For fusion Reaction (7) : ${}^{2}_{1}H + {}^{3}_{2}He + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{4}_{2}He$

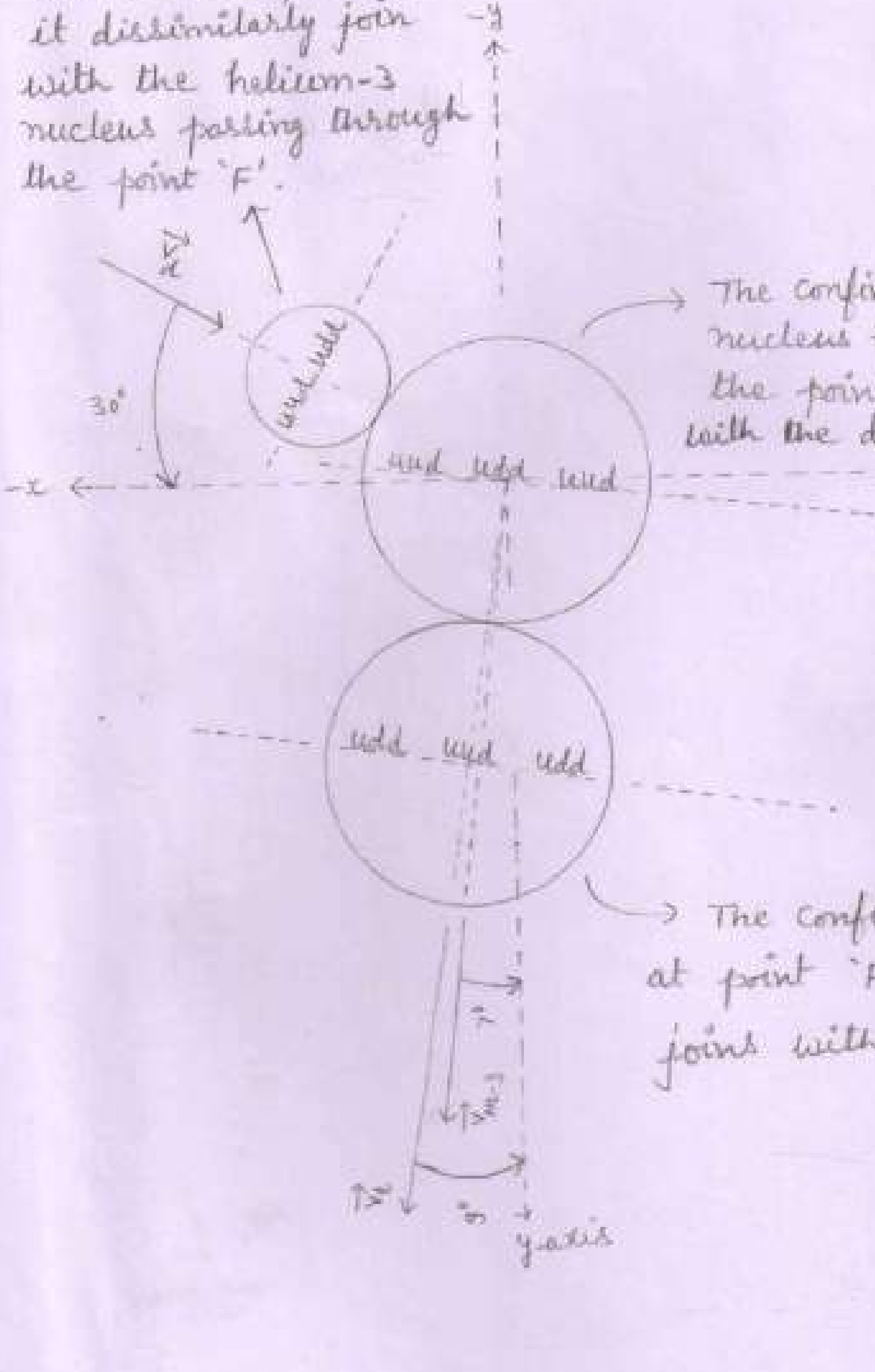
1 Interaction of nuclei :-

As the injected deuteron reaches at point 'F', it interacts [experiences a repulsive force due to confined helion-3 and the confined triton passing through the point 'F'] with the confined helion-3 and the confined triton at point 'F'.

Similarly, as the confined triton reaches at point 'F', it interacts [experiences a repulsive force due to the injected deuteron reaching at point 'F' and the confined helium-3 nucleus passing through the point 'F'] with the injected deuteron reaching at point 'F' and the confined helium-3 nucleus passing through the point 'F'.

The injected deuteron and the confined triton overcomes the electrostatic repulsive force and thus all the three nuclei dissimilarly join with each other.

As the injected deuteron reaches at point F, it dissimilarly join with the helium-3 nucleus passing through the point 'F'.



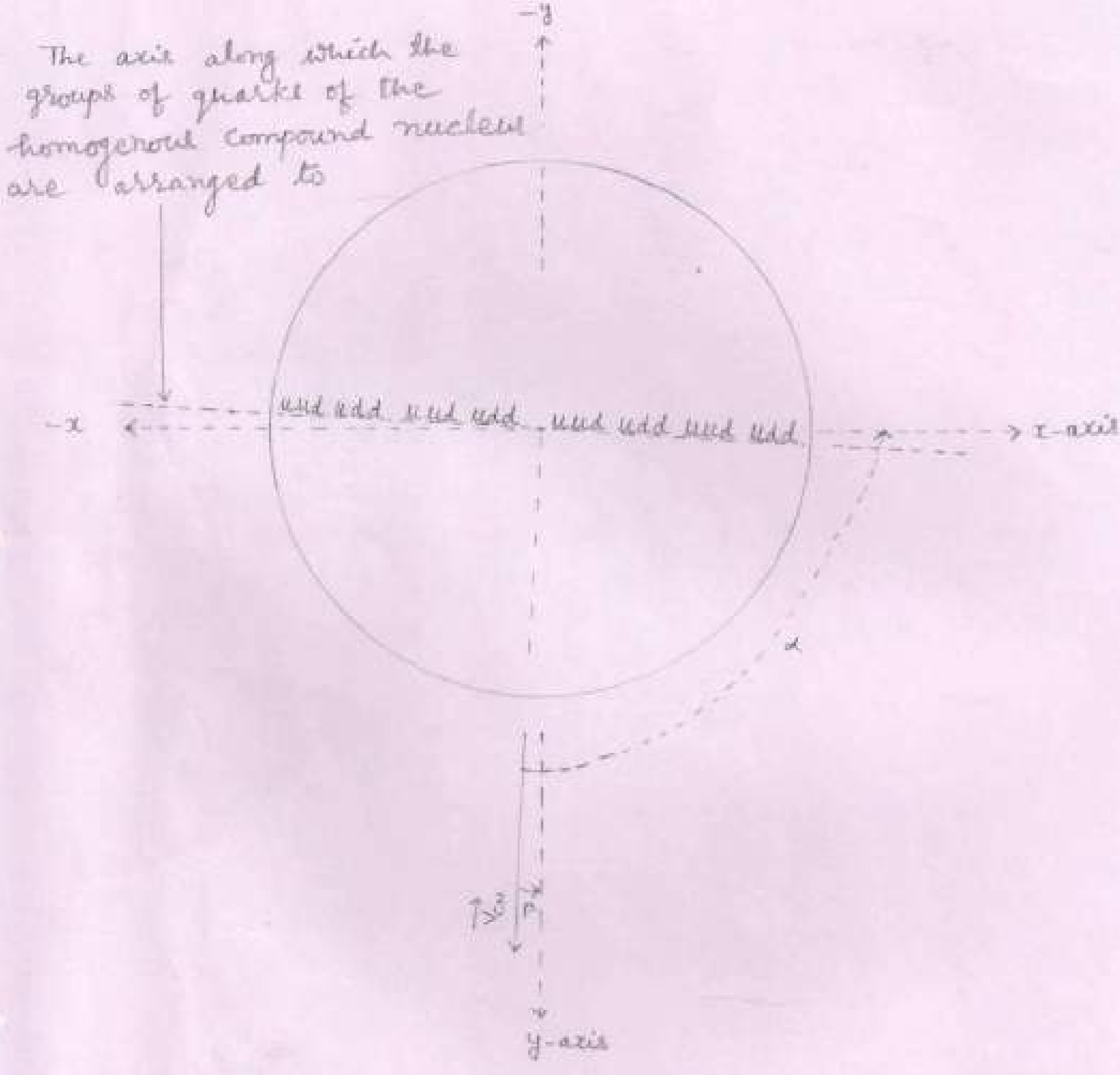
The confined helium-3 nucleus passing through the point 'F', dissimilarly joins with the deuteron and the triton.

x-axis

The confined triton as reaches at point 'F', it dissimilarly joins with helium-3 nucleus

2. Formation of the homogenous compound nucleus :-
The constituents (quarks and the gluons) of the dissimilarly joined nuclei (the injected deuteron, the helium-3 nucleus and the triton) behave like a liquid and form the homogenous compound nucleus having similarly distributed groups of quarks with similarly distributed surrounding gluons.

Thus within the homogenous compound nucleus - each group of quarks is surrounded by the gluons in equal proportion. So, within the homogenous compound nucleus there are 8 groups of quarks surrounded by the gluons.



The homogenous compound nucleus

⇒ where,

$\alpha \simeq 32.87$ degree

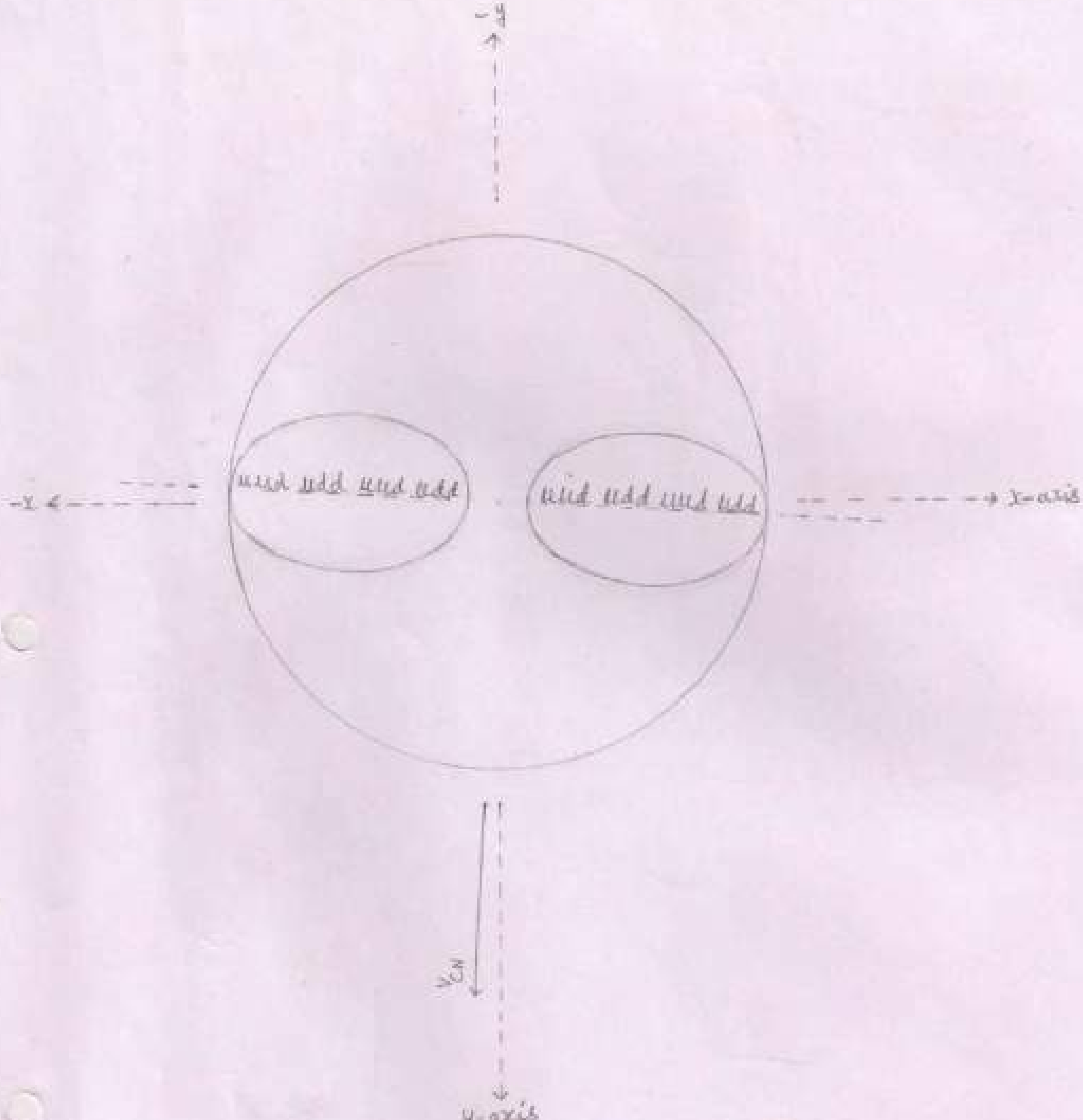
$\beta \simeq 2.87$ degree

3. Formation of lobes within into the homogenous compound nucleus or the transformation of the homogenous compound nucleus into the heterogenous compound nucleus:-

The central group of quarks with its surrounding gluons to become a stable and the next higher nucleus (the helion-4) than the reactant one (the helion-3) includes the other three (nearby located) groups of quarks with their surrounding gluons and rearrange to form the 'A' lobe of the heterogenous compound nucleus.

