I wish to express my appreciation to Eimer and Amend, who constructed the apparatus and furnished the drawings.

E. M. ABRAHAMSON

THE JEWISH HOSPITAL
OF BROOKLYN

## AN IMPROVED PROTOCOL FOR DILUTION SERIES

FOR some years, the author has been using a dilution protocol that avoids the inconveniences of the more commonly used dilution series, and has the following desirable properties:

(1) A suitable number of steps (eight) in each decade of the dilution range.

(2) Ease of preparation.

(3) Accuracy in preparation.

(4) The error, that is introduced by the fact that the liminal value of the phenomenon studied lies between the last negative tube and the first positive tube, is constant throughout the dilution range.

(5) Simple numerical expression of the concentration.

The series is based on a geometrical progression of the reciprocals of the powers of the eighth root of ten, yielding eight equal logarithmic steps in the decade. It is prepared by mixing 2.9983 parts of the previous dilution with 1 part of water. The cumulative error, introduced by mixing 3 parts of the previous dilution with 1 part of water, is less than 0.1 per cent. in the decade, or much smaller than the presumptive error involved in the use of pipettes for making the dilutions. To avoid accumulation of error, it is desirable to make a preliminary series of dilutions of 1/10, 1/100, 1/1000 . . . for the start of each decade. Concentrations can be conveniently expressed in a logarithmic notation (pD = − log of the dilution) similar to the commonly used pH. A typical protocol is given in Table I.

Assuming that the actual liminal value of the phenomenon studied lies midway between the last negative tube and the first positive tube, the error of the result is constant over the entire dilution range at 14.3 per cent. of this mid-value. In the case of the commonly used dilution series, 1/10, 1/20, 1/30 . . . , this error varies from 5.26 per cent. to 33.33 per cent. and averages 12.59 per cent. Should it seem desirable to have the value of pD refer to this probable liminal mid-value, the series can be started with a stock solution that is 1.143/10 instead of 1/10.

TABLE I

PROTOCOL FOR A DILUTION SERIES BASED ON THE RECIPROCALS OF THE POWERS OF THE EIGHTH ROOT OF TEN

| Dilution | Concentration grams per 100 ml. | pD | Preparation of series | |
|---|---|---|---|---|
| | | | ml. of previous dilution | ml. of water |
| 1/10..... | 10.000 | 1.000 | stock solution | |
| 1/13.34 .... | 7.499 | 1.125 | 3 | 1 |
| 1/17.78 .... | 5.623 | 1.250 | 3 | 1 |
| 1/23.71 .... | 4.217 | 1.375 | 3 | 1 |
| 1/31.62 .... | 3.162 | 1.500 | 3 | 1 |
| 1/42.17 .... | 2.371 | 1.625 | 3 | 1 |
| 1/56.23 .... | 1.778 | 1.750 | 3 | 1 |
| 1/74.99 .... | 1.334 | 1.875 | 3 | 1 |
| 1/100..... | 1.000 | 2.000 | 1 of 1/10 stock solution | 9 |
| 1/133.4 .... | 0.7499 | 2.125 | 3 | 1 |
| 1/177.8 .... | 0.5623 | 2.250 | 3 | 1 |
| and continuing | | | | |

Similar protocols could be developed based on the geometrical progression of the reciprocals of the powers of the other roots of ten. These protocols would be useful for the production of coarser or finer series of dilutions. The author has investigated those series from the square root of ten to the tenth root of ten, and none of them seem as convenient for application as the one described.

EDWIN H. SHAW, JR.

UNIVERSITY OF SOUTH DAKOTA

## BOOKS RECEIVED

AUDUBON, JOHN J. *The Birds of America.* Pp. x + xxvi. 500 colored plates. Macmillan. $12.50.

CATTELL, R. B., J. COHEN and R. M. W. TRAVERS, Editors. *Human Affairs.* Pp. xi + 360. 17 plates. Macmillan. $4.25.

*Contributions to the Calculus of Variations, 1933–1937; Theses Submitted to the Department of Mathematics of the University of Chicago.* University of Chicago Press. $3.00.

*Contributions to Virginia Geology.* Bulletin 46, Virginia Geological Survey. Pp. x + 211. Illustrated. State Commission on Conservation and Development, University, Virginia.

DINGLE, HERBERT. *Through Science to Philosophy.* Pp. vi + 363. Oxford University Press. $5.00.

*Scientific Reports of the Great Barrier Reef Expedition, 1928–29.* Vol. I, No. 12, G. W. OTTER, *Rock-destroying Organisms in Relation to Coral Reefs.* Pp. 323–352. 5 figures, 6 plates. British Museum, London. 5/–.

*Scientific Reports of the John Murray Expedition, 1933–34:* Vol. IV, No. 5, SIDNEY J. HICKSON, *The Penntulacea.* Pp. 109–130. 2 figures. No. 6, K. H. BARNARD, *Amphipoda.* Pp. 131–201. 21 figures. No. 7, G. STIASNY, *Scyphomedusae.* Pp. 203–242. 14 figures, 1 plate. No. 8, C. C. A. MONRO, *Polychaeta.* Pp. 243–321. 28 figures. British Museum, London. 5/– each.

SIGERIST, HENRY E. *Socialized Medicine in the Soviet Union.* Pp. 378. Illustrated. Norton. $3.50.

SIMPSON, GEORGE G. *The Fort Union of the Crazy Mountain Field, Montana, and its Mammalian Fauna.* Pp. x + 287. Illustrated. 80 figures. U. S. National Museum Bulletin 169. Smithsonian Institution. U. S. Government Printing Office. $0.45.

Smithsonian Institution. *Annual Report, 1936.* Pp. xiv + 446. Illustrated. U. S. Government Printing Office. $1.50.

STETSON, HARLAN T. *Sunspots and Their Effects from the Human Point of View.* Pp. xv + 201. 15 figures. Whittlesey House, McGraw-Hill. $2.00.

TOLMAN, C. F. *Ground Water.* Pp. xvii + 593. 189 figures. McGraw-Hill. $6.00.

WHEELER, WILLIAM M. *Mosaics and other Anomalies among Ants.* Pp. 95. 18 figures. Harvard University Press. $2.00.

WILLIAMS, SAMUEL R. *Experimental Physics.* Pp. 158. Illustrated. Ginn. $1.00.