Atomic Theory Development

Discovery of the Electron

In 1897, J.J. Thomson used a cathode ray tube to deduce the presence of a negatively charged particle. **: the electron**
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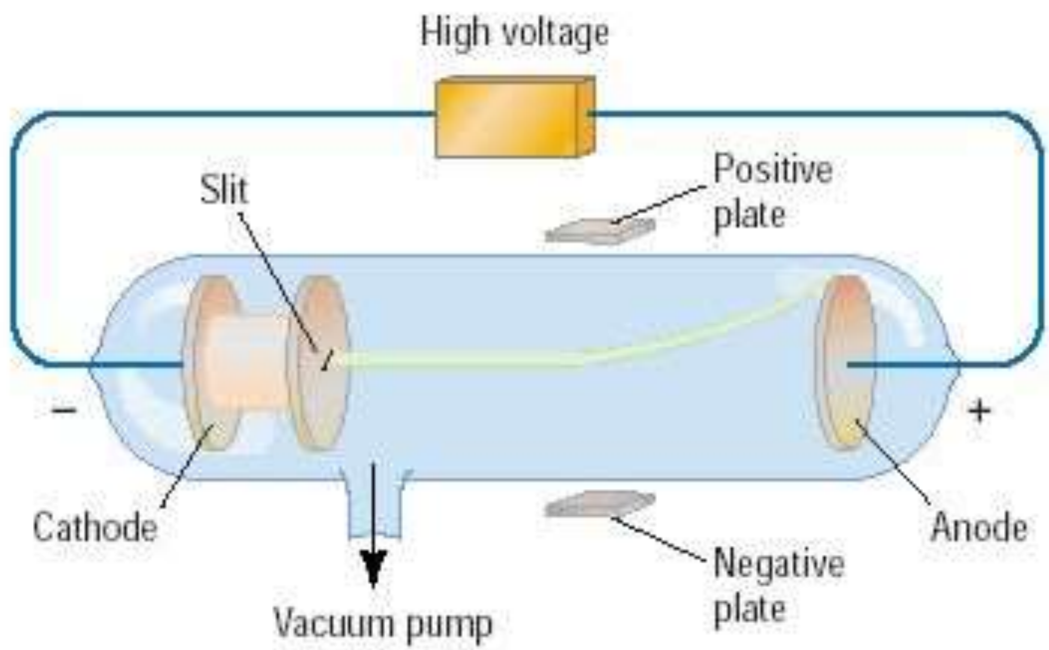


Cathode ray tubes pass electricity through a gas that is contained at a very low pressure.
[Cathode Ray]

J.J. Thomson

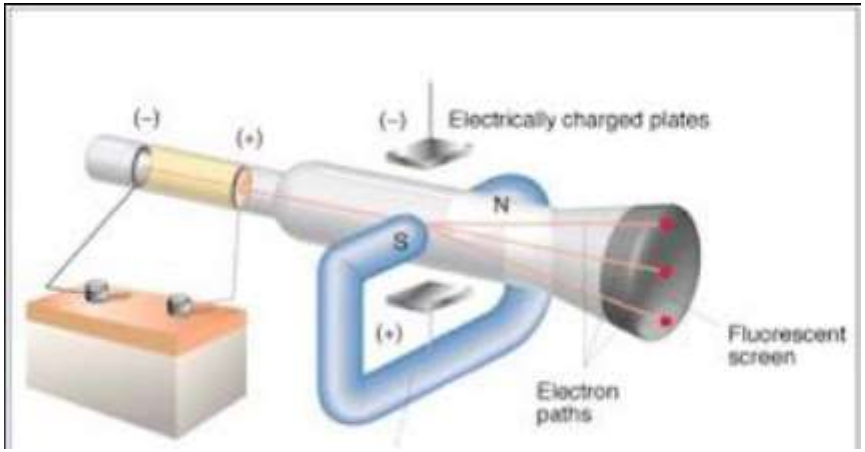
J.J. Thomson

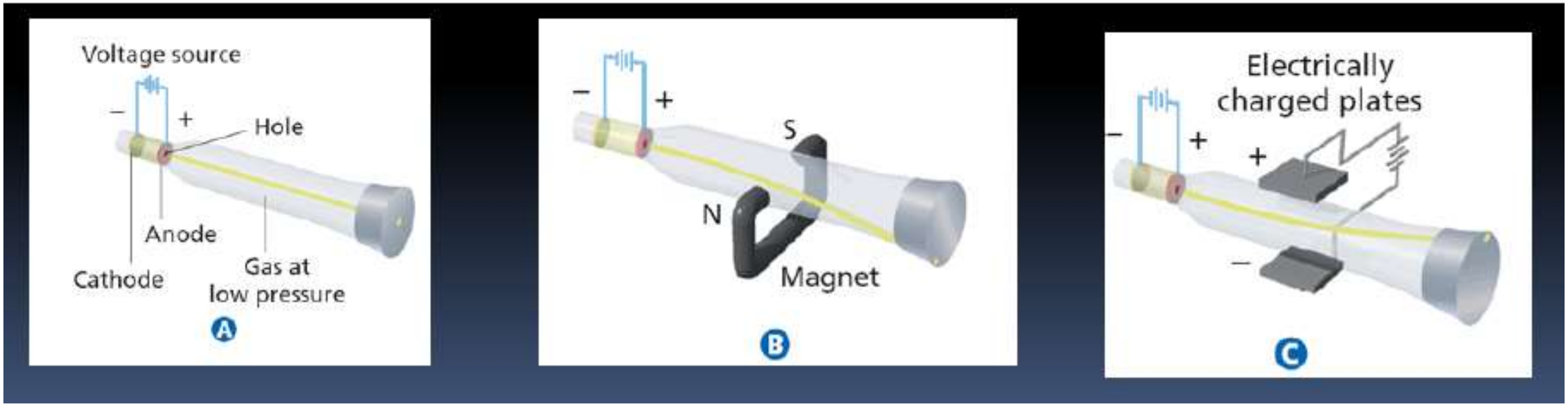
- He proved that atoms of any element can be made to emit tiny negative particles.
- From this he concluded that ALL atoms must contain these negative particles.
- He knew that atoms did not have a net negative charge and so there must be something positive that balances the negative charge.

