B.Sc Part II Physics (Hons)

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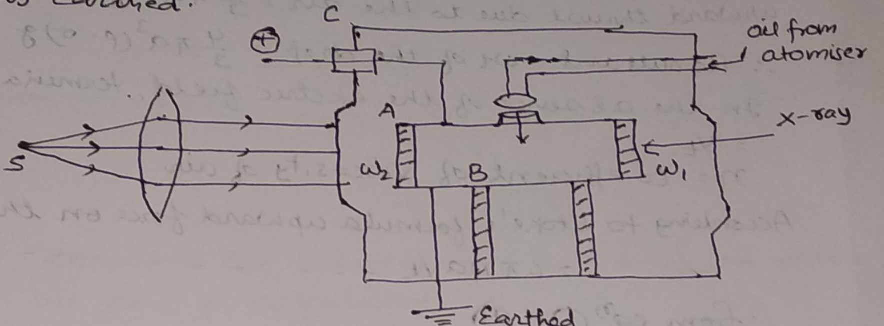
Q Describe with theory Millikan's oil drop method for determing the charge on an electron.

Ans:- The experimental arrangement for determing the charge on an electron by Millikan's oil drop method. The apparatus consists of two plane parallel circular brass plate A and B each 22 cm in diameter and Seperated from one another by glass or Quartz supports. The supports are adjusted carefully to the same height, so that the inner surface of the plates are parallel. the distance between the plates in the original experiments of Millikan was 14.92 mm and this gives an idea about the accuracy needed. P.d of the order of 10000 volts is applied between the plates, using accumulators. The plates are enclosed in a metal chamber C. The plate B is connected to the (+ve) pole of the high tension battery and the plate B is earthed.



Fine drops of low vapour pressure oil of clock or Apieron are sprayed into the space above the plates. These drops pass into the space between the plates A and B through a central hole in A and also they get electrified due to friction at the nozzle of the ~~atomiser~~ atomiser. But to have large nos of ions, the space between the plate is ionised by X-ray or γ-ray; which enters through an Al window W1. The space between the plate is strongly illuminated using air or a filament S. The motion of the oil drops is an angular spacing of 120° between one another. The microscope eye piece is fitted with a caliberated scale and the vertical velocity of the drop can be determined by observing the time taken by the drop to move a measured vertical distance. The drops appear as bright sports of light against a comparatively dark.

THEORY AND WORKING :-

First of all, both the plates A and B are earthed so that the electric field is zero. The downward motion of any one drop is noted and the termial velocity V_t is calculated.

Let the radius of the drop = a.

ρ = density of the oil, σ = density of air, g = acc^n due to gravity. Volume of the drop = $\frac{4}{3}\pi a^3$.

Mass of the drop = $\frac{4}{3}\pi a^3 \rho$.

wt of the drop = $\frac{4}{3}\pi a^3 \rho g$

upward thrust due to the air = $\frac{4}{3}\pi a^3 \sigma g$

∴ Resultant wt of the drop = $\frac{4}{3}\pi a^3 (\rho - \sigma) g$ --- (I)

In the absence of the electric field, termial velocity = V_t

η = Co-efficient of viscosity of air

According to Stoke's formula upward force on the drop

$$= 6\pi\eta a V_t \quad \text{--- (II)}$$

from eq^n (I) & (II) :-

$$\frac{4}{3}\pi a^3 (\rho - \sigma) g = 6\pi\eta V_t$$

$$\therefore a = \sqrt{\frac{9\eta V_t}{2(\rho - \sigma) g}} \quad \text{--- (III)}$$

Knowing the values of ρ, σ, η, g and V_t, the radius of drop 'a' can be calculated.

Now the electric field is applied between the plates so that the plate A is (+ve) and plate B is (-ve). Consequently an ion carrying (-ve) charge will experience a force upward and if this force is greater than the downward force due to wt of drop, the drop begins to move up and soon will attain the terminal velocity. Let the terminal velocity upward under the influence of the electric field be V_c.

The resultant upward force

$$X(ne) - \frac{4}{3}\pi a^3(\rho-\sigma)g$$

Let 'X' be the intensity of electric field and 'n' be the nos of electron on the drop. According to stoke's formula

$$F = 6\pi\eta a V_c$$

$$\therefore X ne - \frac{4}{3}\pi a^3(\rho-\sigma)g = 6\pi\eta a V_c \quad \text{---- (IV)}$$

The strength of electric field is adjusted to neutralise the downward force of gravity, then the drop remains stationary and can be observed in the field of view for a long time. This stationary drop also helps to observed the constant of the size of drop.

$$\therefore V_c = 0$$

from eq^n (IV) $\quad X ne - \frac{4}{3}\pi a^3(\rho-\sigma)g = 0$

$$\Rightarrow X ne = \frac{4}{3}\pi a^3(\rho-\sigma)g$$

$$\therefore ne = \frac{4\pi a^3(\rho-\sigma)g}{3X} \quad \text{------ (V)}$$

from (III) and (V) $\quad ne = \frac{4\pi(\rho-\sigma)g}{3X}\left[\frac{9\eta V_t}{2(\rho-\sigma)g}\right]^{3/2}$

$$= \frac{9\pi}{X}\sqrt{\frac{2\eta^3 V_t^3}{(\rho-\sigma)g}}$$

Knowing the values of η, ρ, σ, g & V_t, the value of ne can be calculated

The value of electronic charge as determined by Millikan's oil drop method was

$$e = (1.601 \pm 0.0002)\times 10^{-19} \text{ coulomb.}$$