While the remaining group of quarks to become a stable nucleus (the helion-4) includes the other three (nearby located) group of quarks with their surrounding gluons [out of the available group of quarks with their surrounding gluons that are not involved in the formation of the lobe 'A'] and rearrange to form the 'B' lobe of the heterogenous compound nucleus.

Thus due to formation of two lobes within into the homogenous compound nucleus, the homogenous compound nucleus transforms into the heterogenous compound nucleus.



Formation of lobes

⇒ Within into the homogenous compound nucleus, both the nuclei are helium-4 and the remaining space is remaining gluon(s).

⇒ Within into the homogenous compound nucleus, one helium-4 nucleus represent the lobe 'A' while the another helium-4 nucleus represent the lobe 'B'.

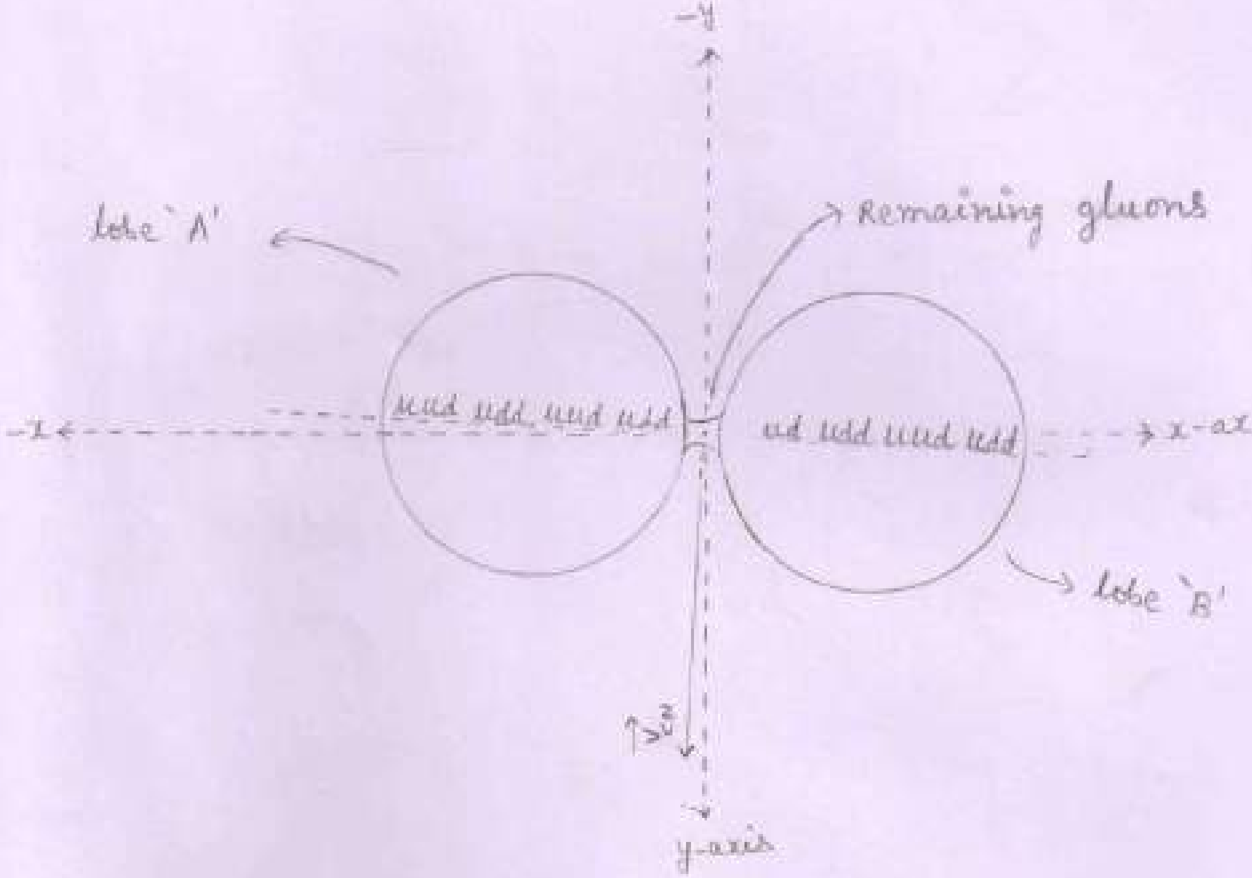
4. Final stage of the heterogenous compound nucleus :-

The process of formation of lobes creates voids between the lobes. So, the remaining gluons [the gluons (or the mass) that are not involved in the formation of any lobe] rearrange to fill the voids between the lobes and thus the remaining gluons form a node between the lobes.

Thus, the reduced mass (or the remaining gluons) keeps both the lobes of the heterogenous compound nucleus joined them together.

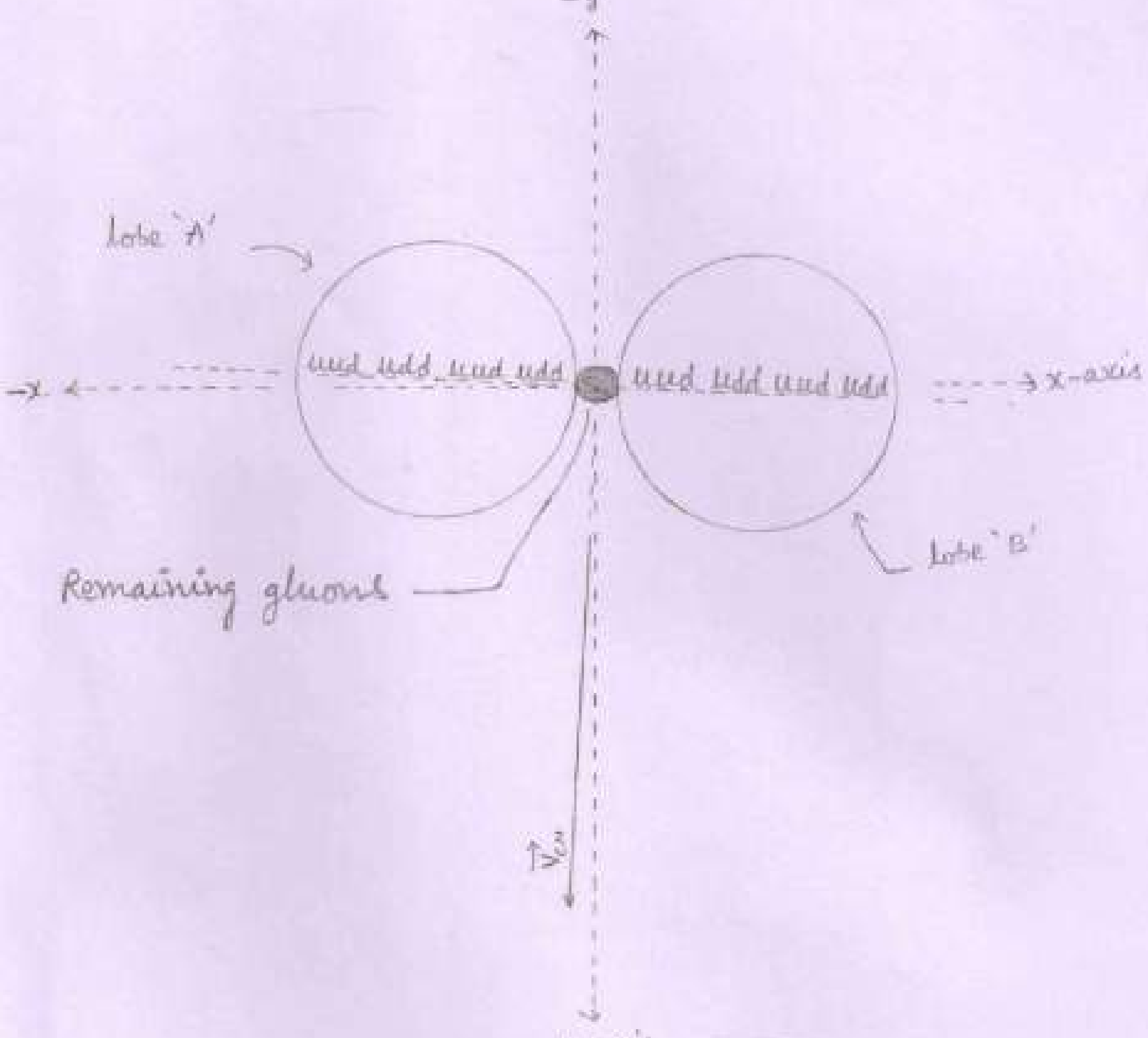
So, finally, the heterogenous compound nucleus becomes like a dumbbell.

Final stage of the heterogenous compound nucleus



4(1)

Final stage of the heterogenous compound nucleus



4(2)

For fusion reaction

$$^{2}_{1}D + ^{3}_{1}T + ^{3}_{2}He \longrightarrow \left[^{8}_{4}Be\right] \longrightarrow 2\,^{4}_{2}He$$

I. For deuteron

1. Minimum kinetic energy required by the deuteron :

For the above described fusion reaction a deuteron has to overcome the electrostatic repulsive force exerted by the other three charged particles. So,

$$E_m = E_{D-D} \times (Z_2)^2$$

$Z_2 = 3$

$E_{D-D} = 5.0622$ Kev

$$\Rightarrow E_m = 5.0622 \times (3)^2 \text{ Kev}$$
$$= 45.5598 \text{ Kev}$$
$$= 0.0455598 \text{ Mev}$$

2. Kinetic energy of deuteron just before fusion :-

(i) Just before fusion, to overcome the electrostatic repulsive force, the deuteron loses energy equal to 45.5598 kev

(ii) So, just before fusion the kinetic energy (E_b) of the deuteron is -

$$E_b = E_{injected} - E_{loss}$$

Momentum (P_b) of the deuteron just before fusion :-

$$P_b = \left[2 m_d E_b \right]^{\frac{1}{2}}$$

$\Rightarrow$ $E_b = 0.0568402 \times \text{Mev}$

$$\Rightarrow P_b = \left[2 \times 3.3434 \times 10^{-27} \times 0.0568402 \times 1.6 \times 10^{-13} \right]^{\frac{1}{2}} \text{kgm/s}$$

$$\Rightarrow P_b = \left[0.60812647897 \times 10^{-40} \right]^{\frac{1}{2}} \text{kgm/s}$$

$$\Rightarrow P_b = 0.7798 \times 10^{-20} \text{ kgm/s}$$

Components of the momentum (P_b) of the deuteron just before fusion :-

1. $\vec{P_x} = P_b \cos\alpha$

$\cos\alpha = \cos 30° = 0.866$

$$\Rightarrow P_x = 0.7798 \times 10^{-20} \times 0.866 \text{ kgm/s}$$
$$= 0.6753 \times 10^{-20} \text{ kgm/s}$$