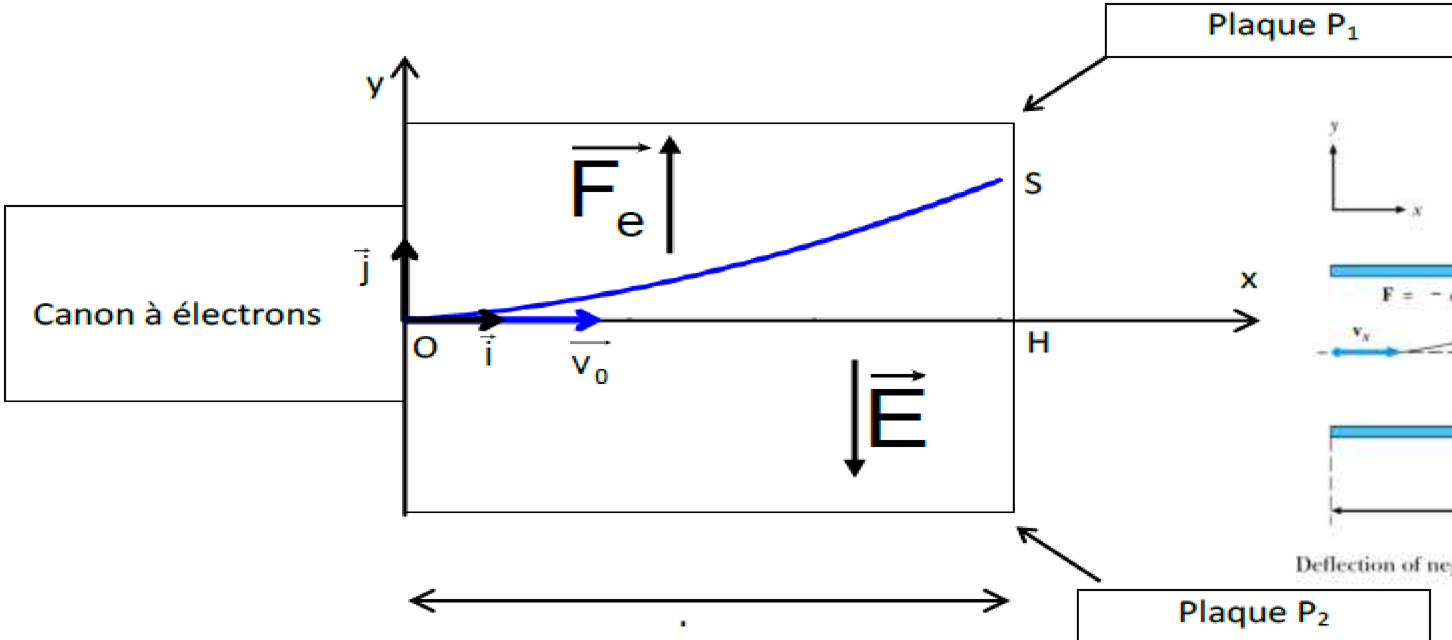
Joseph John Thompson

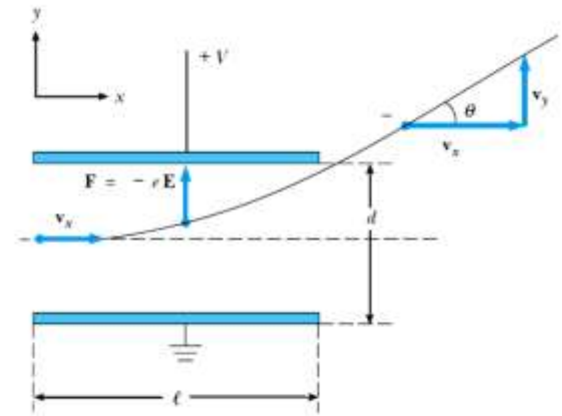
•Thompson discovered by mathematical means that these rays have a small mass and are negative.

•Thompson noted that these negative subatomic particles were a fundamental part of all atoms.









