

THE SURFACE TENSION TEMPERATURE COEFFICIENT.

BY ARTHUR L. FOLEY.

Some fifteen years ago the author described a method of finding the surface tension of liquids by determining with a balance the force required to pull a frame of mica from the liquid.¹ A mica frame, cut in the form

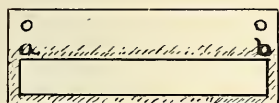


Fig. 1.

shown in Fig. 1 is suspended from one arm of a sensitive balance and the lower edge (a-b) of the upper strip of mica is brought into contact with the liquid. The liquid is then gradually lowered while the pointer of the balance is kept at the turning point by adding weights to the other pan. Eventually

the downpull of the liquid and film is exceeded by the weights on the other arm of the balance, the mica frame is pulled suddenly upward, and the film breaks. The frame is then weighed while still in the liquid. The difference between the two weights gives what is called the maximum weight, from which the method takes its name.

The surface tension is given by the equation

$$T = \frac{wg}{2(1-t)} + \frac{d^2t^2g}{4(1-t)} - \frac{ltg}{4(1-t)} \sqrt{d^2l^2t^2 + 4w(1-t)d}. \quad (1)$$

Where T=surface tension in dynes.

w=maximum weight.

l=length of frame (between legs).

t=thickness of frame.

d=density of liquid.

g=acceleration due to gravity.

When the frames are thin one may use the simple equation

$$T = \frac{wg}{2l}. \quad (2)$$

The maximum weight can be determined again and again with surprising uniformity. Even when one uses mica frames differing greatly in

¹ Proceedings of the Indiana Academy of Science, 1895, p. 67.

Physical Review, Vol. 3, No. 5, 1896, p. 381.

eight centimeters apart on all sides except in front of the glass door. T_1 was a copper vessel or tank connected by lead tubes L_1 and L_2 to the tank T_2 . Both tanks were filled with oil. The oil in the tank T_1 , heated by one or more bunsen burners, passed through the tube L_2 into the tank T_2 and finally back through L_1 into T_1 . A stirrer, driven by an electric motor, aided in producing a rapid circulation of the oil. Tank T_1 and tubes L_1 and L_2 were wrapped with several layers of asbestos paper.

From a flask not shown in the figure water was siphoned to and through the tube G_1 into the evaporating dish D_1 . An overflow G_2 served to keep constant the depth of the water in the dish. The excess of water dropped on sponges S in an evaporating dish D_3 , itself drained by the tube T_3 . The sponges served to keep the space inside the box saturated with watery vapor, or nearly so. An inverted evaporating dish D_2 served to enclose almost completely the frame and liquid and thus insure the saturation of the space about the film on which the measurements were made.

The dish D_1 rested on a wooden platform P supported at one end by a hinge and at the other end by a cord C passing over a cylindrical metal rod which extended to the outside of the box. The height of the water surface was slowly raised or lowered by twisting the rod.

A thermometer t_1 gave the temperature of the oil, t_2 the temperature of the water, t_3 the temperature of the space immediately above the water, and t_4 the temperature of the space outside the inverted evaporating dish. No measurements were made when the thermometers t_2 , t_3 , and t_4 differed by more than a few tenths of a degree. This necessitated a wait of from one to five hours between readings at different temperatures. Three series of readings were taken, each requiring a continuous run of from ten to thirty-six hours—depending upon the number of observations made.

Owing to the condensation on the wire W where it passed through the opening in the tank T_2 it was not practicable to carry the observations higher than 80° . An effort was made to prevent this condensation by driving gently through the opening a stream of warm air from the outside. But this interfered somewhat with the action of the balance and the saturation of the space inside. It did not occur to the writer at the time to try heating the wire by means of an electric coil.

For temperatures below room temperatures the asbestos was removed from the tank T_1 and the tank was surrounded by a large vessel containing

water and ice, or ice and salt, depending on the temperatures required in the tank T_2 .

The water used in this experiment was first distilled in the usual copper still, then with potassium permanganate in glass, then twice again in glass. Just before using the water was boiled for fifteen minutes to drive off absorbed gases, and then rapidly cooled by placing the flask in ice water. The water was siphoned from the flask through a glass siphon with a cock which permitted the flow to be adjusted at will. Before opening the cock the water in the flask was each time brought to approximately the temperature indicated by the thermometer t_1 . It was then passed through the tube G_1 (which had a length of some fifty centimeters inside the oil) into the dish D_1 . Sometimes the measurements were made with the water in D_1 at rest, sometimes with the water flowing very slowly from the tube, this giving a fresh surface as free as possible from absorbed gases or contamination of any kind.

The author feels sure of all his data except his temperature measurements. The thermometers used were bought for high grade instruments. It was the intention to calibrate them at the conclusion of the experiment. By accident they were placed with some others of the same kind and so could not be identified.