2. $\vec{P_y} = P_b \cos\beta$

$\cos\beta = \cos 60° = \frac{1}{2}$

$$\Rightarrow \vec{P_y} = 0.7798 \times 10^{-20} \times 0.5 \text{ kgm/s}$$
$$= 0.3899 \times 10^{-20} \text{ kgm/s}$$

3. $\vec{P_z} = P_b \cos\gamma$

$\cos\gamma = \cos 90° = 0$

$$\Rightarrow \vec{P_z} = 0.7798 \times 10^{-20} \times 0 \text{ kgm/s} = 0 \text{ kgm/s}$$

II. For triton

1. Minimum kinetic energy (E_m) required by the triton :-

For the described fusion reaction, the triton has to overcome the electrostatic repulsive force exerted by the other three positive charges.

$$E_m = \frac{2 k^2 z_1^2 z_2^2 q^4 m_t}{h^2}$$

$z_1 = 1$

$z_2 = 3$

$m_t = 5.0072 \times 10^{-27}$ kg

$$\Rightarrow E_m = \frac{2 \times (9 \times 10^9)^2 \times 1^2 \times 3^2 \times (1.6 \times 10^{-19})^4 \times 5.0072 \times 10^{-27}}{(6.62 \times 10^{-34})^2} \text{ J}$$

$$\Rightarrow E_m = \frac{47844.5410713 \times 10^{18} \times 10^{-76} \times 10^{-27}}{43.8244 \times 10^{-68}} \text{ J}$$

$$\Rightarrow E_m = 1091.73294035 \times 10^{-17} \text{ J}$$

$$\Rightarrow E_m = 682.3330 \times 10^2 \text{ ev}$$

$$\Rightarrow E_m = 68.23330 \text{ kev}$$

$$\Rightarrow E_m \simeq 0.0682 \text{ Mev}$$

2. Just before fusion, the kinetic energy (E_b) of the triton :-

(i) Just before fusion, the triton, to overcome the electrostatic repulsive force, loses the energy equal to the minimum kinetic energy (E_m). That is, just before fusion, the triton loses energy equal to 0.0682 Mev.

(ii) So, just before fusion, the kinetic energy (E_b) of the triton is -

$$E_b = E_{injected} - E_{Loss}$$

$$E_b = [1.1583 \text{ Mev}] - [0.0682 \text{ Mev}]$$

$$\Rightarrow E_b = 1.0901 \text{ Mev}$$

Note : $E_{Injected}$ = Injected energy of the triton is the energy with which the triton is produced at point 'F'.

3. Just before fusion, the momentum (P_b) of the triton :-

$$P_b = \left[2 m_t E_b \right]^{\frac{1}{2}}$$

$E_b = 1.0901$ Mev

$$\Rightarrow P_b = \left[2 \times 5.0072 \times 10^{-27} \times 1.0901 \times 1.6 \times 10^{-13} \right]^{\frac{1}{2}} \text{ Kgm/s}$$

$$\Rightarrow P_b = \left[17.466715904 \times 10^{-40} \right]^{\frac{1}{2}} \text{ Kgm/s}$$

$$\Rightarrow P_b = 4.1793 \times 10^{-20} \text{ Kgm/s}$$

4. Just before fusion, the components of momentum ($\vec{P}_b$) of the triton :-

The triton is produced at point 'F'. The final velocity ($\vec{V}_f$) of the triton make angles

$$\alpha \simeq 99^0$$
$$\beta \simeq 9^0$$
$$\gamma = 90^\circ$$

with positive x, y and z-axes respectively. So, just before fusion, the components of momentum of the triton are-

1. $\vec{P}_x = P_b \cos\alpha$

$$P_b = 4.1793 \times 10^{-20} \text{ Kgm/s}$$
$$\cos\alpha \simeq \cos 99^\circ \simeq -0.15$$

$$\Rightarrow \vec{P}_x = 4.1793 \times 10^{-20} \text{ Kgm/s} \times (-0.15)$$
$$= -0.6268 \times 10^{-20} \text{ Kgm/s}$$

2. $\vec{P}_y = P_b \cos\beta$

$$\cos\beta \simeq \cos 9^\circ \simeq 0.98$$

$$\Rightarrow \vec{P}_y = 4.1793 \times 10^{-20} \times 0.98 \text{ Kgm/s}$$
$$= 4.095 \times 10^{-20} \text{ Kgm/s}$$

3. $\vec{P}_z = P_b \cos\gamma$

$$\cos\gamma = \cos 90^\circ = 0$$

$$\Rightarrow \vec{P}_z = 4.1793 \times 10^{-20} \times 0 \text{ Kgm/s}$$
$$= 0 \text{ Kgm/s}$$

The components of the momentum of the compound nucleus.

According to	Just before fusion, the components of momentum of the deuteron at point `F'.	At point `F', just before fusion, the components of momentum of the triton	The components of the momentum of the helium-3 nucleus, at point `F'	At point `F', the components of momentum of compound nucleus formed due to fusion.
0	1	2	3	4 = 1+2+3
x-axis	$\vec{P}_x = 0.6753 \times 10^{-20}$ kgm/s	$\vec{P}_x = -0.6268 \times 10^{-20}$ kgm/s	$\vec{P}_x = -0.4710 \times 10^{-20}$ kgm/s	$\vec{P}_x = -0.4225 \times 10^{-20}$ kgm/s
y-axis	$\vec{P}_y = 0.3899 \times 10^{-20}$ kgm/s	$\vec{P}_y = 4.095 \times 10^{-20}$ kgm/s	$\vec{P}_y = 3.9094 \times 10^{-20}$ kgm/s	$\vec{P}_y = 8.3943 \times 10^{-20}$ kgm/s
z-axis	$\vec{P}_z = 0$ kgm/s	$\vec{P}_z = 0$ kgm/s	$\vec{P}_z = 0$ kgm/s	$\vec{P}_z = 0$ kgm/s

Note : Just before fusion, there is no any lose in energy of the confined helium-3 nucleus passing through the point `F'. So, the components of momentum of the helium-3 remains same of that with which it was produced at point `F'.

$\Rightarrow$ Mass of the compound nucleus (M) :-

$$M = (m_d + m_t + m_{he-3})$$

Components of velocity of Compound nucleus ($\vec{V}_{CN}$) :-

1. $\vec{V}_x = V_{CN} \cos\alpha = \dfrac{M V_{CN} \cos\alpha}{M} = \dfrac{\vec{P_x}}{M}$

$\vec{P}_x = MV_{CN} \cos\alpha = -0.4225 \times 10^{-20}$ kg m/s

$M = 13.35689 \times 10^{-27}$ kg

$\Rightarrow \vec{V}_x = V_{CN} \cos\alpha = \dfrac{-0.4225 \times 10^{-20}}{13.35689 \times 10^{-27}} \dfrac{\text{kg m/s}}{\text{kg}}$

$\Rightarrow \vec{V}_x = V_{CN} \cos\alpha = -0.0316 \times 10^{7}$ m/s

2. $\vec{V}_y = V_{CN} \cos\beta = \dfrac{M V_{CN} \cos\beta}{M} = \dfrac{\vec{P_y}}{M}$

$\vec{P}_y = MV_{CN} \cos\beta = 8.3943 \times 10^{-20}$ kg m/s

$\Rightarrow \vec{V}_y = V_{CN} \cos\beta = \dfrac{8.3943 \times 10^{-20}}{13.35689 \times 10^{-27}} \dfrac{\text{kg m/s}}{\text{kg}}$

$\Rightarrow V_y = V_{CN} \cos\beta = 0.6284 \times 10^{7}$ m/s

3. $\vec{V}_z = V_{CN} \cos\gamma = \dfrac{M V_{CN} \cos\gamma}{M} = \dfrac{\vec{P_z}}{M}$

$\vec{P}_z = MV_{CN} \cos\gamma = 0$ kg m/s

$\Rightarrow \vec{V}_z = V_{CN} \cos\gamma = \dfrac{0}{13.35689 \times 10^{-27}} \dfrac{\text{kg m/s}}{\text{kg}}$

$\Rightarrow \vec{V} = V \cos\gamma = 0$ m/s

Velocity of the compound nucleus (V_{CN}) :-

$$V_{CN}^2 = V_x^2 + V_y^2 + V_z^2$$

$$\vec{V}_x = V_{CN} \cos\alpha = -0.0316 \times 10^7 \text{ m/s}$$

$$\vec{V}_y = V_{CN} \cos\beta = 0.6284 \times 10^7 \text{ m/s}$$

$$\vec{V}_z = V_{CN} \cos\gamma = 0 \text{ m/s}$$

$$\Rightarrow V_{CN}^2 = (0.0316 \times 10^7)^2 + (0.6284 \times 10^7)^2 + (0)^2 \text{ m}^2/\text{s}^2$$

$$\Rightarrow V_{CN}^2 = (0.00099856 \times 10^{14}) + (0.39488656 \times 10^{14}) + (0) \text{ m}^2/\text{s}^2$$

$$\Rightarrow V_{CN}^2 = 0.39588512 \times 10^{14} \text{ m}^2/\text{s}^2$$

$$\Rightarrow V_{CN} = 0.6291 \times 10^7 \text{ m/s}$$

Angles that make the velocity of compound nucleus ($\vec{V}_{CN}$) with positive x, y and z-axes respectively.

1. With x-axis

$$\cos\alpha = \frac{V_{CN}\cos\alpha}{V_{CN}} = \frac{\vec{V}_x}{V_{CN}}$$

$$\vec{V}_x = V_{CN}\cos\alpha = -0.0316\times10^7 \text{ m/s}$$
$$V_{CN} = 0.6291\times10^7 \text{ m/s}$$

$$\Rightarrow \cos\alpha = \frac{-0.0316\times10^7}{0.6291\times10^7}\,\frac{\text{m/s}}{\text{m/s}} = -0.0502$$

$$\Rightarrow \alpha \simeq 92.87 \text{ degree} \qquad [\because \cos(92.87) = -0.050]$$

2. With y-axis

$$\cos\beta = \frac{V_{CN}\cos\beta}{V_{CN}} = \frac{\vec{V}_y}{V_{CN}}$$

$$\vec{V}_y = V_{CN}\cos\beta = 0.6284\times10^7 \text{ m/s}$$

$$\Rightarrow \cos\beta = \frac{0.6284\times10^7}{0.6291\times10^7}\,\frac{\text{m/s}}{\text{m/s}} = 0.9988$$

$$\Rightarrow \beta \simeq 2.87 \text{ degree} \qquad [\because \cos(2.87) = 0.998]$$

3. With z-axis

$$\cos\gamma = \frac{V_{CN}\cos\gamma}{V_{CN}} = \frac{\vec{V}_z}{V_{CN}}$$

$$\vec{V}_z = V_{CN}\cos\gamma = 0 \text{ m/s}$$

$$\Rightarrow \cos\gamma = \frac{0}{}\;\text{m/s} = 0$$

The Splitting of the heterogenous compound nucleus :-

⇒ The heterogenous compound nucleus, due to its instability, splits according to the lines parallel to the direction of the velocity of the compound nucleus ($\vec{V}_{CN}$) into three particles – the helium-4 nucleus, the helium-4 nucleus and the reduced mass (Δm).

out of them, the two particles (the helium-4 nucleus and the helium-4 nucleus) are stable while the third one (the reduced mass) is unstable.

⇒ According to the law of inertia, each particle that has separated from the compound nucleus has an inherited velocity ($\vec{V}_{inh}$) equal to the velocity of the compound nucleus ($\vec{V}_{CN}$).

