

**THE DROP METHOD OF MEASURING SURFACE TENSION.**

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Qualitative illustrations of surface tension phenomena abound so that there is no lack of material for the experimental study of this, to most pupils, fascinating field. But when it comes to measuring the amount of tension, difficulties arise, for in all methods, a clean surface is required, and a clean liquid surface is one of the hardest things to get and still harder to maintain. For secondary schools, the capillary tube method is altogether too elaborate and difficult, at least, if properly performed. The film method as described by Edwin H. Hall (this journal, Vol. IX, p. 759) is simple and direct enough, and in a slightly different way (an improved spiral spring balance and a saddle shaped strip of metal being used) I have had my students employ the method for a number of years. The drop method, however, I have finally adopted, mainly because it gives uniformly accurate results, requires very simple apparatus and manipulation, and seems to be within the comprehension of most students.

*Theory of the Method.* When a liquid issues in drops from a vertical tube whose radius is  $r$ , each drop clings to the tube and does not fall off until its weight  $w$  just exceeds the tension of the surface of the liquid around the circumference of the tube. Denoting by  $T$  the surface tension (grams per centimeter), we have then

$$w = 2\pi r T.$$

As the measurements of the tube's radius cannot be carried out satisfactorily with the instruments commonly available in secondary school laboratories, the method has to be made relative rather than absolute. If the same tube be used with another liquid, we have

$$w' = 2\pi r T',$$

and, by division,

$$\frac{w'}{w} = \frac{T'}{T}$$

If we know the surface tension of some standard liquid, say water, weighings of drops coming under similar conditions from one and the same tube will enable us to find the surface tension of a second liquid.

It should be added that the above formula is not strictly true, as a small proportion of a drop always clings to the tube, so that the weight of the detached drop is a little less than that called for by the formula. While it is possible to determine the weight of this remnant, it is hardly practicable to have it done by high school students. Rather is it better to so choose the liquids that the weights of the drop remnants are practically in the same ratio as the weights of the detached drops, as, in that case, the ratio of the falling drops remains the same despite the circumstance that some of a drop remains clinging to the tube. I have found by using water as the standard liquid and aqueous solutions as the liquids to be tested that the influence of the remanent drop is negligible.

*Practice of the Method.* A bottle of any convenient size is fitted with a cork pierced with two holes. Through one of these holes passes an L-tube and through the other a siphon. A piece of rubber tubing is slipped over the L-tube and may be pinched together by a Hoffman clamp. In lieu of a clamp a small hole or slit may be cut in one side of the rubber tubing and a glass rod shoved in so as to reach past the opening. By moving the rod so as to expose more or less of the opening a nice adjustment of the amount of air admitted into the bottle may be secured. The bottle is filled with the liquid to be tested and the siphon set in action by blowing through the L-tube. By adjusting the clamp the speed of flow through the siphon may be easily regulated or the flow stopped entirely.

At the end of the outer arm of the siphon is attached by means of a bit of rubber tubing a burette tip. As most liquids wet glass, there is a tendency for them to creep up around the sides of the tube so that the drops become irregular in size. By coating the tip of the tube with wax (beeswax, paraffin or similar substances) this wetting does not take place in the case of liquids not dissolving the wax, and the drops are remarkably uniform in size and weight. To prepare such a jet tube, draw out a piece of glass tubing to small diameter in a flame, make a file scratch at the middle of the constricted part, warm a little and rub with wax. Twirl the tube around while it cools so as to cover it with a thin and uniform coating of the wax. When the tube is cold, bend it a little and almost invariably it will break squarely off at the scratch, thus making two jets of equal size with a sharply defined wax coating at their orifices.

The bottle is set up on blocks or on a stand so that the tip is high enough for a beaker or tumbler to be placed under it to catch the drops. Adjust the clamp so that the drops form at the rate of about one a second and then catch in a weighed beaker or other suitable dish a hundred drops or so. Weigh the dish and the water collected, and, without emptying it out, catch another lot of drops. As many lots can be caught and weighed as time permits. The weight of a counted lot of drops divided by their number obviously gives the weight of a single drop.

