A Level Physics A

H556/01 Modelling physics

Question Set 5

1 A group of students are conducting an experiment in the laboratory to determine the value of absolute zero by heating a fixed mass of gas. The volume of the gas is kept constant.

Fig. 17.1 shows the arrangement used by the students.

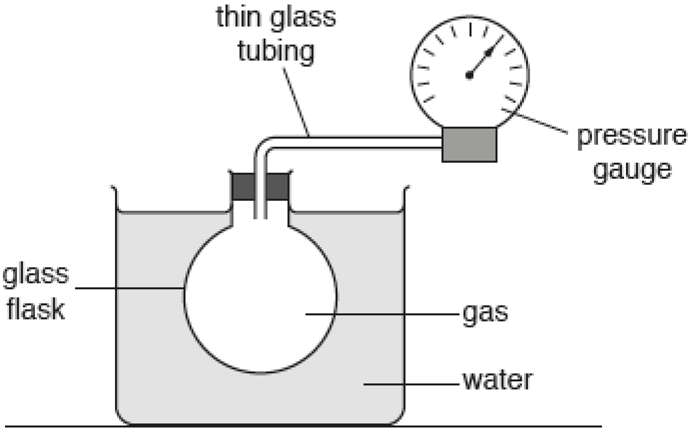

Fig. 17.1

The gas is heated using a water bath. The temperature θ of the water is increased from 5 °C to 70 °C. The temperature of the water bath is assumed to be the same as the temperature of the gas. The pressure p of the gas is measured using a pressure gauge.

The results from the students are shown in a table.

θ / °C	p / kPa
5 ± 1	224 ± 3
13 ± 1	231 ± 3
22 ± 1	238 ± 3
35 ± 1	248 ± 3
44 ± 1	
53 ± 1	262 ± 3
62 ± 1	269 ± 3
70 ± 1	276 ± 3

(a) Describe and explain how the students may have made accurate measurements of the temperature θ. **[2]**

- Heat the water bath slowly so that thermal equilibrium is maintained between the water and the gas

- Use a thermometer with a ±1°C scale, ensuring to view the scale from the same height to reduce parallax

(b) Fig. 17.2 shows the pressure gauge. Measurements of *p* can be made using the kPa scale or the psi (pounds per square inch) scale. The students used the psi scale to measure pressure and then converted the reading to pressure in kPa.

Fig. 17.2

(i) Suggest why it was sensible to use the psi scale to measure *p*. **[1]**

Smaller spaces between increments

(ii) The students made a reading of *p* of 37.0 ± 0.5 psi when *θ* was 44 ± 1 °C. Convert this value of *p* from psi to kPa. Complete the table for the missing value of *p*.
Include the absolute uncertainty in *p*.

1 pound of force = 4.448 N
1 inch = 0.0254 m **[2]**

$37 \frac{\text{pounds}}{\text{square inch}} = 37.0 \times \frac{4.448}{0.0254^2} = 255093 \text{ Pa} = 255 \text{ kPa}$

Relative uncertainty $= \frac{0.5}{37} = 0.0135$

Absolute uncertainty $= 0.0135 \times 255 = 3$ kPa (1 s.f.)

(c) Fig. 17.3 shows the graph of p against θ.

