AN APPARATUS FOR THE ESTIMATION OF SURFACE TENSION IN BIOLOGICAL FLUIDS

R. D. BARNARD
University of Chicago.

During a study conducted on energy transformations in biological systems, a necessity arose for a method of rapid estimation of surface tension without removal of the fluid to be measured from its container. Advantage was taken of the fact that the gas-liquid interfacial tension of a system will govern the volume of a bubble of gas formed at an orifice within the liquid. By measuring the number of bubbles formed per unit volume of gas, the volume of one bubble can be calculated, and this bubble volume is related to the surface tension by the formula:

$$Sx = \frac{Vw\ D\ Sw}{Vx}$$

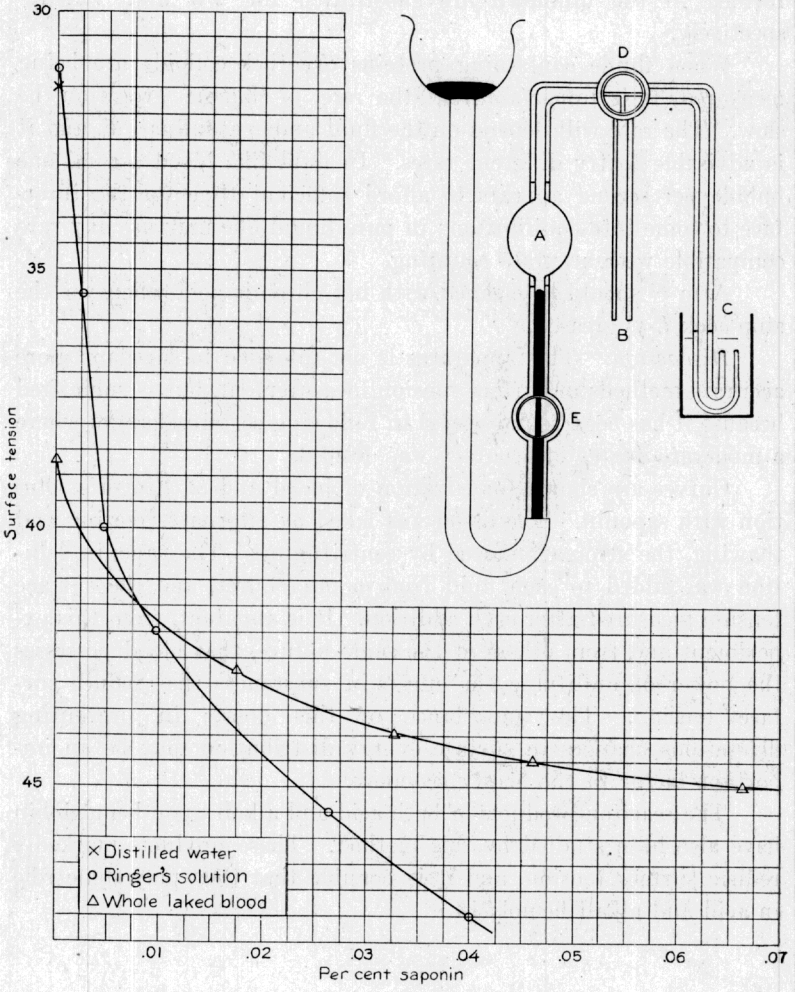
where Sx is the surface tension of the unknown; Sw, the surface tension of water; Vw, the bubble volume of water; Vx, the bubble volume of the unknown; and D, the density.

The apparatus is shown in the figure, and its construction from a three-way, T-shaped, 1.5-mm. bore, capillary stop-cock is obvious from the diagram. The two continuous arms are bent parallel and in the same plane as the side arm; in arm *A* a bulb of about 1 cc. capacity is blown, and the opening of this arm communicates through a one-way stop-cock to a leveling bulb which is attached to the apparatus by a rubber tube.

Arm *C* is doubled back upon itself one centimeter from the end, and the office is made smooth and round by fire polishing. Three marks are made on the apparatus, one below and one above the bulb in arm *A*, and one on arm *C*, two centimeters above the bend. The leveling bulb is filled with mercury.

Determination: First, *E* is turned so that *B* and *C* communicate, and *C* is immersed in triple-distilled water until the orifice of *C* is submerged and the water has risen to the mark on *C*. Then *E* is turned so that *A* and *B* communicate, and the mercury is allowed to rise to the lower mark on arm *A*. Next, the one-way stop-cock *D* is closed, and *E* is turned so that *A* and *C* communicate. Then *D* is partially opened, and the air in the bulb

is slowly displaced through the water, so that about two bubbles are formed per second. The bubbles are counted, and when the mercury reaches the upper mark, *D* is closed, an estimation being made of the fraction of the bubble usually remaining in the orifice.



To duplicate the determination, *E* is turned so that *B* and *C* communicate, when the water returns to the mark. Then *A* and *B* are made to communicate, the leveling bulb is lowered while the return of the level of mercury to the lower mark is controlled by *D*.

This serves to calibrate the apparatus. The entire procedure is then repeated for the unknown.

For calculation of the surface tension by the formula given above, the number of bubbles formed in water and the number formed in the unknown are substituted for Vw and Vx, respectively.

When fluids containing proteins or other colloids are being measured, it is important that the rate of bubble evolution be slow. The rate will depend on the fluid under examination, and it is advisable to try different rates. In fluid like blood serum, one bubble per second appears to afford sufficient time for the interface to come into equilibrium; in pure liquid one may use any rate compatible with accurate counting.

Arm *C* should be cleaned with hot chromic acid whenever the stop-cock *E* is greased.

Discussion. This apparatus is not intended to supplant more accurate methods of surface tension measurement, but is submitted because it has been found useful in following certain changes where a moderate degree of accuracy was desired.

Curves are shown for titration of blood and of Ringer's solution with saponin. The blood was laked by alternate freezing and thawing, the stroma removed by centrifuging. The saponin solution was added to each fluid from a microburet, and the surface tension measured after each addition. It is apparent, from this experiment and from others of the same nature, that blood possesses the power of nullifying the effects of substances that reduce surface tension. The importance of this power in preventing deleterious changes in surface energy distribution may be an important factor in the bodily economy.

The reaction products of both acid and alkali upon hemoglobin have also been studied by this method. These products markedly reduce surface tension, and it is possible that they play some rôle in acid and alkali hemolysis.