⇒ So, for conservation of momentum

$$M\vec{V}_{CN} = (m_{he-4} + \Delta m + m_{he-4})\vec{V}_{CN}$$

Where,

M = mass of the compound nucleus

$\vec{V}_{CN}$ = velocity of the compound nucleus

m_{he-4} = mass of the helium-4 nucleus

Δm = reduced mass

The inhereted velocity ($\vec{V}_{inh}$) of the particles :-

Each particle that has separated from the compound nucleus has an inhereted velocity ($\vec{V}_{inh}$) equal to the velocity of the compound nucleus ($\vec{V}_{CN}$).

I. The inhereted velocity ($\vec{V}_{inh}$) of the each helium-4 nucleus :-

$$V_{inh} = V_{CN} = 0.6291 \times 10^{7} \text{ m/s}$$

The components of inhereted velocity ($\vec{V}_{inh}$) of the each helium-4 nucleus :-

1. $\vec{V}_x = V_{inh} \cos\alpha = V_{CN} \cos\alpha = -0.0316 \times 10^{7}$ m/s

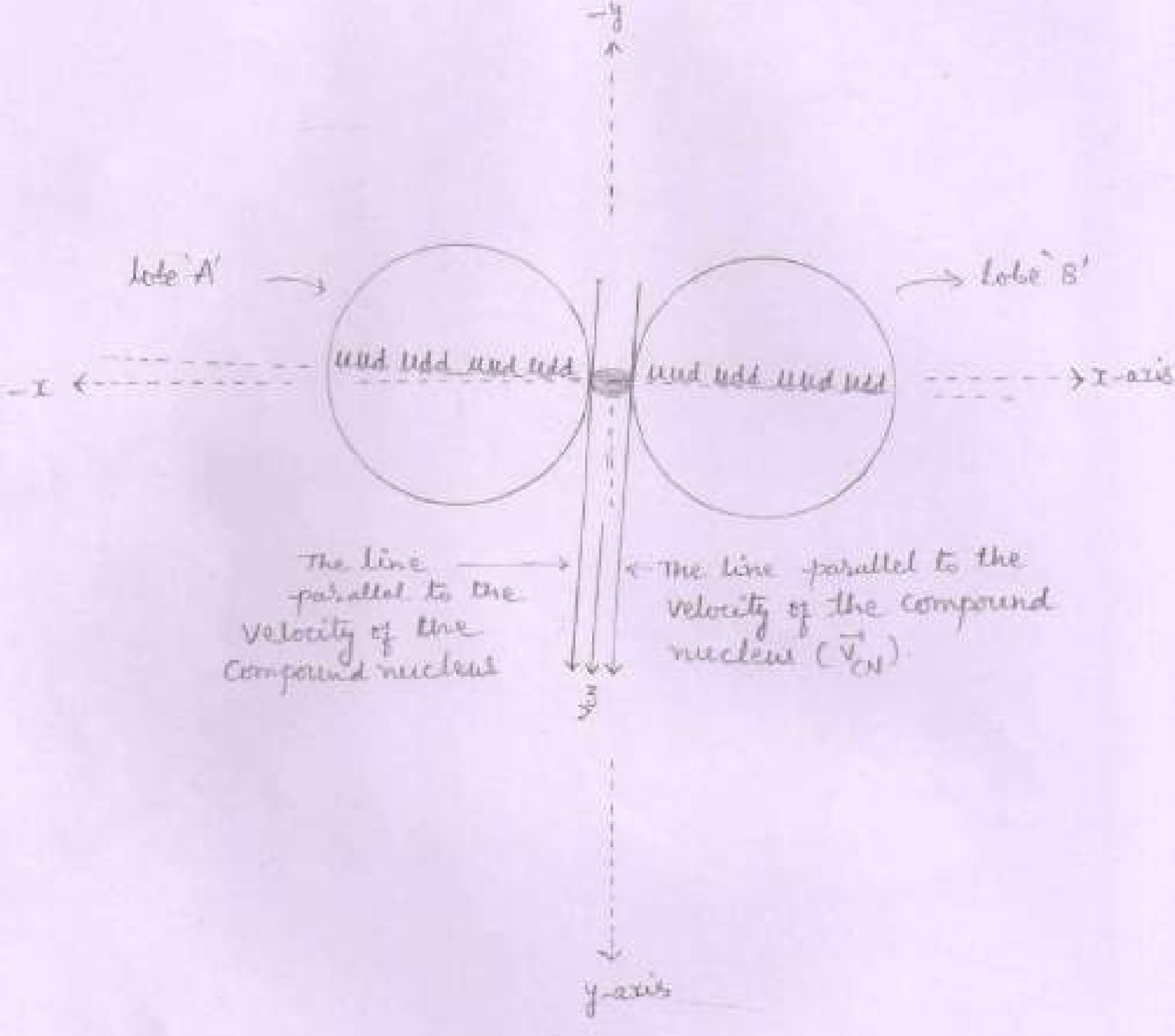
2. $\vec{V}_y = V_{inh} \cos\beta = V_{CN} \cos\beta = 0.6284 \times 10^{7}$ m/s

3. $\vec{V}_z = V_{inh} \cos\gamma = V_{CN} \cos\gamma = 0$ m/s

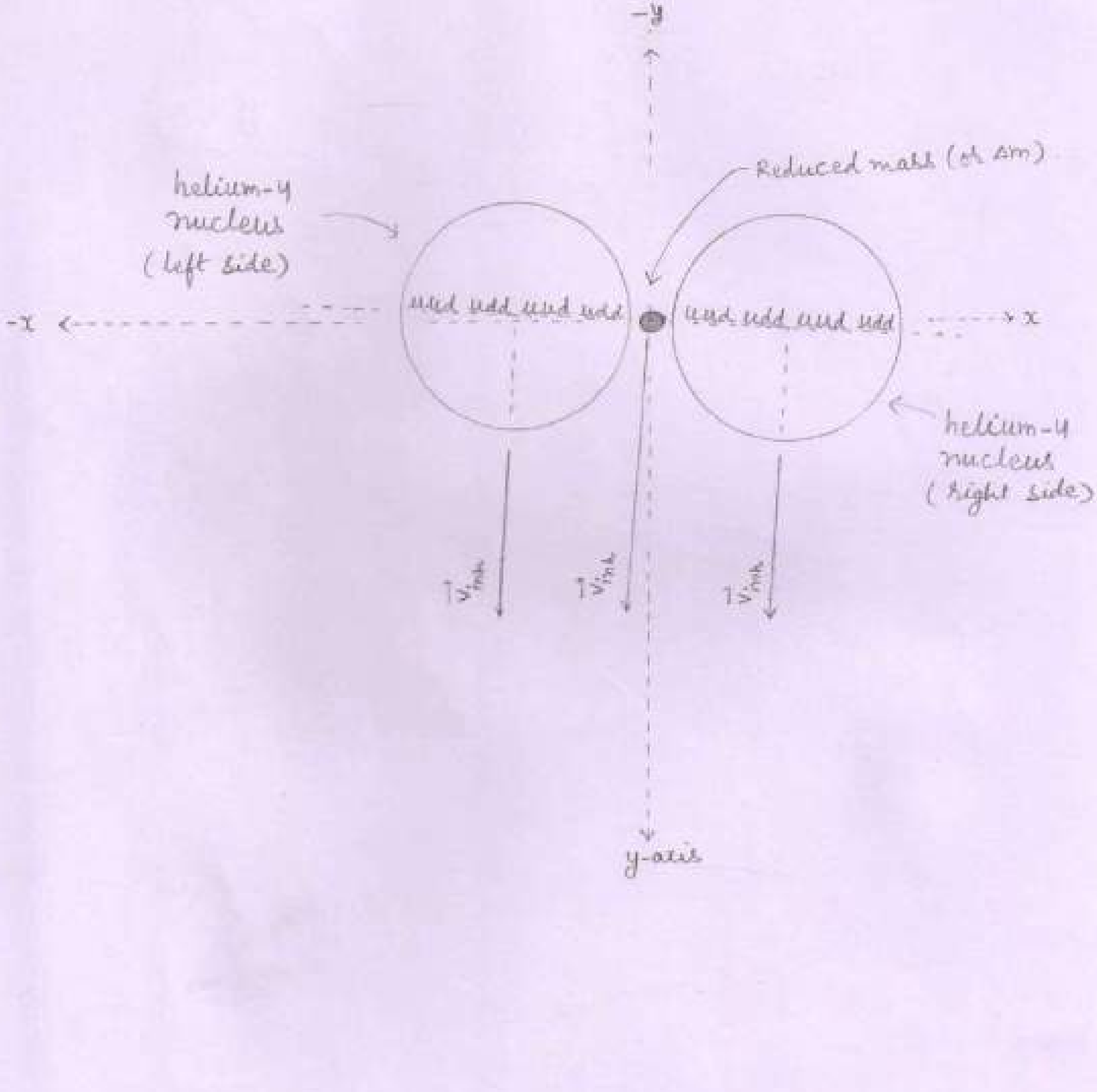
II. The inhereted velocity ($\vec{V}_{inh}$) of the reduced mass (Δm) is –

$$V_{inh} = V_{CN} = 0.6291 \times 10^{7} \text{ m/s}$$

The splitting of the heterogenous compound nucleus



The splitting of the heterogenous compound nucleus



Propellation of the particles

1. Reduced mass (Δm) :

$$\Delta m = [m_d + m_t + m_{He-3}] - 2[m_{He-4}]$$

$$\Rightarrow \Delta m = [2.01355 + 3.0155 + 3.014932] - 2[4.0015] \text{ amu}$$

$$\Rightarrow \Delta m = [8.043982] - [8.003] \text{ amu}$$

$$\Rightarrow \Delta m = 0.040982 \text{ amu}$$

$$\Rightarrow \Delta m = 0.040982 \times 1.6605 \times 10^{-27} \text{ Kg}$$

$$\Rightarrow \Delta m = 0.068050611 \times 10^{-27} \text{ Kg}$$

2. Inhereted kinetic energy (E_{inh}) of reduced mass :-

$$E_{inh} = \frac{1}{2} \Delta m \, v_{inh}^2 = \frac{1}{2} \Delta m \, V_{CN}^2$$

$$v_{inh}^2 = v_{CN}^2 = 0.38857325 \times 10^{14} \text{ m}^2/\text{s}^2$$

$$\Rightarrow E_{inh} = \frac{1}{2} \times 0.068050611 \times 10^{-27} \times 0.38857325 \times 10^{14} \text{ J}$$

$$= 0.01322132354 \times 10^{-13} \text{ J}$$

$$= 0.0082 \text{ Mev}$$

3. Released energy (E_R):

$$E_R = \Delta m c^2$$
$$= 0.040982 \times 931 \quad Mev$$
$$= 38.1542 \quad Mev$$

