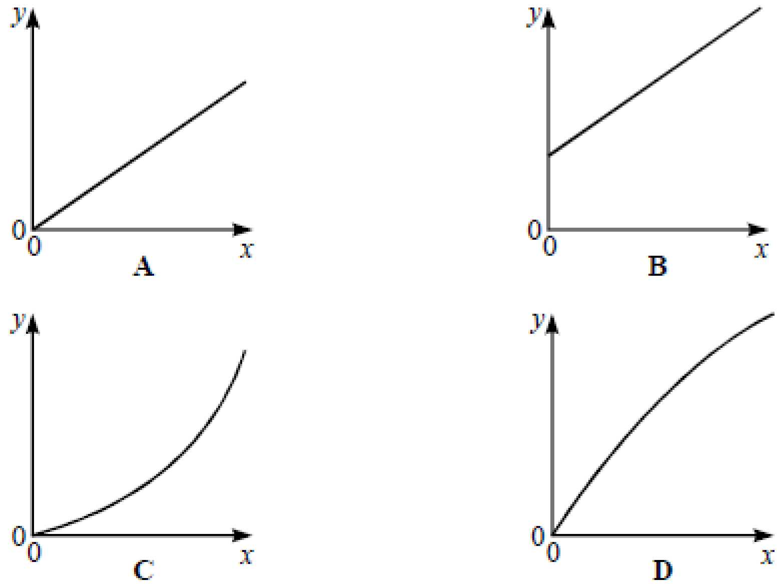
B $\frac{5}{3}p$ ☐

C $\frac{4}{3}p$ ☐

D $\frac{3}{2}p$ ☐

(Total 1 mark)

13 Which one of the graphs below shows the relationship between the internal energy of an ideal gas (y-axis) and the absolute temperature of the gas (x-axis)?



(Total 1 mark)

14 The temperature of a room increases from 283K to 293K. The r.m.s. speed of the air molecules in the room increases by a factor of

A 1.02

B 1.04

C 1.41

D 2.00

(Total 1 mark)

Mark schemes

1

(a) (it takes) 130 J / this energy to raise (the temperature of) a mass of 1 kg (of lead) by 1 K / 1 °C (without changing its state) ✓

1 kg can be replaced with unit mass.

Marks for 130J or energy.

+1 kg or unit mass.

+1 K or 1 °C.

Condone the use of 1 °K

1

(b) (using $Q = mc\Delta T + ml$)
= 0.75 × 130 × (327.5 – 21) + 0.75 × 23000 ✓
(= 29884 + 17250)
= 47134 ✓
= 4.7 × 10^4 (J) ✓

For the first mark the two terms may appear separately i.e. they do not have to be added.

Marks for substitution + answer + 2 sig figs (that can stand alone).

3

[4]

2

(a) 1. fixed mass or fixed number of molecules / moles ✓
2. constant temperature ✓

Allow alternatives to fixed mass such as 'sealed vessel' or 'closed system'.

Not amount of gas as this is ambiguous.

The temperature must not be specific.

2

(b) (i) $(V_2 = \frac{P_1}{P_2} \times V_1 \times \frac{T_2}{T_1})$

$$V_2 = \frac{1.0 \times 10^5}{4.4 \times 10^5} \times 0.0016 \times \frac{350}{290}$$

or $(V = \frac{nRT}{P})$

V = 0.067 × 8.31 × 350 / (4.4 × 10^{-4}) ✓
= 0.00044 (m^3) ✓ (4.39 × 10^{-4} m^3)

1st mark comes from use of valid equation with substitutions.

In the alternative look out for 0.067 = 1 /15 = (0.0016 / 0.024)

And $R = N_A k$

Correct answer gains full marks

If no other answer is seen then 1 sig fig is wrong.

2

(ii) (proportion of a mole of trapped air
= volume of cylinder / volume of mole)
= 0.0016 / 0.024 = 0.067 (mol) ✓ (0.0667)
or
(use of $n = pV/RT$)
= $1.0 \times 10^5 \times 0.0016 / (8.31 \times 290) = 0.066$ (mol) ✓ (0.0664)
or
= $4.4 \times 10^5 \times 0.00044 / (8.31 \times 350) = 0.067$ (mol) ✓ (0.0666)

Answers range between 0.066 − 0.067 mol depending on the volume carried forward.

