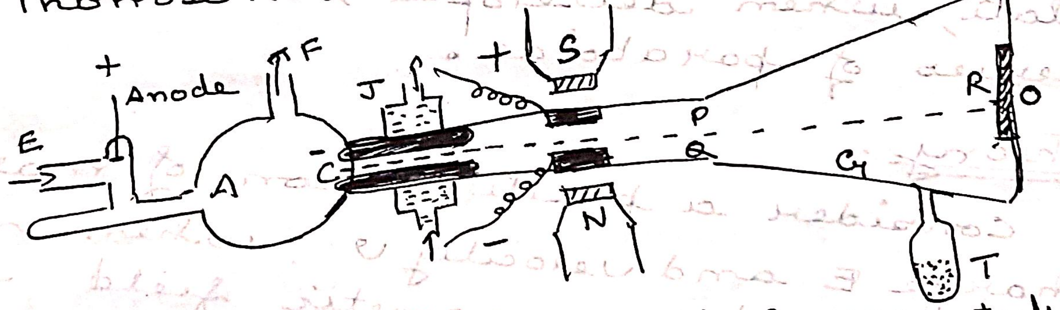
Positive Rays :

Properties :

1) These rays affect a photographic plate produce fluorescence and penetrate thin Aluminium foil.

2) They are deflected by electric and magnetic fields. The direction of deflection indicates that they are positively charged particles. Fa the same electric and magnetic fields, the magnitude of deflection suffered by positive rays is much smaller than that of cathode rays. therefore, the positive rays pardicles are much heavier than the electrons.

Thomson's Parabola Method.



It consist of a discharge tube (A) in which pressure of the gas is about 10^{-5}m of mercury. The anode is held in a side tube. A steady stream of the gas is allowed to flow in through a capillary tube (E) and after circulating in A is pumped off at (F). The cathode (C) is perforated with an extremely fine hole. The cathode is cooled by water jacket (J).

The positive ions produced in A fly towards the cathode and those reaching it axially pass straight through the

the fine hole and emerge from the opposite end of the cathode as a narrow beam. This beam is subjected to parallel electric and magnetic fields simultaneously. An electric field is applied between the plates P and Q. The electric beam is perpendicular to the positive ray beam. N and S are the poles of a strong electromagnet. After passing through these fields, the beam enters a highly evacuated camera G and is received on a photographic plate R. The liquid air-trap (T) helps to keep the pressure in G quite low, eventhough pressure in A is comparatively large. The photographic plate, when developed, shows a series of parabolae.

Theory:

Consider a positive ion of mass M, charge E and velocity v. When no electric field or magnetic field is applied, the positive ion strikes the screen at O. This is called the undeflected spot.

Action with electric field:

Let an electric field of strength X acts over a length l of the path of ion. Force on the ion $= XE$

$a = \frac{F}{m}$.

acceleration $= \frac{XE}{m}$

displacement $s = \frac{1}{2} \frac{XE}{m} t^2$

$t = l/v$ $\quad = \frac{1}{2} \frac{XE}{m} (l/v)^2$

$s = ut + \frac{1}{2}at^2$, $u = 0$

$v = d/T$

$t = \frac{d}{v}$

After leaving the field, the ion moves in a straight line and finally strikes the plate at a distance x from O. x is proportional to S as well as

$$S = \frac{XEl^2}{2mv^2}$$

$$x \propto S$$

$$x = k_1 S \qquad = k_1 \frac{XE}{\cancel{2}m v^2} \quad ①$$

$$x = k_1 \frac{XEl^2}{2mv^2} \qquad k_1 = \frac{l^2}{2}$$

where k_1 is a constant.

Action with magnetic field.

