

Lesson 38: Millikan's Oil Drop Experiment

The work of people like J.J. Thomson allowed us to find out about the existence of negatively charged electrons.

- In 1909 [Robert A. Millikan](#) came up with an experiment to measure the charge on an electron, called the **Oil Drop Experiment**.

The apparatus was actually quite simple...

- There were two parallel plates set at a specific distance apart with a known voltage between them.
 - That way we know the electric field strength.
 - The **top plate** is positive, and the **bottom plate** is negative.
- Millikan drilled a very small hole in the center of the top plate.
- He then used an **atomizer** to spray very fine drops of **mineral oil** over the top plate.
 - An atomizer is like those fancy perfume bottles you see that have a ball you squeeze to make the perfume spray out.
 - Friction between the nozzle of the atomizer and the mineral oil droplets caused some of the drops to gain a small charge (charging by friction).

Did YOU KNOW?

Millikan had the help of a graduate student named Harvey Fletcher. Millikan took full credit for the experiment, and in return Fletcher took credit for a dissertation he was writing on methods of measuring charge. This was a secret that Fletcher took to his grave.

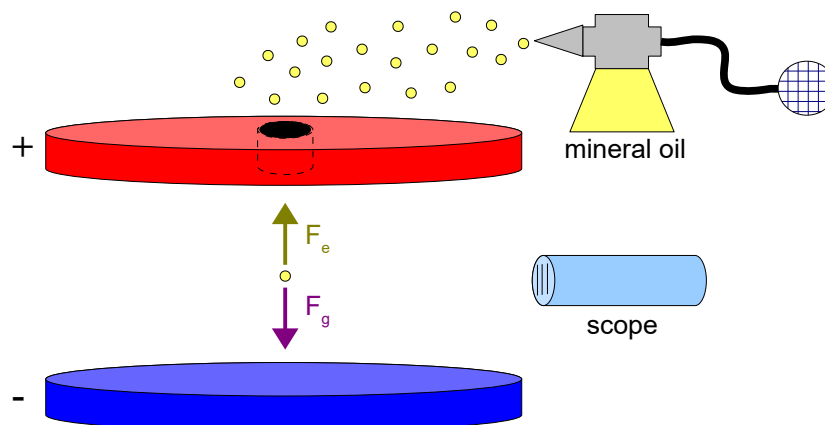


Illustration 1: Millikan's Oil Drop Experiment.

Just by chance, some of the oil drops might fall down the hole in the top plate.

- If they have a positive charge, we expect them to go accelerating down to the negative plate and crash into it.
- If they have a negative charge, something different might happen.
 - If the **force due to gravity** (F_g) pulling the drop down is exactly balanced by the **electric force** (F_e) pushing it up, the drop should float between the two plates.

Did YOU KNOW?

Atomizers were the basis for the invention of gasoline carburetors on cars.

Since the force due to the electric field and the force due to gravity are balanced, it is possible to derive an equation to calculate the charge on the droplet.

$$F_e = F_g$$

$$q \vec{E} = mg$$

$$q \frac{V}{d} = mg$$

$$q = \frac{mgd}{V}$$

q = charge (C)
 m = mass of oil droplet (kg)
 g = acceleration due to gravity (m/s²)
 d = distance between plates (m)
 V = voltage (V)

Measuring the mass of the oil droplet is a bit of a tough one, especially since it usually only floated for a couple of seconds and then splattered on one of plates.

- Millikan had a solution to this problem...
 - First, he used a miniature telescope with hash lines etched onto the glass. When he looked into the scope he'd see something like *Illustration 2*.
 - By knowing the distance between the hash marks, Millikan could measure the diameter of the oil drops. Then he could figure out the volume of the oil drop.
 - Then he would use the density of mineral oil to find the mass of the oil drop.

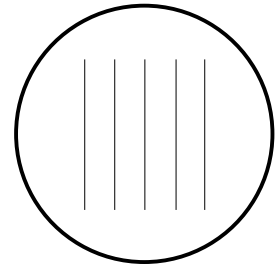


Illustration 2: Hash lines are scratched into the lens.

Millikan spent thousands of hours squinting through that scope, desperately trying to see drops float and quickly measure their diameter.

- After thousands of trials, Millikan had enough successful trials to show that all of the charges he calculated were multiples of one number, 1.60e-19 C.
 - Since he never found a smaller common multiple of this charge, he concluded this must be the charge on a single electron.
- Because it is the most basic charge possible we call it an **elementary charge**, “e” on data sheets.
- The idea that charge could be quantized (broken down to an indivisible piece) had been proven.
 - This is sometimes called the **quantization of charge**.
- Since we now have both the charge-to-mass ratio (q/m) and the charge of an electron, we can also work out the mass of an electron, 9.11e-31 kg.

Did YOU know?

As of 1986 the most precise and accurate measurement of the elementary charge is 1.60217653(14)e-19 C. The last two numbers are in brackets because although they are considered “questionable”, they might still be applied in some calculations.

Example 1: An oil drop in a Millikan apparatus is determined to have a mass of 3.3×10^{-15} kg. It is observed to float between two parallel plates separated by a distance of 0.95 cm with 340 V of potential difference between them. **Determine** how many excess (extra) electrons are on the drop.

$$F_e = F_g$$
$$q = \frac{mgd}{V}$$
$$q = \frac{3.3 \times 10^{-15} (9.81) (0.0095)}{340}$$
$$q = 9.04539706 \times 10^{-19} = 9.0 \times 10^{-19} \text{ C}$$

But the question asked how many excess electrons are on the drop, not for the charge. Since we know one electron has a charge of 1.60×10^{-19} C...

$$9.04539706 \times 10^{-19} \text{ C} \left(\frac{1 \text{ electron}}{1.60 \times 10^{-19} \text{ C}} \right) = 5.65337316 \text{ electrons}$$

Since it is impossible to have part of an electron, we round this off to get the final answer of **six excess electrons**.

Homework

p763 #1, 2

p764 #1