Ideal gas law by barometer

FizziQ activity · High school · 30 min

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A smartphone sealed in a jar records pressure with the FizziQ barometer as temperature changes, verifying Gay-Lussac's law and estimating absolute zero. High school.

Learning objectives

- Measure atmospheric pressure variations with the smartphone barometer
- Verify Gay-Lussac's law (P proportional to T at constant V)
- Plot a P(T) graph and perform a linear extrapolation
- Estimate absolute zero from the P(T) extrapolation
- Understand the limitations of the ideal gas model

Instruments and sensors

Barometer · Thermometer · Hygrometer · Pressure sensor · Temperature sensor · Humidity sensor

Materials

- Smartphone or tablet with FizziQ
- An airtight glass jar (mason jar type)
- Ice or a freezer
- Warm water (40-50°C)
- External thermometer (if the phone lacks one)
- Note: the protocol remains adaptable to any comparable pressure and temperature data-acquisition tool.

Protocol

1. Verify that your smartphone has a barometer. A temperature sensor and hygrometer are a bonus but not required.
2. Open FizziQ and configure simultaneous recording of the Barometer and any other available sensors (thermometer, hygrometer).
3. Start the recording and place the smartphone in the airtight jar. Seal carefully.
4. Leave the system at room temperature for 2 minutes to stabilize. Note P_0 and T_0.
5. Place the jar in a freezer or surround it with ice. Wait 5 to 10 minutes for the temperature to drop by at least 15°C.
6. Observe the evolution: pressure decreases with temperature, relative humidity increases.
7. Remove the jar from the cold and warm it gently (warm water around the jar, 40-50°C). The pressure rises.
8. Stop the recording and analyze the data.
9. For each data point, calculate the ratio P/T (in kelvin). Verify that this ratio remains constant to within a few percent.
10. Plot P versus T (in kelvin). A straight line through the origin confirms Gay-Lussac's law. Extrapolation to P = 0 gives an estimate of absolute zero.

Expected results

The pressure decreases by 5 to 10 hPa during a 20°C cooling. The ratio P/T (in kelvin) remains constant to 1-2%. Relative humidity increases in the cold, with possible condensation. The graph P(T in kelvin) is a straight line. Extrapolation to P = 0 gives approximately -273°C.

Questions

- Why must the ratio P/T be calculated in kelvin rather than Celsius?
- What factors explain why P/T is not perfectly constant?
- How could you improve the precision of the absolute zero estimate?
- Why does the phone's internal heat generation affect the results?
- What would happen if the jar seal leaked during the experiment?
- How does this experiment relate to the behavior of real gases?

Going further

- Extrapolate the P(T) line to P = 0 to estimate absolute zero
- Use a flexible bag instead of a rigid jar to observe volume changes at constant pressure
- Record over a full day and correlate pressure changes with outdoor temperature
- Compare results from jars of different sizes
- Use a second phone outside the jar as a temperature reference