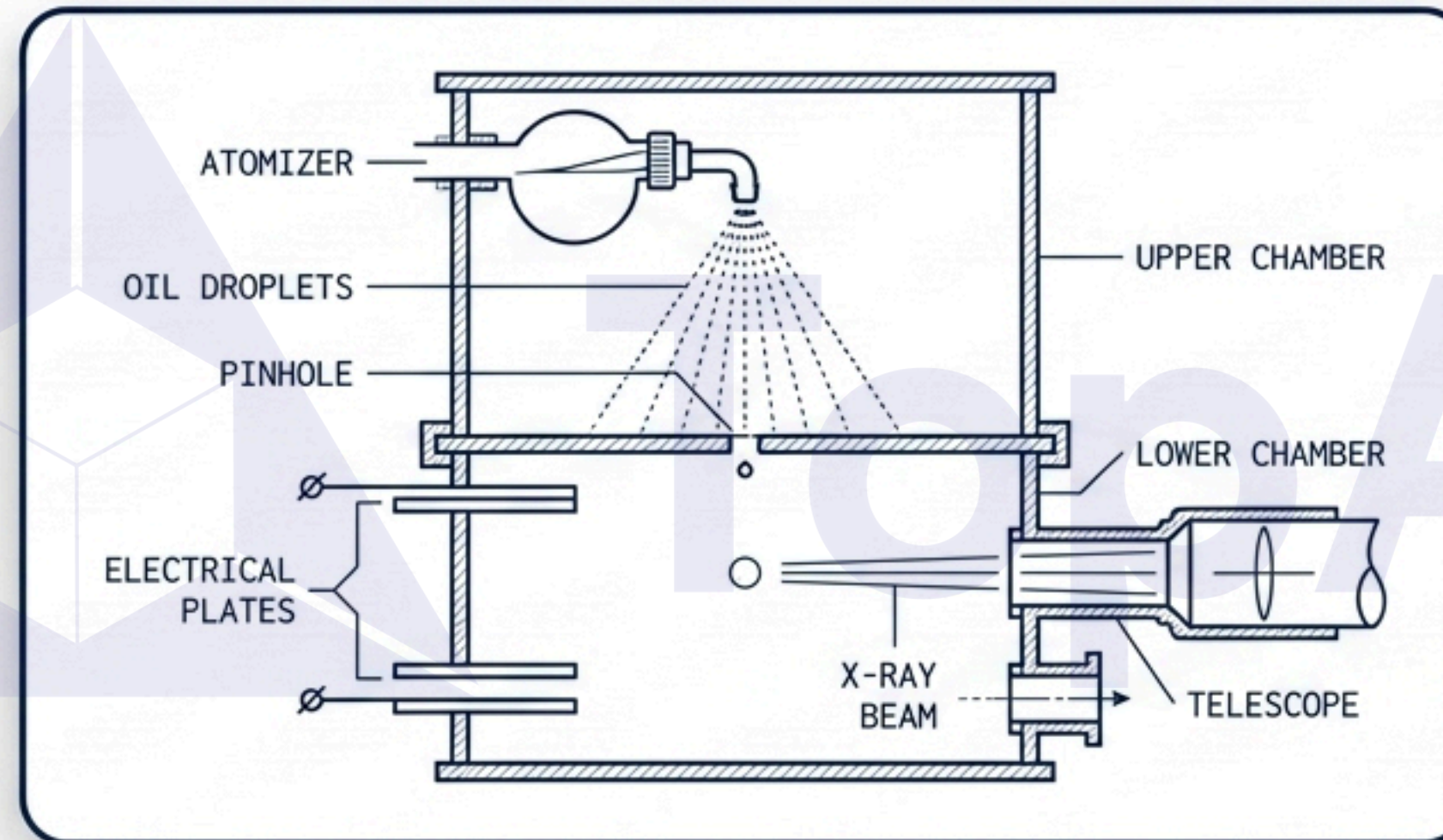


2.1.3 Charge on the Electron

R.A. Millikan's Oil Drop Experiment (1906–14)



- Objective: To determine the absolute electrical charge of a single electron.
- Method: Measuring the effect of electric fields on ionized oil droplets.
- Result: Discovery of the elementary charge and quantization.

