

PHYSICS

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Semi-quantitative exercises illustrating the effect of pressure and volume changes for fixed amounts of air

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INTRODUCTION

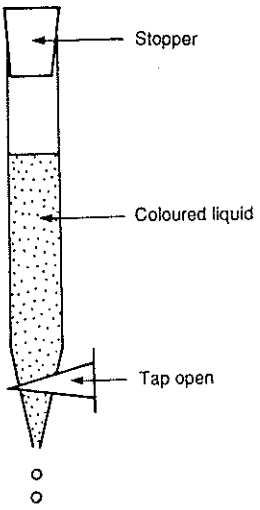
In reviewing the problem-solving skills of high school chemistry students, Gabel, Sherwood and Enochs (1984, p.232) found that 'few students used reasoning skills in solving any problems whatsoever. They not only relied almost entirely on algorithms but in many cases made them fit problems in inapplicable situations'. These authors proceed to conclude that 'one way of helping students overcome this algorithmic mode is to make certain that students understand the chemical concepts qualitatively before they are presented quantitatively'. Osborne and Schollum (1983, p.22) also conclude after a three-year study of science teaching and learning at the 11-14 year-old age level in New Zealand that 'long before pupils can be introduced to the representational and explanatory levels of chemistry it is important that pupils understand the chemist's view of chemical substances, and their changes, at the descriptive and functional levels'.

A recent study of the historical development of the pressure-volume gas law (de Berg, 1988) emphasises the role of Boyle's qualitative experiments on air in providing a foundation for the emergence of the quantitative law. A school textbook analysis of the emergence of the pressure-volume law (de Berg, 1989) reveals an almost complete dearth of the use of qualitative exercises impinging on the quantitative P-V law. In this article, examples of such qualitative (or semi-quantitative) exercises dealing with the effects of pressure and volume changes for fixed amounts of air are presented and discussed.

SEMI-QUANTITATIVE EXERCISES

The following demonstrations all involve pressure-volume changes to a fixed amount of air at a constant temperature, conditions under which Boyle's pressure-volume law would apply. Following the demonstration, students are required to record what happens in each case and provide an explanation for what they see. Some examples of actual student responses and scientifically acceptable responses to the question 'Why it happens?' are given for demonstrations 1 and 2.

Demonstration 1 - Burette



What happens: With the tap fully open and no stopper in the top, the liquid flows freely from the tap. When the stopper is inserted in the top of the burette a little more liquid flows through the tap; then it stops flowing even though the tap is fully open and liquid remains in the burette.

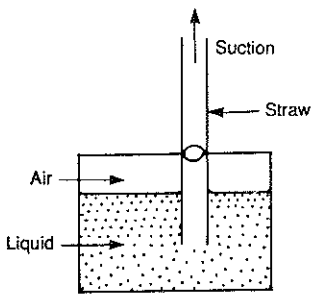
Why it happens (A scientifically acceptable explanation): When the stopper is inserted and a little liquid flows out, the volume of enclosed air above the liquid increases thus reducing the pressure of air in this space below atmospheric pressure. A point is reached where this reduced air pressure plus the pressure due to the height of water remaining in the burette just balances the external atmosphere pressure and no further water-flow occurs from the burette.

Why it happens (An actual student [16 year-old] response): When the bung is placed in the top of the burette it stops any more air entering the burette - as there is no longer any air pushing on the liquid so it doesn't flow any more until the bung is removed.

Students tend not to initially relate the observation here to pressure and volume changes of air. Typically they consider confined volumes of air as not exerting any pressure at all. This has important implications in the empirical derivation of Boyle's law where the pressure and volume of confined amounts of air are measured.

Demonstration 2 - Popper juice container

What happens: As one drinks, the sides of the cardboard container collapse. When one stops drinking, a bubbling noise is heard in the liquid and the sides of the container return to their normal positions.

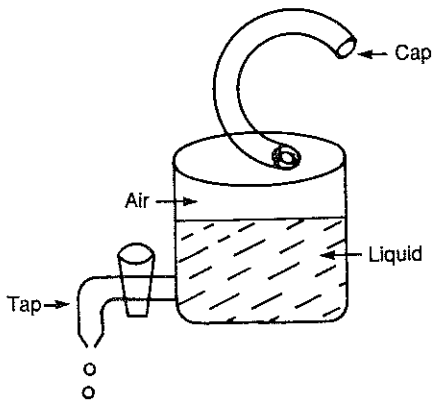


Why it happens (A scientifically acceptable explanation): The insert for the straw provides a neat seal for the air above the juice. When some of the juice is drunk the volume of the fixed amount of air above the juice increases thus reducing the pressure of the air. The pressure of the air external to the popper is now greater than the pressure of the internal air thus causing the sides to collapse. When suction is complete atmospheric air enters the popper to equalise the pressure and the sides of the container return to their normal position.

Why it happens (An actual student [20 year-old diploma student] response): The sides collapsed because the straw of the popper is sealed in - no air can enter the carton to make the pressure 'equal', therefore the sides collapse.

Students do not intuitively understand changes such as those demonstrated here in terms of pressure and volume changes of fixed amounts of air. They will tend to state the obvious as in the example above or as another student said, 'The sides caved in on the box because the air pressure is greater on the outside than the inside'. Isolating the concepts of pressure and volume and locating the fixed amount of air is crucial before discussing inverse proportion for pressure and volume.

