and from the limed plot (Plot No. 23), 452.2 pounds.

The deviation from the optimum (broken) line with respect to position, form and length between sampling dates shows in each case the nature of the disequilibrium between CaO-MgO-K_2O resulting from the different treatments.

WALTER THOMAS

DEPARTMENT OF HORTICULTURE,
THE PENNSYLVANIA STATE COLLEGE

SCIENTIFIC APPARATUS AND LABORATORY METHODS

AN INEXPENSIVE SURFACE TENSIOMETER[1]

LLOYD and Scarth (SCIENCE, 64: 253, 1926) devised a simple and cheaply made tensiometer which combined the ring method of measuring surface tension with the essential mechanism of a chainomatic balance.

In our own laboratory we have made a few improvements on their device for measuring surface tension, improvements worth offering to instructors with classes too large for duplication of the excellent but comparatively expensive Du Nouy tensiometer. It is even possible that many research workers may find this apparatus in its improved form adequate for their needs.

The total cost of materials is less than one dollar if a nickel wire ring is made, and not more than three dollars if a standard platinum ring is purchased. Any chemist can build this tensiometer in a few hours.

The accuracy possible is rather astonishing. Readings within 0.1 dyne of the true values for pure liquids have been made by our own students.

The diagram will indicate the general features. Instead of using a single thin strip of bamboo for the balance lever (as advised by Lloyd and Scarth), we now obtain greater stiffness, and a desirable length with light weight, by connecting two bamboo strips, approximately 35 cm long, with two strips 5 cm long placed near the mid-point. The long strips of bamboo are bent sufficiently to permit tying together with strong thread or thin wire at the ends.

Between the two short bracing strips is placed a thin sheet of aluminum, approximately 0.7×3 cm, to serve as a fulcrum rest. The aluminum strip is twisted at the ends to grasp the short bracing strips of bamboo and is smoothly creased in the middle to give a resting place on the razor edge. We have considerably increased the delicacy of beam movement by using a safety razor blade as fulcrum. Of course this blade is firmly attached to the substantial wooden support (at the left). A strip of metal, bent at a right angle and perforated for two screws, makes a good support. Two very light wire hooks are attached to the ends of the beam or balance arm—one as support for the wire ring and the other as point of attachment for one end of the chain.

The ring may be purchased or shaped from platinum or nickel wire (24–28 gauge) by bending around a glass tube of approximately 1.3 cm diameter. Of course, a length of this wire extends almost vertically about 3 cm as a "handle" or arm of the ring. A small loop shaped at the end permits the ring to swing freely from the end of the beam. Platinum rings are best, yet nickel rings are almost as good. It is not difficult to weld two platinum supporting wires to meet above the ring.

[1] Several students have offered useful suggestions, notably Malcolm Keiser and Croom Beatty.

In our laboratory we have found the light aluminum chain attached to ten-cent jewelry (Woolworth's and others) to be very suitable for this tensiometer. This chain is extended in length with a piece of strong thread which passes through a small metal ring (or screw-eye) near the top of the vertical board. Near the bottom of the board this thread is wound around a wooden cylinder (half of a common spool or a wooden drawer knob) so attached to the board that it turns stiffly when desired. The smaller the links in the chain the more accurate the readings.

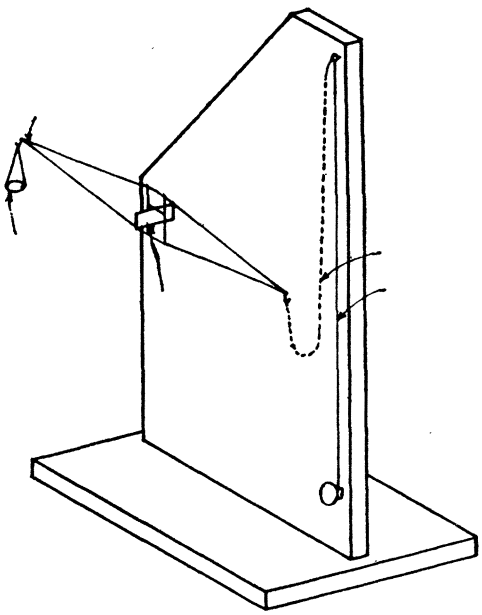

FIG. 1

After trying various lengths of beam to secure the best combination of lightness, stiffness and accuracy, we decided that a length of about 35 cm was most desirable.

The wooden support for the moving parts consists of two common boards nailed together at right angles, as shown in the diagram. A maximum height of 55 cm allows sufficient movement of the chain, and a width of about 27 cm is suitable for the vertical board. A coat of shellac prevents warping.