THE HISTORICAL PROBLEM

Why e/m_e Was Not Enough

An equation with two unknowns

Thomson's Ratio (1897)

- J.J. Thomson successfully deflected cathode rays using electric and magnetic fields.
- He definitively established the Charge-to-Mass Ratio of the electron.

$$e/m_e = 1.758820 \times 10^{11} \text{ C kg}^{-1}$$

The Missing Link

While Thomson proved electrons exist as fundamental particles, the ratio alone could not yield the actual mass or the absolute charge.

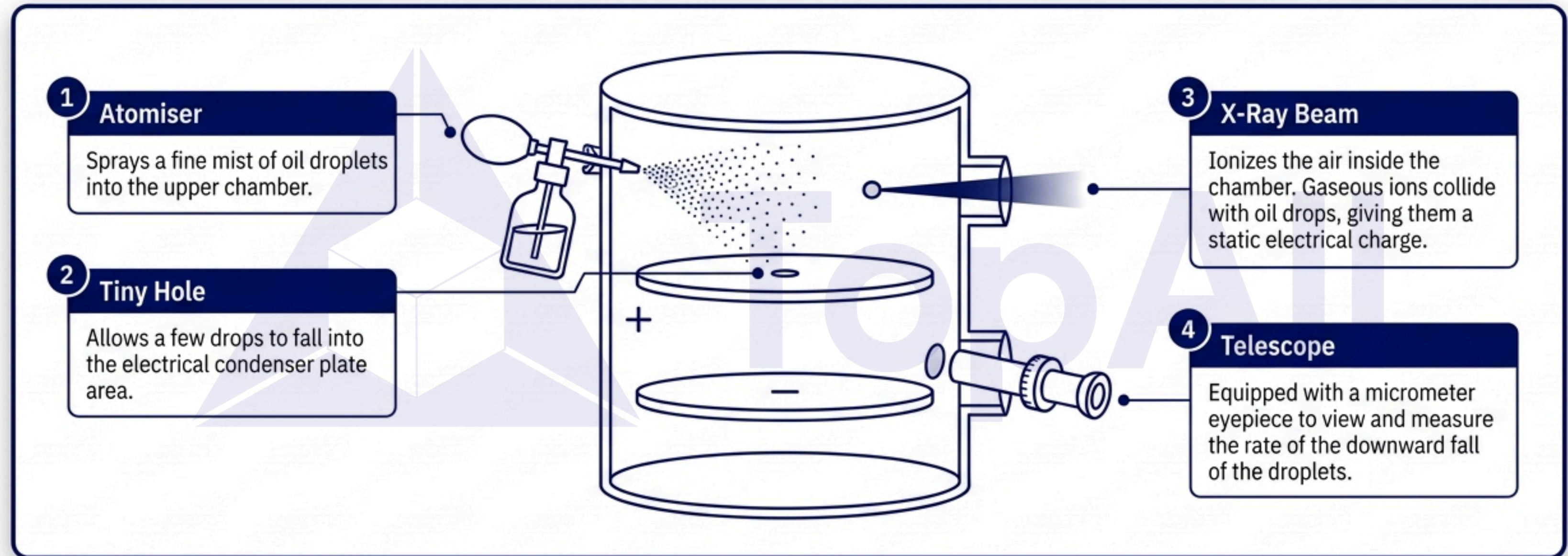
$$e = ?$$

$$m_e = ?$$

To unlock the mass of the electron, scientists first needed to find a way to isolate and measure its exact charge.

Millikan's Oil Drop Experiment Setup

Isolating sub-atomic charges on macroscopic droplets



Key-Takeaway Box

By observing the rate of fall in the absence of an electric field, Millikan could first determine the mass of the oil droplets.



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$$E=mc^2$$



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Key Highlights

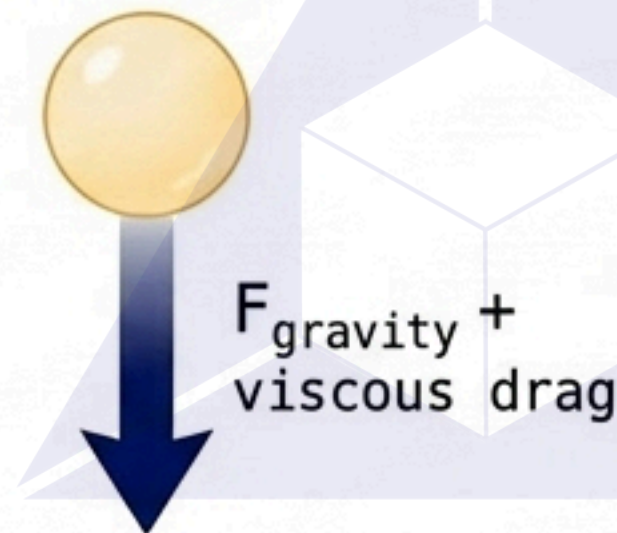
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How Electric Field Controlled Oil Drop Motion

