

Gas laws, kinetic theory and thermal energy

Physics grades 11-12 (A Level · IB · Class 11-12) · Lab answers

The sample data give a straight line with a gradient near 0.34 kPa/°C and an intercept at 94.0 kPa. The values below use these numbers, so your own results will differ slightly depending on your readings.

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Question 1 Plotting the graph

The points lie close to a straight line with a positive gradient that does not pass through the origin. The pressure increases by equal steps for equal temperature steps, so **p increases linearly with θ** : $p = m\theta + c$.

Question 2 Gradient

Gradient = $\Delta p / \Delta \theta = (128.2 - 94.0) / (100 - 0) = 34.2 / 100 = \mathbf{0.342 \text{ kPa/}^\circ\text{C}} \approx \mathbf{0.34 \text{ kPa/}^\circ\text{C}}$.

Question 3 Estimating absolute zero

At $p = 0$: $\theta = -c / m = -94.0 / 0.34 = \mathbf{-276 \text{ }^\circ\text{C}}$. A least-squares fit of the six points gives $m = 0.345 \text{ kPa/}^\circ\text{C}$ and $c = 93.9 \text{ kPa}$, so $\theta = -272 \text{ }^\circ\text{C}$, consistent with this estimate.

Question 4 Comparing with the accepted value

Difference = $3 \text{ }^\circ\text{C}$. Percentage difference = $(3 / 273) \times 100 = \mathbf{\text{about } 1 \%}$. The experiment agrees well with the accepted value of $-273 \text{ }^\circ\text{C}$.

Question 5 Why kelvin is better

For a fixed amount of gas at constant volume, $pV = nRT$ gives $p = (nR/V)T$, so p is proportional to the kelvin temperature. In degrees Celsius $T = \theta + 273$, which adds a constant, so $p = (nR/V)(\theta + 273)$ is linear but has an intercept. **Proportionality holds only from the absolute zero of the scale.**

Question 6 Sources of error

Any two of: air in the tube and gauge is at room temperature, not the bath temperature (so not all the gas is heated); the air inside lags behind the thermometer reading; the bung leaks slightly; the gauge has poor resolution; the thermometer is in the bath, not in the flask. **These shift the intercept and gradient.**

Question 7 Uncertainty in temperature

Percentage uncertainty = $(1 / 20) \times 100 = 5 \%$. At 100 °C it would be only 1 %. The uncertainty matters more at low temperatures, where the reading is smaller.

Question 8 Improving the method

Any two of: stir for longer so the gas reaches the bath temperature; put the whole flask and tube in the bath; use a digital probe with 0.1 °C resolution; take more readings and repeat each; extend the range with a colder salty-ice bath. **Less systematic error gives a more reliable estimate of absolute zero.**