Deflection of negative particles by an electric field.

$$\vec{F_e} = m_e * \vec{a} = -e\vec{E} \Rightarrow \vec{a} = \frac{-e * \vec{E}}{m_e}$$

$$\vec{a}\begin{cases} a_x = 0 \\ a_y = \dfrac{e.E}{m} \end{cases} \qquad \vec{a} = \frac{d\vec{v}}{dt} \qquad \vec{v}\begin{cases} v_x = 0 + C_1 \\ v_y = \dfrac{e.E}{m_e}.t + C_2 \end{cases}$$

$$\text{À } t = 0 \qquad \vec{v_0}\begin{cases} v_{0x} = v_0 \\ v_{0y} = 0 \end{cases} \Rightarrow C1 = v_0 \text{ et } C2 = 0.$$

$$\vec{v}\begin{cases} v_x = v_0 \\ v_y = \dfrac{e.E}{m_e}.t \end{cases}$$

$$\vec{a} = \vec{a_x} + \vec{a_y}$$

$$a_x = 0 \text{ et } a_y = \frac{e*E}{m_e}$$

$$a_y = \frac{d^2y}{dt^2}$$

$$\frac{d^2y}{dt^2} = \frac{e*E}{m_e}$$

$$y = \frac{1}{2}\left(\frac{e*E}{m_e}\right)t^2$$

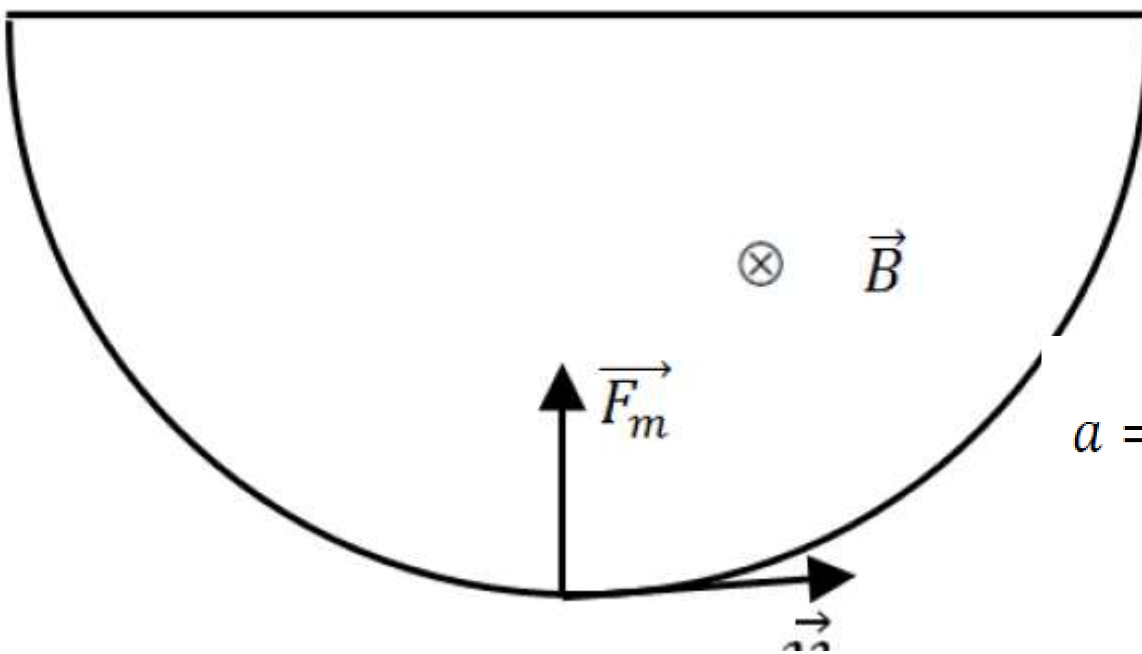
$$\frac{d^2x}{dt^2} = 0 \Longrightarrow \frac{dx}{dt} = v = v_0$$