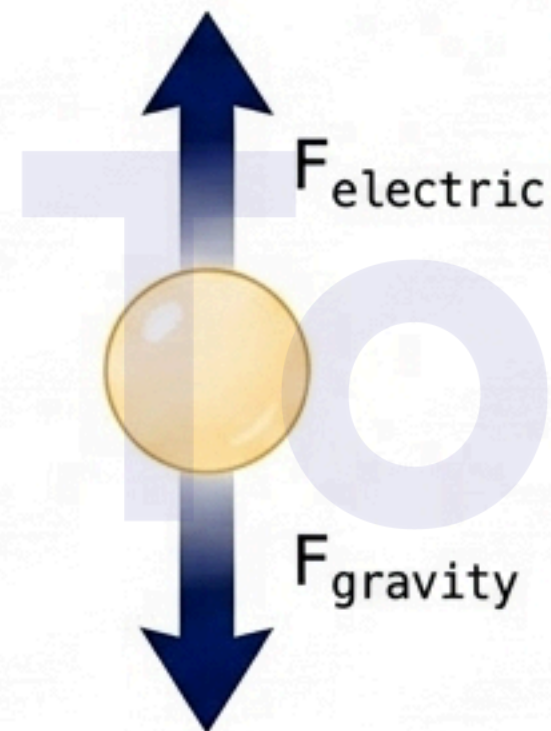
Balancing gravity against electrostatic forces

Field OFF (Falling)



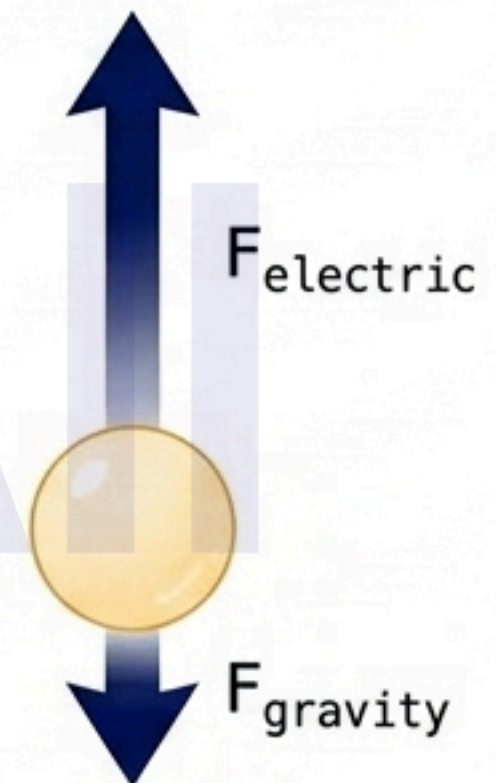
Oil drop falls at a constant terminal velocity due to gravity. Mass is calculated here.

Field ON (Suspended)



Voltage is applied. The negative charge on the drop is attracted to the positive upper plate, halting the fall.

Field STRONG (Rising)