A magnetic field of strength B is applied over the same length l in the same direction as that of the electric field. The positive ion will now be deflected by this field in a direction at right angles to that in which it was deflected by the electric field. It will strike the plate at a distance y from O such that Oy is perpendicular to Ox in the plane of the plate.

$$y = \overset{0}{u}t + \tfrac{1}{2}at^2$$

Force on ion $= BEv$

acceleration $= \frac{BEv}{m}$

displacement $= s' = \frac{1}{2}\left(\frac{BEv}{m}\right)t^2 \qquad t = \frac{l}{v}$

$$= \frac{1}{2}\left(\frac{BE\cancel{v}}{m}\right)\frac{l^2}{v^{\cancel{2}1}}$$

On emerging from the field, the ions moves in a straight line and finally strikes the plate at a distance y from ~~oy~~ O.

y is proportional to s' as well as to the distance between the field and the plate.

$$y \propto \frac{BEl^2}{2mv}$$

$$|||^{ly} \quad y = k_2 \frac{BE}{mv}$$

$$y = k_2 \frac{BEl^2}{2mv}$$ — ② k_2 is constant.

combined action of electric and magnetic fields.

The combined effect of the two fields is found by eliminating v ① and ②.

Squaring ② ~~&~~ dividing by (1)

$$\frac{y^2}{x} = \frac{k_2^2 \frac{B^2E^2}{m^2v^2}}{k_1 \frac{XE}{mv^2}} \Rightarrow \left(\frac{k_2^2}{k_1}\frac{B^2}{X}\right)\frac{E}{m}$$

$$= \frac{k_2^2 B^2 E^{\cancel{2}\,1}}{m^{\cancel{2}}\cancel{v^2}} \times \frac{\cancel{m}\cancel{v^2}}{k_1 X\cancel{E}}$$

$$\frac{y^2}{x} = \left(\frac{k_2^2}{k_1}\frac{B^2}{X}\right)\frac{E}{m} \qquad \text{——— ③}$$

If the fields are kept at a constant value (B and X constant) and if E/M is constant, then by (3), y^2/x = constant, which is the equation of a parabola. As equation (3) is independent of v particles of same E/m but different velocities will fall on different points on the same parabola

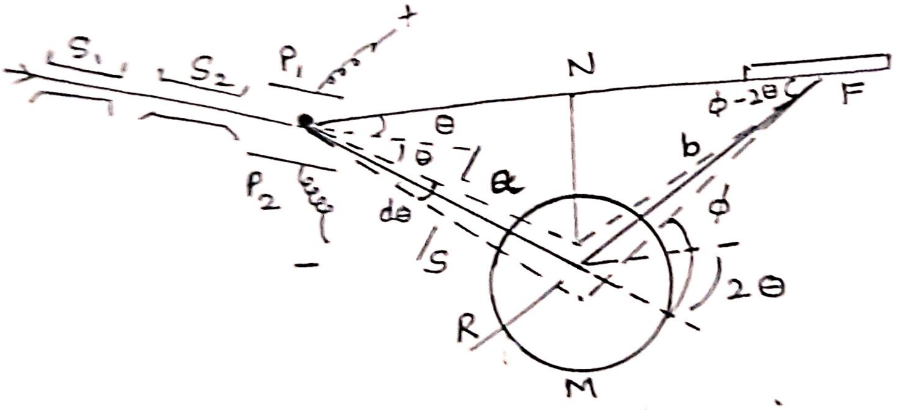
$$\frac{y}{x} = \frac{k_2 B}{k_1 X} v \quad \text{ie} \quad \boxed{\frac{y}{x} \propto v}$$

. Thus the position of any individual particle on the parabola will depend on the velocity of the particle. Hence the entire parabola is a velocity dispersion or velocity spectrum.

determination of E/M.

The values of E/M can be calculated from equation ③ by measuring the coordinates of x and y for a point on the parabola evaluating the constant k_1 and k_2 for the apparatus and knowing B and X.

Aston's Mass spectrograph.



The stream of positive ions obtained from a discharge tube is rendered into a fine beam by passing it between two narrow slits S_1 and S_2. This beam enters the electric field between the metal plates P_1 and P_2. Due to the action of the electric field (X), all positive ions having the same value of E/M are not only deviated by an angle θ from the original path but are dispersed