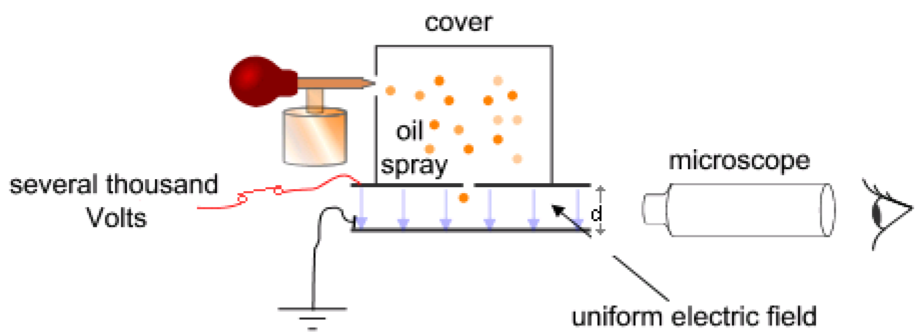
The Millikan Experiment

Aim
To find the charge of the electron by showing that small oil drops have a charge that can be expressed as:

$$q = n * e$$

where n is a whole number and e is the charge of the electron.

Apparatus



Drawing from: http://en.wikipedia.org/wiki/Oil-drop_experiment, 1-4-2009

Within a cylindrical plastic housing are mounted two parallel capacitor plates with a mutual distance of d = 6 mm. The plates will be connected to a special power supply establishing a potential difference U (0 – 600 V). Through two small openings in the vertical wall of the housing oil-drops are sprayed between the plates. A lamp connected to a potential difference of 6 V from the power supply illuminates the oil drops. A mounted microscope makes it possible to observe the oil-drops. Some of the oil-drops are ionised and then carrying a small charge q.

Theory

- Mass of oil-drop: $m = (4\pi/3)\, r^3\, \rho$, r radius, ρ mass density of oil = 800–900 kg/m3 – in principle corrected for the buoyancy of air, we use 870 kg/m3
- Gravity force: $F_g = m\, g$ ($g = 9.82$ m/s^2)
- Electrical field: $E = U/d$ (U potential difference, d distance between capacitor plates = 6 mm)
- Electrical force: $F_e = q\, E$ (q charge of oil-drop)
- Frictional force on oil-drop in air, Stokes' law:
  $F_f = 6\pi\, \eta\, r\, v$ (η viscosity of air = 1.8 10^{-5} Ns/m^2, v constant speed of oil-drop)
- Without potential difference, oil-drop falling with constant speed, $F_g = F_f$.
  From this you can derive an expression of r.
- With potential difference U, oil-drop at rest, $F_g = F_e$.
  Form this you can derive an expression of q.
- Programme your calculator or PC to find q when given v and U (SI-Units), and/or put up a formula expressing q by a number, v and U (SI-Units).

The Millikan Experiment

The experiment

Before starting the measurements the build-in ocular scaling of the microscope must be calibrated. This is done by carefully dismounting the capacitor plates and mount an objective scale in the centre of the housing. Adjust the focus of the ocular. Both scales have division-lines of 0.1 mm. Find the calibration factor (magnification factor). After this calibration the focusing of the ocular should not be changed, but you can still change the focusing of the objective (moving the microscope as a whole) using the big ribbed knob. Mount the capacitor and connect it to the power supply.

The measurements require some manipulative skills. Your tools are:

- Spraying the oil-drops between the plates
- Choosing an oil-drop.
- Vary the potential difference over the capacitor to make an oil-drop stand still.
- With no potential difference observe the falling oil-drop and calculate its speed (taking the calibration into account).
- Consider how to choose and measure oil-drops with as small a charge as possible.
- Consider best strategy: Choosing an oil-drop by observing the drops while falling (with no potential difference) or by first choosing a potential difference and then observe oil-drops (almost) at rest.
- Make calculations of q frequently during the experiment so that you can adjust your strategy towards the goal: to determine the charge of the electron.
- Be well prepared to this experiment having tables and calculators ready – maybe programming your calculator or PC to make immediate calculations.
- Be careful and patient – this experiment is not an easy one.

Millikan experiment

1) Potential diff. $U = 0 \Rightarrow$ oil drop has constant speed when:

$$F_g = F_{fric} \rightarrow \frac{4\pi}{3} r^3 \rho g = 6\pi \eta r v$$

$$\Rightarrow r = \sqrt{\frac{9\eta v}{2\rho g}}$$

2) Potential diff. $U > 0 \Rightarrow$ oil drop at rest when:

$$F_g = F_{el} \Rightarrow \frac{4\pi}{3} r^3 \rho g = \frac{q U}{d}$$

$$\Rightarrow q = \text{const} \times \frac{V^{3/2}}{U}$$

where $$\text{const} = \frac{9\sqrt{2}\,\pi\,\eta^{3/2} d}{\rho^{\frac{1}{2}} g^{\frac{1}{2}}}$$

Calibration factor:

Both scale in microscope and objective scale mounted have division-lines of 0.1 mm.

18 bars on microscope scale correspond to 10 bars of object scale.

$\therefore$ 1 bar on microscope scale $= \frac{10}{18} \times 0.1 \text{ mm} = \frac{1 \times 10^{-4}}{1.8}$ m

Magnification is $\times 1.8$.

Problem with boyancy of air?

$$\text{Error, rel} = \frac{\rho_{air}}{\rho_{oil}} = \frac{1.29}{870} \approx 0.15\%$$

"Efficient" ρ would be: $\rho = \rho_{oil} - \rho_{air}$.