The results obtained in this investigation are given in the following table and are plotted in Fig. 3.

Temperature of the Water—	Tension in Dynes per cm.
1.0°	
1.4.....	74.95
6.6.....	74.176
10.7.....	73.667
16.5.....	73.087
21.8.....	72.20
29.2.....	70.795
37.3.....	69.32
50.4.....	67.36
51.0.....	67.27
61.6.....	65.50
67.5.....	64.45
72.6.....	63.71

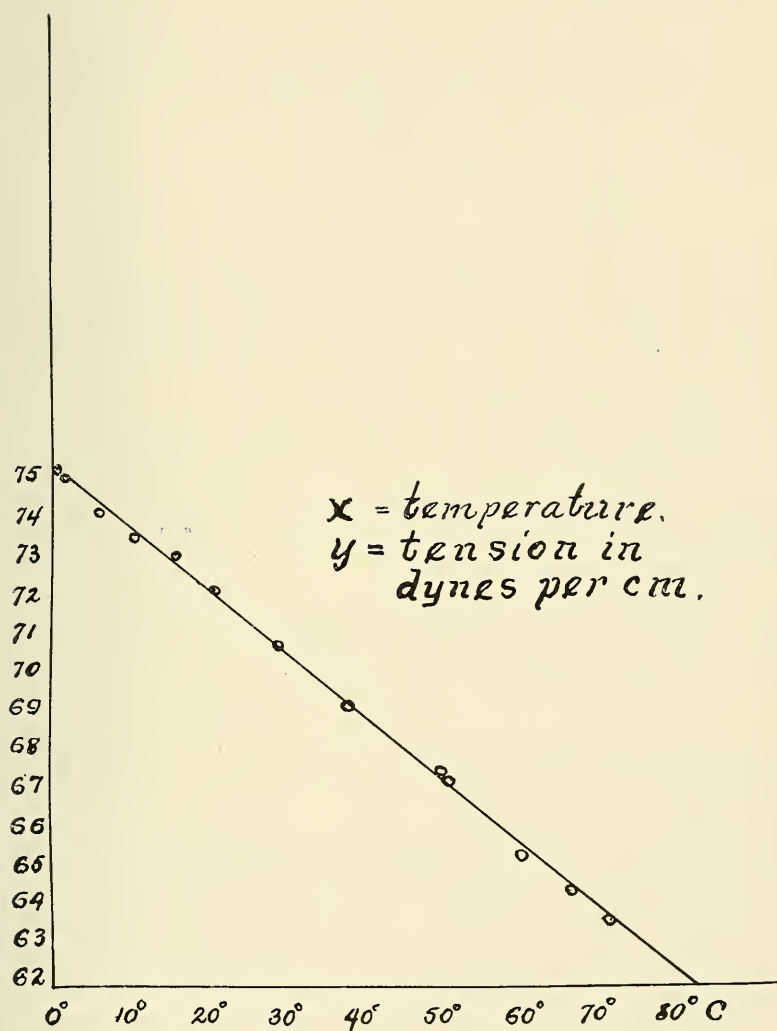


Fig 3.

From the plot one obtains the following values :

Surface tension at 0° C.=75.5 dynes per cm.

Surface tension at 18° C.=72.6 dynes per cm.

Surface tension of 80° C.=62.6 dynes per cm.

Temperature coefficient=.161 dynes per cm.

T. Prector Hall² gives the following values :

Tension at 0° C.=75.48 dynes.

Tension at 18° C.=72.96 dynes.

Tension at 80° C. (calculated)=64.28 dynes.

Temperature coefficient=.14 dynes.

Hall tabulates the results of nineteen different investigations by fourteen investigators giving a mean of all of Tension=75.4 dynes at 0° C. and temperature coefficient ranging from .141 dynes to .204 dynes per cm. Hall adopts .14 dynes as the most probable value.

It will be observed that the author's result for the tension at zero temperature agrees with the results obtained by others, but that his values at higher temperatures are considerably lower, giving a much larger temperature coefficient. The differences are entirely too large and too regular to be attributed to experimental errors.

Hall claims that absorbed gases tend to raise the surface tension of water and to increase the temperature coefficient. He claims also that the surface tensions of different samples of water are not the same. The author rather inclines to the view that the smaller values obtained at higher temperatures in this investigation are due to the fact that the measurements were made on water in contact with air saturated with watery vapor, while the conditions under which most of the other investigations have been made give the tension of water in contact with moist air, but not saturated air. Perhaps the actual temperature of the film under such conditions is not given correctly by a thermometer placed in the liquid. Evaporation into the air lowers the temperature of the surface film—possibly considerably below the temperature of the body of the liquid. Whatever the actual magnitude of this effect may be, it tends always to give too high values for the surface tension at high temperatures—the drier the air the higher the values.

² New method of measuring surface tension. *Philosophical Magazine*, November, 1893, Vol. 36, p. 412.