A BRIEF EXAMINATION OF THE ELECTRICAL PROPERTIES OF EGG-WHITE.¹

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IN connection with the subject of the production of electricity by animals, the writer became interested in making a brief examination of the electrical properties of albumen as found in the white of an egg. As the method employed in the test appears to be a good one for biologists to use in making similar tests, and as the results obtained were, to say the least, unexpected, the writer believes his experiment is worthy of record. As only one sample of egg-albumen was examined with care (though three other samples were superficially examined, and these exhibited similar properties), it is considered that the data are insufficient to establish "standard values." The method, however, of making the test is easy to apply and gives results without ambiguity.

A rough preliminary measurement was made to determine the electrical resistance of a fresh hen's egg between two copper wires inserted in the ends of the egg, each wire extending into the egg through its shell about 0.5 centimetre. It appeared at once that the fresh egg was the seat of a considerable electromotive force which would cause a galvanometer of moderate sensibility to deflect off its scale quite violently. By applying 24 volts to the electrodes in the ends of the egg for one minute and then joining these terminals to a millivoltmeter the instrument registered from 0.1 to 0.2 millivolt for the several minutes that it was observed. A fresh egg was selected to which *no* electric potential had been applied, and this also was found to be the seat of an electromotive force of the order of a millivolt. It was apparent that, if the resistance and other electrical properties of an egg (and, as appeared later, even the white of an egg when removed and placed in a container) were to be measured, some method similar to one of the methods used for determining the properties of a cell of battery must be employed. It was thereupon decided to set as the objects of the investigation, to measure (for a single sample) the specific resistance of egg-white, and to determine the residual electromotive force retained

¹ Communicated by the author.

by a specimen of egg-white placed in a Kohlrausch cell, after the sample had been submitted for 600 seconds to 4 volts. It was further decided to trace the curves, called the potential difference curve, the polarization curve, the internal resistance curve, the current curve, and the recovery curve. These curves give the chief electrical characteristics of a battery and are suitable for giving similar information regarding the white of an egg and, presumably, of any sample of an organic fluid.

FIG. 1.

FIG. 2.

The precision of the measurements which follow is as good as the method permits of, because the observations were taken with care and all matters which could influence the precision received attention.

The albumen was taken from a perfectly fresh hen's egg and placed in a Kohlrausch cell of the form illustrated in Fig. 1. The cell had been previously washed out with acid, water, alcohol, and ether, and was quite clean and free from any water molecules. This cell was then placed in the system of electrical circuits shown in Fig. 2.

In these circuits, Ga is a D'Arsonval galvanometer used with a telescope and scale. Its deflections, when used as a ballistic instrument, were nearly proportional to the quantity of electricity discharged through its coil. C is a mica condenser of 1.5 microfarads capacity. S is the Kohlrausch cell containing the egg-albumen to be tested. R is a resistance. Ba is two cells of storage battery. This could be replaced with a Weston standard cell when it was required to determine the extent of the galvanometer deflection when the condenser C is charged to a known electromotive force and then discharged through the galvanometer. K_C is a key which in position 1 charges the condenser and when in position 2 discharges it through the galvanometer. K_{Ba} is a key which when closed submits the contents of the cell S to a potential difference of approximately 4 volts. K_R is a key which when closed joins the resistance R to the terminals of the cell S .

The procedure adopted was as follows: Before any electromotive force had been applied to the contents of S , K_C was joined to 1 and then to 2. The galvanometer deflected, indicating that the albumen in cell S had a potential. The albumen was then stirred with a glass rod and again tried for a potential. It was found to still have a potential, but a potential *the polarity of which could often be reversed* by stirring. Before stirring, the galvanometer deflected approximately 1.8 divisions toward the left-hand end of the scale, and, after stirring, approximately 2 divisions toward the right-hand end of the scale. As a previous determination of the value of a scale division in volts gave 1 scale division = 0.0096 volt, the albumen was thus shown to be the seat of a potential which before stirring was $1.8 \times 0.0096 = 0.017$ volt in one direction, and after stirring $2 \times 0.0096 = 0.019$ volt in the opposite direction.

The key K_{Ba} was now closed, the other key being open, for exactly 600 seconds. This subjected the albumen to an applied potential of 4.13 volts for this number of seconds. Key K_R was then opened, and immediately thereafter the following program, to give data for the curves, was carried out: With K_{Ba} at all times open, and K_R open, K_C is joined to 1 and the condenser is charged with the potential possessed by the cell S . K_C is joined to 2 and the condenser discharged through the galvanometer. The deflection of this is noted. Then K_R is

closed, and after an interval of 1 minute the condenser is again charged and discharged. K_R is now maintained closed for 68 minutes, except that at intervals of two minutes it is opened just long enough to charge and discharge the condenser by means of the key K_C . At these intervals the readings taken give the electromotive force of the cell upon open circuit. The condenser is also charged, K_R being closed, at intervals of two minutes which alternate with the open-circuit readings.

At the end of 68 minutes K_R was opened permanently and open-circuit readings were taken at brief intervals. In this way the data was obtained for plotting the curve of the recovery of the potential of the cell.