$$x = v_0 * t \Rightarrow t = \frac{x}{v_0}$$

$$y = \frac{1}{2}\left(\frac{e*E}{m_e}\right) * \frac{x^2}{v_0^2}$$

$$\overrightarrow{F_m} = e * (\vec{v} \wedge \vec{B}).$$

$$f_m = |qvB \sin \alpha|$$



$$a = \frac{v^2}{r} \quad \Longrightarrow \quad \frac{e}{m} = \frac{v}{B*r}$$

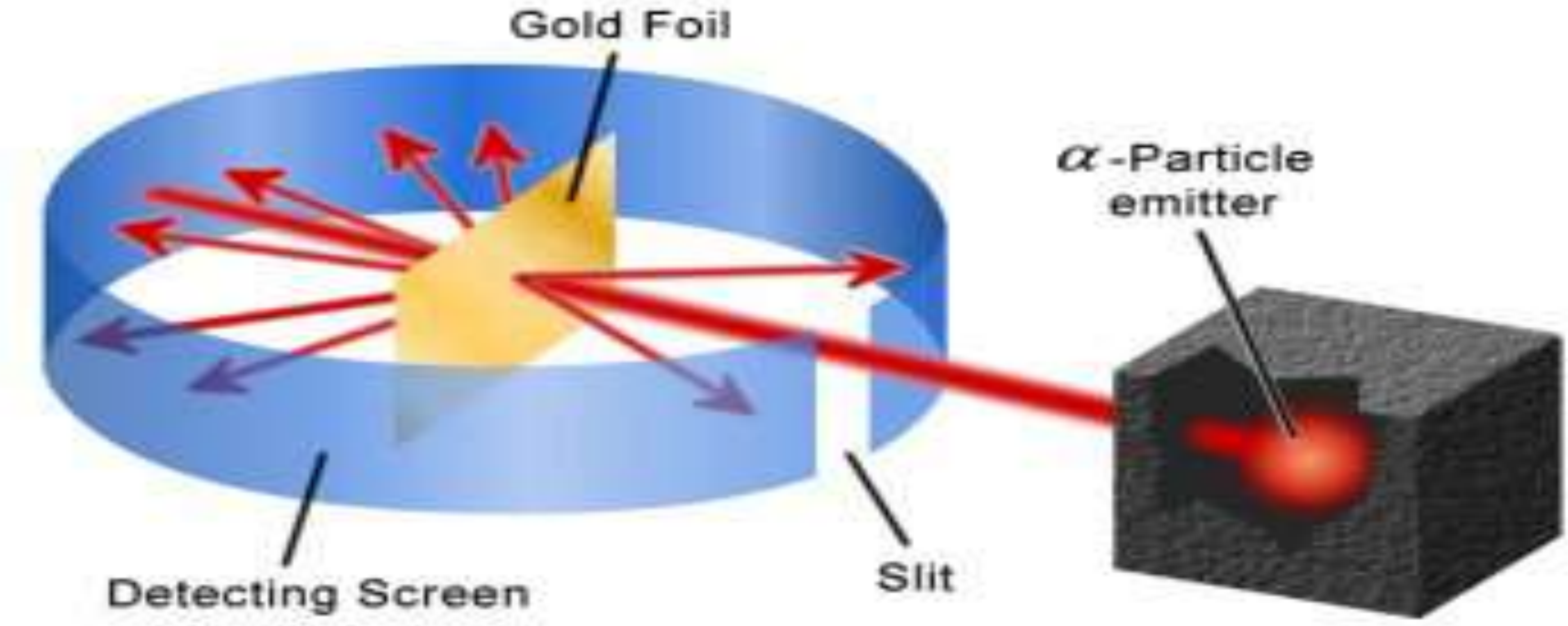
$$F_m = q * v * B \text{ (car sin 90 = 1)}$$

$$\sum F = m * \vec{a} \Rightarrow \quad m * a = e * v * B \qquad \frac{e}{m} = \frac{2*y*E}{B^2 x^2}$$

$$\overrightarrow{F_e} = \overrightarrow{F_m}$$

Rutherford

- Discovered the Nucleus and the Positive Protons
- Surmised atoms are made of mostly empty space
- Didn’t know about the Neutrons
- Famous Gold Foil Experiment



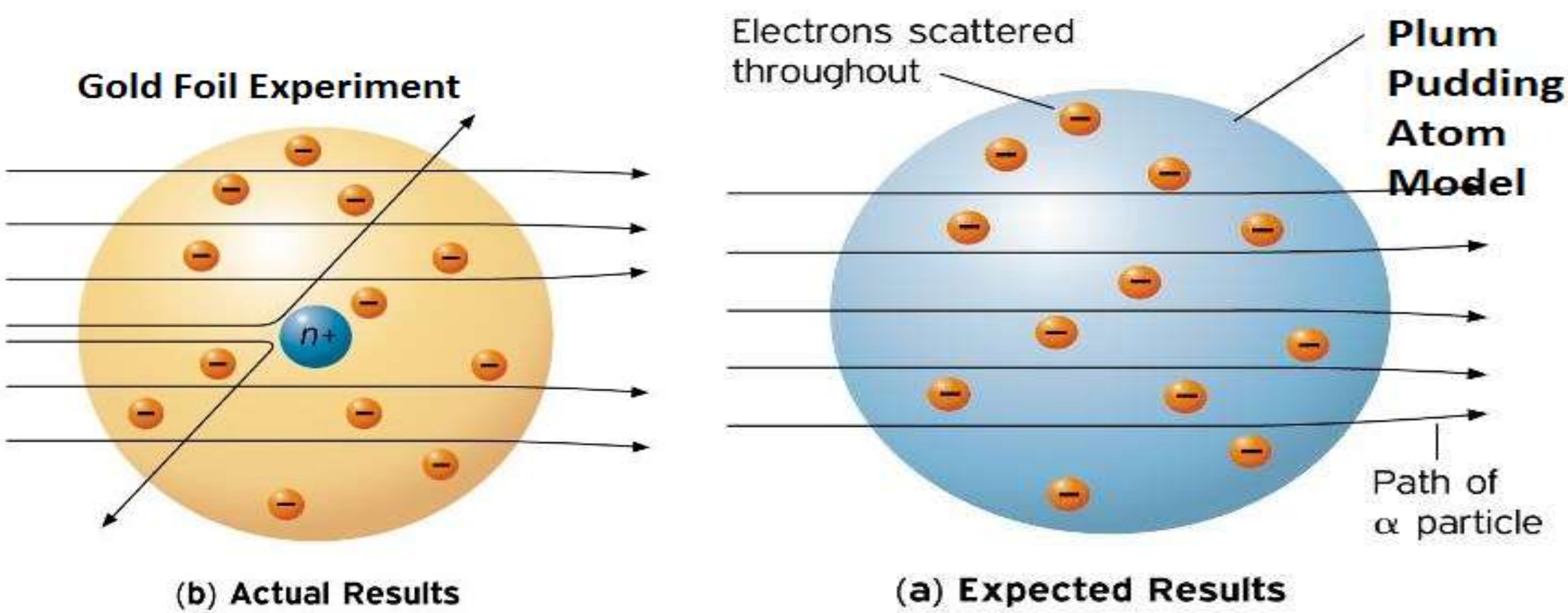
- Particles shot through thin sheet of gold
- Most shots went straight through
- A small amount were deflected
- Hence… The atoms must be made of mostly empty space with a small dense nucleus

