Changes in temperature, changes in pressure

Common behaviour

Gases are remarkable because they are all so similar. Solids vary considerably because they are tightly bound, and the details of the bonding between the particles affect the properties of the material. Gases are not tightly bound, so are much simpler. Increasing either the mass or speed (or both) of the particles that make up the gas is likely to result in more violent collisions, so increasing the pressure of the gas. It is best to do one thing at a time, so as to keep the story simple, so keep the mass of the particles, and the number of particles, constant.

Increasing the temperature increases the speed of the particles, so expect this change to increase the pressure. Here you are asked to find as exact a relationship as you can between temperature and pressure.

You will need

* beaker, 400 cm3
* pressure sensor
* thermometer
* gas sample

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| SafetyStrong heating of glass is always hazardous, so protect your eyes, and, in the second example, use a safety screen.  |



Thinking about the measurements

You need to measure how the temperature of a fixed number of particles affects the pressure. In a school laboratory you may be constrained by the range of temperatures you can reach (remembering that all of the fixed mass of gas must be at one temperature), or the resolution of the pressure meter over this range of temperatures.

A traditional solution



1. Take readings of pressure for the widest range of temperatures that you can manage

(0–100 C?). This is only likely to give a small range of pressures (think about the range of temperatures the gas could exist at). Plot a graph as you go.

1. Look for a pattern in the results and then plot a presentation graph, showing the pattern clearly.
2. Are there any regions of the graph that do not fit your pattern as well? Can you account for these deviations in ways that relate back to the state of the gas at that point – or other likely weaknesses in the experimental arrangement?

A more sophisticated solution



1. Strongly warm the air in a Bunsen flame. Remove the boiling tube from the flame and start capturing data, perhaps for 10 minutes.
2. Once you have checked that your plots of pressure / time and temperature / time are sensible, try plotting pressure / temperature. Look for a clear relationship.
3. Any of your plots may have revealed regions where the readings are not sensible, and you may be able to relate this to the particulars of the experiment that you have just carried out. Once you have eliminated these, produce some presentation-quality graphs.

You have

1. Measured how the pressure of a gas changes with its temperature.
2. Thought carefully about why the experiment is set up in a particular way.
3. Produced a set of presentation-quality graphs describing the relationships you found.

Safety

The most likely failure is the bung being blown out. The second most likely is the boiling tube breaking. A safety screen or screens should be placed to protect the experimenter from both modes of failure.

Changes in temperature, changes in volume

Common behaviour

Gases are remarkable because they are all so similar. One of their similarities is that they occupy all the volume that they are placed in, exerting pressure on all of the walls. If the container is flexible then warming the gas can change the volume of the container. Pressure increases as the gas is warmed, then decreases as the molecules become more spread out when the container expands. The walls of the container come to equilibrium again when the pressure inside the container is equal to the atmospheric pressure on the outside of the walls.

Increasing the temperature increases the speed of the particles, so expect this change to increase the volume. Here you are asked to find as exact a relationship as you can between temperature and volume.

You will need

* Charles’ law apparatus



Thinking about the measurements

You need to measure how the temperature of a fixed number of particles affects the volume. In a school laboratory you may be constrained by the range of temperatures you can reach (remembering that all of the fixed mass of gas must be at one temperature), and by the need to have a container for the gas which allows the volume to change, but which does not leak gas. The traditional solution uses a liquid to trap the gas and to provide a flexible wall to the container so allowing changes in volume to be measured.

A traditional solution

Safety

The traditional apparatus uses a narrow bore tube but not a capillary tube, e.g. a bore of

1 to 1.5 mm. It is now difficult to obtain tubing of this size and a bore of 2 to 3 mm is used.

The air was traditionally trapped by a short thread of concentrated sulphuric acid to ensure that the air is dry. The acid drains down a tube with wider bore than that described above. Consequently, the experimenter is tempted to refill the tube just before the experiment.

In this case, the tube must be heated in an oven to about 200 °C, held upside down with its open end under the surface of the acid in a small test tube or beaker until it has cooled sufficiently to draw a small thread from the acid and allowed to return to room temperature.

A face shield or goggles must be worn during this procedure.



1. Take readings of volume for the widest range of temperatures that you can manage

(0–100 C?).This is only likely to give a small change in volume. Plot a graph as you go.

1. Look for a pattern in the results and then plot a presentation graph, showing the pattern clearly.
2. Are there any regions of the graph that do not fit your pattern so well? Can you account for these deviations in ways that relate back to the state of the gas at that point – or other possible weaknesses in the experimental arrangement?

Working towards a neater solution

1. You need, if possible, to find a wider range of temperatures.
2. Plan to record the volume automatically
3. Check your apparatus for leaks.
4. You will probably find that data are gathered over time – so try plotting temperature / time and volume / time to make sure that the data gathered make sense before processing the information.
5. Any of your plots may have revealed regions where the readings are not sensible, and you may be able to relate this to the particulars of the experiment that you have just carried out. Once you have eliminated these, produce some presentation-quality graphs.

Changing pressure and volume by changing temperature



This diagram shows how temperature affects pressure and volume, suggesting extrapolation to absolute zero. In turn this provides a basis for the absolute zero of temperature.