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Search for Fractional Charge on Tungsten Particles

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The charge on some small tungsten particles was measured to test for the presence of fractional excess charges. In a sample of 3×10^{-10} g, or 10^{12} atoms, of tungsten, no excess charges of $+\frac{1}{3}e$ or $-\frac{1}{3}e$ were found.

An experiment performed recently by LaRue, Fairbank, and Hebard[1] indicated that charges of about $\pm\frac{1}{3}e$ were occasionally present on superconducting niobium spheres suspended in a magnetic field. They suggested that the fractional charges came from contact with a tungsten surface in the course of a heat treatment. We have subsequently measured the charge on some small tungsten particles, using a variation of the method used by Millikan[2] to measure the electronic charge.

The experimental apparatus is diagramed in Fig. 1. A vertical electric field is applied between two parallel circular plates, with controls to vary the magnitude and sign of the voltage across the plates. The tungsten particles to be investigated are formed above the top plate in an arc discharge between the tungsten electrodes. The particles are then forced through a hole in the upper plate by flexing the top cover of the apparatus. They are illuminated by an incandescent light source and observed through a telemicroscope, at a magnification of about 15. A suitable particle is selected by the observer on the basis of how much light it reflects and how fast it drifts with the electric field off. The electric field is then adjusted until the particle remains suspended, without drifting up or down. The balance of electric and gravitational forces on the suspended particle gives

$$mg = qE, \tag{1}$$

where m and q are the mass and charge of the particle, E is the applied electric field, and g is the acceleration of gravity.

The charge on the particle under observation changes spontaneously from time to time, and can be made to change more frequently by introducing a radioactive source into the region between the plates. A series of measurements was taken for each particle, and $1/E$, the inverse of the nulling field, was calculated for each measurement. Results for one particle are shown in

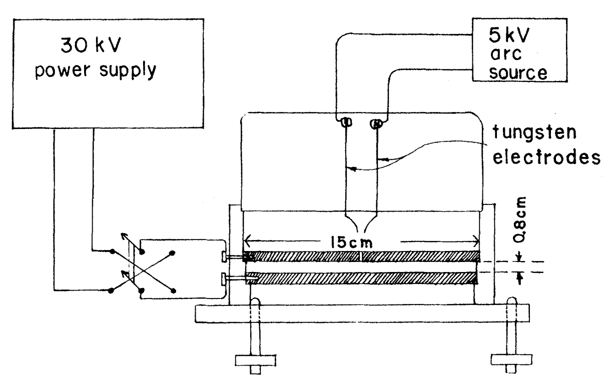

FIG. 1. Diagram of the experimental apparatus.

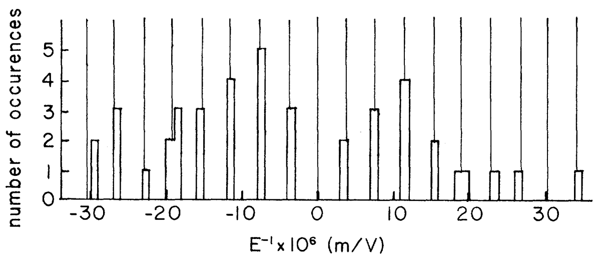

FIG. 2. Histogram of the inverse of the nulling field, for all measurements of one particle. The lines indicate calculated positions based on the fit to the data described in the text.

Fig. 2. As $1/E$ is proportional to the charge on the particle, the equal spacing of the measurements shows that the charge always changes by integral multiples of a unit of charge. The fact that the measurements are symmetrical about zero shows that there is no excess nonintegral charge on the particle. With an excess charge, the measurements would be spaced in a similar way, but shifted to the right or to the left.

We have analyzed measurements on 77 particles. The measurements were fitted to the form

$$y_n = a + bn, \qquad (2)$$

where $y_n = 1/E_n$ is the inverse of the nulling field, and n is an integer assigned to each measurement by inspection of the data. Experimental measuring errors were assigned, based on the observed variation of repeated measurements on a single particle for the same value of n. Typical errors were 2–4%. We define the residual charge q_r by $q_n = q_r + ne$, where e is the electronic charge. Then Eq. (1) can be rewritten as

$$1/E_n = q_r/mg + ne/mg. \qquad (3)$$

Comparing Eqs. (2) and (3), we see that the residual charge can be calculated from the fit parameters a and b: $q_r = ea/b$.

After the minimum-χ^2 fit was performed, a set of measurements was considered good if (a) there were at least five separate measurements of E; (b) the best-fit value of χ^2 was less than three times the number of degrees of freedom; and (c) the error on the residual charge was less than 4% of one electronic charge.

The values of q_r for 69 well-measured particles are shown in Fig. 3. These values agree well

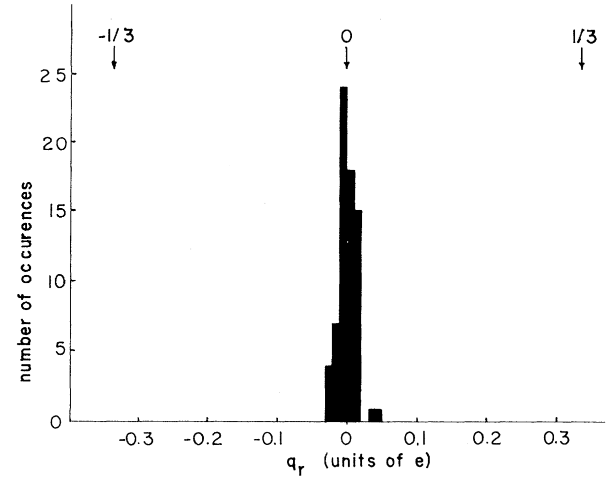

FIG. 3. Values of the residual charge for 69 well-measured particles.

with the assumption that q_r is Gaussianly distributed about zero, and no value of q_r is within 9 standard deviations of $+\frac{1}{3}e$ or $-\frac{1}{3}e$. We conclude with high statistical reliability that none of our particles held an excess charge of $\pm\frac{1}{3}e$. The mass of each particle tested was calculated from the fit parameter b: $m = e/gb$. The sum of the masses of our sample of well-measured particles is 3.61×10^{-10} g. Assuming the chemical state to be WO_2, we have tested 3.07×10^{-10} g, or 1.10×10^{12} atoms, of tungsten. While other workers[1,3,4] have tested samples as large as 10^{-4} g of iron, niobium, and other materials for the presence of quarks, our experiment is the first result published for any element heavier than niobium. In the future, we plan to extend these measurements to other heavy elements.

We would like to acknowledge the help of Robert Johnson and Michael Welch.

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[2]R. A. Millikan, *The Electron* (Univ. of Chicago Press, Chicago, 1917).

[3]See review by Y. S. Kim, Contemp. Phys. 14, 289 (1973).

[4]V. B. Braginsky, L. S. Kornienko, and S. S. Poloskov, Phys. Lett. 33B, 613 (1970).