Gold Foil Experiment Results

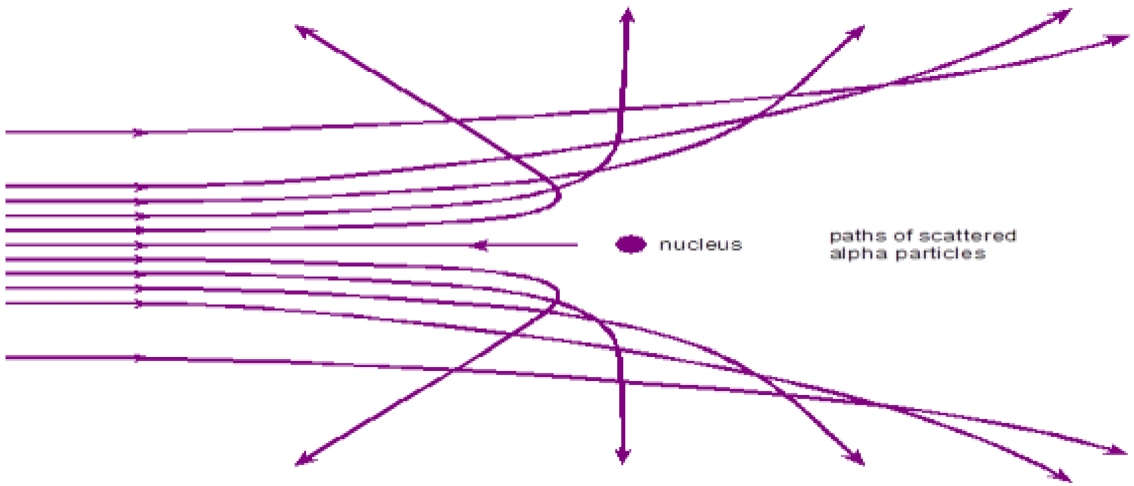
most alpha particles go straight through the gold foil

A few alpha particles are sharply deflected

- Using J.J Thomson's Plum Pudding atomic model, Rutherford predicted the alpha particles would pass straight though the gold foil. That's not what happened.



Rutherford's picture of alpha scattering



Most of the alpha particles passed through the gold foil undeviated

A few alpha particles were deflected from their path but continued through the gold foil

But about 1:8000 were turned through a large angle. The experiment takes place in a vacuum to avoid problems of a absorption by air.

Conclusion

A small number of alpha particles had rebounded because they collided with something much larger and heavier and which contains a concentrated region of positive charge.

The back scattering of αs through large angles implies (i) all the positive charge is concentrated together

(ii) the mass of the concentrated positive charge must be quite a bit larger than of an α particle.

Rutherford assumed that (i) Coulomb's Law was obeyed down to very small distances

(ii) most of the mass of the nucleus was concentrated into a very small volume – the nuclear atom that resembles a miniature solar system

'proof'' that Coulomb's Law **is** valid down to distances about the size of a nucleus

Rutherford’s Findings

- If previous models were correct alpha particles would have passed straight through the the gold
- Most of the particles passed right through
- * A few particles were deflected
- * VERY FEW were greatly deflected

Conclusions:

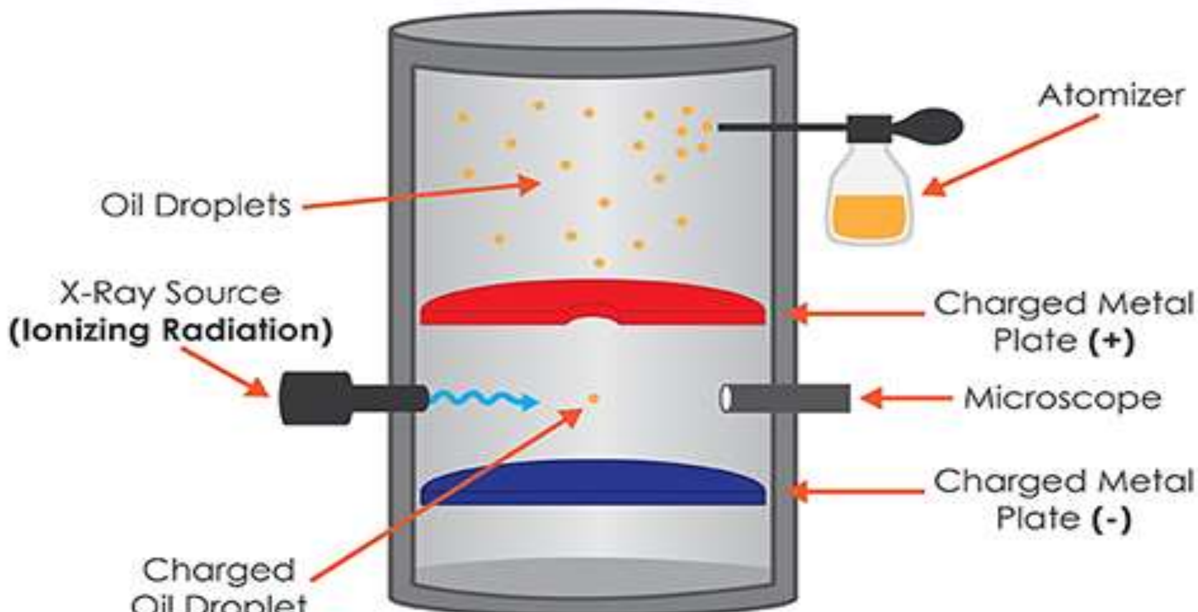
- 1The nucleus is small
- 2 The nucleus is dense
- 3 The nucleus is positively charged

