Full Formal Report, Lab 4A: Millikan Oil Drop

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(Dated: March 13th, 2019)

The goal of this lab was to find the charge of the electron by slightly charging oil drops in a very fine mist. By creating a slight positive, negative, or neutral potential on the plate below the drops, the drops would move up or down, at a speed that could be calculated by using the grid in the microscope used to observe the drops. The found charge for an oil drop was $6.485^{-18} \pm 1.873 \times 10^{-19} C$ which falls within range of an integral multiple of 4 of the expected electron charge, 1.602×10^{-19}.

I. INTRODUCTION

The Millikan oil drop experiment was a incredibly ingenious experiment that gave a very accurate measurement for the charge of the electron. The electric charge carried by a particle (oil drop) may be calculated by measuring the force experienced by the particle in an electric field of known strength. By selecting droplets which rise and fall slowly, it is certain that the drop has a small number of excess electrons. If the charges on these drops are integral multiples of a certain smallest charge, then this is a good indication of the atomic nature of electricity. Since a different droplet has to be used for measuring each charge, there remains the question as to the effect of the drop itself on the charge. This uncertainty can be eliminated by changing the charge on a single drop while the drop is under observation. An ionization source placed near the drop will accomplish this. In fact, it is possible to change the charge on the same drop several times. If the results of measurements on the same drop then yield charges which are integral multiples of some smallest charge, then this is proof of the atomic nature of electricity.

II. THEORETICAL MODEL

Terminal velocity of the oil droplets is reached within a few milliseconds of movement, so the net force is zero, (for no electric field) giving us:

$$mg = kv_f \tag{1}$$

And, when under the influence of an electric field:

$$qE = mg + kv_r \tag{2}$$

Where v_r is the velocity of the rise. Eliminating k and solving for q, we get:

$$q = \frac{mg(v_f + v_r)}{Ev_f} \tag{3}$$

We can rewrite mg as:

$$mg = \frac{4}{3}\pi a^3 \rho g \tag{4}$$

Substituting this in:

$$q = \frac{4\pi a^3 \rho g(v_f + v_r)}{3Ev_f} \tag{5}$$

Using Stokes Law, we can solve for a

$$\sqrt{\frac{9\eta v_f}{2\rho g}} \tag{6}$$

Since this becomes inaccurate for speeds less than 0.1 cm/s, and since the speeds observed will be less than 0.01 cm/s, we have to apply a correcting factor for ν, giving us:

$$\eta_{eff} = \eta\Big(\frac{1}{1+\frac{b}{pa}}\Big) \tag{7}$$

Where b is a constant, p is the atmospheric pressure, and a is the uncorrected a

Substituting all of this in, we get:

$$q = \frac{4\pi\rho g}{3}\left(\sqrt{\frac{9\eta v_f}{2\rho g}\Big(\frac{1}{1+\frac{b}{pa}}\Big)}\right)^3 \frac{v_f + v_r}{Ev_f} \tag{8}$$

Where E is given by:

$$E = \frac{V}{d} \tag{9}$$

Now, subbing this in and rearranging, we finally have:

$$q = \frac{4\pi d}{3}\left(\sqrt{\frac{1}{\rho g}\Big(\frac{9\eta}{2}\Big)^3}\right) \times \sqrt{\left(\frac{1}{1+\frac{b}{pa}}\right)^3} \times \frac{(v_f + v_r)\sqrt{v_f}}{V} \tag{10}$$

A. Data

*See attached tables for Raw data + analysis

III. CONCLUSION

We found that the charge on the drops observed was $6.485^{-19} \pm 1.873 \times 10^{-19} C$ However, these drops were moving fast, and very likely had an integral multiple of charge on them, rather than a single electron. The expected value was $1.602 \times 10^{-19} C$, and an integral multiple of 4 of this value would be 6.485^{-18}, which would fall in the uncertainty range of the found charge. This lab was difficult to conduct, and several things could have impacted the results. Picking slower moving droplets would definitely have helped to narrow down the charge of the electron. There could have been issues with the measured values of the plate separation, as well as the pressure, since a phone was used, rather than a barometer for the room. There could have been issues with timing, as it was difficult to see the drops at times. Overall, the charge found was on the same order as the expected charge, just off by a factor of 4. The uncertainty is pretty egregious, so the actual veracity of this whole lab is questionable.

ACKNOWLEDGEMENTS

I acknowledge the support of the Wabash College Physics Department.

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