(answer alone gains mark)

Working must be shown for a CE

Ans = $V_2 \times 151$

1

(iii) (mass = molar mass × number of moles)
mass = 0.029 × 0.0667 ✓ (0.00193 kg)
(density = mass / volume)
density = 0.00193 / 0.0016 = 1.2(1) kg m^{-3} ✓
(no continuation errors within this question but allow simple powers of 10 arithmetic errors which will lose one mark)

CE mass = 0.029 × (b)(ii)

CE density = (0.029 × (b)(ii)) / 0.0016

or (18.1 × (b)(ii)

2

(c) the (average / mean / mean-square) speed of molecules increases (with absolute temperature) ✓
as the mean kinetic energy is proportional to the (absolute) temperature
Or
Reference to $KE_{mean} = 3/2\, kT$ ✓ but mean or rms must feature in the answer somewhere.

2

[9]

3

(a) (i) $n = PV/RT = 3.2 \times 10^5 \times 1.9 \times 10^{-3}/8.31 \times 285$

n = 0.26 mol ✓ (0.257 mol)

1

(ii) $P_2 = \frac{T_2}{T_1} \times P_1 = \frac{295}{285} \times 3.20 \times 10^5$ ✓

3.31×10^5 Pa ✓(allow $3.30\text{-}3.35 \times 10^5$ Pa)

3 sig figs ✓sig fig mark stands alone even with incorrect answer

3

(b) similar -(rapid) **random** motion

- range of speeds

different - **mean** kinetic energy

- root **mean** square speed

- **frequency** of collisions

2

[6]

4

(a) (i) energy = 800 × 60 = 48 × 10^3J **(1)**

(ii) (use of $\Delta Q = mc\Delta\theta$ gives) 48 × 10^3 = 60 × 3900 × $\Delta\theta$ **(1)**
$\Delta\theta$ = 0.21 K **(1)** (0.205 K)
(allow C.E. for value of energy from (i)) 3

(b) $\Delta Q = ml$ gives 500 × 60 **(1)** = m × 2.3 × 10^6 **(1)**
m = 0.013 kg **(1)**

3

(c) not generating as much heat internally **(1)**
still losing heat (at the same rate)
[or still sweating] **(1)**
hence temperature will drop **(1)**

lmax 2

[8]

5

(a) moving driver has momentum **(1)**
in sudden impact momentum must be lost in v. short time **(1)**
$F = \Delta(mv) / \Delta t$ (or $F = ma$) **(1)**
air bag increases stopping contact time **(1)**
hence reduces force (or reduces force by decreasing the deceleration) **(1)**

(max 5)

(b) seat belt applies force to smaller area than air bag **(1)**
causing greater pressure on parts of body **(1)**

(2)

(c) air initially at v. high pressure occupies small volume **(1)**
on expansion volume increases and pressure decreases **(1)**
temperature of gas decreases as it expands **(1)**
pressure caused by momentum change in molecular collisions **(1)**

(max 3)

[10]

6 (a) (i) Use of $V = \pi r^2 L$

3.47×10^{-2} or 3.5×10^{-2} (m)

Sub including V and L (condone L=18)

Or rearrangement to make r subject of correct equation

Condone power 10 error on L

1 mark for following answers

1.7×10^{-2}, 1.7×10^{-3}, 3.5×10^{-3} (m)

2

(ii) Use of $pV = NkT$ or $T = 19 + 273$ or $T = 292$ seen

Allow rearrangement making N subject $N = \frac{pV}{kT}$

Correct use of $pV = NkT$ substitution

4.26×10^{21} seen or 4.3×10^{21} seen

Condone sub of 19 for T for 1st mark in either method

Or (N =) $\frac{1.01 \times 10^5 \times 1.7 \times 10^{-4}}{1.38 \times 10^{-23} \times 292}$ seen with pV = NkT seen

Alternative use of pV = nRT ***and*** *N = nN_A in first and second marks*

First mark condone T = 19

Second mark pV = nRT seen with use of and 7(.08) × 10^{-3} × 6(.02) × 10^{23} seen