The same tip may now be transferred to a second bottle containing a salt solution, and the weight of a counted number of its drops found as above. The other tip from the same piece of glass tubing may be used, if its identification is sure. I have found it easier to have each pupil use one and the same tip instead of trying to keep track of the tips of equal size. The change of a tip from one bottle to another takes but an instant.

*Precautions and Results.* The chief precautions to be observed are that the drops are not formed too rapidly and that the same speed of formation is maintained in each trial. While adjusting the speed of formation the drops should be caught in a dish to prevent wetting the table. The drops should be made to strike the sides of the receiving vessel so as to avoid loss from spattering.

I have used in my classes 10 per cent solutions of sodium chloride, ammonium chloride and copper sulphate, as these are familiar and readily obtainable substances. Of course, any others may be chosen. The more accurate the weighings, the more accurate, naturally, the determinations. But if the balances used are capable of weighing only to tenths of a gram, accurate results may nevertheless be obtained by counting out large number of drops. The loss from evaporation, while slight, still necessitates that the weighings be made promptly after the drops are caught.

The accuracy of the method is surprisingly great. If the temperature of the room remains practically constant, the weights of a hundred drops taken in succession are practically the same. But as surface tension varies not inconsiderably with the temperature and as the temperature of the liquids is not regulated by any special means, differences will usually be found. The method is a research method and with proper conditions is capable of yielding very accurate results.

When a class has completed the experiment, the liquids may be drawn back into the bottles out of the siphons and the clamp at the L-tube closed. The apparatus may then be stored and is ready at a moment's notice for use with the class of the following year. I have used the same apparatus without change or refilling for three successive years with large classes, keeping dust off the bottles during storage by covering them over with paper bags. The only renovation then required was fresh rubber tubing and liquids.

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The total production of refined lead, desilverized and soft, from domestic and foreign ores in 1909 was approximately 444,363 short tons, worth at the average New York price \$38,215,000, as compared to a production of 396,433 tons in 1908 and 414,189 tons in 1907. These figures do not include an estimated output of 12,860 tons of antimonial lead, as against 13,629 tons in 1908 and 9,910 tons in 1907. Of the total production, desilverized lead of domestic origin, exclusive of desilverized soft lead, is estimated at 209,698 tons, as against 167,790 tons in 1908; and desilverized lead of foreign origin comprised 87,379 tons, compared with 97,761 tons in 1908. The production of soft lead from Mississippi Valley ores is estimated at 147,286 tons, as compared with 130,882 tons in 1908, and 129,607 tons in 1907. Missouri apparently retained first place among the lead-producing States.—*U. S. Geol. Survey.*

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The total production of quicksilver in the United States in 1909 was 20,425 flasks of 75 pounds each, valued, at the average New York price in 1909, at \$943,022. A comparison of these figures with those given for 1908—19,752 flasks, valued at \$824,146—shows an increase for 1909 of only 673 flasks, but an increase in value of \$118,876. Prices have steadily risen during the last three years, and unless production should greatly increase will probably remain fairly attractive to producers that are operating at reasonably low costs. In 1907 the average prices per flask for quicksilver were, for New York, \$41.50; for San Francisco domestic, \$39.60; and for San Francisco export, \$38.17. In 1908 these prices rose, respectively, to \$44.84, \$44.17, and \$42.54. In 1909 the corresponding prices rose further, to \$46.17, \$45.33, and \$43.33. The production by States shows a decrease in California from 16,984 flasks in 1908 to 15,700 flasks in 1909; an increase in Texas from 2,832 flasks in 1908 to 3,925 flasks in 1909; and an increase in combined output from Nevada and Oregon from 346 flasks in 1908 to 800 flasks in 1909. In 1909, for the first time in many years, there was a small production in Nevada, but no production was reported from either Arizona or Utah.—*U. S. Geol. Survey.*