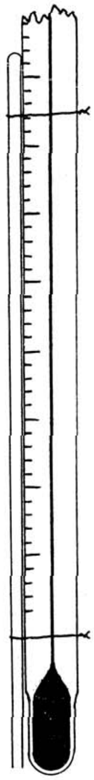
A SIMPLE CHARLES' LAW EXPERIMENT

V. R. DAMERELL
Western Reserve University, Cleveland, Ohio

Some time ago the writer devised a Charles' law experiment suitable for general chemistry classes; this has since been used and improved in the writer's own classes for the past several semesters. The experiment is new, to the writer's best knowledge; it is sufficiently accurate, and it is easier to carry out than any other experiment used to verify Charles' law that is familiar to the writer. Because of its simplicity the method is presented here for possible consideration by other chemistry teachers.



The basis for the experiment is the fact that in a narrow tube, where the ratio of length to diameter is 50 or more to one, the length of the tube is virtually proportional to the volume of gas in the tube. Furthermore, as a cooling specimen of gas sucks a column of liquid into such a tube, the changing length of the gas column is not only proportional to the changing gas volume, but the inner meniscus of the liquid enables that length to be measured. A ratio of gas-column lengths can then be substituted for the usual ratio of gas volumes in the Charles' law equation. This permits the following experiment.

A 10-cm. portion (or longer) of small-bore glass tubing is sealed at one end and fastened to a thermometer, open end down, with two pieces of string or pliable wire, as shown in the illustration. The students can work individually or in groups as they remove sections of tubing from longer pieces, seal one end in a flame, and fasten the sections to thermometers. Meanwhile an oil bath is prepared for class use. This is conveniently a large beaker containing a good grade of motor oil which will have only a small vapor pressure at, say, 100°C. The depth of the bath must be sufficient completely to cover the tubes attached to the thermometers. The temperature of the bath should be constant, or very slowly rising. With an 800-ml. beaker of oil this last condition is easily met by use of a hot plate, or by warming the oil with a brisk flame and then cutting down the flame to small size.

The students now put the thermometers with attached tubes into the oil bath and leave them until their thermometers register the same temperature as the bath thermometer, at which time it is assumed that the gas column in the tube is also at bath temperature. The bottom, open end of the tube is now examined through the side of the beaker. Any projecting air bubble is shaken off, since it is important that the air column extend only to the end of the tube.

The temperature is now recorded, and the thermometer is lifted part way from the oil bath, but not yet far enough so that the open end of the tube comes out of the oil. This step is to allow the tube to cool so that oil begins to enter. In a few seconds, when an oil column a few millimeters in length has entered the tube, the thermometer and attached tube are taken out of the bath, placed horizontally on any convenient surface, and allowed to cool to room temperature. The inner meniscus of the little oil column now marks the end of the contracting gas column.

When the thermometer shows room temperature the gas column is assumed to be at the same temperature. A milliliter rule is now used to measure (*a*) the inside length of the entire tube, and (*b*) the length from the inside of the closed end to the oil meniscus. Measurement (*a*) is the length of the gas column at bath temperature, while measurement (*b*) is the gas-column length at room temperature. These measurements, together with the two temperatures, comprise the data. Two sets of experimental results which are typical are shown below:

	Experiment A	*Experiment B*
Air-column length at 96°C. (Inside length of entire tube)	109 mm.	105 mm.
Air-column length at 24°C. (From closed end to oil meniscus)	88 mm.	85.5 mm.

Various calculations can be made from this data. The version of Charles' law which applies here is:

$$\frac{\text{Air-column length I}}{\text{Air-column length II}} = \frac{\text{Absolute temperature I}}{\text{Absolute temperature II}}$$

These two ratios can be calculated and compared.

$$\frac{109}{88} = 1.24; \qquad \frac{105}{85.5} = 1.23; \qquad \frac{(96 + 273)}{(24 + 273)} = 1.24$$

Results like these, accurate to about one per cent, can readily be obtained by students. The accuracy is undoubtedly aided by the fact that the two errors caused by hydrostatic pressure of the oil and vapor pressure of the oil are in opposite directions, and hence tend to nullify each other. In another calculation the length of the air column at room temperature can be computed and compared to the observed length. Still another possibility is to calculate absolute zero on the centigrade scale. Thus:

$$\frac{109}{88} = \frac{96 + X}{24 + X}$$

and $-X$ will be what the student finds for absolute zero on the centigrade scale (−278°C. in this experiment). Of the various possible calculations students perhaps find this one the most interesting.

The bath must not be too hot, because the oil vapor pressure then becomes significant. At 140°C., for example, results were poor. A solvent-extracted neutral oil with a viscosity of 300 (SUV) at 100°F. was in the bath.

$$\frac{103.5}{68.5} = 1.51; \qquad \frac{140 + 273}{25 + 273} = 1.39$$

The experiment has been described here as it would be done by general chemistry students. Refinements beyond this are, of course, possible and some instructors may wish to make small corrections for hydrostatic pressure of the oil, for oil vapor pressure, for the exposed stem of the thermometer, etc. Stirring and thermostatting of the oil bath may also be preferred. In the absence of these refinements the students can still get a satisfactory verification of Charles' law, performing the experiment in the simple manner described.