Gay-Lussac's law: absolute zero

FizziQ activity · High school · 25 min

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In the online FizziQ Web ideal gas simulation at constant volume, high school students record pressure and temperature, then extrapolate P(T) to absolute zero.

Learning objectives

- Experimentally verify Gay-Lussac's law (P/T = constant at constant V)
- Record pressure and temperature simultaneously during an isochoric transformation
- Plot P versus T and verify the linear relationship
- Estimate absolute zero by extrapolating the P(T) graph to P = 0
- Understand the connection between Gay-Lussac's law and the ideal gas law

Instruments and sensors

FizziQ Web Ideal Gas simulation

Materials

- Computer, tablet, or smartphone with FizziQ Web
- Note: the protocol remains adaptable to any comparable simulation or data-plotting tool.

Protocol

1. Open the Ideal Gas simulation in FizziQ Web. Position the piston at mid-stroke and do not touch it for the entire experiment.
2. Select the quantities to record: enable Pressure and Temperature.
3. Set the temperature to the minimum (273 K = 0°C). Note the corresponding pressure.
4. Click REC to start recording. Slowly increase the temperature from 273 K to 333 K (60°C) by moving the temperature slider gradually.
5. Stop the recording. The P and T data are exported to the experiment notebook.
6. Plot the graph of P versus T (in kelvin). Is the curve a straight line?
7. Calculate the ratio P/T for several data points. Is this ratio constant?
8. If you plotted P(T) in kelvin, the line should pass through the origin. If you plot P versus temperature in °C, at what negative temperature does the line cross P = 0?
9. Extrapolate the P(T in °C) line to P = 0. At what temperature does the line cross the axis? This value is an estimate of absolute zero.
10. Compare your value with the theoretical absolute zero (-273.15°C = 0 K). Write a conclusion about the relationship between pressure and absolute temperature.

Expected results

The graph P(T in kelvin) is a straight line through the origin, confirming P = (nR/V) × T. The ratio P/T is constant for all measurements. When plotted in °C, the line crosses the P = 0 axis at approximately -273°C, providing an experimental estimate of absolute zero. The precision depends on the range of temperatures explored and the linearity of the data.

Questions

- Why is pressure proportional to absolute temperature rather than to temperature in °C?

- What would physically happen if you could cool a gas down to absolute zero?
- How can you verify that the volume truly stayed constant during the experiment?
- Why does the graph P(T in °C) not pass through the origin while P(T in K) does?
- What is the physical meaning of the slope of the P(T) line?
- How would the graph change if you repeated the experiment at a different (but still constant) volume?

Going further

- Perform the same experiment at two different volumes (piston in two positions) and compare the slopes of the P(T) lines
- Compare the simulation results with those from a real experiment using a smartphone barometer
- Calculate the number of moles n from the slope and the known volume
- Investigate what happens if the piston is not perfectly fixed during the experiment
- Estimate absolute zero from only two data points and evaluate the precision compared to using the full dataset