Millikan's experiment

1909 - Robert Millikan - Oil Drop Experiment

º confirms electron has (-) charge

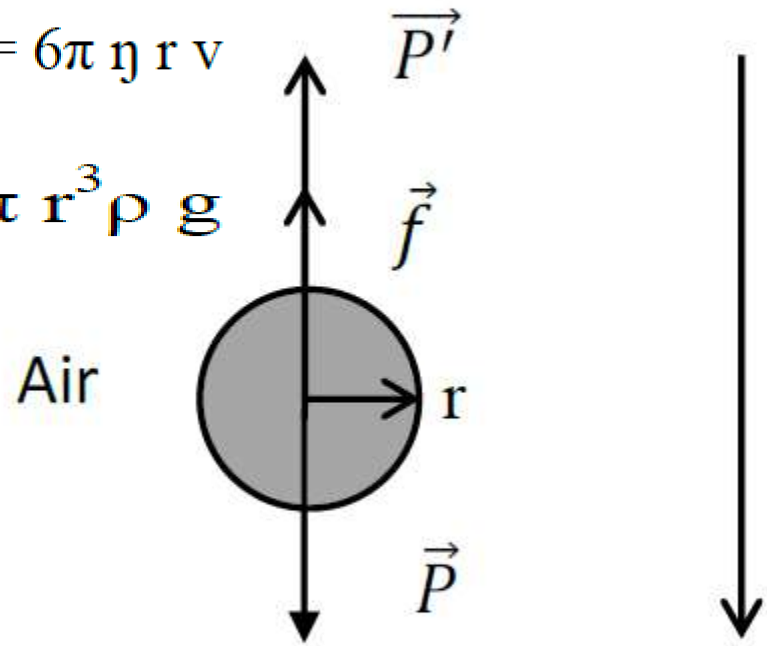
º determines e- has mass; but it is very small.



$$f = 6\pi \eta r v$$

$$p = mg = 4/3 \pi r^3 \rho g$$

$$p' = m' g = 4/3 \pi r^3 \rho^\circ g$$



$p + p' + f = ma = 0$

v (prise comme valeur constante)