3

(iii) (NV=)$1.7 \times 10^{-4} \times 7 \times 10^{-4}$ or 1.19×10^{-7} seen

2.76×10^{-29} to 3.0×10^{-29} (m3) condone 1 sf here

Penalise where product does not equal 1.19×10^{-7}

2

(iv)
- the volume of molecule(s) is negligible **compared to** volume occupied by gas
- the particles are far apart / large spaces between particles (compared to their diameter)
- **Therefore** Time during collisions is negligible compared to time between collision
- **Therefore** intermolecular forces are negligible

Allow volume of one molecule is negligible compared to total volume

Max 3

(b) Use of $\frac{1}{2} m<c^2> = 3/2\ kT$ sub or rearrangement
Condone c_{rms} as subject for 1 mark
Condone power 10 error
Condone T = 19 in 1st MP
Correct sub with $<c^2>$ as subject including correct power 10
2.57×10^5 or 2.6×10^5 (on answer line)
m2 s^{-2}

Alternatively:

use of $pV=1/3\ Nm<c^2>$ sub or rearrangement

Condone c_{rms} as subject for 1 mark

Condone power 10 error

Condone T = 19 in 1st MP

Correct sub with $<c^2>$ as subject including correct power 10

$2.7(4) \times 10^5$ (from $N = 4 \times 10^{21}$) (on answer line)

2.57×10^5 for $N = 4.26 \times 10^{21}$

$2.5(48) \times 10^5$ for $N = 4.3 \times 10^{21}$

$m^2\ s^{-2}$

condone alternative units where correct:

Pa $m^3\ kg^{-1}$

J kg^{-1}

4

(c) (i) $p_1L_1 = k_1$ and $p_2L_2=k_2$

(consistent power 10)

i.e. 2 sets of **correct** data
seen in sub
allow incomplete sub with 2
similar k (18×10^3) values seen

$p_1L_1 = k_1$, $p_2L_2 = k_2$ *and* $p_3L_3 = k_3$

(consistent power 10)

i.e. 3 sets of **correct data**
seen in sub

Comparison of k values followed by conclusion

Presents a factorial of L leading to an inverse of the factorial change in P (correct data)

*Repeats this process for **second** data set for same factorial change (correct data)*

***States** the relationship seen and **states** the conclusion*

3

(ii) Temperature or internal energy

Allow mass / number of particles / mean square speed (of molecules)

1

(d) L decreases then volume decreases (therefore more particles in any given volume) / V = πr^2 L / V is (directly) proportional to L
Decreased volume Increases number of collisions (with walls every second)
Decreased volume causes <u>Rate of change</u> of momentum to increase
Increased <u>rate of change</u> of momentum causes <u>force</u> (exerted on walls) to <u>increase</u> (causing an increase in pressure)

Allow converse argument but must be consistent

$p = \frac{\frac{1}{3} Nm \overline{c^2}}{\pi r^2 L}$ *or equivalent*

must be correct equation with V in terms of L

with p as subject

4

[22]

7 (a) the number of atoms in 12g of carbon-12
or the number of particles / atoms / molecules in one mole of substance ✓

not – N_A quoted as a number

1

(b) (i) mean kinetic energy (= 3 / 2 kT) = 3 / 2 × 1.38 × 10^{-23} × (273 + 22)
= 6.1 × 10^{-21} (J) ✓

6 × 10^{-21} J is not given mark

1

(ii) mass of krypton atom
= 0.084 / 6.02 × 10^{+23} ✓
(= 1.4 × 10^{-25} kg)
$\overline{c^2}$(= 2 × mean kinetic energy / mass

= 2 × 6.1 × 10^{-21} / 1.4 × 10^{-25})
= 8.7 - 8.8 × 10^4 ✓
$m^2\ s^{-2}$ or J kg^{-1} ✓

1st mark is for the substitution which will normally be seen within a larger calculation.
allow CE from (i)
working must be shown for a CE otherwise full marks can be given for correct answer only
no calculation marks if mass has a physics error i.e. no division by N_A note for CE

answer = (i) × 1.43 × 10^{25}

3

(c) (at the same temperature) the mean kinetic energy is the same
or

gases have equal $\frac{1}{2}mc_{rms}^2$
or
mass is inversely proportional to mean square speed / m ∝ 1 $/\overline{c^2}$ ✓

