

Question Number	Answer	Mark
1) (a)	Temperature (of gas) [treat references to oil/room as neutral] Mass of air/gas Or number of atoms/molecules/moles of air/gas [accept amount of air/gas, number of particles of air/gas]	(1) (1) 2
(b)	Assumption: idea that volume occupied by trapped air \propto length of air in tube [e.g. volume = cross-sectional area \times length] $pL = \text{a constant}$ [accept $pV = \text{a constant}$] Or if p doubles, L halves At least 2 pairs of p, L values correctly read from graph Readings show that $pL = 4500$ (kPa cm) [± 100 kPa cm] Or Readings show that p doubles when L is halved [Accept references to V instead of L] <u>Example of calculation</u> $p = 400$ kPa, $L = 11.0$ cm $pL = 400 \times 11.0 = 4400$ $p = 200$ kPa, $L = 23.0$ cm $pL = 200 \times 23.0 = 4600$	(1) (1) (1) 4 (1)
(c)	Use of $pV = NkT$ [Allow use of $pV = nRT$ and $N = n.N_A$] Conversion of temperature to kelvin $N = 8.4 \times 10^{20}$ [Accept answers in range 8.1×10^{20} to 8.4×10^{20}] [Answer in range but with an incorrect temperature conversion score max 2] <u>Example of calculation</u> $N = \frac{450 \times 10^3 \text{ Pa} \times 0.10 \text{ m} \times 7.5 \times 10^{-5} \text{ m}^2}{1.38 \times 10^{-23} \text{ JK}^{-1} \times (273 + 20) \text{ K}} = 8.35 \times 10^{20}$	(1) (1) (1) 3
(d)(i)	No change	(1) 1
(d)(ii)	Similar curve Shifted higher Or shifted to the right [an annotated diagram can score full marks]	(1) (1) 2
Total for question		12

Question Number	Acceptable Answer	Additional Guidance	Mark
2) (i)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> • The intercept represents the temperature of the air at which the volume occupied would be zero (1) • This is the absolute zero (of temperature) (1) • Absolute zero is the lowest attainable temperature (1) <p>Or absolute zero is the temperature at which the atoms/molecules of the gas have zero kinetic energy</p>	For MP3 accept atoms/molecules stop moving	3
(ii)	<p>MAX 4</p> <p>Resolution:</p> <ul style="list-style-type: none"> • It is correct that uncertainties would be reduced by using high resolution instruments (1) • But the instruments are not high resolution (1) • There could be a systematic error (in the measurements) (1) <p>Graph:</p> <ul style="list-style-type: none"> • The points do not lie on a perfect straight line (1) Or the true relationship may not be linear • Temperature intercept may not be accurate (1) Or there may be extrapolation errors • More points are needed Or a wider range is needed (1) 		4

3) Analysis, conclusions and evaluation (15 marks)

Part	Mark	Expected Answer	Additional Guidance
(a)	A1	NkT/A	$290Nk/A$
(b)	T1	$\frac{1}{h} / \text{m}^{-1}$	Column heading. Allow equivalent unit. e.g. h^{-1} / m^{-1}
	T2	2.5 or 2.50 2.8 or 2.78 3.1 or 3.13 3.6 or 3.57 4.2 or 4.17 4.8 or 4.76	A mixture of 2sf and 3sf is allowed.
	U1	From ± 0.03 to ± 0.1 , ± 0.11 or ± 0.12	Allow more than one significant figure.
(c) (i)	G1	Six points plotted correctly	Check second and fifth plots <u>and</u> other anomalous plots. Must be less than half a small square. Ecf allowed from table.
	U2	All error bars in $\frac{1}{h}$ plotted correctly	Half square or greater loses the mark. Ecf allowed from table.
(ii)	G2	Line of best fit	If points are plotted correctly then lower end of line should pass between (2.20, 1.0) and (2.30, 1.0) and upper end of line should pass between (4.75, 2.1) and (4.85, 2.1). Allow ecf from points plotted incorrectly – examiner judgement.
	G3	Worst acceptable straight line. Steepest or shallowest possible line that passes through <u>all</u> the error bars.	Line should be clearly labelled or dashed. Should pass from top of top error bar to bottom of bottom error bar or bottom of top error bar to top of bottom error bar. Mark scored only if error bars are plotted.
(iii)	C1	Gradient of best fit line	The triangle used should be at least half the length of the drawn line. Check the read offs. Work to half a small square. Do not penalise POT.
	U3	Uncertainty in gradient	Method of determining absolute uncertainty Difference in worst gradient and gradient.
(d)	C2	Value of $N = \frac{\text{gradient} \times A}{kT}$	Gradient must be used. Allow ecf from (c)(iii) but penalise POT.
	U4	Determines uncertainty in N	Method required. Do not check calculation.
(e) (i)	C3	Method to determine h	$h = \frac{NkT}{\rho A} = 1.111 \times 10^{-20} \times N$; $T = 278 \text{ K}$ Must use answer from (d).
	C4	Between 0.361 and 0.391 given to 2 or 3 sf	Must be in range. Allow 0.36, 0.37, 0.38 or 0.39. Assume metres unless otherwise specified.
(ii)	U5	Percentage uncertainty	% uncertainty in N + % uncertainty in T [Allow ΔT to be 0.5 or 1]