$a = dv/dt = 0$

après projection

$p - p' - f = 0.$

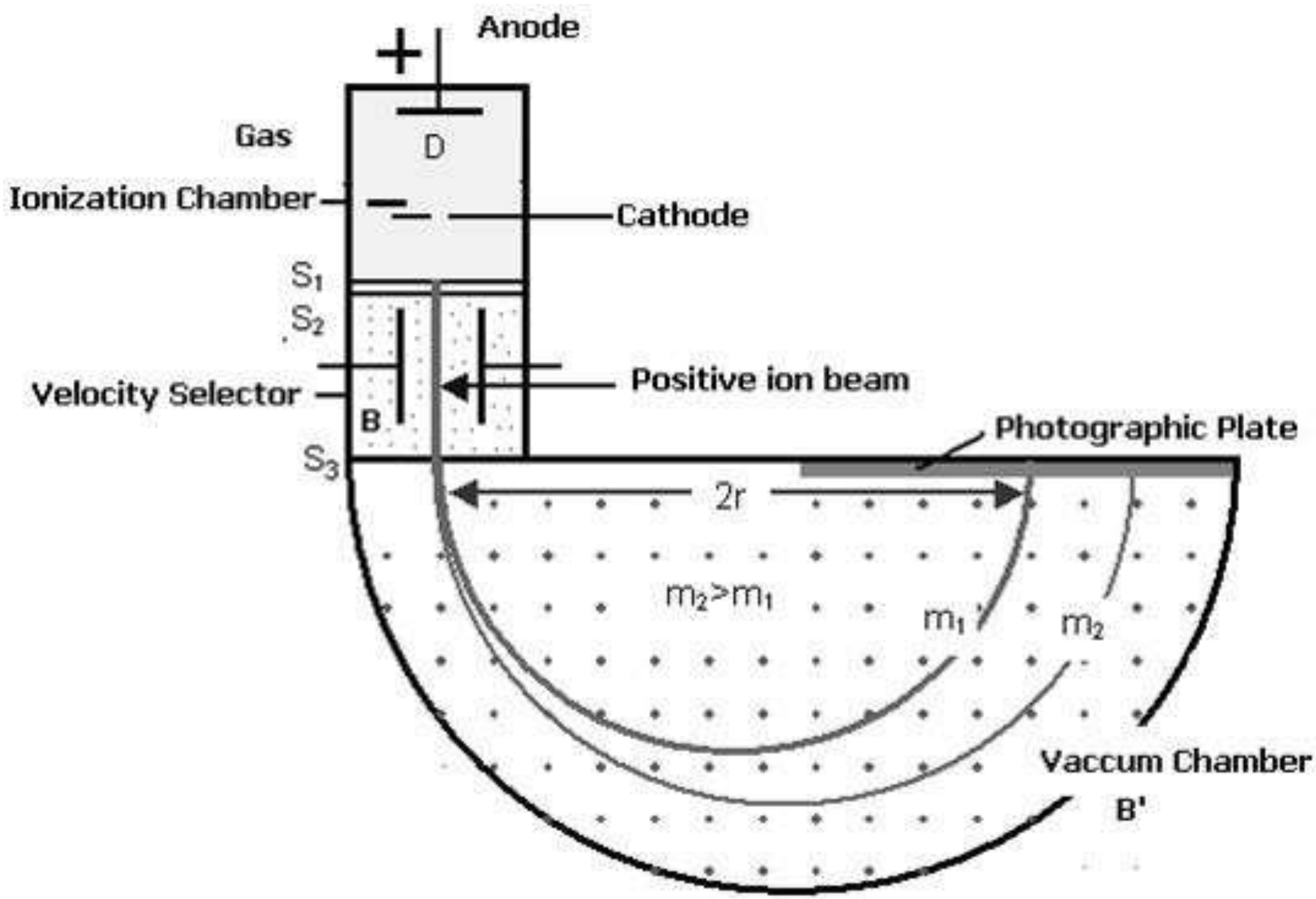
$p - p' = f$

$4/3\ \pi r^3 (\rho - \rho°)\ g = 6\ \pi\ \eta\ r\ v$

$r^2 = 9\ \eta\ v / 2\ (\rho - \rho°) g$

$$r^2 = 9\ \eta\ v / 2\ \rho\ g$$

Bain Bridge Mass Spectrograph



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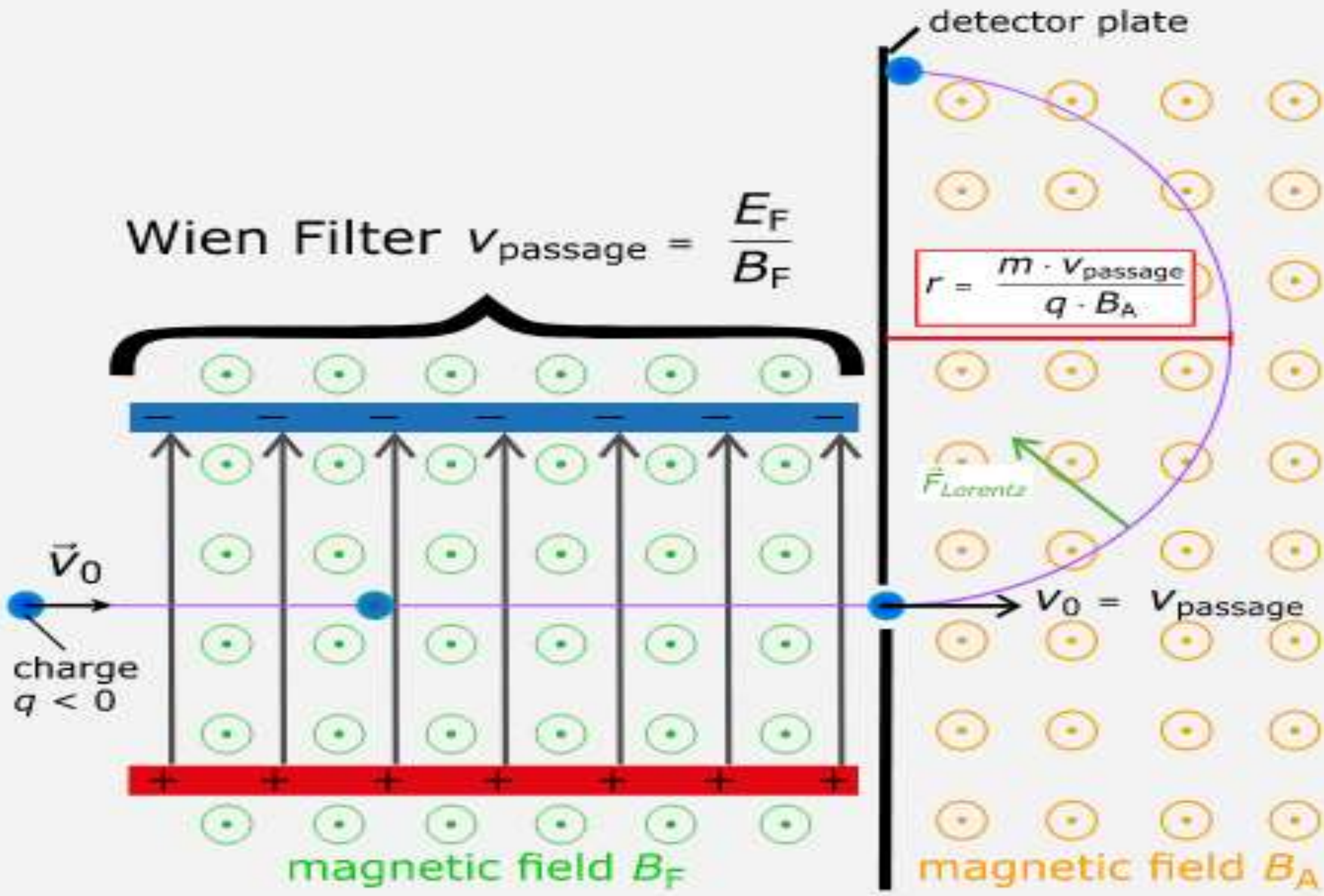


They trace lines on the photographic plate called **mass spectrum**.