The dish containing the liquid for surface tension measurement is most simply held in the hand, but is best supported at the proper level for greater accuracy with an adjustable platform.

A graduated scale (sheet of graph paper) on the supporting board makes it possible to record accurately the changing positions of the end snap or any other marked link in the aluminum chain. To make a reading the beam is leveled so that the end at the right (with projecting wire pointer) points directly to a "rest mark" or heavy line appropriately drawn on the sheet of graph paper pasted on the board. The clean vessel of liquid is raised until contact is made with the ring and the chain adjusted so that there is no pulling away from the liquid. If ethanol or other liquid of low surface tension is to be used, the chain must be pulled up rather high before releasing the beam. The chain is lowered cautiously until the increasing weight of the sagging loop just tears the ring from contact with the surface of the liquid. This procedure is repeated cautiously until the scale reading corresponding to the breaking point can be determined accurately. At the breaking point the position on the arbitrary vertical scale of the snap or other marked link of the chain is observed. This position on the scale is set down as the scale reading corresponding to the surface tensions of that particular liquid, at room-temperature.

To prevent violent movement of the beam as the ring pulls away from the liquid, we placed a small right angle hook on the vertical board so that the beam in level position moves only a little above or below it. This was possible because of the two-splint construction of the beam. The ring must be cleaned before use (and on changing liquids) by dipping in alcohol, in water, and finally by brief heating in a blue flame. Fingers must not touch the ring.

To calibrate the apparatus, such scale readings are determined for a few pure liquids of known surface tension.

To illustrate the application to an unknown, we offer the "key" diagram for one particular tensiometer built by a student. A sheet of graph paper pasted on the vertical board serves as scale and permits plotting of a reference curve. On the horizontal axis is a scale of surface tension values in dynes, while on the vertical axis is an arbitrary scale of such units as are read with this particular tensiometer. For seven pure liquids, points on coordinate or graph paper were plotted in accordance with scale readings, and true surface tension values (corrected to the temperature of operation) obtained from reference books. In actual practice with this particular tensiometer, these seven points

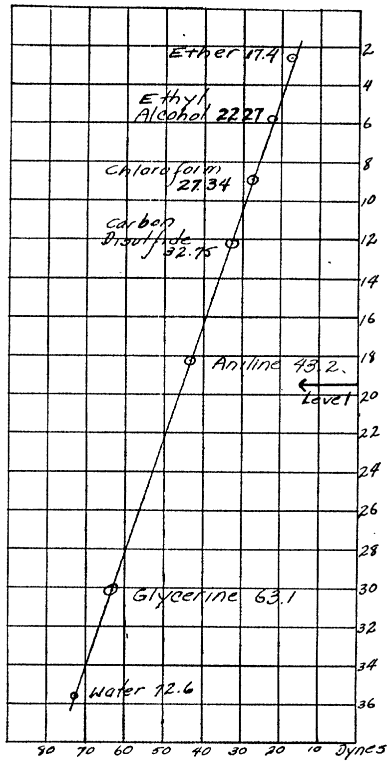

FIG. 2

were connected with a single straight line—excellent confirmation of accuracy.

After determining the scale reading for an unknown, as 22.5, for example, a glance at the diagram indicates a corresponding surface tension value of 50 dynes.

(Excellent detailed instructions for use of the Du Nouy tensiometer are found in Bulletin 101, printed by the Central Scientific Company of Chicago. An elaborate chainomatic tensiometer is sold by the Arthur H. Thomas Company of Philadelphia.)

HARRY N. HOLMES

SEVERANCE CHEMICAL LABORATORY,
OBERLIN COLLEGE

BOOKS RECEIVED

BROWN, HARRY B. *Cotton; History, Species, Varieties, Morphology, Breeding, Culture, Diseases, Marketing, and Uses.* Second edition. Pp. xiii + 592. 140 figures. McGraw-Hill. $5.00.

COWDRY, E. V. *A Textbook of Histology; Functional Significance of Cells and Intercellular Substances.* Second edition. Pp. 600. 323 figures. Lea and Febiger. $7.00.

HOGG, JOHN C. *An Introduction to Chemistry.* Pp. xiv + 365. 115 figures. Oxford University Press. $2.00.

MESSER, HAROLD M. *An Introduction to Vertebrate Anatomy.* Pp. xvi + 406. 374 figures. Macmillan. $3.50.

ROGERS, CHARLES G. *Textbook of Comparative Physiology.* Second edition. Pp. xviii + 715. 158 figures. McGraw-Hill. $5.50.

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