Demonstration 3 - Drink container



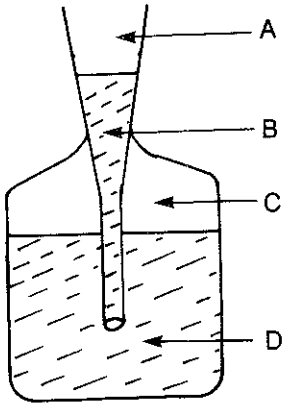
The diagram represents a plastic drink container fitted with a tap and a plastic cap for sealing off the air above the liquid.

What happens: When the cap is inserted in the top of the container, the liquid ceases to flow after a short time even though the tap is still open.

Why it happens: Explanation to be given by students.

Demonstration 4 - Funnel and bottle

The diagram below represents oil being poured through a funnel into a plastic bottle. Identify which letter refers to the fixed amount of air, describe what happens during the pouring process, and give an explanation for what happens.



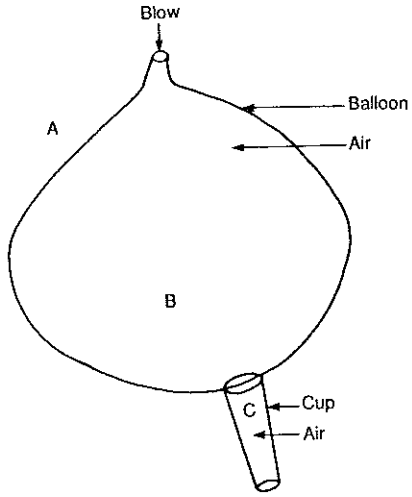
Fixed mass of air: To be identified by students (A, B, C or D).

What happens: As the liquid is passed through the funnel into the bottle a stage is reached when the liquid ceases to flow through the funnel even though the bottle is not filled. (A good seal between the bottle and the funnel is required for this to happen.)

Why it happens: Explanation to be given by the students.

Demonstration 5 - Balloon and cups

The diagram below represents air being blown into a balloon as a plastic or paper cup is pushed into the exterior of the balloon. Identify which letter refers to the fixed amount of air during the blowing process, describe what happens after sufficient air has been blown into the balloon, and give an explanation for what happens.



Fixed mass of air: To be identified by students (A, B or C).

What happens: After sufficient air has been blown into the balloon, the cup remains attached to the balloon.

Why it happens: Explanation to be given by the students.

CONCLUSION

The foregoing are just five examples of the type of semi-quantitative exercise which is important preparation for students learning the pressure-volume quantitative work. Many more examples of a similar type, but with slight variations, can be developed to provide further experience in handling the variables of quantitative laws in semi-quantitative or qualitative settings. Some of the advantages of using these exercises can be summarised as follows:

- Students learn to locate which part of the system represents the fixed mass of air.
- Students learn to distinguish between mass, volume and pressure of air.
- Students learn that an isolated body of air still exerts a pressure even though it is not directly in contact with the atmosphere.
- An analysis of students' concepts enables the teacher to plan strategies accordingly.
- An opportunity may exist for students to revise their own concepts as more examples are examined.

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Implementing computer aided science experiments

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What makes an ordinary Yorkshire secondary school attract international attention? The school is Ackworth, and the time shortly after the Chernobyl crisis. Using standard laboratory equipment and a microcomputer, their physics department monitored fall-out levels, which were the only measurements taken in the district. This report which appeared in *New Scientist* (Needham, 1986) highlighted a special, yet under-used role computers can play in science labs.

Computers have a unique capability as school laboratory instruments. Essentially, the computer is connected (or 'interfaced') electrically to an external sensor, and at pre-determined time intervals records the sensor reading. The value is stored to be processed or displayed later. In conjunction with a small variety of sensors, one computer may replace many instruments.

In some experiments, a small sensor is ideal for reaching into a difficult location; in others it can detect minute or fleeting changes in the variable. Then again, its advantage may be its untiring capacity to collect massive quantities of data over extended times, as was done by Ackworth School.

Of the many practical applications of computer aided science experiments (CASE), a selection has been drawn from a number of teaching laboratories and outlined below, together with explanations of the physical components utilized.

EQUIPMENT, SENSORS AND THE GAME PORT

Equipment is readily obtainable these days. As schools move to 16-bit computers for word-processing and administrative usages, older 8-bit machines are becoming available for the laboratory.

Most microcomputers have a game port or socket to receive game controls, and this provides the key to easy interfacing. Game ports measure external resistance or voltage variations (more commonly the former). It is a matter of finding a sensor that directly converts the variable to be measured into a changing resistance; or, if none is available, mechanically link the variable to an existing sensor. The actual connections are made using a nine-pin plug or, for simplicity, attach the two wires from a sensor by clips to the correct socket pins. These connections can be identified from diagrams in the computer's reference manual (see Figure 1).

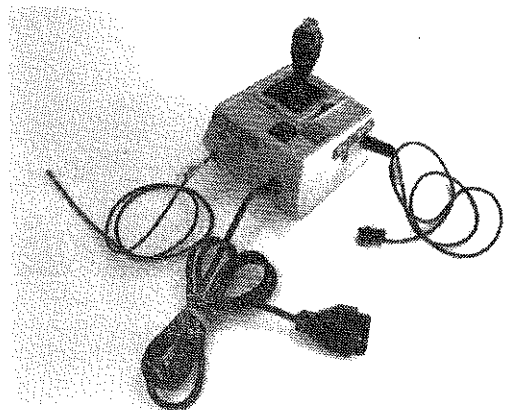


FIGURE 1: A games control tapped to provide two swithes and two variable resistors.