All the data obtained by the above procedure was carefully recorded. The values for the electromotive forces in volts, the current in amperes, the resistance in ohms, and the specific resistance are obtained from the relations:

$$E_x = \frac{dx}{ds} E_s \dots\dots\dots (1)$$

where E_s is the electromotive force of the standard cell used and ds the corresponding deflection, and E_x is any other electromotive force corresponding to the deflection dx .

$$X = \frac{E - E_1}{E_1} R \dots\dots\dots (2)$$

where E is the open circuit electromotive force, E_1 the fall of potential over the external resistance R , and X the resistance from terminal to terminal of the cell under test.

$$\gamma_t = \frac{R'_t}{R_t} \rho_t, \dots\dots\dots (3)$$

is an equation which gives the specific resistance γ_t (namely, resistance between opposite faces of a centimeter-cube) of the substance at a temperature of t degrees. To obtain the data for solving equation (3) the cell is filled with a saturated NaCl solution of known specific resistance ρ_t . R'_t is the measured resistance at temperature t of the cell filled with albumen, and R_t is that of the cell when filled with the saturated salt solution. The resistance of the cell in this latter case is measured by the well-known Kohlrausch method, in which a slide wire bridge,

telephone detector, and current from a small induction coil are used.

The features of interest obtained in this test upon the electrical properties of egg-white are well set forth by the curves (Fig. 3) drawn from the data obtained by the measurements.

In obtaining the data and in drawing the curves the following constant values were used:

FIG. 3.

The resistance R (Fig. 2) was chosen 100 ohms.

The capacity C (Fig. 2) was chosen 1.5 microfarads.

The temperature of the contents of the cell at the time of the test was 22°C .

In reducing the resistivity of the albumen by using formula (3) the value ρ_t assigned to saturated NaCl solution at 22°C . was 4.24 ohms, and the measured resistance of the saturated NaCl solution in the cell was 9.66 ohms. The electromotive force

of the standard Weston cadmium cell used in obtaining the value in volts of the galvanometer deflections was 1.0194 volts. A galvanometer deflection of 1 small scale division was equivalent to charging the condenser to a potential of 0.0096 volt.

The polarization curve shows that immediately after disconnecting the battery *Ba* (Fig. 2), which had applied for 10 minutes 4.13 volts to the cell, the cell retained an electromotive force of 2.2 volts. This electromotive force fell rapidly, because the cell was delivering current through 100 ohms external resistance. But at the end of one minute it still had an electromotive force of 1.56 volts and was delivering 10.5 milliamperes. At the end of 68 minutes its electromotive force was about 0.1 volt.

It does not appear at all unexpected or unnatural that any substance, capable of being electrolyzed, should exhibit an electromotive force when placed in a cell with platinum electrodes after being subjected to a voltage. The gases which would form upon the surface of the two electrodes would, for a time, make the cell act in precisely the manner of an open-circuit battery. It is hard, however, to understand, even if albumen is an electrolyte, why the recovery of the electromotive force of the cell (as shown by the recovery curve) should be so rapid and reach 0.99 volt in 33 minutes. Nor would an inorganic electrolyte exhibit, as did the albumen, an electromotive force before it had been subjected to a potential.

The resistance curve, shown in dotted line, is deduced from the polarization and terminal potential difference curves. As the curve is obtained by dividing the difference of two very small quantities by a small quantity and then multiplying by 100, the precision obtained is very low. For this reason the resistance curve is given in dotted line and only suggests the order of magnitude of the resistance. Apparently the resistance of the albumen decreases somewhat with the time. By equation (3) the resistivity can be calculated. Thus

$$\gamma_t = \frac{\rho_t}{R_t} \quad R'_t = \frac{4.24}{9.66} R_t = 0.439 R_t$$

If we call $R'_t = 70$ ohms at 30 minutes as a fair average value, we obtain $\gamma_{22} = 30.7$ as the resistivity for a centimeter-cube of the albumen at 22° C.

Probably a determination of resistivity by an alternating-current method would give a different and lower value, as a very rough test that was made seemed to indicate.

It was found by the writer that, if an egg is subjected to a very high potential, the albumen coagulates about the electrodes. This apparently greatly increases its resistance and very little current flows.

If an extended and more exhaustive investigation were to be made of the electrical properties of albumen, it would be desirable to fill the cell with a saturated salt solution and take data for a set of curves similar to those for albumen. The comparison of the curves in the two cases would bring out the peculiarities of the organic material.

The albumen molecules are altogether too complex to make it safe to suggest any hypotheses based upon this brief investigation as to the nature of the electric conduction of albumen, or to attempt to account for the presence of an electric potential in albumen which has not been previously subjected to an electromotive force.

The observations in the above investigation were made at the writer's request by Mr. H. H. Lester.

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Corrosion of Water Mains. R. KRZIZAN. (*Z. öffentl. Chem.*, xviii, 433.)—A portion of a cast-iron water main which had been in service for twenty years suddenly became defective. It had been asphalted inside and outside, but the corrosion went right through. A number of conical holes were scattered irregularly over the surface and were surrounded by graphite-like material containing particles of metallic iron. An analysis of the material showed the composition to be: metallic iron 5.98 per cent., ferric oxide and hydroxide 34.09, ferrous phosphate 9.63, ferrous silicate 37.16, ferrous sulphate 0.47, carbon 11.42, sulphur 0.097, manganese 1.362, copper 0.296 per cent. There was nothing in the water running through the pipe to account for this formation. The clay in which the pipe lay contained crystals of gypsum distributed irregularly in it. The corrosion is attributed to local currents set up by contact between the graphite particles and the iron in the presence of a solution of calcium sulphate at the points round the pipe where the crystals of gypsum were contained in the clay.