$\overline{c^2}$ or mean square speed of krypton is less ✓

1st mark requires the word <u>mean / average</u> or equivalent in an algebraic term

2nd mark 'It' will be taken to mean krypton. So, 'It is less' can gain a mark
allow 'heavier' to mean more massive'
allow vague statements like speed is less for 2nd mark but not in the first mark

2

[7]

8 (a) the energy required to change the state of a unit mass of water to steam / gas ✓
when at its boiling point temperature / 100°C / without a change in temperature) ✓

allow 1 kg in place of unit
allow liquid to vapour / gas without reference to water
don't allow 'evaporation' in first mark

2

(b) (i) thermal energy given by copper block (= $mc\Delta T$)
= 0.047 × 390 × (990 – 100)
= 1.6 × 10^4 (J) ✓
2 sig figs ✓

can gain full marks without showing working
a negative answer is not given credit

sig fig mark stands alone

2

(ii) thermal energy gained by water and copper container
(= $mc\Delta T_{water} + mc\Delta T_{copper}$)
= 0.050 × 4200 × (100 – 84) + 0.020 × 390 × (100 – 84)
or
= 3500 (J) ✓ (3485 J)
available heat energy (= 1.6 × 10^4 – 3500) = 1.3 × 10^4 (J) ✓

allow both 12000 J and 13000 J

allow CE from (i)
working must be shown for a CE
take care in awarding full marks for the final answer – missing out the copper container may result in the correct answer but not be worth any marks because of a physics error
(3485 is a mark in itself)
ignore sign of final answer in CE
(many CE's should result in a negative answer)

2

(iii) (using $Q = ml$)

$m = 1.3 \times 10^4 / 2.3 \times 10^6$

$= 0.0057$ (kg) ✓

Allow 0.006 but not 0.0060 (kg)

allow CE from (ii)

answers between 0.0052 → 0.0057 kg resulting from use of 12000 and 13000 J

1

[7]

9 B

[1]

10 A

[1]

11 D

[1]

12 C

[1]

13 A

[1]

14 A

[1]

Examiner reports

1 This question was performed well by a majority of students. The explanation of a specific heat capacity in part (a) was very straightforward. The calculation in part (b) was done well by all but the weakest students even though it contained parts dealing with both specific heat capacity and latent heat. It was in choosing an incorrect number of significant figures that students lost the most marks.

2 (a) Many students easily gave the correct answers here. Weaker responses combined the question with an ideal gas assumptions question. It was common to see the ‘at constant temperature’ followed by ‘all collisions are assumed to be elastic’ or similar. So the constant mass was referred to in a minority of scripts.

(b) (i) The best responses were able to manipulate pV/T=constant for the initial and final states to give the correct final volume for full credit. As more data was available in the question the more circuitous route of employing pV=nkT was also used by some students to gain full credit. Students who correctly set-up either of these approaches but fell short of the accepted final answer due to arithmetical errors were given partial credit. Weaker responses failed to take into account the difference in temperature between the initial and final states and gained no credit due to this physics error.

(ii) This turned out to be easy for some and difficult for others. Some had already tacked the problem by the approach they took to part (b)(i) and simply repeated their work. Some students did run into difficulty because they chose to use the wrong volume or they calculated the number of molecules rather than the number of moles present.

(iii) The density equation was known by almost all students but it was in substituting the data where mistakes were made. The wrong volume was selected by some whilst others could not find the mass of the gas using the molar mass. In fact some thought these masses are identical.

(c) The obvious first marking point that the speed of the molecules increases with increased temperature was known by almost all students. It was interesting to note that many thought that gas molecules vibrate but this point was ignored in the marking. Very few students related the mean kinetic energy to the temperature in an equation or as a proportional relationship. Instead they spent time establishing the link between speed and kinetic energy and ignored the link to temperature.