4. Total energy (E_T):

$$E_T = E_{th} + E_R$$
$$= 0.0082 + 38.1542 \quad Mev$$
$$= 38.1624 \quad Mev$$

Increased kinetic energy (E_{inc}) of the either one of the helion-4 :—

$$E_{inc} = \frac{m_{He-4}}{m_{He-4} + m_{He-4}} \times E_T$$

$$= \frac{E_T}{2}$$

$$E_T = 38.1624 \text{ Mev}$$

$$\Rightarrow E_{inc} = \frac{38.1624}{2} \text{ Mev}$$

$$\Rightarrow E_{inc} = 19.0812 \text{ Mev}$$

Increased velocity of the each helion-4

$$V_{inc} = \left[\frac{2E_{inc}}{m_{He-4}}\right]^{\frac{1}{2}}$$

$$\Rightarrow V_{inc} = \left[\frac{2 \times 19.0812 \times 1.6 \times 10^{-13}}{6.64449 \times 10^{-27}}\right]^{\frac{1}{2}} \text{ m/s}$$

$$\Rightarrow V_{inc} = \left[\frac{61.05984 \times 10^{-13}}{6.64449 \times 10^{-27}}\right]^{\frac{1}{2}} \text{ m/s}$$

$$\Rightarrow V_{inc} = \left[9.1895450215 1 \times 10^{14}\right]^{\frac{1}{2}} \text{ m/s}$$

$$\Rightarrow V_{inc} = 3.0314 \times 10^{7} \text{ m/s}$$

Angles of propellation

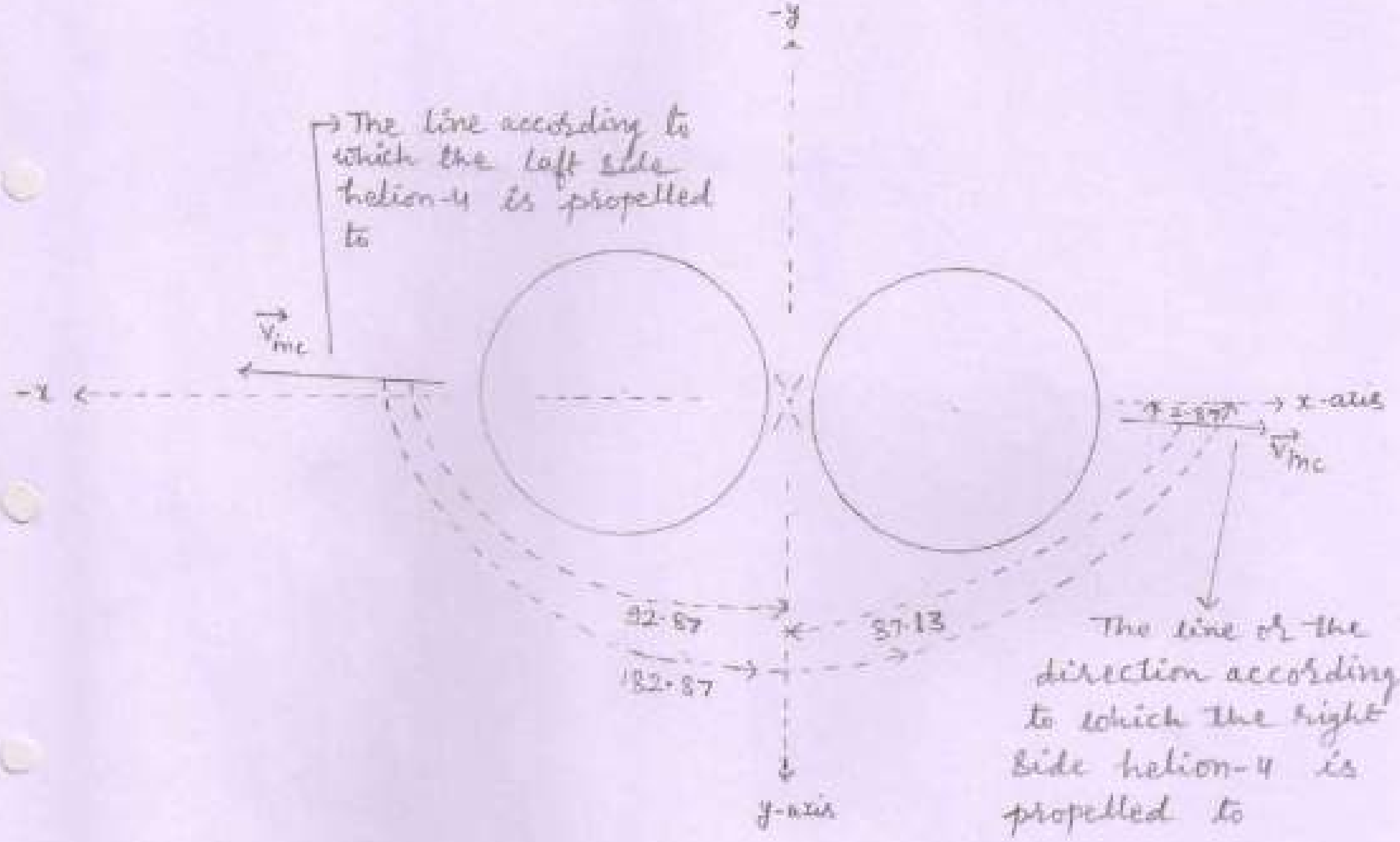
1. As the reduced mass converts into energy, the total energy (E_T) propell both the particles with equal and opposite momentum according to a ray (line) perpendicular to the direction (line) of the velocity of the compound nucleus ($\vec{V}_{CN}$).

2. At point 'F', as $\vec{V}_{CN}$ makes 92.87 degree angle with x-axis, 2.87 degree angle with y-axis and 90° angle with z-axis.

3. So, the right hand sided helium-4 nucleus is propelled making 2.87 degree angle with x-axis, 87.13 degree angle with y-axis and 90° angle with z-axis.

4. While the left hand sided helium-4 nucleus is propelled making 182.87 degree angle with x-axis, 92.87 degree angle with y-axis and 90° angle with z-axis.

Propellation of the particles



Components of the increased velocity ($\vec{V}_{inc}$) of the right side propelled helium-4 nucleus :-

1. $\vec{V}_x = V_{inc} \cos\alpha$

$V_{inc} = 3.0314 \times 10^7$ m/s

$\cos\alpha = \cos(2.87) = 0.99$

$\Rightarrow \vec{V}_x = 3.0314 \times 10^7 \times 0.99$ m/s

$= 3.0010 \times 10^7$ m/s

2. $\vec{V}_y = V_{inc} \cos\beta$

$\cos\beta = \cos(87.13) = 0.05$

$\Rightarrow \vec{V}_y = 3.0314 \times 10^7 \times 0.5$ m/s

$= 0.1515 \times 10^7$ m/s

3. $\vec{V}_z = V_{inc} \cos\gamma$

$\cos\gamma = \cos 90^\circ = 0$

$\Rightarrow \vec{V}_z = 3.0314 \times 10^7 \times 0$ m/s $= 0$ m/s

Components of the increased velocity ($\vec{V}_{inc}$) of the left side propelled helium-4 nucleus :-

1. $\vec{V}_x = V_{inc} \cos\alpha$

$V_{inc} = 3.0314 \times 10^7$ m/s

$\cos\alpha = \cos(182.87) = -\cos(2.87) = -0.99$

$\Rightarrow \vec{V}_x = 3.0314 \times 10^7 \times (-0.99)$ m/s

$= -3.0010 \times 10^7$ m/s

2. $\vec{V}_y = V_{inc} \cos\beta$

$\cos\beta = \cos(92.87) = -\cos(87.13) = -0.05$

$\Rightarrow \vec{V}_y = 3.0314 \times 10^7 \times (-0.05)$ m/s

$= -0.1515 \times 10^7$ m/s

3. $\vec{V}_z = V_{inc} \cos\gamma$

$\cos\gamma = \cos 90^\circ = 0$

$\Rightarrow \vec{V}_z = 3.0314 \times 10^7 \times 0$ m/s $= 0$ m/s

Components of the final velocity ($\vec{v}_f$) of the particles :-

I. For the right side propelled helium-4 nucleus.

According to	Inhereted velocity ($\vec{v}_{inh}$)	Increased velocity ($\vec{v}_{inc}$)	Final velocity ($\vec{v}_f$) $\vec{v}_f = \vec{v}_{inh} + \vec{v}_{inc}$
x-axis	$\vec{v}_x = -0.0316 \times 10^7$ m/s	$\vec{v}_x = 3.001 \times 10^7$ m/s	$\vec{v}_x = 2.9694 \times 10^7$ m/s
y-axis	$\vec{v}_y = 0.6284 \times 10^7$ m/s	$\vec{v}_y = 0.1515 \times 10^7$ m/s	$\vec{v}_y = 0.7799 \times 10^7$ m/s
z-axis	$\vec{v}_z = 0$ m/s	$\vec{v}_z = 0$ m/s	$\vec{v}_z = 0$ m/s

II. For the left side propelled helium-4 nucleus :-

According to	Inhereted velocity ($\vec{v}_{inh}$)	Increased velocity ($\vec{v}_{inc}$)	Final velocity ($\vec{v}_f$) $\vec{v}_f = \vec{v}_{inh} + \vec{v}_{inc}$
x-axis	$\vec{v}_x = -0.0316 \times 10^7$ m/s	$\vec{v}_x = -3.001 \times 10^7$ m/s	$\vec{v}_x = -3.0326 \times 10^7$ m/s
y-axis	$\vec{v}_y = 0.6284 \times 10^7$ m/s	$\vec{v}_y = -0.1515 \times 10^7$ m/s	$\vec{v}_y = 0.4769 \times 10^7$ m/s
z-axis	$\vec{v}_z = 0$ m/s	$\vec{v}_z = 0$ m/s	$\vec{v}_z = 0$ m/s

Final velocity (v_f) of the right side propelled helium-4

$$v_f^2 = v_x^2 + v_y^2 + v_z^2$$

$$\vec{v}_x = 2.9694 \times 10^7 \text{ m/s}$$
$$\vec{v}_y = 0.7799 \times 10^7 \text{ m/s}$$
$$\vec{v}_z = 0 \text{ m/s}$$

$$\Rightarrow v_f^2 = (2.9694 \times 10^7)^2 + (0.7799 \times 10^7)^2 + (0)^2 \text{ m}^2/\text{s}^2$$

$$\Rightarrow v_f^2 = (8.81733636 \times 10^{14}) + (0.60824401 \times 10^{14}) + (0) \text{ m}^2/\text{s}^2$$

$$\Rightarrow v_f^2 = 9.42558037 \times 10^{14} \text{ m}^2/\text{s}^2$$

$$\Rightarrow v_f = 3.0701 \times 10^7 \text{ m/s}$$

Final kinetic energy of the right side propelled helium-4 nucleus :-

$$E = \frac{1}{2} m_{he-4} v_f^2$$

$$v_f^2 = 9.42558037 \times 10^{14} \text{ m}^2/\text{s}^2$$

$$\Rightarrow E = \frac{1}{2} \times 6.64449 \times 10^{-27} \times 9.42558037 \times 10^{14} \text{ J}$$

$$= 31.3140872563 \times 10^{-13} \text{ J}$$
$$= 19.5713 \text{ Mev}$$

$$\Rightarrow m_{he-4} v_f^2 = 6.64449 \times 10^{-27} \times 9.42558037 \times 10^{14} \text{ J}$$

$$= 62.6281 \times 10^{-13} \text{ J}$$

The forces acting on the right side propelled helium-4 nucleus :-

1. $F_y = q V_x B_z \sin\theta$

$\vec{V_x} = 2.9694 \times 10^7$ m/s

$\vec{B_z} = -1$ Tesla

$q = 2 \times 1.6 \times 10^{-19}$ C

$\sin\theta = \sin 90° = 1$

$\Rightarrow F_y = 2 \times 1.6 \times 10^{-19} \times 2.9694 \times 10^7 \times 1 \times 1$ N

$= 9.5020 \times 10^{-12}$ N

From the right hand palm rule, the direction of force $\vec{F_y}$ is according to negative y-axis. So,

$\vec{F_y} = -9.5020 \times 10^{-12}$ N

2. $F_z = q V_x B_y \sin\theta$

$\vec{B_y} = 1$ Tesla

$\sin\theta = \sin 90° = 1$

$\Rightarrow F_z = 2 \times 1.6 \times 10^{-19} \times 2.9694 \times 10^7 \times 1 \times 1$ N

$= 9.5020 \times 10^{-12}$ N

From the right hand palm rule, the direction of force $\vec{F_z}$ is according to negative z-axis. So,

$\vec{F_z} = -9.5020 \times 10^{-12}$ N

3. $F_x = q V_y B_z \sin\theta$

$\vec{V_y} = 0.7799 \times 10^7$ m/s

$\sin\theta = \sin 90° = 1$

$\Rightarrow F_x = 2 \times 1.6 \times 10^{-19} \times 0.7799 \times 10^7 \times 1 \times 1$ N

$= 2.4956 \times 10^{-12}$ N

From the right hand palm rule, the direction of force $\vec{F}$ is according to positive x-axis.

