Core practical 14: Investigate the relationship between the pressure and volume of a gas at fixed temperature

Objective

- To measure the volume of a gas at constant temperature but varying pressure

Safety

- Students should carry out this work with due attention to safety and complete an appropriate risk assessment.
- Safety goggles are required throughout the practical work.

Specification links

- Practical technique 1
- CPAC 1a, 2c, 3b, 5a

Procedure

Research

1. Find out about the apparatus used to investigate Boyle's law and the way it is used in practice.
2. Write a plan to conduct an investigation into Boyle's law and produce a risk assessment. You should include two precautions you will take to improve accuracy.

Practical

1. Use the Boyle's law apparatus and your plan to carry out your investigation safely.

Notes on procedure

- This investigation offers the opportunity to write a plan and consider the safety of both the apparatus and students. Although the risks are slight, the hazards should be identified correctly and an appropriate risk analysis written, identifying the precautions to be taken. It is expected that students will write their own plan and can carry out the work unaided.
- CPAC 1a is shown in students' successful results and CPAC 2c is shown in their plan, where they should comment on temperature changes. CPAC 5a comes from their planning, which should be in their laboratory notebooks. Additionally, CPAC 3b can be judged from their risk assessment.
- Students should work out that they require safety goggles as part of their risk assessment. Ensure that no practical work takes place without the use of these.

Answers to questions

1. Student's answer may include:
   - Carried out the pressure changes slowly and left some time between them so that the temperature of the gas was unaffected by the volume change.
   - Increased the pressure to give a decreasing volume. Could not decrease the pressure to obtain repeat readings because the oil would cling to the walls of the tube if the volume of gas increased, making the volume readings too large.
2. Some possible hazards include:
   - The apparatus could have fallen over.
   - The pressure pump, with sufficient force, could have been unstable.
   - The tubing or joints could have burst under the increased pressure.

   The precautions taken may include:
   - The apparatus was weighted or clamped to improve stability and the apparatus was not near the edge of the bench.
   - Care was taken when pressing on the pump, especially at high pressures, to ensure that the action was vertically down and above the base of the pump.
   - No action could be taken to completely avoid the apparatus bursting at high pressure, but the apparatus was closely observed as the work was carried out and safety goggles were worn by all.
3. Line-of-sight observation was made, at the same horizontal level as the bottom of the meniscus. The reading was taken from the adjacent scale.
4. The air is contained above the oil and the length scale starts from the top. Since the cross section A of the tube is constant, the volume V above the oil is proportional to the length l since $V = A \times l$. The practical seeks to establish proportionality so this does not affect the result.

Sample data

p/kPa	l/cm
108	45.6
121	40.6
129	38.0
150	32.0
166	28.8
179	26.6
197	24.1
215	22.1
230	20.6
238	20.0
245	19.3

Results will depend on apparatus and quantity of gas.

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All the maths you need

- Recognise and make use of appropriate units in calculations.
- Use ratios, fractions and percentages.
- Use an appropriate number of significant figures.
- Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined by addition, subtraction, multiplication, division and raising to powers.
- Substitute numerical values into algebraic equations using appropriate units for physical quantities.
- Translate information between graphical, numerical and algebraic forms.
- Plot two variables from experimental or other data.
- Understand that $y = mx + c$ represents a linear relationship.
- Determine the slope and intercept of a linear graph.
- Sketch relationships which are modelled by $y = \frac{k}{x}$, $y = kx^2$, $y = \frac{k}{x^2}$, $y = kx$, $y = \sin x$, $y = \cos x$, $y = e^{\pm x}$, and $y = \sin^2 x$, $y = \cos^2 x$ as applied to physical relationships.

Equipment

- Boyle's law apparatus
- pressure pump
- safety screen

Procedure

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Practical

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Analysis of results

1. Use ICT to display your data as a straight line graph and calculate the constant in the law.
2. Estimate the uncertainty in your value for the constant.
3. Discuss how successful your precautions were in improving accuracy.

Learning tips

- Boyle's law tells us that the pressure p and volume V are related by the expression $p \times V = \text{constant}$

Questions

1. Describe the precautions you took to improve the accuracy of your measurements and explain how they worked.
2. Describe any safety hazards you identified and explain how your safety precautions worked in practice.
3. Describe how you observed the level of the oil when recording the volume.
4. Explain why it is sufficient to measure the length of the oil column and not the volume of the air directly.

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Objective	Safety
● To measure the volume of a gas at constant temperature but varying pressure	● Students should carry out this work with due attention to safety and complete an appropriate risk assessment.
Equipment per student/group	**Notes on equipment**
Boyle's law apparatus	Standard apparatus
pressure pump	Tyre pump: car or bicycle
safety screen	Set up the screen directly in front of the apparatus. It is possible for students to do this experiment using syringes with masses to compress the gas, in which case the safety screen will not be required.
safety goggles	Students should work out that they require these as part of their risk assessment, so ensure they are available.
Notes	