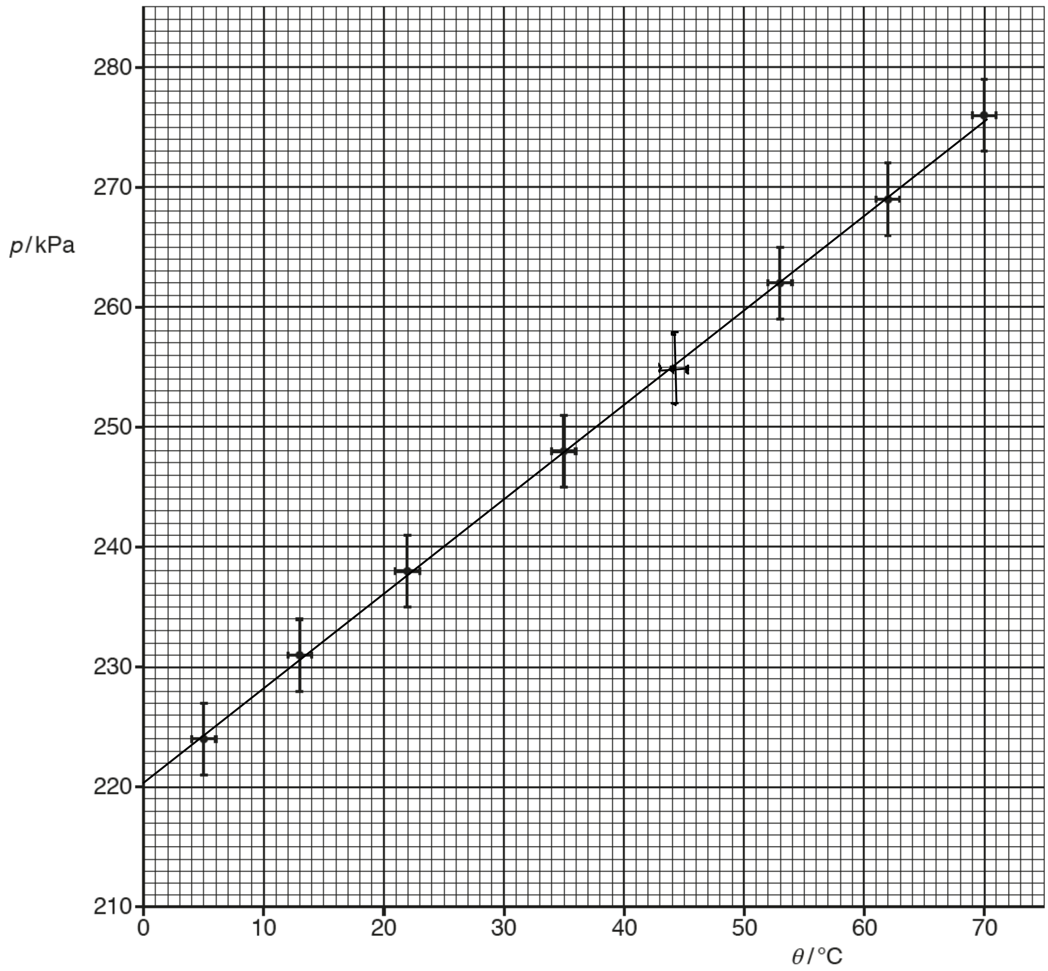

Fig. 17.3

(i) Plot the missing data point and the error bars on Fig. 17.3. **[1]**

(ii)* Explain what is meant by *absolute zero*. Describe how Fig. 17.3 can be used to determine the value of absolute zero.

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Determine the value of absolute zero. You may assume that the gas behaves as an ideal gas. **[6]**

Absolute zero is the minimum possible temperature where kinetic energy is 0. This means that internal energy at absolute zero is at a minimum. Absolute zero is about $-273°C$.

$pV = nRT$ so for a constant volume of gas $p \propto T$. Therefore a graph of p against θ is straight line of form $y = mx + c$. Absolute zero is the temperature at the x axis, so where pressure (which is $\propto$ |KE|) $= 0$.

From graph, y intercept $c = 220$. Gradient $= \frac{275 - 220}{70} \approx 0.786 = m$

$p = 0.786\theta + 220$ → set $p = 0$

$\frac{-220}{0.786} = \theta$ → $\theta = -280°C$ = Absolute zero

(d) Describe, without doing any calculations, how you could use Fig. 17.3 to determine the actual uncertainty in the value of absolute zero in **(c)(ii)**. **[2]**

- Draw a line of worst fit (that still fits in error bars)
- Find a new value of absolute zero. The difference between this and −280 is the absolute uncertainty

(e) The experiment is repeated as the water bath quickly cools from 70 °C to 5 °C. Absolute zero was found to be −390 °C.

Compare this value with your value from **(c)(ii)** and explain why the values may differ. Describe an experimental approach that could be taken to avoid systematic error in the determination of absolute zero. **[4]**

This value is lower than the value in (c)(ii). This is because when the water is cooling quickly, the temperature of the gas lags behind that of the water. This shifts the entire graph to the left, hence giving a falsely low value for absolute zero. To avoid this, you could measure the temperature of the gas directly.

Total Marks for Question Set 5: 18