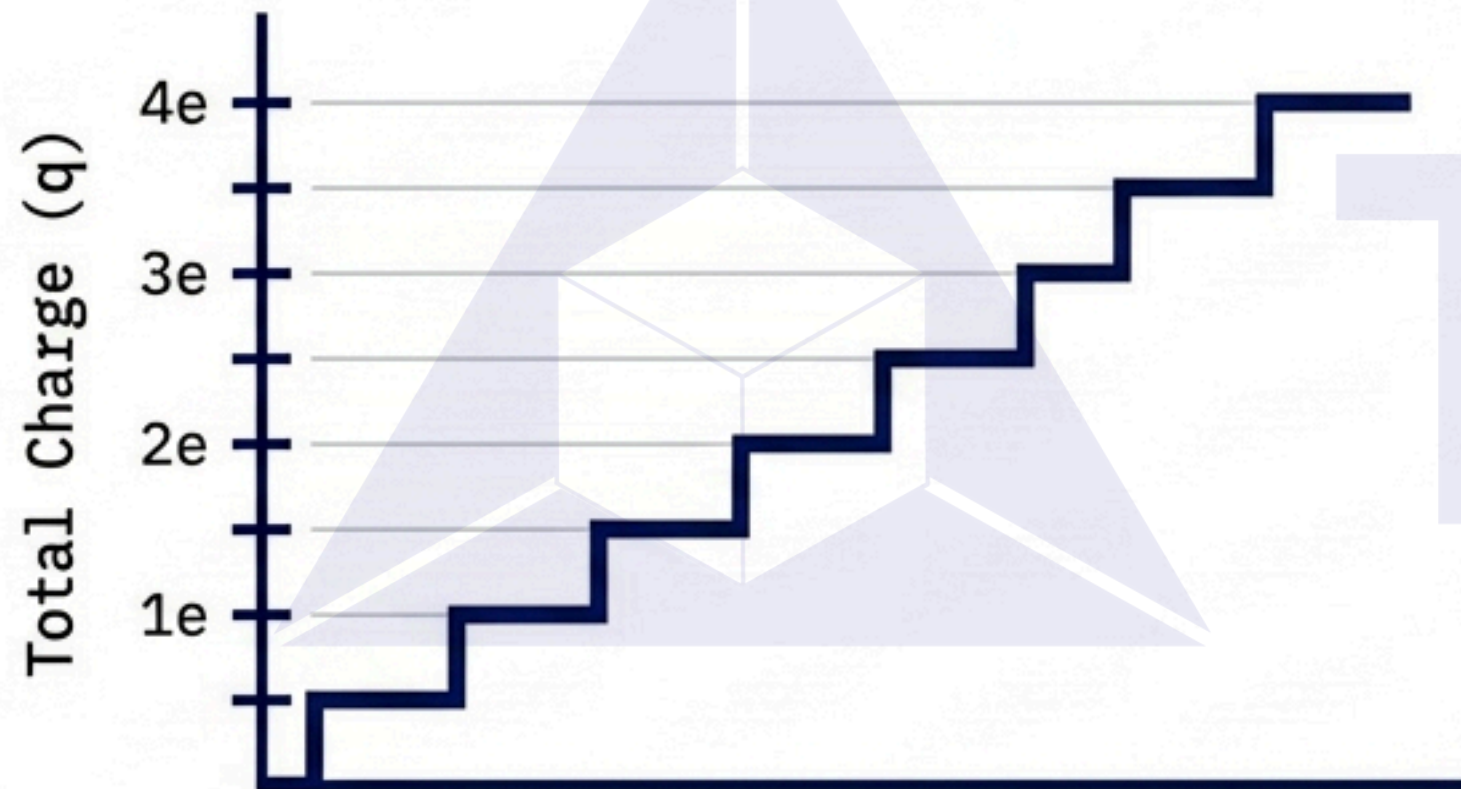
Voltage is increased. The drop is accelerated upward against gravity.

By carefully measuring the exact electrical field strength needed to make the droplet stationary, Millikan calculated the exact charge q residing on the drop.

Quantisation of Charge and Value of e

Charge exists only in discrete packets

The 'Staircase' of Charge



- Millikan observed the charge on thousands of oil drops.
- He noticed the charge q was never a continuous, random value.
- It was always a whole-number multiple of a specific base minimum value.

$$q = n e$$

- q = Total charge on the droplet
 n = Integer (1, 2, 3 ...) representing the number of electrons
 e = The elementary charge

$$e = -1.6 \times 10^{-19} \text{ C}$$

(Present accepted value: $-1.602176 \times 10^{-19} \text{ C}$).

Because charge is always an integral multiple of e , electrical charge is said to be quantised.

Final Recap: fixed elementary charge on electron

Closing the loop on Thomson's ratio

The Electron is Quantised

- Electrons are the basic constituent of all atoms.
- Every single electron carries the exact same fundamental, indivisible charge.

$$\text{Charge (e)} = -1.6022 \times 10^{-19} \text{ C}$$

Unlocking the Mass

By combining Millikan's value of e with Thomson's e/m_e ratio, the true mass of the electron was finally calculated.

$$m_e = \frac{e}{e/m_e}$$
$$m_e = \frac{1.6022 \times 10^{-19} \text{ C}}{1.7588 \times 10^{11} \text{ C kg}^{-1}}$$

$$\text{Mass (m}_e\text{)} = 9.1094 \times 10^{-31} \text{ kg}$$

The Millikan Oil Drop Experiment proved that charge is quantised and allowed physicists to establish the definitive mass and charge of the electron, providing the foundation for modern atomic structure models.



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