

TAP 601- 6: Changes in temperature, changes in volume

Common behaviour

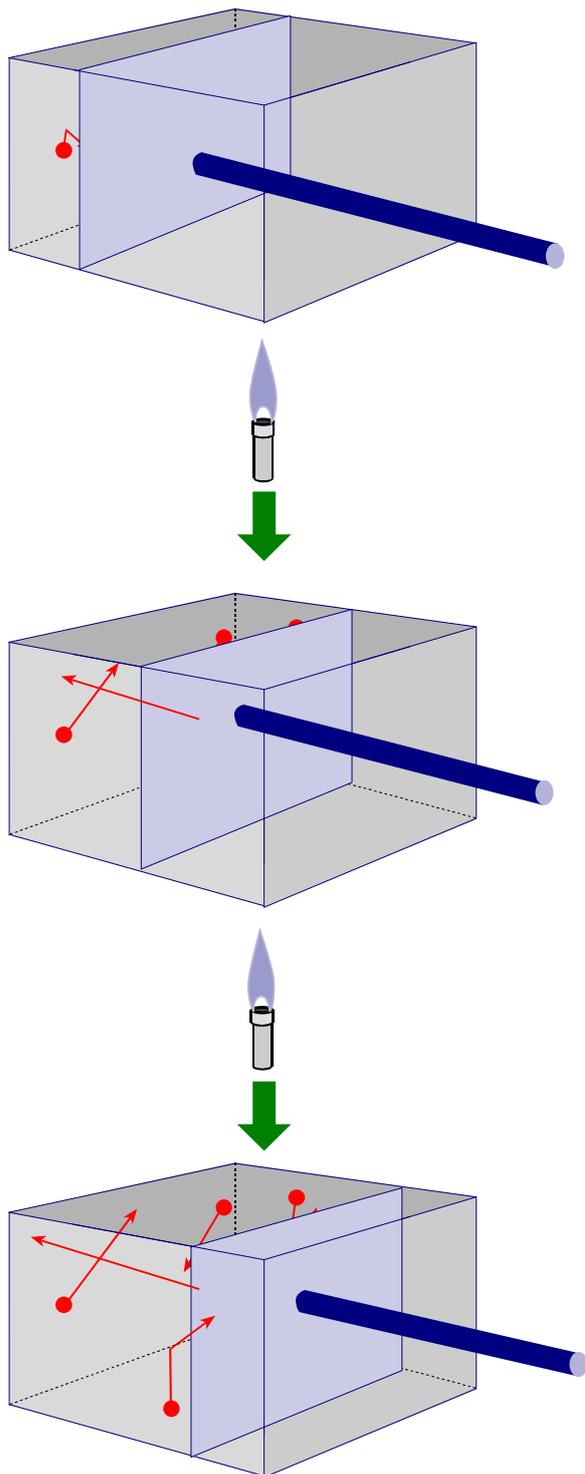
Gases are remarkable because they are all so similar. One of their similarities is that they occupy all the volume that they are placed in, exerting pressure on all of the walls. If the container is flexible then warming the gas can change the volume of the container. Pressure increases as the gas is 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

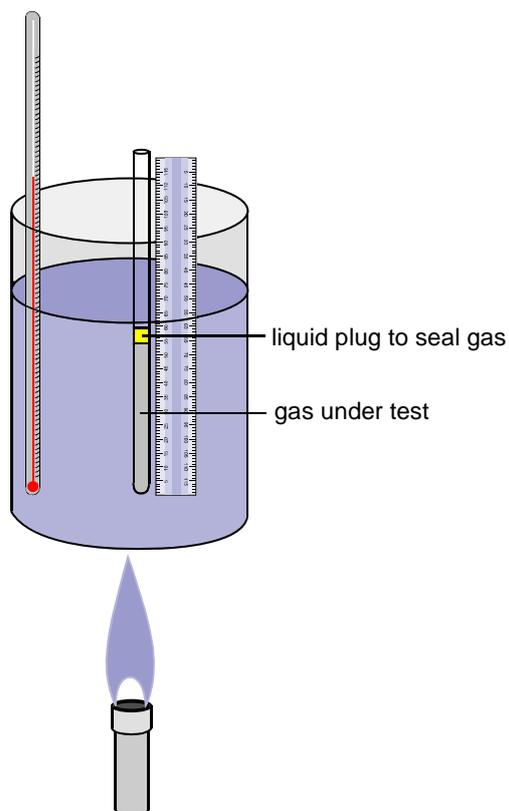
- ✓ Charles' law apparatus

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



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.
2. Look for a pattern in the results and then plot a presentation graph, showing the pattern clearly.
3. 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?
- 4.

Working towards a neater solution

1. You need, if possible, to find a wider range of temperatures.
2. Aim to record the volume automatically, perhaps using a potential divider arrangement connected to a syringe.
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.

You have

1. Measured how the volume 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 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.

Practical advice

In this activity it is important that students do not simply collect data and then plot a graph. They also need to be encouraged to appreciate a little of the ingenuity that has resulted in the apparatus being put together in the way that it has. It is also important that students imagine the gas molecules at work, producing the increase in volume by blindly colliding with the container walls more and more often as the temperature rises.

Alternative approaches

Producing a datalogged version of this experiment is not easy. The problems revolve around the measurement of volume, where a linear position sensor allied to a syringe look attractive. However, the difficulties in making the syringe airtight result in considerable discrepancies.

External reference

This activity is taken from Advancing Physics chapter 13, 40E