4. Resultant force (F_R) acting on the right side propelled helium-4 nucleus [when the right side propelled helium-4 nucleus is at point 'F']

$$F_R^2 = F_x^2 + F_y^2 + F_z^2$$

$$F_x = 2.4956 \times 10^{-12} \text{ N}$$

$$F = F_y = F_z = 9.5020 \times 10^{-12} \text{ N}$$

$$\Rightarrow F_R^2 = F_x^2 + 2F^2$$

$$\Rightarrow F_R^2 = (2.4956 \times 10^{-12})^2 + 2(9.5020 \times 10^{-12})^2$$

$$\Rightarrow F_R^2 = (6.22801936 \times 10^{-24}) + 2(90.288004 \times 10^{-24}) \text{ N}^2$$

$$\Rightarrow F_R^2 = (6.22801936 \times 10^{-24}) + (180.576008 \times 10^{-24}) \text{ N}^2$$

$$\Rightarrow F_R^2 = 186.80402736 \times 10^{-24} \text{ N}^2$$

$$\Rightarrow F_R = 13.6676 \times 10^{-12} \text{ N}$$

Radius of the circular orbit to be followed by the right side propelled helium-4 nucleus :-

$$r = \frac{mv^2}{F_R}$$

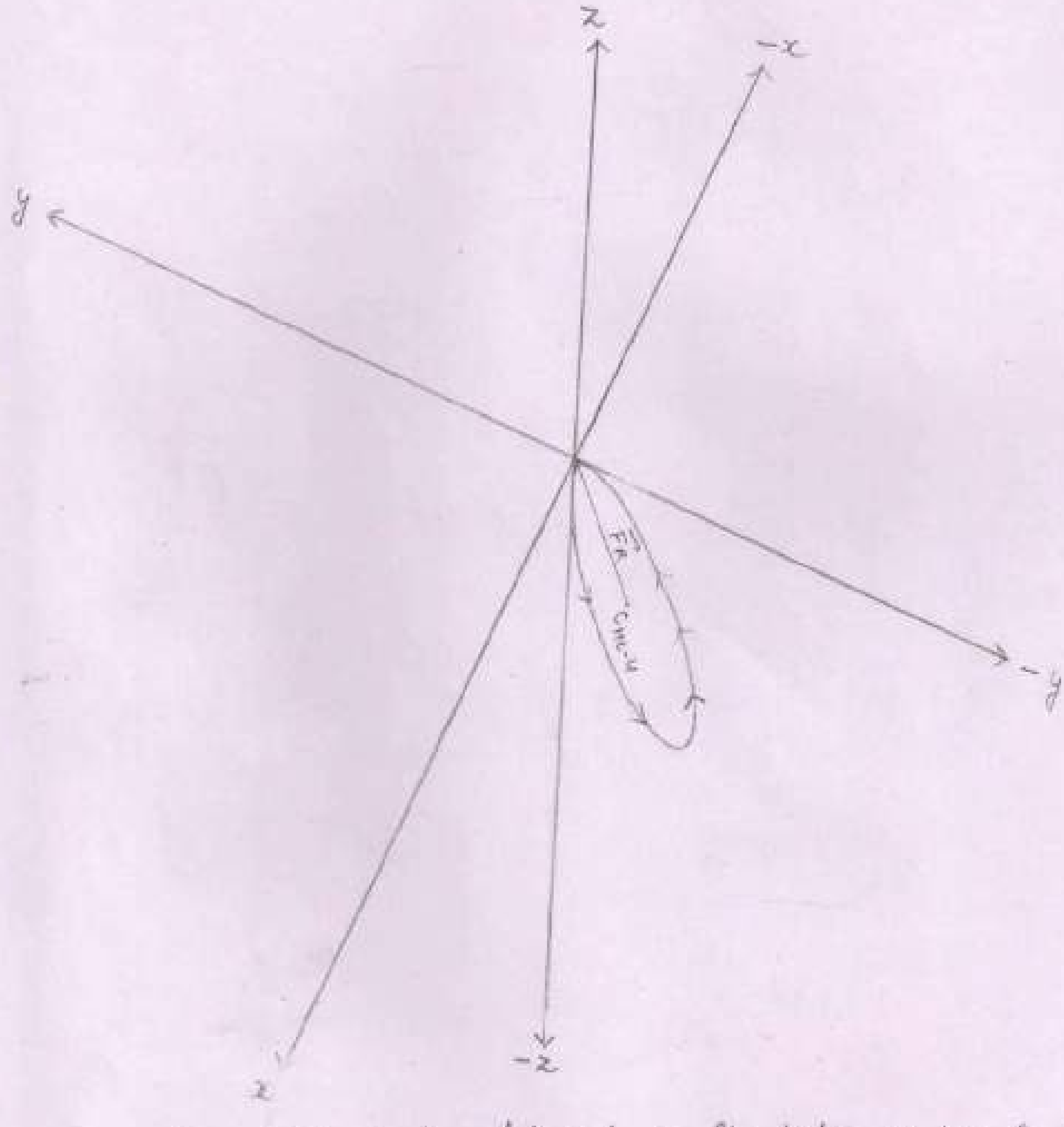
$mv^2 = 62.6281 \times 10^{-13}$ J

$F_R = 13.6676 \times 10^{-12}$ N

$$\Rightarrow r = \frac{62.6281 \times 10^{-13}}{13.6676 \times 10^{-12}} \frac{J}{N}$$

$$\Rightarrow r = 4.58223 \times 10^{-1} \text{ m}$$

$$\Rightarrow r = 45.8223 \times 10^{-2} \text{ m}$$



⇒ The circular orbit to be followed by the helion-4 lies in the IV (down) quadrant made up of positive x axis, negative y axis and the negative z axis.

⇒ C_{He-4} = center of the circle to be followed by the helion-4

Angles that make the resultant force (F_R) [acting on the helium-4 nucleus when the helium-4 is at point 'F'] with positive x, y and z-axes.

I. For the right side propelled helium-4 nucleus:-

1. With x-axis

$$\cos\alpha = \frac{F_R \cos\alpha}{F_R} = \frac{\overrightarrow{F_x}}{F_R} = \frac{2.4956 \times 10^{-12}}{13.6676 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\alpha = 0.1825$

$\Rightarrow \alpha \simeq 79.5$ degrees $[\because \cos(79.5) = 0.1822]$

2. With y-axis

$$\cos\beta = \frac{F_R \cos\beta}{F_R} = \frac{\overrightarrow{F_y}}{F_R} = \frac{-9.5020 \times 10^{-12}}{13.6676 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\beta = -0.6952$

$\Rightarrow \beta \simeq 134$ degrees $[\because \cos(134) = -0.6946]$

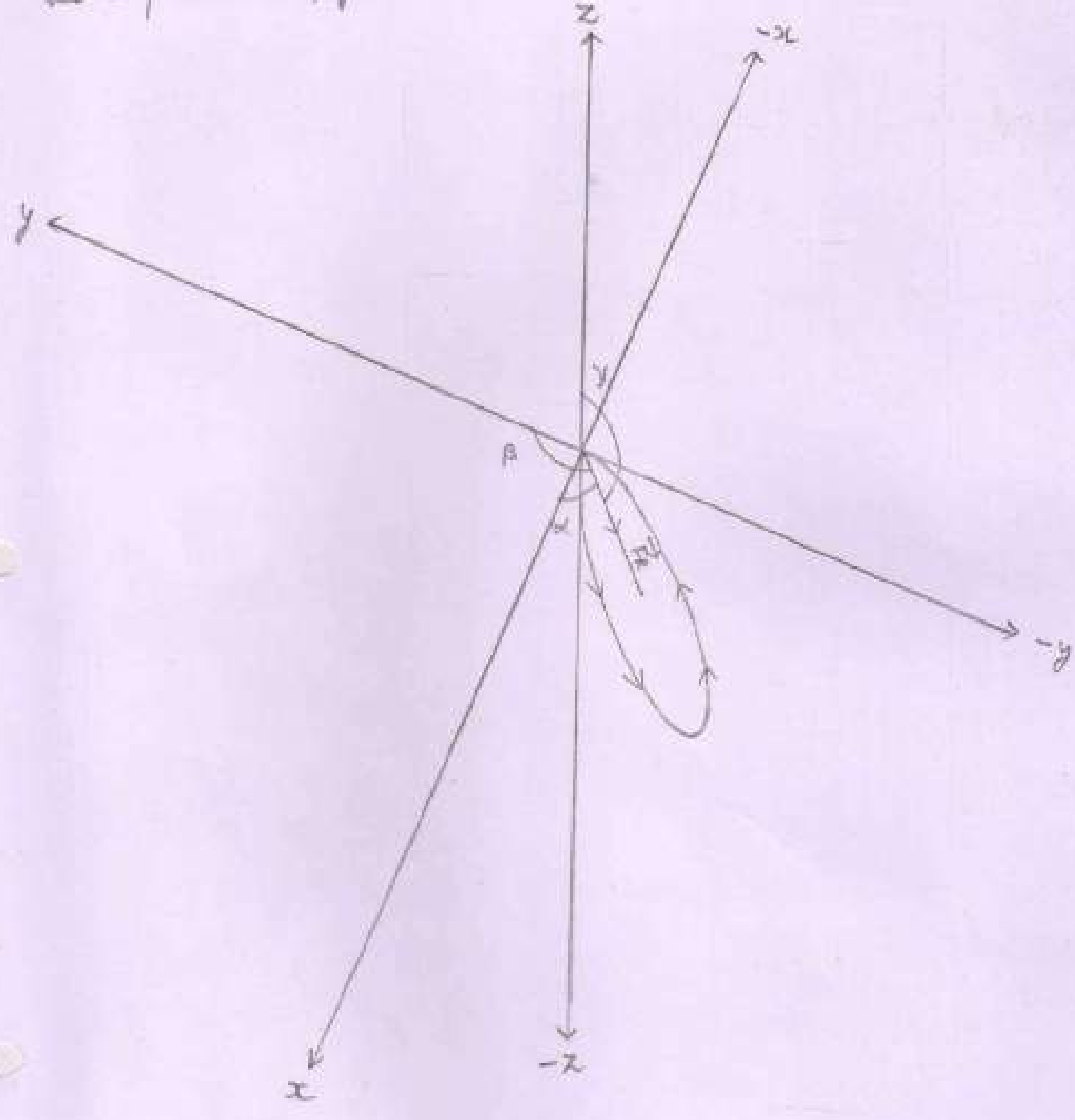
3. With z-axis

$$\cos\gamma = \frac{F_R \cos\gamma}{F_R} = \frac{\overrightarrow{F_z}}{F_R} = \frac{-9.5020 \times 10^{-12}}{13.6676 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\gamma = -0.6952$

$\Rightarrow \gamma \simeq 134$ degrees

Angles that make the resultant force ($\vec{F_R}$) at point F with positive x, y and z axes.



