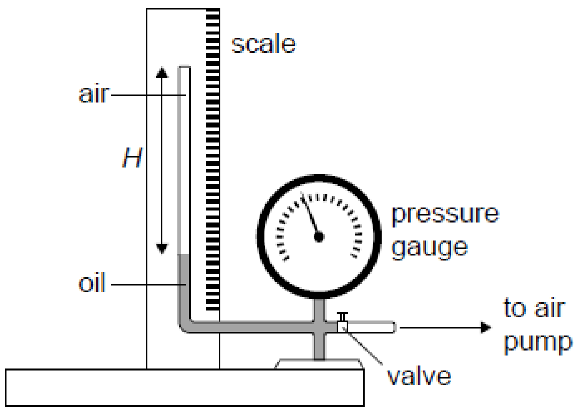
SL Paper 3

The equipment shown in the diagram was used by a student to investigate the variation with volume, of the pressure p of air, at constant temperature.

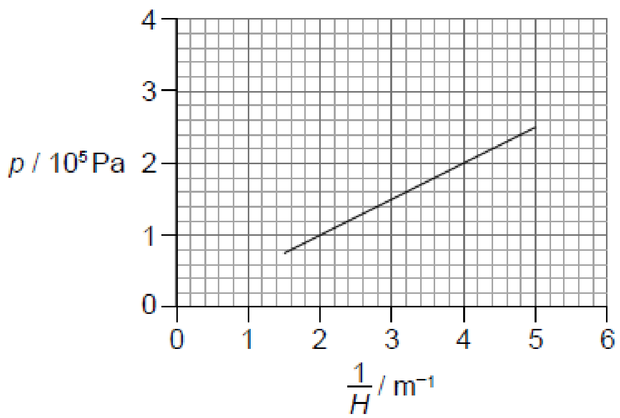
The air was trapped in a tube of constant cross-sectional area above a column of oil.



The pump forces oil to move up the tube decreasing the volume of the trapped air.

a. The student measured the height H of the air column and the corresponding air pressure p. After each reduction in the volume the student waited for some time before measuring the pressure. Outline why this was necessary. [1]

b. The following graph of p versus $\frac{1}{H}$ was obtained. Error bars were negligibly small. [3]



The equation of the line of best fit is $p = a + \frac{b}{H}$.

Determine the value of b including an appropriate unit.

c. Outline how the results of this experiment are consistent with the ideal gas law at constant temperature. [2]

d. The cross-sectional area of the tube is 1.3×10^{-3} m^2 and the temperature of air is 300 K. Estimate the number of moles of air in the tube. [2]

e. The equation in (b) may be used to predict the pressure of the air at extremely large values of $\frac{1}{H}$. Suggest why this will be an unreliable estimate of the pressure. [2]

Markscheme

a. in order to keep the temperature constant

in order to allow the system to reach thermal equilibrium with the surroundings/OWTTE

Accept answers in terms of pressure or volume changes only if clearly related to reaching thermal equilibrium with the surroundings.

[1 mark]

b. recognizes *b* as gradient

calculates *b* in range 4.7×10^4 to 5.3×10^4

Pa m

*Award **[2 max]** if POT error in b.*
Allow any correct SI unit, eg kg s^{-2}.

[3 marks]

c. $V \propto H$ thus ideal gas law gives $p \propto \frac{1}{H}$

so graph **should be** «a straight line through origin,» as **observed**

[2 marks]

d. $n = \frac{bA}{RT}$ ***OR*** correct substitution of one point from the graph

$n = \frac{5\times10^4\times1.3\times10^{-3}}{8.31\times300} = 0.026 \approx 0.03$

Answer must be to 1 or 2 SF.

Allow ECF from (b).

