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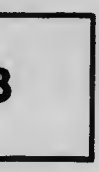

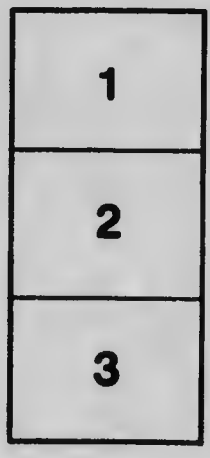

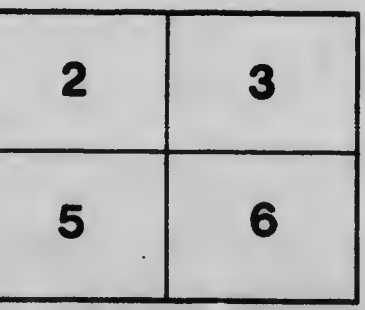

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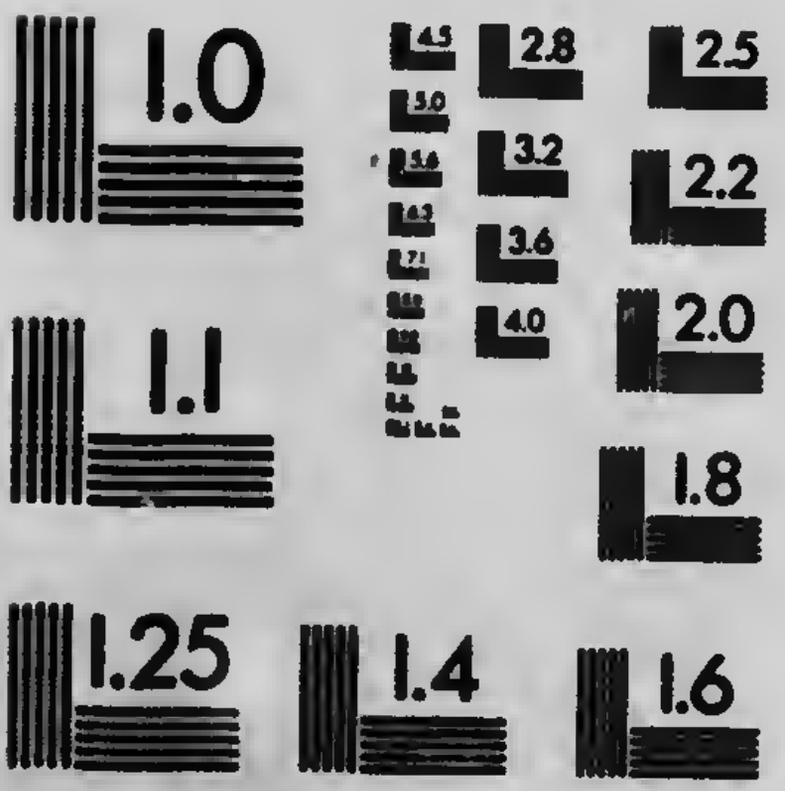

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PAPERS FROM THE CHEMICAL LABORATORIES

No. 96: SOME LECTURE EXPERIMENTS ON SURFACE TENSION, BY FRANK B. KENRICK

(REPRINTED FROM THE JOURNAL OF PHYSICAL CHEMISTRY, VOL. XVI)

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SOME LECTURE EXPERIMENTS ON SURFACE TENSION[1]

BY FRANK B. KENRICK

Surface tension affords abundant scope for attractive lecture experiments. The experiments outlined in this paper have been used for many years by the writer, and although less spectacular than many described in the literature, have been found very effective in making clear the principles of surface tension in its application to the chemical phenomena of solubility and adsorption.

1. Mechanical Model.—This serves to illustrate the definition of surface tension in work units as the maximum quantity of work that can be gained when a surface is decreased in area by one square centimeter. A projection cell 40 mm × 10 mm and 60 mm high, the upper edges of which have been coated with a film of paraffin wax, is filled almost to overflowing with water. On the surface is floated a thin shaving of cork 30 mm × 5 mm × 1 mm, to which is attached a fine cotton thread about 40 mm long terminating in a little glass hook. The thread passes over a small pulley made from a pill box and a pin resting in a double Y-shaped glass bearing. Three weights of glass or bent wire, weighing about 0.1 gram, 0.07 gram and 0.04 gram may be hung on the hook. The middle weight approximately balances the surface tension, while the lighter one on being pulled down with a pair of tweezers is lifted again by the surface tension. A fall of 1 cc produces one square centimeter of surface: *viz.*, 0.5 cm^2 on the forward under side of the cork which is wet with water and 0.5 cm^2 on the upper surface of the liquid in the cell. The whole of an apparatus of the size described may be pro-

