P30 Unit D – Atomic Physics

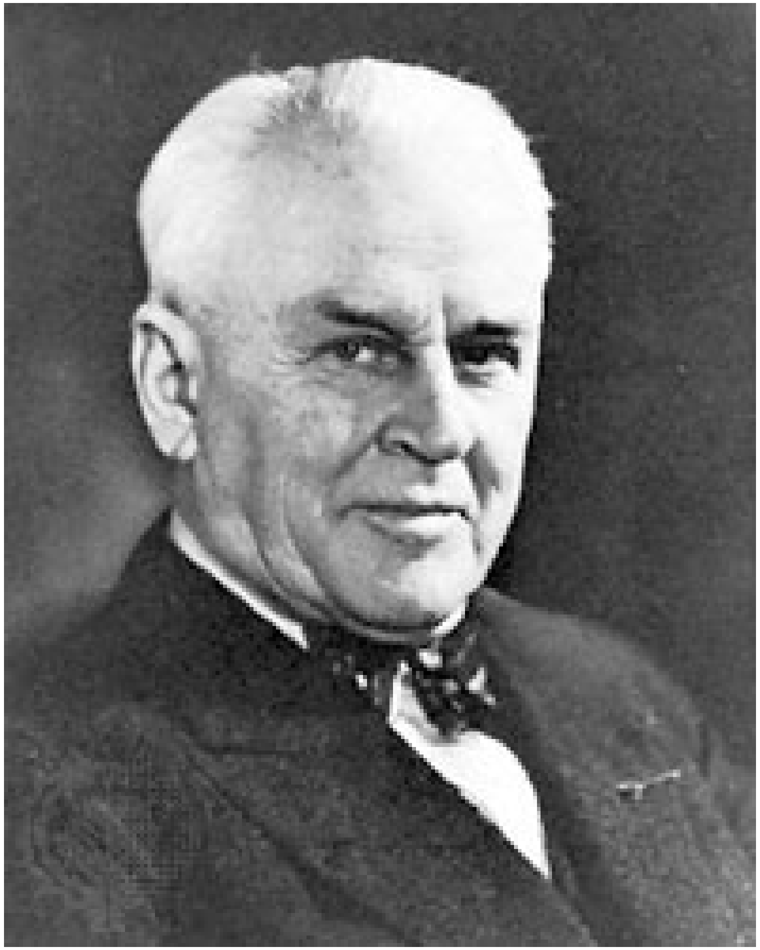
The Millikan Experiment

Lesson 4

POS Checklist

- explain Millikan’s oil-drop experiment and its significance relative to charge quantization. (from Unit B)

Starring…



- Robert A. Millikan (1868-1953)
- Nobel Prize in Physics (1923) for his determining of the elementary charge on an electron.
- Professer at University of Chicago (1910)
- Confirmed Einstein's Photoelectric effect experiment.
- Obtained exact value of Plank's Constant

The Problem…

- Thompson discovered the electron in 1897 using a gold-foil and cathode ray tube apparatus.
- But he didn't know how much charge was on a single electron.

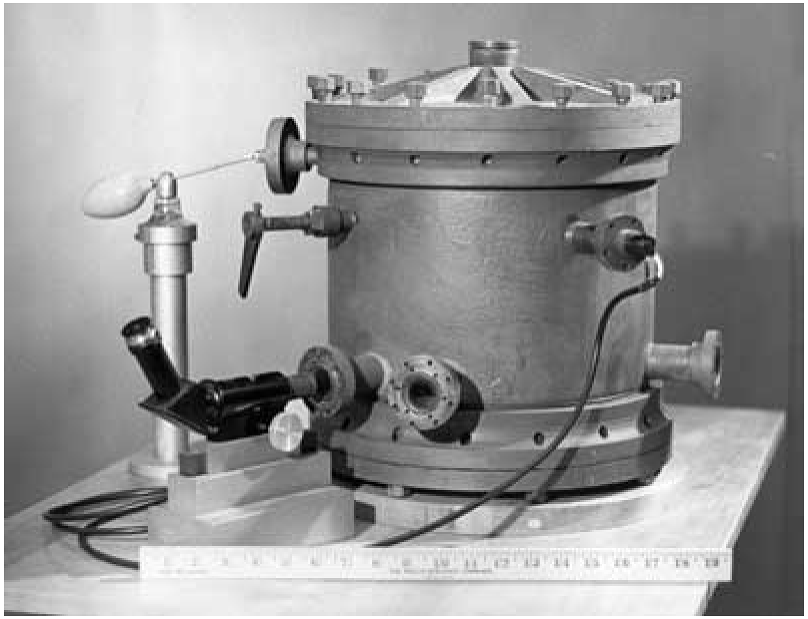
J.J. Thompson

Enter: Millikan

- Millikan designed an experiment to determine the charge on a single electron.
- The experiment used ideas near and dear to us:
    - Charged parallel plates
    - Gravitational and electrical forces
    - The total force

Experimental Design:

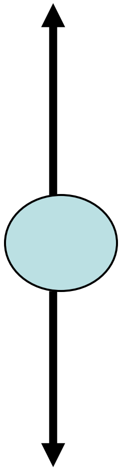
- large steel chamber with microscope and atomizer attached.
- atomizer sprayed a fine mist of oil into the chamber.
- oil becomes charged by friction when passing through the nozzle of the atomizer.



- Through the microscope, he could watch the oil drops fall.
- He placed parallel plates in the chamber and activated it when a good looking drop came along.
- The electric force acting on the drop counteracted gravity, suspending the drop.

- By measuring the diameter of the drop (and knowing its density), he could determine the drop’s mass.
- By setting the force of gravity equal to the force of electricity, he could find the electric force acting on the drop.
- By knowing the electric field strength, he could find the charge on the drop.

- Millikan set the force of gravity equal to the electric force. When these forces were balanced, the drops were suspended or achieved a constant velocity.



$F_e = q|E|$

$F_g = mg$

$F_e = F_g$

$q|E| = mg$

$$\boxed{q = \frac{mg}{|E|}}$$

Charge on a drop of oil

- After repeating the experiment many times for many different drops, Millikan found that the drops always had charges which were multiples of the elementary charge.
- He therefore concluded the elementary charge was 1.60×10^{-19} C.

Importance of Discovery

- Not only was it useful to know the elementary charge value, but this experiment proved that charge is quantized.
- This means that there is a fundamental building block of charge that can not be broken down any further: the electron.

Controversy:

- Millikan did not work alone: he had a partner, Harvey Fletcher, who should have shared in the credit.
- However, a deal was made between them that Millikan could claim full credit for this experiment if Fletcher could claim full credit for another since forgotten experiment for his dissertation.
- The Oil Drop experiment went on to win the Nobel Prize.
- Fletcher kept the secret until his death.

Controversy 2

- There is evidence that Millikan only reported *some* of the values he got from the experiment.
- Other values which would have given his experiment a higher degree of error (and less clout) were “thrown out”.
- This would have thrown his % error from about 1% to 2%.

Questions:

- An oil drop weighs 1.9×10^{-15} N. It is suspended in an electric field of 6.0×10^{3} N/C.
  - What is the charge on the drop?
  - How many excess electrons does the drop carry?

Questions:

- A positively charged drop weighs 6.4×10^{-13} N. An electric field of 4.0×10^{6} N/C suspends the drop.
  - What is the charge on the drop?
  - How many electrons is the drop missing?
  - If three more electrons were removed from the drop, what field would be needed to balance the drop?

Homework

- Millikan Oil Drop Lab (on computer)