lines of transpiration and green weights in plants in relation to the dry matter produced, the observations covering the full life of the crop, coming to complete and normal fruitage.

In the case where wheat seedlings were grown a second time in the same supposedly toxic solutions a better growth would be expected if these substances had the effect of simply rendering the nutrients of the kernels less readily transformed into available food, and it is quite possible that crushed wheat kernels placed in these solutions, thus eliminating the vital activities of seedlings, might have affected them as favorably as did the growth of the first crop and might have caused a disappearance or a reduction in the amount of the toxic substance. These experiments, therefore, can not be considered fully demonstrative. For the same reason, and because transpiration is not a measure of growth, the experiments with nitrates and with lime are also inconclusive.

But granting that the data of Bulletin 47 do demonstrate that the substances experimented with are truly toxic to wheat seedlings under the highly cramped and abnormal conditions of the experiment, it will be conceded quite rash to affirm that these substances in like quantities would be found similarly toxic in the soil under field conditions until it were known, not only that such substances do exist in the field soils, but also that they are more abundant in those which are unproductive.

The unwarranted publication of such positive conclusions as those quoted becomes still more evident when an effort is made to give quantitative expression to the recorded data of Bulletin 47 in terms of field conditions correlated with other contentions of the Bureau of Soils. It is maintained by the bureau, but without sufficient evidence, that the capillary movement of soil moisture under crop conditions is of negligible magnitude and that for this reason the roots of crops, in order to secure moisture and plant food and also in order to place the active absorbing root tips into fresh soil not poisoned by their own excreta, are compelled to constantly advance into previously unoccupied soil, and they are known to spread throughout a depth exceeding three to four feet in the case of most crops. The toxic substances of unproductive soils must, therefore, be deeply distributed throughout the root zone and to a depth of at least four feet. But the strongest solution used in the experiments of Bulletin 47, of 1,000 parts per million, means not less than 2,800 pounds per acre of field where the water content of the soil is 20 per cent. and it would mean 700 pounds per acre for the surface foot alone. In the case of 100 parts per million the amounts would be 70 pounds and 280 pounds per acre for depths of one and four feet, respectively. In the light of failures up to the present time to isolate these toxic substances from soils it will hardly be seriously contended that any such large amounts of toxic substances do exist in unproductive soils. But the smaller amounts experimented with, as recorded in Bulletin 47, either had little or no effect or they produced positive increases in growth. If, therefore, the data of the bureau along this line of toxic substances are to be given serious consideration at all, Bulletin 47 must be regarded as suggesting that on account of the probably small amounts of these toxic substances present in soils, and on account of their observed small, or else stimulative, effect when present in such quantities, toxic substances are either negligible factors in soil fertility or else they are beneficial to crops.

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## SPECIAL ARTICLES

### A NEW APPARATUS FOR MEASURING ELECTROLYTIC RESISTANCE[1]

THE measurement of electrolytic resistance differs from that of a metallic conductor in several respects. The most evident difference is that the electrolyte has no definite shape or size. Cells of various forms have been devised to hold the solution while it is being measured and I would hardly venture to add another to the list were it not for the fact that the

[1] Paper read before Section B of the American Association for the Advancement of Science and the American Physical Society in joint session, Chicago, December 31, 1907.

form shown in Fig. 1 has proved so very useful in the laboratory and also that several teachers who have seen the apparatus have desired a duplicate for their work. And there may be others who would find such a cell as useful as this one has been.

The principal object in the design of this cell is to present the concept of "molecular conductivity" of an electrolyte in such a clear and concise form that no one who is capable of making electrical measurements can misunderstand it. The apparatus consists of a strong glass tube provided with a small side tube for filling. Both ends are ground plane and closed by platinum-faced electrodes, the whole being firmly clamped together in a suitable framework. Good insulation between the electrodes is provided by making a portion of this framework of ebonite, as shown in the figure. Crushing strains due to the unequal contraction of glass and metal are avoided by

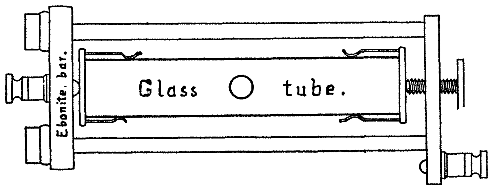


FIG. 1

the use of heavy rubber washers, one on each side, which take up the extra length without much increase in pressure. It has been found that a moderate pressure is sufficient to prevent leakage between the ends of the glass tube and the mental electrodes. The apparatus is supported by four short legs not shown in the figure.

The resistance of the column of liquid contained in this tube is measured by the method of Wheatstone's bridge, using a telephone and alternating current. The specific resistance, $s$, of such a conductor has the same meaning as for a metallic wire and is given by the same relationship,

$$s = r\,A/L,$$

where $A$ is the cross-section and $L$ the length of the column whose resistance is $r$ ohms. Both $A$ and $L$ can be measured directly, and each has a very definite and unmistakable meaning which is readily understood by the student. This can not be said regarding the equivalent "constant" of a cell which has no definite dimensions.

The specific conductivity, $c$, or the conductivity of a centimeter cube of the solution from one face to the opposite one, follows at once as the reciprocal of this. Or

$$c = 1/s = L/rA.$$

Since the conductivity of an electrolyte depends upon the amount of the substance in solution—that is, upon the number of ions per cubic centimeter—if the conductivities of different solutions are to be compared it is necessary to express the concentrations in comparable terms. This is usually done by stating the number of gram molecules, $m$, of substance that are dissolved in each cubic centimeter of the solution. The molecular conductivity, $\mu$, of an electrolyte is then defined as the conductivity of a centimeter cube of the solution per gram molecule of salt within this cube. In symbols,

$$\mu = c/m.$$

Presented thus there is rarely a student who does not understand from the first the meaning and significance of the molecular conductivity of an electrolyte. No claim is made that this apparatus is specially adapted for refined research or that it is the best form for the expert. For example, it can not well be placed in a constant temperature bath as is necessary for all refined measurements. But nevertheless when working at room temperatures, and using solutions which have stood in the same room for some time, very satisfactory results can be obtained, and for the purpose for which it was designed this apparatus has met every requirement.

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## THE AMERICAN ASSOCIATION OF MUSEUMS

THE American Association of Museums will hold its third annual meeting in Chicago, May 5–7, as the guest of the Chicago Art