⇒ Where,

$\alpha \simeq 79.5$ degrees

$\beta \simeq 134$ degrees

$\gamma \simeq 134$ degrees

The cartesian coordinates of the points $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$ located on the circumfrence of the circle to be followed by the right side propelled helium-4 nucleus are-

1. $\cos\alpha = \dfrac{x_2 - x_1}{d}$

$d = 2 \times r$

$d = 2 \times 45.8223 \times 10^{-2}\ m$

$d = 91.6446 \times 10^{-2}\ m$

$\cos\alpha = 0.18$

$\Rightarrow x_2 - x_1 = d \times \cos\alpha$

$\Rightarrow x_2 - x_1 = 91.6446 \times 10^{-2} \times 0.18\ m$

$\Rightarrow x_2 - x_1 = 16.4960 \times 10^{-2}\ m$

$\Rightarrow x_2 = 16.4960 \times 10^{-2}\ m \quad [\because x_1 = 0]$

2. $\cos\beta = \dfrac{y_2 - y_1}{d}$

$\cos\beta = -0.69$

$\Rightarrow y_2 - y_1 = d \times \cos\beta$

$\Rightarrow y_2 - y_1 = 91.6446 \times 10^{-2} \times (-0.69)\ m$

$\Rightarrow y_2 - y_1 = -63.2347 \times 10^{-2}\ m$

$\Rightarrow y_2 = -63.2347 \times 10^{-2}\ m$

3. $\cos\gamma = \dfrac{z_2 - z_1}{d}$

$\cos\gamma = -0.69$

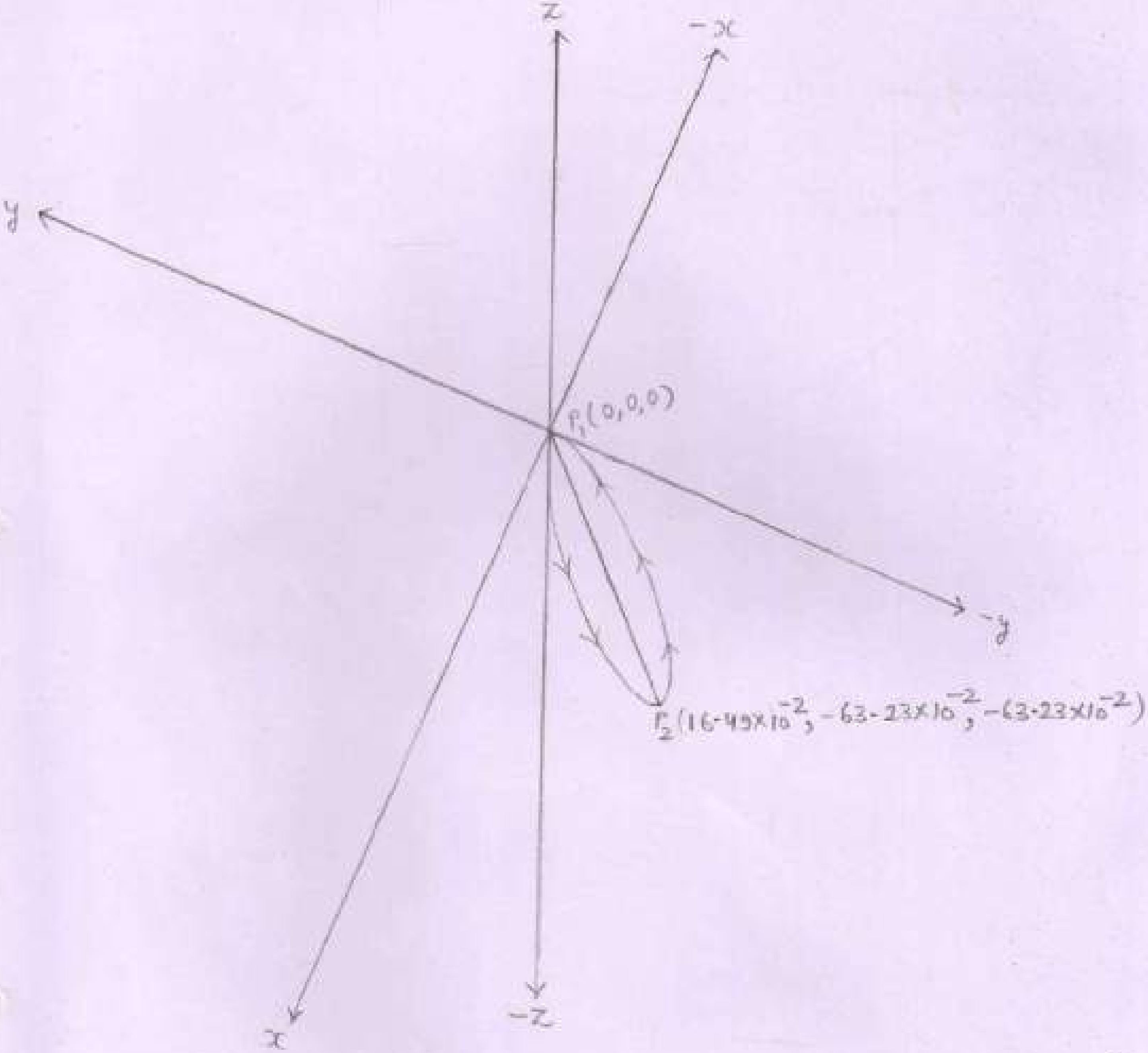
$\Rightarrow z_2 - z_1 = d \times \cos\gamma$

$\Rightarrow z_2 - z_1 = 91.6446 \times 10^{-2} \times (-0.69)\ m$

$\Rightarrow z_2 - z_1 = -63.2347 \times 10^{-2}\ m$

$\Rightarrow z_2 = -63.2347 \times 10^{-2}\ m \quad [\because z_1 = 0]$

The cartesian coordinates of the points $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$



⇒ The cartesian coordinates of the points $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$ located on the circumfrence of the circle obtained by the Right side propelled helion-4

⇒ The line $\overline{P_1P_2}$ is the diameter of the circle.

Final velocity (v_f) of the left side propelled helium-4 nucleus :-

$$v_f^2 = v_x^2 + v_y^2 + v_z^2$$

$\vec{v}_x = -3.0326 \times 10^7$ m/s
$\vec{v}_y = 0.4769 \times 10^7$ m/s
$\vec{v}_z = 0$ m/s

$$\Rightarrow v_f^2 = (3.0326 \times 10^7)^2 + (0.4769 \times 10^7)^2 + (0)^2 \; m^2/s^2$$

$$\Rightarrow v_f^2 = (9.19666276 \times 10^{14}) + (0.22743361 \times 10^{14}) + (0) \; m^2/s^2$$

$$\Rightarrow v_f^2 = 9.42409637 \times 10^{14} \; m^2/s^2$$

$$\Rightarrow v_f = 3.0698 \times 10^7 \; m/s$$

Final kinetic energy of the left side propelled helium-4 nucleus :-

$$E = \frac{1}{2} m_{he-4} v_f^2$$

$v_f^2 = 9.42409637 \times 10^{14} \, m^2/s^2$

$$\Rightarrow E = \frac{1}{2} \times 6.64449 \times 10^{-27} \times 9.42409637 \times 10^{14} \; J$$

$$\Rightarrow E = 31.3091570447 \times 10^{-13} \; J$$

$$\Rightarrow E = 19.5682 \; MeV$$

$$\Rightarrow m_{he-4} v_f^2 = 6.64449 \times 10^{-27} \times 9.42409637 \times 10^{14} \; J$$
$$= 62.6183 \times 10^{-13} \; J$$

The forces acting on the left side propelled helium-4 nucleus :-

1. $F_y = q V_x B_z \sin\theta$

$\vec{V}_x = -3.0326 \times 10^7$ m/s

$\vec{B}_z = -1$ Tesla

$q = 2 \times 1.6 \times 10^{-19}$ C

$\sin\theta = \sin 90° = 1$

$\Rightarrow F_y = 2 \times 1.6 \times 10^{-19} \times 3.0326 \times 10^7 \times 1 \times 1$ N

$= 9.7043 \times 10^{-12}$ N

From the right hand palm rule, the direction of force $\vec{F_y}$ is according to positive y-axis. So,

$$\vec{F_y} = 9.7043 \times 10^{-12} \text{ N}$$

2. $F_z = q V_x B_y \sin\theta$

$\vec{B_y} = 1$ Tesla

$\sin\theta = \sin 90° = 1$

$\Rightarrow F_z = 2 \times 1.6 \times 10^{-19} \times 3.0326 \times 10^7 \times 1 \times 1$ N

$= 9.7043 \times 10^{-12}$ N

From the right hand palm rule, the direction of force $\vec{F_z}$ is according to positive z-axis. So,

$$\vec{F_z} = 9.7043 \times 10^{-12} \text{ N}$$

3. $F_x = q V_y B_z \sin\theta$

$\vec{V_y} = 0.4769 \times 10^7$ m/s

$\sin\theta = \sin 90° = 1$

$\Rightarrow F_x = 2 \times 1.6 \times 10^{-19} \times 0.4769 \times 10^7 \times 1 \times 1$ N

$= 1.5260 \times 10^{-12}$ N

From the right hand palm rule, the direction of force $\vec{F}$ is according to positive x-axis. So,

4. Resultant force (F_R) acting on the helium-4 nucleus [when the helium-4 is at point 'F'] :-

$$F_R^2 = F_x^2 + F_y^2 + F_z^2$$

$$F_x = 1.5260 \times 10^{-12}\ N$$

$$F = F_y = F_z = 9.7043 \times 10^{-12}\ N$$

$$\Rightarrow F_R^2 = F_x^2 + 2F^2$$

$$\Rightarrow F_R^2 = (1.5260 \times 10^{-12})^2 + 2(9.7043 \times 10^{-12})^2\ N^2$$

$$\Rightarrow F_R^2 = (2.328676 \times 10^{-24}) + 2(94.17343849 \times 10^{-24})\ N^2$$

$$\Rightarrow F_R^2 = (2.328676 \times 10^{-24}) + (188.34687698 \times 10^{-24})\ N^2$$

$$\Rightarrow F_R^2 = 190.67555298 \times 10^{-24}\ N^2$$

$$\Rightarrow F_R = 13.8085 \times 10^{-12}\ N$$

Radius of the circular orbit to be followed by the left side propelled helium-4 nucleus :-

$$r = \frac{mv^2}{F_R}$$

$mv^2 = 62.6183 \times 10^{-13}$ J

$F_R = 13.8085 \times 10^{-12}$ N

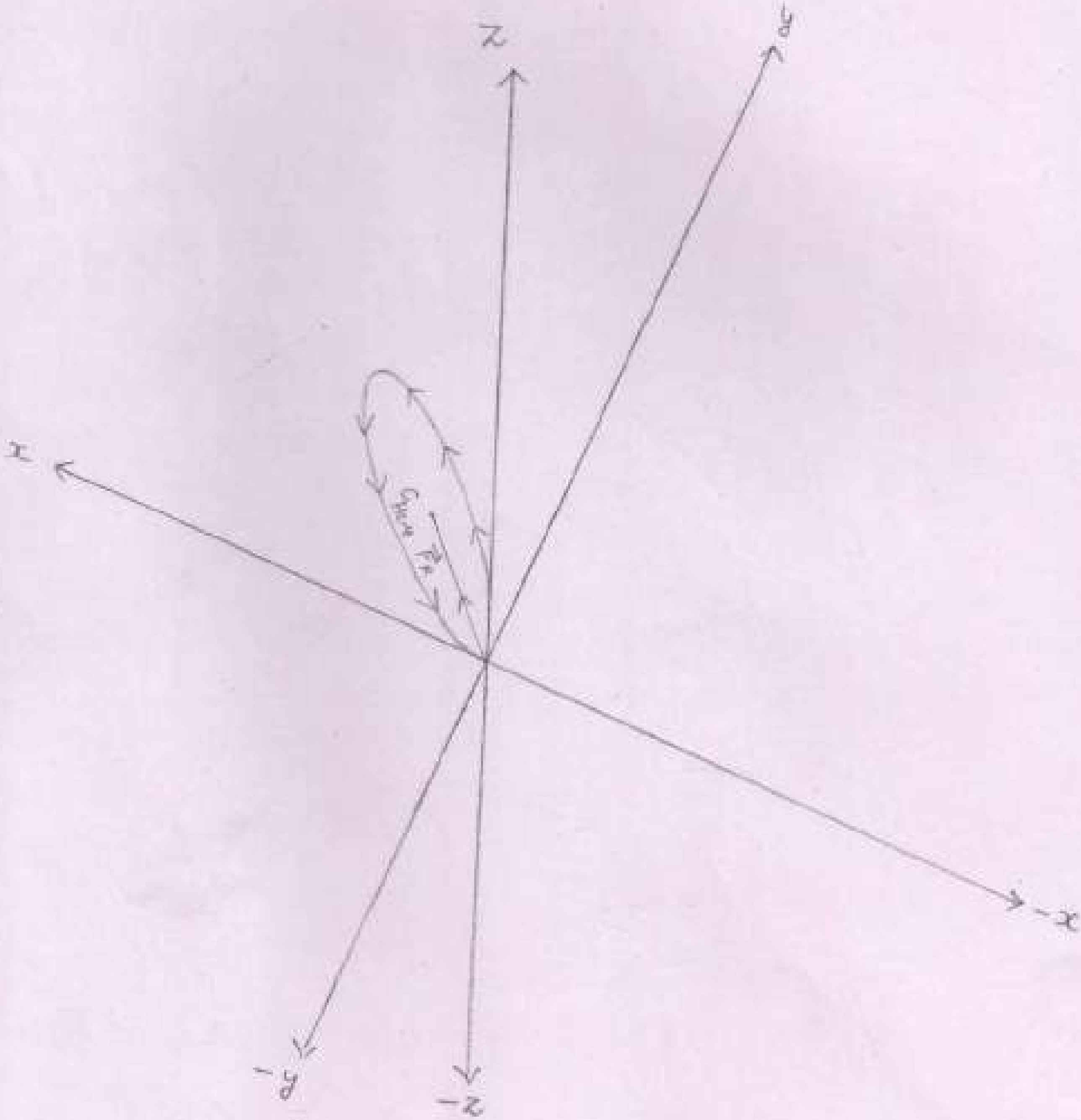
$$\Rightarrow r = \frac{62.6183 \times 10^{-13}}{13.8085 \times 10^{-12}} \frac{J}{N}$$

$$\Rightarrow r = 4.53476 \times 10^{-1} \text{ m}$$

$$\Rightarrow r = 45.3476 \times 10^{-2} \text{ m}$$

⇒ The circular orbit to be followed by the helion-4 lies in the I (up) quadrant made up of the positive x axis, positive y axis and the positive z-axis.