[Total: 15]

Uncertainties in Question 3)**(c) (iii)** Gradient [U3]

Uncertainty = gradient of line of best fit – gradient of worst acceptable line

Uncertainty = $\frac{1}{2}$ (steepest worst line gradient – shallowest worst line gradient)**(d)** [U4]Uncertainty = worst $N - N$

$$\Delta N = \frac{\Delta m}{m} \times N$$

$$\Delta N = \Delta m \times \frac{A}{kT}$$

(e) [U5]

$$\text{Percentage uncertainty} = \frac{\Delta h}{h} \times 100$$

Percentage uncertainty = percentage uncertainty in N + percentage uncertainty in T

4)

Answer	Marks
Defining the problem	
temperature (of the water)/ θ is the independent variable and volume per unit time/ Y is the dependent variable or vary θ and determine Y	1
keep temperature of room/surroundings <u>constant</u>	1
Methods of data collection	
labelled diagram of workable experiment including: <ul style="list-style-type: none"> • beaker open to air • water, labelled • workable method to heat water 	1
method to determine (change in) volume, e.g. measuring cylinder or method to determine (change in) mass, e.g. top-pan balance	1
measure time with a <u>stop-watch/timer</u> (for change in volume/mass or evaporation)	1
use a thermometer to measure θ or labelled thermometer in water in diagram	1
Method of analysis	
plot a graph of $\lg Y$ against $\lg \theta$ (or $\ln Y$ against $\ln \theta$)	1
$s = \text{gradient}$	1
$k = 10^{\text{y-intercept}}$ (for $\ln Y$ against $\ln \theta$: $k = e^{\text{y-intercept}}$)	1

Answer	Marks
Additional detail including safety considerations	Max. 6
D1 use of (protective) gloves to handle <u>hot</u> beaker/water	
D2 keep surface <u>area constant</u> (by using the same cylindrical container)	
D3 keep water temperature <u>constant</u> (while water is evaporating)	
D4 method to keep temperature constant while water is evaporating e.g. adjust heater/gently heat water to maintain temperature/use a water bath	
D5 use a large surface area to increase the rate of evaporation	
D6 $Y = \frac{\text{initial volume} - \text{final volume}}{\text{time}}$ or $\frac{\Delta V}{\text{time}}$	
D7 $\lg Y = s \lg \theta + \lg k$	
D8 relationship valid if a straight line	
D9 insulation/lagging around (sides) of beaker (not a lid)	
D10 switch off fans or close windows <u>to avoid draughts</u>	

5)

Defining the problem

- P Vary pressure.
- P For different values of pressure, measure frequency.
- D Keep frequency of sound wave generated constant.
- D Keep temperature of the air constant.

Methods of data collection

- M Labelled diagram of apparatus: container with source of sound.
- M Method of varying p : e.g. use of pump to remove air/valve to allow air in.
- M Method of measuring p : e.g. Bourdon gauge/pressure gauge/manometer.
- M Use microphone connected to oscilloscope to measure frequency.
- D Method to determine the period of the wave including the use of the timebase.
- D $f = 1/\text{period}$.

Method of analysis

- A Plot f against p^2 ; allow $\lg f$ against $\lg p$.
- A Relationship is correct if graph is a straight line through the origin.
- A $k = \text{gradient}$.

Safety considerations and additional detail

- D Use a safety screen/goggles to prevent glass entering eyes if glass container shatters.
- D Use of y-axis on c.r.o. to check that initial sound has constant amplitude.
- D Need to seal points where wires pass through bell jar.
- D Use loud sound to obtain measurable readings at low pressures.
- D Check temperature with a thermometer.

Award P, M and A marks where seen. Award a maximum of 6 D marks.

[Total: 15]