[2 marks]

e. very large $\frac{1}{H}$ means very small volumes / very high pressures

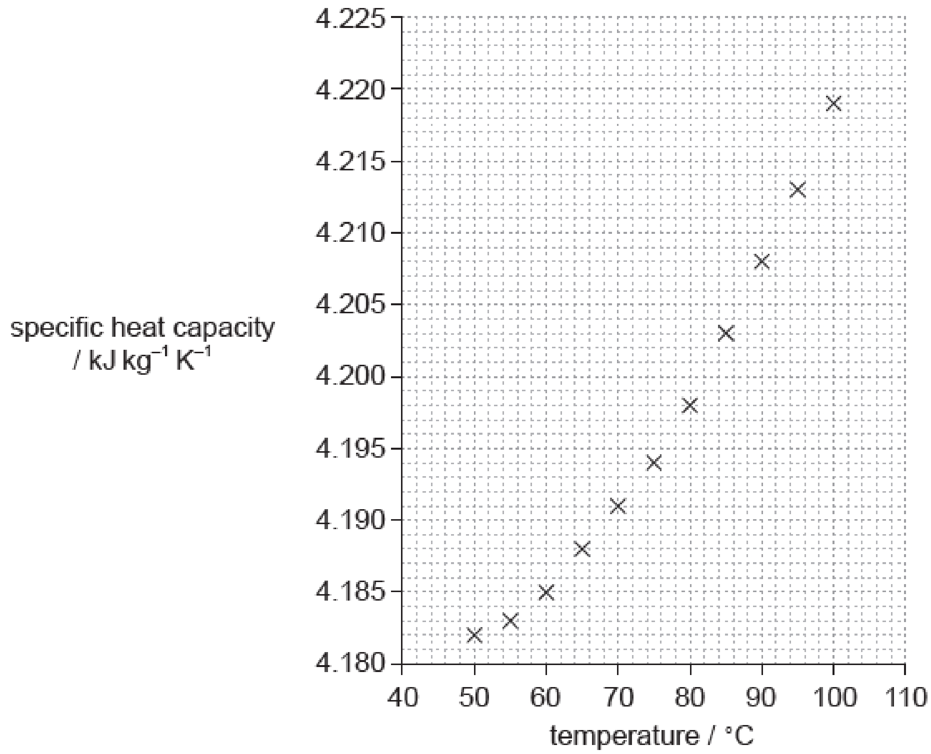
at very small volumes the ideal gas does not apply
OR
at very small volumes some of the assumptions of the kinetic theory of gases do not hold

[2 marks]

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]
d. [N/A]
e. [N/A]

In an experiment, data were collected on the variation of specific heat capacity of water with temperature. The graph of the plotted data is shown.



The uncertainty in the values for specific heat capacity is 5%.

Water of mass (100 ± 2) g is heated from (75.0 ± 0.5) °C to (85.0 ± 0.5) °C.

a. Draw the line of best-fit for the data. [1]

b.i. Determine the gradient of the line at a temperature of 80 °C. [3]

b.ii. State the unit for the quantity represented by the gradient in your answer to (b)(i). [1]

c.i. Calculate the energy required to raise the temperature of the water from 75 °C to 85 °C. [1]

c.ii. Using an appropriate error calculation, justify the number of significant figures that should be used for your answer to (c)(i). [3]

Markscheme

a. single smooth curve passing through all data points

Do not accept straight lines joining the dots

Curve must touch some part of every x

b.i. tangent drawn at 80 °C

gradient values separated by minimum of 20 °C

9.0×10^{-4} «kJ kg^{-1} K^{-2}»

Do not accept tangent unless "ruler" straight.

Tangent line must be touching the curve drawn for MP1 to be awarded.

Accept values between 7.0 × 10^{-4} and 10 × 10^{-4}.

Accept working in J, giving 0.7 to 1.0

b.ii. kJ kg^{-1} K^{-2}

Accept J instead of kJ

Accept °C^{-2} instead of K^{-2}

Accept °C^{-1} K^{-1} instead of K^{-2}

Accept C for °C

c.i. «0.1 x 4.198 x 10 =» 4.198 «kJ» ***or*** 4198 «J»

Accept values between 4.19 and 4.21

c.ii. percentage uncertainty in ΔT = 10%

«2% + 5% + 10%» = 17%

absolute uncertainty «0.17 × 4.198 =» 0.7 «kJ» therefore 2 sig figs

OR

absolute uncertainty to more than 1 sig fig and consistent final answer

Allow fractional uncertainties in MP1 and MP2

Watch for ECF from (c)(i)

Watch for ECF from MP1

Watch for ECF from MP2

Do not accept an answer without justification

Examiners report

a. [N/A]
b.i. [N/A]
b.ii. [N/A]
c.i. [N/A]
c.ii. [N/A]