### The Value of the Electronic Charge

A notable contribution to our knowledge of the value of the electronic charge $e$ has just been made by Schopper.[1] A method based on the original work of Rutherford and Geiger[2] and of Regener[3] was used, namely a simultaneous measurement of the number of $\alpha$-particles emitted by a radioactive substance in a given time interval, and of the total charge carried by these particles. The final equation for $e$ contains four factors, (1) a geometrical factor $R$, which measures the ratio of the number of $\alpha$-particles counted to the number collected on the electrometer, (2) the average charge $J$, in int. coulombs, acquired per unit time by the electrometer, (3) the average number of $\alpha$-particles $\bar{n}$ entering the counting chamber per unit time, and (4) the average multiple $\epsilon$ of the electronic charge carried per $\alpha$-particle. In terms of these factors we have

$$e=(J\cdot R)/(\bar{n}\cdot\epsilon).$$

It is not possible, from the published information, to check the value or the accuracy of $J$ and of $R$. We therefore confine our remarks to $\epsilon$ and $\bar{n}$.

The value of $\epsilon$ is slightly less than two, due to the repeated gain and loss of electrons by an $\alpha$-particle, during its passage through matter. Schopper quotes values of 1.997 (Rutherford), 1.996 (Kapitza) and 1.992 (Henderson), and uses $1.995\pm0.0015$ as an average. We are unable to check any of these values. The data of Rutherford and of Henderson are shown most clearly in Fig. 3, p. 163 of Henderson's paper.[4] The ordinate $y$ is the cube root of the relative abundance of doubly and singly charged $\alpha$-particles from Ra C′, slowed down by foils of various thicknesses and materials. The abscissa is $V/V_0$, where $V_0$ is the initial velocity ($1.922\times10^9$ cm/sec.) of the particles. All but one of the 25 experimental points shown in this figure lie quite accurately on the straight line $y=-0.830+6.466x$. For polonium $\alpha$-particles, used by Schopper, the velocity corresponds to $x=0.827$. Hence $y=4.517$, $y^3=92.16$ and $\epsilon=(2\times92.16+1\times1)/93.16=1.989_3$. The mean error $1.5\times10^{-3}$, adopted by Schopper, is a very conservative estimate of the mean error of this new value.

Kapitza appears to have made no measurements in the desired velocity range. Hence $1.989_3$ is the best average value. Schopper's results may be due to the erroneous assumption $x=1$, since the equation just quoted then yields $\epsilon=1.994_4$. Our new value of $\epsilon$ is 0.29 percent less than his adopted average value, and the resulting value of $e$ is accordingly increased by the same amount. Using Schopper's own published values of $R$, $J$, $\bar{n}$ and $\epsilon$, we find $e=4.766_{47}\times10^{-10}$ abs-*es*-units (he gives 4.768), whereas our new value of $\epsilon$ gives $e=4.780_1$.

To obtain $\bar{n}$, the average of many observations ($n_0$) of the number of $\alpha$-particles per unit time, Schopper uses the formula $\Sigma y/\Sigma x$, where $y$ is the counted number of particles reduced to a standard epoch (his $N_0$), and $x$ is the corresponding time interval which varies from 9 to 23 hours.[5] This formula may be written $\Sigma x(y/x)/\Sigma x$, and obviously corresponds to weighting each determination of a slope $y/x$(=his $n_0$) proportional to the $x$ interval. When the variations in $n_0$ are due solely to statistical fluctuations, this is the correct formula to use in order to give the most reliable average result $\bar{n}$. However, in calculating the mean error in $\bar{n}$, Schopper uses a formula applying only to the *unweighted* average $\Sigma(y/x)/k$, where $k$=number of observations. Since only about one-quarter of the individual $n_0$ values are given, we cannot check his result $\bar{n}=33.132\pm0.030$ counts per minute, but the value of $\bar{n}$, calculated from the published portion of the data, is $33.133_6\pm0.236$ percent, or $\pm0.244$ percent when calculated by Schopper's formula. It is thus evident that the method of calculating the mean error makes a negligible difference.

Schopper justifies his assumption that the variations in $n_0$ are purely statistical, by showing that the observed proportional mean error in $\bar{n}$ agrees with the calculated value (the reciprocal of the square root of the total number of counted particles). The observed and calculated errors agree well, even in the case of the small portion of the data published, for which one finds the predicted error to be 0.19 percent, only slightly less than the observed values just given. Hence his adopted mean errors in $\epsilon$ and $\bar{n}$ appear reasonable, but whether the final probable error in $e$ is as small as his adopted 0.1 percent seems more questionable, although we are not in a position to judge.

Our recalculated value 4.780 is 0.25 percent above the oil-drop value[6] ($4.768\pm0.005$), but it is still far below the value 4.805 given indirectly by the grating wavelengths of x-ray lines, using the present accepted structure and constants of calcite. This last value of $e$ results from the assumption that ruled grating wavelengths are 0.22 percent larger than Siegbahn's crystal wavelengths. This figure was obtained by Bearden[7] for wavelengths between 1.4 and 2.3A, and has just been accurately verified by Bäcklin,[8] for a wavelength 8.3A. It thus seems established that the discrepancy between the grating and crystal wavelengths is close to 0.22 percent, *independent* of wavelength, but the cause of the discrepancy remains as mysterious as ever.

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[1] E. Schopper, Zeits. f. Physik **93**, 1 (1934).
[2] E. Rutherford and H. Geiger, Proc. Roy. Soc. **A81**, 141, 162 (1908).
[3] E. Regener, Ber. Preuss. Akad. d. Wiss. **38**, 948 (1909).
[4] G. H. Henderson, Proc. Roy. Soc. **A109**, 157 (1925).
[5] His first listed value of $n_0$ should be 33.148 (not 33.158), and his fourth should be 32.712 (not 33.712).
[6] R. T. Birge, Rev. Mod. Phys. **1**, 1 (1929) and Phys. Rev. **40**, 228 (1932).
[7] J. A. Bearden, Phys. Rev. **37**, 1210 (1931).
[8] E. Bäcklin, Nature **135**, 32 (1935).

### Artificial Radioactivity Induced by Cosmic Rays

In these columns, J. E. I. Cairns[1] has recently presented experimental data on the frequency of "Stösse," which lead him to suggest that cosmic rays produce artificial radioactivity in the lead shields of his apparatus. His data are from two runs of 1344 and 1524 hours, respectively. In the first, he obtained 927 bursts, with 14 doubles, i.e., pairs of bursts separated in time by one minute or less. He states that this number of doubles is 94 times that to be expected from probability considerations. In the second