[1] Expts. Nos. 1, 2, 4, 6 and 7 were shown at a local meeting of the American Chem. Soc. at Niagara Falls, January, 1909. 3(*a*) and 5 at a lecture at the Research Laboratory, General Electric Co., January, 1911, and 3(*b*) in a lecture by Mr. Howe and the writer at the Washington meeting of the American Chem. Soc., December, 1911.

jected with an ordinary lantern. While quantitative results cannot, of course, be expected, this is a useful experiment to have thrown on the screen when the meaning of surface tension is being explained. The fact is often overlooked that the definition of surface tension as the force acting across a line 1 cc long, etc., presupposes that there is a movable edge of surface to which a weight or other dynamometer can be attached, and that consequently the idea of surface tension at the boundary of a solid is excluded by this definition whereas the definition in terms of work is applicable to every case in which the area of surface can be changed by any reversible process for which the work can be determined.

2. *Two Drops.*—This is analogous to the well known experiment with large and small soap bubbles on the ends of a U-tube.[1] It is the writer's experience that soap bubbles work very well in the preparation room but generally burst at the critical moment in the lecture. Drops of water have not this disadvantage, and are more closely analogous to the chemicals whose behavior this experiment is designed to illustrate. (S 3.) The diagram (Fig. 1 A) shows suffi-

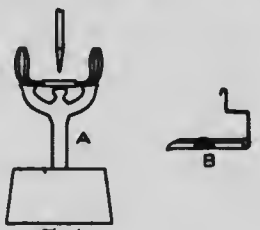

Fig. 1

ciently clearly the arrangement of the apparatus. The upper ends of the capillary tubes should be ground to flat discs about 1.7 mm in diameter and coated with paraffin wax. The two halves of the U-tube are connected by a piece of the fine rubber tubing (0.5 mm bore) used for covering spectacle frames. The U-tube is completely filled with water, and while the rubber connection is closed by pressure with a

[1] C. V. Boys: "Soap Bubbles," 1890, p. 55.

screw driver or other hard object, a small and large drop are piled up on the ends of the tube with a fine-pointed pipette. On releasing the pressure the large drop grows bigger at the expense of the small one. The whole apparatus may be projected with an ordinary lantern, or, if it is made very compact, with a low-power projecting microscope.

3. *Surface Tension and Solubility.*—This is a chemical application of the principle illustrated in Exp. 2. The increase in the solubility of gypsum caused by a fine state of division, first determined by Hulett[1] may be shown as a lecture experiment in either of the two following ways:

(*a*) The following materials are required: a "*normally saturated gypsum solution*," made according to Hulett's method, by stirring gently for some hours about 300 cc water with 30 grams coarsely powdered gypsum, from which the fine particles have been previously rinsed with water. This solution may be kept indefinitely, and shown in contact with the crystals. *Finely powdered gypsum*, made by grinding about a gram of the crystals to an *impalpable* powder in an agate mortar. *Sodium phosphate solution*; a solution is made up containing 100 grams sodium phosphate ($Na_2HPO_4.12H_2O$) and 2.5 grams sodium hydroxide per liter. About 29 cc of this solution (the exact amount must be found by trial) is colored dark pink with phenolphthalein and diluted with water to 100 cc.

The experiment is carried out as follows: To one of two beakers, each containing about 50 cc of normally saturated gypsum solution, is added a pinch (about 0.5 gram) of the finely powdered gypsum. This is shaken for a moment and then both[2] liquids are immediately filtered through previously arranged filters. The first filtrate may be poured through again if not perfectly clear. Twenty cc of each filtrate are then put in two projection cells in the lantern and shown on the screen. On adding 10 cc of the sodium

[1] Zeit. phys. Chem., **37**, 385 (1901).

[2] It is best to treat both liquids in exactly the same way, since the point of the experiment is to show a small difference in concentration.

phosphate solution to each cell, the liquid which was shaken with the gypsum turns colorless while the other remains pink. The experiment takes only two minutes to perform; if more time is available for filtration, etc., it may be carried out on a larger scale without the lantern, and an actual titration made, by which a difference of 10 percent can be shown in the concentrations.