Thus all these ions traverse a semicircular path of radius **R** given by

$$qE = Bqv$$

$$v = E/B \quad B'qv = \frac{mv2}{R}$$

$$R = \frac{mv}{Bq} = \frac{mE}{B^2 q}$$ since $$v = \frac{E}{B}$$

Since B and v are constant,

$$R \propto m \Rightarrow R = km$$

Thus if x is the distance of line from S3 then $R = \frac{x}{2}$

$$\therefore \frac{x}{2} = \frac{mE}{B^2 q} \Rightarrow x = \frac{2mE}{B^2 q}$$

$$M = \frac{qB^2}{2E} x$$

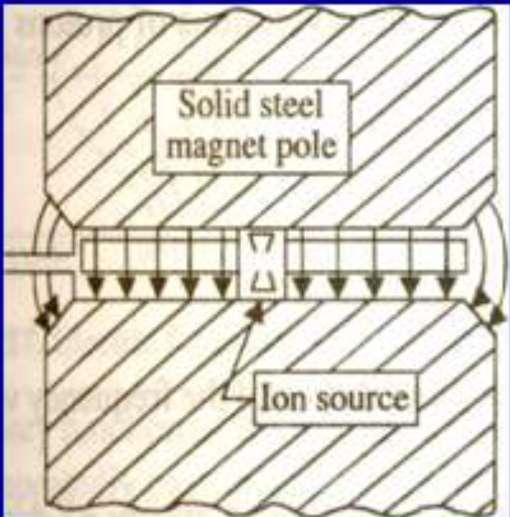
$$M = kx$$

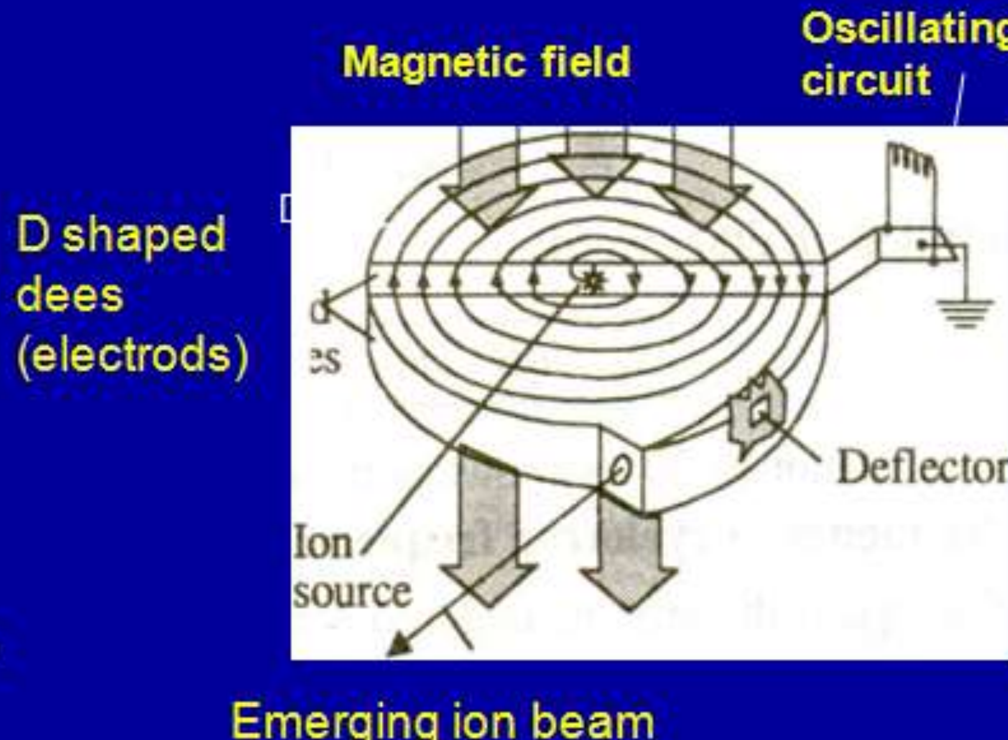
$$M \propto x$$

Linear separation

$$\Delta x = x_2 - x_1 = \frac{2E(M_2 - M_1)}{B^2 q}$$

So, mass scale is linear.





Cyclic oscillator

- Ions will move in a circular path of radius $r = \frac{mv}{Bq}$
- At each rotation charged particle gains the energy $E = 2qV$

- The time for complete circular path

$$T = \frac{2\pi r}{v} = \frac{2\pi m}{Bq}$$

- The frequency of the oscillation is given by

$$f = \frac{1}{T} = \frac{Bq}{2\pi m}$$

- Condition for progressive acceleration

$$T_0 = T = \frac{2\pi m}{Bq}$$

$$\nu_0 = \nu = \frac{Bq}{2\pi m}$$

- Kinetic energy of the ion emerging from the cyclotron is given as

$$E = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{BqR}{m}\right)^2 = \frac{q^2B^2R^2}{2m}$$