B.Sc Part II (Physics Hons)
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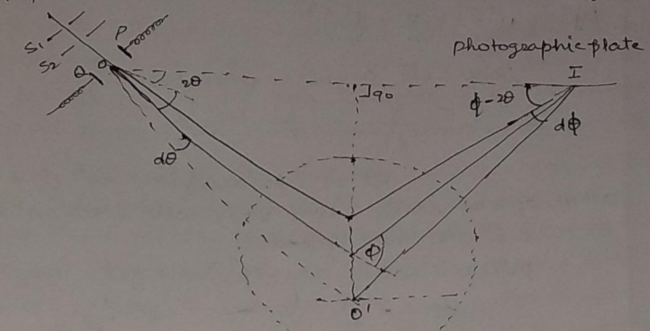
Ques:- Describe the principle and working of Aston's Mass spectrograph. How do you obtain linear mass scale and high resolving Power?

Ans:-



An aston's mass spectrograph is a device by which existance of isotopes of an element and its masses are determined, which is more senseitive than thomson's mass spectrograph. The parabolic traces obtained by thomson's mass spectrograph did not show good intensity because of poor focussing of the ions on the photographic plate. This led to a good deal of error in the measurement. Aston improved upon the results by making use of the device of velocity focussing the experimental arrangement as shown in figure, where electric field is applied to the ions coming out of the slit S_1 and S_2, they are deflected and dispersed, depending upon difference in their velocities. These ions then enter the magnetic field which has a directions such that the deflection produced by it is oppositely directed to that produced by the electric field. Hence while the electric field produces dispersion, the magnetic field produces convergence of the ions of different velocities. The distance of the centres of the electric field, the magnetic field and the photographic plate are kept according to the ratio of the intensities of the deflecting field such that all ions of the same e/m value but different velocities are finally focussed on the photographic plate and produces a sharp and intense line trace.

Suppose, the ions move a distance l in the electric field of intensity E. An ion of mass m, charge e, velocity v will be ~~latertg~~ laterally deflected in this field by

$$y = \frac{1}{2}\frac{eE}{m}\left(\frac{l}{v}\right)^2 \quad \text{where } \frac{l}{v} = t$$

Hence the angular deviation of the ion

$\theta = \frac{y}{l} = \frac{1}{2}\frac{Ee}{m}\frac{l}{V^2}$ ---------- (i)

If the same ion moves a distance l, through the magnetic field of intensity H, it will be laterally deflected by $y' = \frac{1}{2}\frac{HeV}{m}\left(\frac{l'}{V}\right)^2$

Hence its angular deviation

$\phi = \frac{y'}{l'} = \frac{1}{2}\frac{He}{m}\frac{l'}{V^2}$ ---------- (ii)

It is obvious from eq^n (i) & (ii) that angular deviation of the ions will vary with their velocities if the value of E and L' are kept fixed.

Differentiating the eq^n (i), we get

$d\theta = -\frac{eE}{m}\cdot\frac{L}{V^3}dv = -2\theta\frac{dv}{v}$ ---------- (iii)

$\therefore \frac{d\theta}{\theta} = -2\frac{dv}{v}$

Similarly differentiating the eq^n (ii) we get

$d\phi = -\frac{1}{2}\frac{Hel'}{mV^3}dv = -\phi\frac{dv}{v}$ ---------- (iv)

$\therefore \frac{d\phi}{\phi} = -\frac{dv}{v}$

Comparing eq^n (iii) & (iv) $\frac{d\theta}{\theta} = 2\frac{d\phi}{\phi}$

Let the distance of the centre of the electric field from the centre of the magnetic field be 'a' and the distance of the photographic plate from the centre of the magnetic field be 'b', then the total divergence produced by the electric field $= (a+b)d\theta$. The ions will again converge on the photographic plate if the convergence produced by the magnetic field $bd\phi$ is equal to the divergence produced by the electric field. Hence

~~(a+b)~~ $(a+b)\,d\theta = b\,d\phi$

$\Rightarrow \frac{a+b}{b} = \frac{d\phi}{d\theta}$

$\Rightarrow \frac{a}{b} + 1 = \frac{\phi}{2\theta}$

$\Rightarrow \frac{a}{b} = \frac{\phi}{2\theta} - 1 = \frac{\phi - 2\theta}{2\theta}$ ---------- (v)

$\therefore \frac{b}{a} = \frac{2\theta}{\phi - 2\theta}$

This is the required condition for good focussing of the ions and can be acheived by adjusting the value of θ & ϕ by adjusting E and H. Under this condition, it is clear that the ratio of ~~its angle OIO' and IOO'~~ the sides OO' and O'I of $\Delta OO'I$ should be equal to the ratio of its angle OIO' and IOO'. Hence angle $OIO' = \phi - 2\theta$ and $IOO' = 2\theta$. This leads to the conclusion that for good focussing of the ions condition eq^n (V) should be satisfied and the surface of the photographic plate should be kept inclined at an angle θ to the origenal direction of the ions.

Masses of the unknown ions are calculated by drawing a ~~cab~~ calibration curve with the observation of the distance of the trace on the photographic plate of the unknown ions and some known ions from any point on the plate. The ratio of the masses of any ~~k~~ unknown ion and a known ion can also be calculated by adjusting the intensity of the electric field, keeping the magnetic field constant.

Let the trace of an ion of mass 'm' is obtained at some point of the plate with electric field E and the trace of the ion of mass "m'" is obtained at the same point with field E', the from eq^n (I) & (II), we get

$$\frac{E}{E'} = \frac{m'}{m}$$

Thus the value of E and E' being known m' can be calculated if m is known. Aston was the first to show that if the atomic weights of the elements be expressed in unit of 1/16 of the atomic weight of oxygen, are all integral.