(*b*) The above experiment may be shown more strikingly by the use of an adaptation of Töpler's "Schlierenapparat" to lantern projection,[1] by which concentration streams in a liquid are made visible on the screen. A flat cell containing water, with a transparent gypsum crystal hung just below the surface, is first projected with the lantern. As the gypsum dissolves, a narrow stream of solution is seen flowing down from the lowest point of the crystal. Next the crystal is hung in the normally saturated gypsum solution; no stream is visible. Finally a little glass trough containing a pinch of the finely powdered gypsum is hung in a slightly inclined position in the same cell. In a few seconds a stream of concentrated solution is seen flowing down from the lower end of the trough. The trough may be made by splitting a small thin-walled glass tube and sealing a glass hanger to it as shown in Fig. 1, *B*.

The writer has tried to show, by this means, the simultaneous solution and crystallization of gypsum in a slightly "supersaturated" solution, but the rate of separation of the gypsum is so extremely slow compared with the rate of solution that streams of weaker solution could never be seen rising from the crystal.

4. *Surface Concentration in Saponin Solution.*—A very simple experiment showing that the surface tension of a freshly formed surface of saponin solution is practically the same as that of water may be carried out as follows. Two beakers are filled to exactly the same depth of about 2 cm—one with water and the other with a saponin solution con-

[1] A description of this will shortly appear in THIS JOURNAL by W. Lash Miller and the present writer.

taining 0.2 gram per 100 cc. A glass tube of 2.5 mm bore and 20 cm long, with the lower end cut off obliquely, is held upright in the water with the end resting on the bottom of the beaker, a piece of thread having been previously tied round the tube to mark the height to which the water rises. The effect of sucking up the water in the tube and letting it fall is first shown on the screen. The same thing is then done with the saponin solution. The liquid drops rapidly as before pauses a moment at the high water mark and then falls slowly to a much lower level corresponding to the normal surface tension of the solution.

5. Surface Concentration of Methyl Violet Solution.— During the last few years several experiments have been described giving direct evidence of surface concentration in certain solutions, and quite recently Donnan and Barker[1] have made a quantitative investigation of this phenomenon. The surface concentration in methyl violet solution may be demonstrated by the following lecture experiment:

300 cc of an aqueous solution of methyl violet (0.25 gram per liter) are shaken vigorously in a 1 liter separating bulb so as to produce a foam, and then allowed to stand for four minutes to allow the liquid to drain away from between the bubbles. The clear liquid is next drawn off into a beaker and the foam allowed to subside until more than 1 cc of liquid has collected above the tap, which will require perhaps three or four minutes longer. The settlings are then drawn off into a second beaker. By diluting exactly 1 cc of each liquid with 20 cc of water, and placing the diluted liquids in a double glass cell (1 cm thick) before the lantern, the color of the foam settlings is seen to be slightly, but unmistakably, darker than the unfoamed liquid.

The time required for the foam to subside varies. If it should take too long the process may be hastened by gentle stirring, through the mouth of the separating bulb, with a glass rod moistened with amyl alcohol. This amount of amyl alcohol does not itself affect the color of the liquid.

[1] Proc. Roy. Soc., **85 A**, 557 (1911).

6. Emulsification of Oil by Potash.—This may be shown rather strikingly as follows: A strip of fine copper or iron gauze is folded on itself four or five times so as to make a pad which fits into the bottom of a projection cell (1 cm thick). About 20 drops of olive or linseed oil are allowed to soak into the gauze pad from a pipette, care being taken to keep the sides of the cell free from oil. The cell is then filled about 4 cm deep with water. When this is projected on the screen the oil is seen protruding in little humps through the meshes of the gauze, but the water-oil surface tension prevents it floating up through the water. Directly a little potash solution is added to the water the humps of oil elongate and flow in a number of thin streams to the surface where they form an emulsion.

7. Oil-films on Water.—This experiment shows that the action between oil and water is purely a surface phenomenon. A glass rod, round which is stuck a label rubbed with linseed oil, is supported about 3 cm above the bottom of a 300 cc beaker. Tap water is allowed to run into the beaker and flow over the edges until the surface is clean enough to show camphor movements. If the beaker is placed in front of the condensing system of a lantern, with the surface of the liquid well above the centre of the field, the moving camphor can be plainly seen on the screen. If, now, bubbles of air are blown into the water from a clean tube they have no effect on the camphor movements so long as they do not touch the oil, although they stir the liquid, but as soon as they are allowed to brush up past the rod the movements cease.

University of Toronto, Chemical Laboratory,
March, 1912