α AND β PARTICLES IN ELECTRIC FIELDS

- If we were to compare the behaviour of α and β particles in an electric field on the basis of their masses:

4 atomic mass units

$m_\alpha = 4u = 4(1.66 \times 10^{-27})$ kg
$m_\beta = m_e = 9.11 \times 10^{-31}$ kg

mass of 1 electron

- Hence, we can say that m_α is roughly $2000 \times m_\beta$
- Since m_α is greater, it has more inertia and is therefore more difficult to deflect
- As such, deflection of β > deflection of α

- However, if we were to compare on the basis of their charges:

$q_\alpha = +2e$
$q_\beta = -1e$

- It can be said that the charge of an α particle is twice that of a β particle.
- Since a higher charge results in a stronger force exerted on the particle in an electric field, deflection of β < deflection of α

- Considering both together:
  $m_\alpha = 2000\, m_\beta$
  $q_\alpha = 2q_\beta$

- The effect of mass outweighs that of charge
- Therefore, overall deflection of α < deflection of β

- Comparing on the basis of speed

V_α = 10 % of speed of light
V_β = 90% – 99% of speed of light

- Since α travels slower than β, the electric field gets plenty of time to apply an electric field on an α particle

- Whereas the β particle has a much higher speed and passes through the electric field, therefore the time it spends inside the electric field is less, hence it undergoes a smaller deflection.

- On this basis, deflection of α > deflection of β

- Comparing the acceleration of the two particles due to the electric field:

$F = ma$

$Eq = F$ Find $\frac{a_\alpha}{a_\beta}$

$Eq = ma \rightarrow \boxed{a = \frac{Eq}{m}}$

$$\frac{a_\alpha}{a_\beta} = \frac{\frac{\cancel{E}q_\alpha}{m_\alpha}}{\frac{\cancel{E}q_\beta}{m_\beta}}$$

$$= \frac{\frac{q_\alpha}{m_\alpha}}{\frac{q_\beta}{m_\beta}}$$

$$= \frac{q_\alpha \times m_\beta}{m_\beta \times q_\beta}$$

$$= \frac{2\cancel{e} \times 9.11\times10^{-31}}{4(1.67\times10^{-27}) \times 1\cancel{e}}$$

$$= \frac{2(9.11\times10^{-31})}{4(1.67\times10^{-27})}$$

$$\frac{a_\alpha}{a_\beta} = \frac{2.7\times10^{-4}}{1}$$ → Ans

IONIZATION BY α PARTICLES

Calculations where energy is given in units of eV (electron-volt) rather than Joules:

Q. What is an eV?
A. An alternate unit for energy

Converting eV → Joules:

$1\,eV = 1.6\times10^{-19}\,J$
$1\,KeV = 1.6\times10^{-16}\,J$ → Need to be learned
$1\,MeV = 1.6\times10^{-13}$

- An α particle requires $9.4\times10^{-21}\,J$ to ionize an air molecule

Example:

Q. In a certain situation an α particle is travelling with 31 eV of energy. Calculate the number of ions of air molecules that can be produced by this particle per unit length.

Step 1: Convert to J

$J = (1.6 \times 10^{-19}) \times 31$

$= 5 \times 10^{-18}$ J $\rightarrow$ Total energy available

Step 2: $\dfrac{5 \times 10^{-18}}{9.4 \times 10^{-21}}$ $\rightarrow$ Energy required to ionize 1 air molecule

$= 530 \rightarrow$ Total number of air molecules that can be ionized with 31eV of energy

Step 3: Avg range of α particle is 4-5cm.

↳ take 4.5cm as distance travelled $= 0.045$m

$\dfrac{530}{0.045}$

Ans $\longrightarrow$ 11800 $\rightarrow$ ions produced per meter