3 Part (a)(i) was an easy introductory question, which most students got correct. Part (a)(ii) was also successfully attempted in a majority of scripts. Use of the ideal gas equation again was more popular than using pressure is proportional to temperature. A small percentage of papers gave answers to only 2 significant figures rather than the 3 required. A majority of students only scored one mark out of two for part (b). They correctly referred to the random motion but failed to refer to a mean when giving some quantity, such as kinetic energy, that increases with temperature.

4 Questions involving thermal energy have caused problems for candidates in previous papers, but this question was well answered. It also proved to be a good discriminator. Weaker candidates did have problems, however, in structuring their calculations in a logical way, leading to errors in the final answers.

The explanation in part (c) was answered well by good candidates who, in some cases, provided considerable detail which was worthy of more than the two marks allocated.

6

Part (a) (i) was completed correctly by the majority of candidates. Common mistakes seen were not converting L into metres and neglecting to double the radius to obtain the final answer.

Over ¾ of candidates achieved full marks for the calculation in part (a) (ii) with most candidates choosing to use $PV = NkT$ to obtain the answer. A smaller number of candidates used $PV = nRT$ and $N = n\,N_A$; although this method involved slightly more working it was performed correctly.

Part (a) (iv) proved difficult for most candidates; a comparison of volume of the particles and the volume occupied by the gas was made but few could use this to support an assumption of kinetic theory.

The vast majority of candidates correctly carried out the calculation in part (b) but some of these had problems with the unit for mean square speed often quoting this unit as m s^{-1}. Other candidates misread the question and found the rms speed.

Candidates were familiar with the technique required to analyse data presented in a graph to show proportionality but some candidates lost marks through poor communication of their working.

Part (d) was another explanation type question where candidates had difficulty scoring marks. The question was set in a context which was slightly removed from a standard explanation of the relationship between pressure and volume. Candidates seemed unfamiliar with how to use kinetic theory to explain this relationship. An explanation based on change in force due to change in rate of change of momentum was required to achieve full marks and unfortunately this was lacking from most candidates' answers. When this was attempted many of these candidates stated that the rate of change of momentum had increased due to the particles travelling faster even though the compression had happened at constant temperature.

7

A majority of candidates obtained the mark for part (a) by stating it was equal to the number of atoms in one mole of substance. Very few gave the full definition which relates to carbon-12. Many candidates must have been aware of the definition because they tried to incorporate it into what they put down. For example, 'The number of atoms in one mole of carbon-12'. Sometimes the halfway approach went wrong and we saw, 'The number of particles in 1 atom of carbon-12', or similar. There were also a few candidates who took a kinetic theory equation, which had Avogadro constant, which they then rearranged to make the constant the subject. This was not regarded as a definition.

In part (b)(i) was an easy substitution into an easy equation and most candidates scored the mark.

By contrast in (b)(ii) it was only the very best candidates who completed the whole of the question. The main problem was that the majority did not appreciate that the mass of an individual krypton atom was required in the equation for mean kinetic energy. The other surprising difficulty was the unit of mean square speed. Only about a quarter of candidates got this correct.

In part (c) most candidates scored the mark for krypton's mean square speed being less. As expected the most common error in the explanation was to suggest the kinetic energies of both gases are the same rather than having the same means for their kinetic energies.

8 A majority of candidates only scored one mark in part (a). These candidates either forgot to indicate a unit mass or, as in a majority of cases, they omitted the phrase, 'without a change in temperature', or equivalent. A few had problems in appreciating whether energy was required or whether energy was given out. It was very noticeable that at the lower ability end candidates have a poor vocabulary associated with this area of physics. Phrases like, 'to change water to a gas without changing state', or 'condense water into steam', and others showed a lack of distinction between boiling and evaporation.

The calculation of part (b)(i) did not hold many difficulties for the bulk of the candidates but the significant figure issue did. In part (b)(ii) most candidates were relatively clear how to tackle this question. It was in the detail that errors were made. The most significant was to forget about the copper can, which also gained energy to reach the final temperature. Also at the lower ability end there were many opportunities to make arithmetic errors.

The scores were much better for part (b)(iii) albeit from an error carried forward from part (b)(ii) in many cases. So the use of the latent heat equation is not difficult to grasp for a majority of candidates. The main error was from rounding off incorrectly or making errors in powers of 10 when converting to SI units.