⇒ C_{He-4} = center of the circle to be followed by the helion-4.



Angles that make the resultant force (F_R) [acting on the left side propelled helium-4 nucleus when the helium-4 is at point 'F'] with positive x, y and z-axes.

I. For the left side propelled helium-4 nucleus :-

1. With x-axis

$$\cos\alpha = \frac{F_R \cos\alpha}{F_R} = \frac{\vec{F_x}}{F_R} = \frac{1.5260 \times 10^{-12}}{13.8085 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\alpha = 0.1105$

$\Rightarrow \alpha \simeq 83.6$ degree

2. With y-axis

$$\cos\beta = \frac{F_R \cos\beta}{F_R} = \frac{\vec{F_y}}{F_R} = \frac{9.7043 \times 10^{-12}}{13.8085 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\beta = 0.7027$

$\Rightarrow \beta \simeq 44.5$ degree

3. With z-axis

$$\cos\gamma = \frac{F_R \cos\gamma}{F_R} = \frac{\vec{F_z}}{F_R} = \frac{9.7043 \times 10^{-12}}{13.8085 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\gamma = 0.7027$

$\Rightarrow \gamma \simeq 44.5$ degree

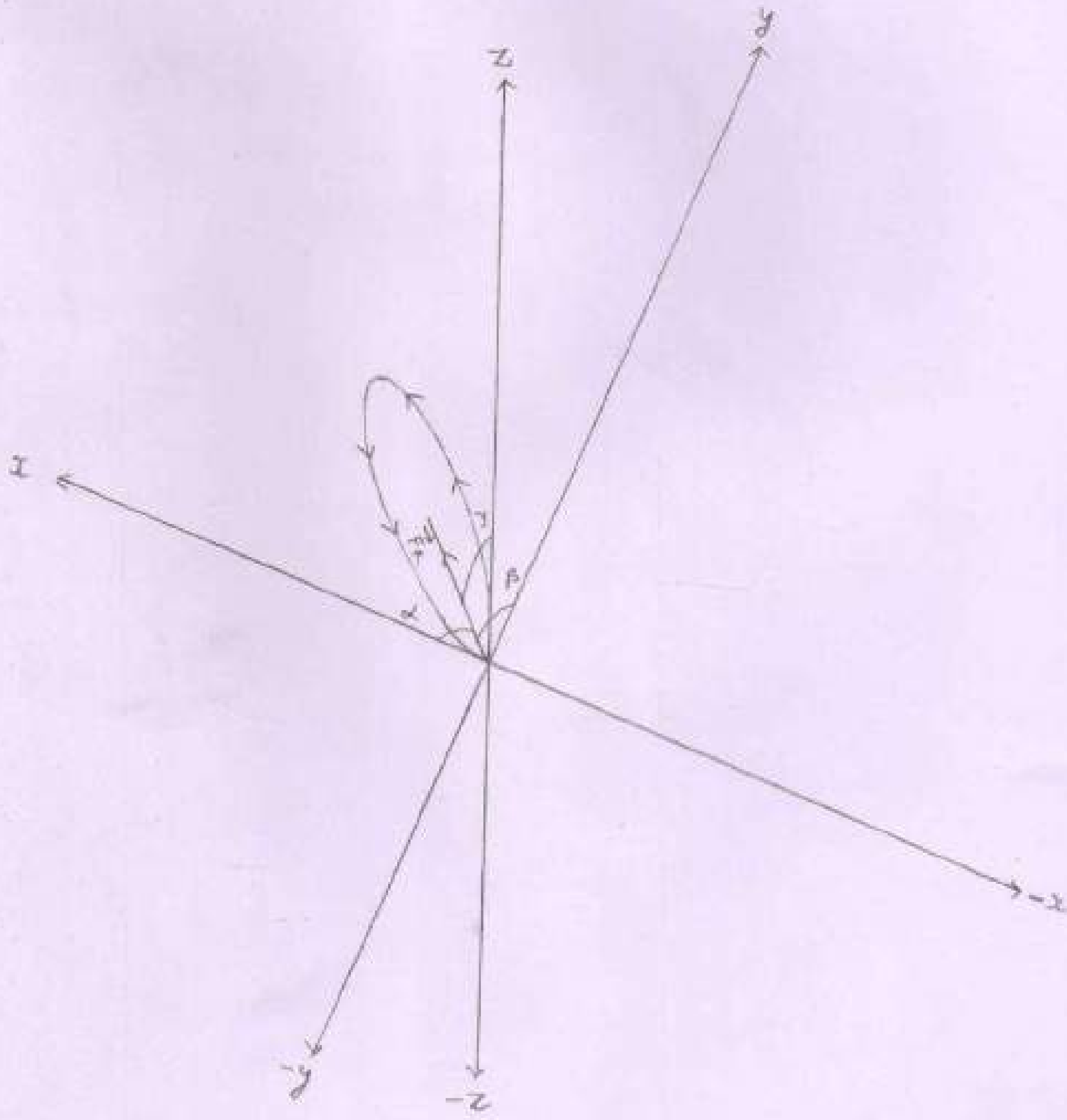
Angles that make the resultant force ($\vec{F}_R$) at point F with positive x, y and z axes.

⇒ Where,

$\alpha \simeq 83.6$ degree

$\beta \simeq 44.5$ degree

$\gamma \simeq 44.5$ degree



The Cartesian coordinates of the points $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$ located on the circumfrence of the circle to be followed by the left side propelled helium-4 nucleus :-

1. $\cos\alpha = \frac{x_2 - x_1}{d}$

$d = 2 \times r$

$d = 2 \times 45.3476 \times 10^{-2}\, m$

$d = 90.6952 \times 10^{-2}\, m$

$\cos\alpha = 0.11$

$\Rightarrow x_2 - x_1 = d \times \cos\alpha$

$\Rightarrow x_2 - x_1 = 90.6952 \times 10^{-2} \times 0.11\, m$

$\Rightarrow x_2 - x_1 = 9.9764 \times 10^{-2}\, m$

$\Rightarrow x_2 = 9.9764 \times 10^{-2}\, m \; [\because x_1 = 0]$

2. $\cos\beta = \frac{y_2 - y_1}{d}$

$\cos\beta = 0.70$

$\Rightarrow y_2 - y_1 = d \times \cos\beta$

$\Rightarrow y_2 - y_1 = 90.6952 \times 10^{-2} \times 0.70\, m$

$\Rightarrow y_2 - y_1 = 63.4866 \times 10^{-2}\, m$

$\Rightarrow y_2 = 63.4866 \times 10^{-2}\, m \; [\because y_1 = 0]$

3. $\cos\gamma = \frac{z_2 - z_1}{d}$

$\cos\gamma = 0.70$

$\Rightarrow z_2 - z_1 = d \times \cos\gamma$

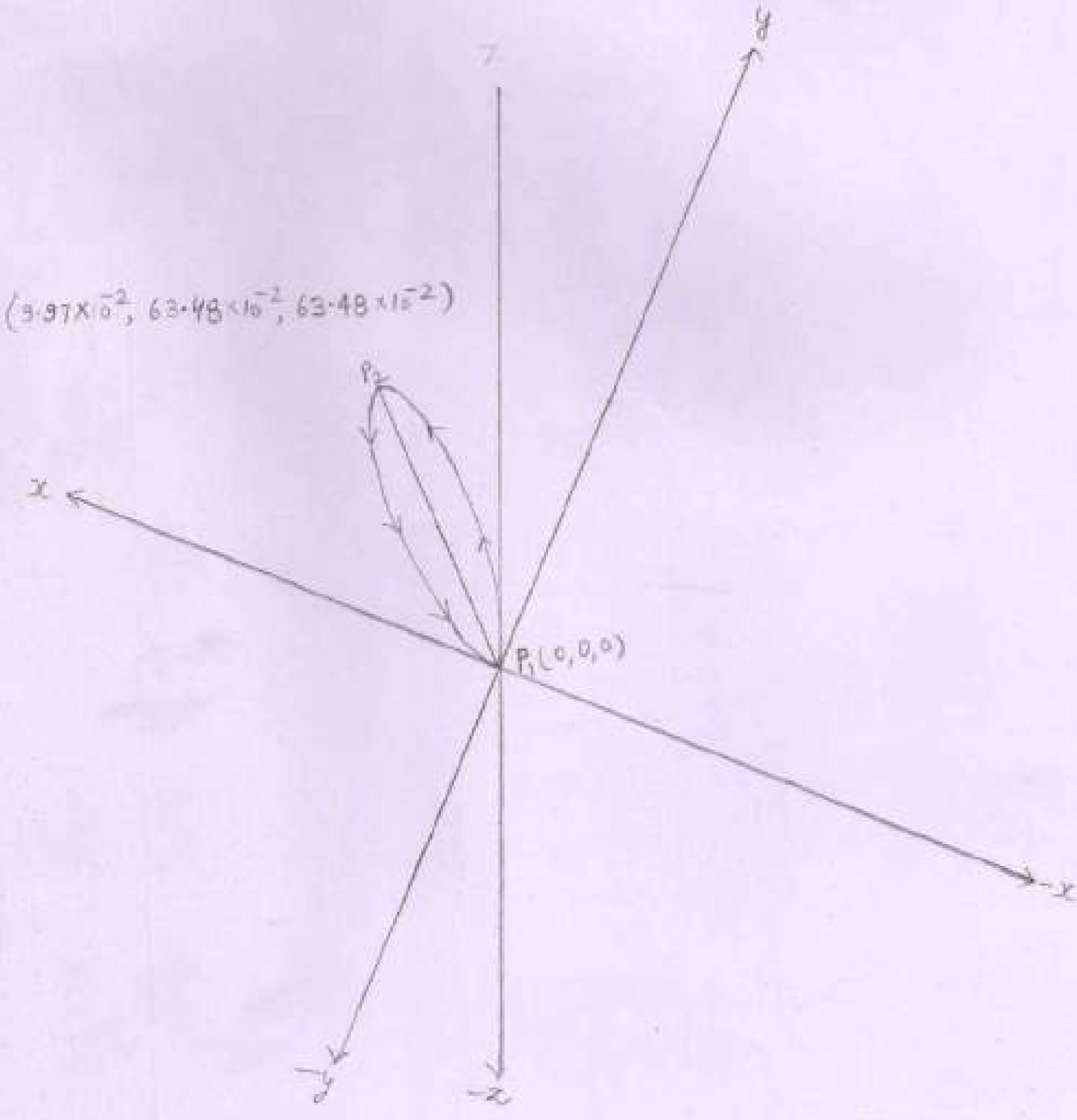
$\Rightarrow z_2 - z_1 = 90.6952 \times 10^{-2} \times 0.70\, m$

$\Rightarrow z_2 - z_1 = 63.4866 \times 10^{-2}\, m$

$\Rightarrow z_2 = 63.4866 \times 10^{-2}\, m \; [\because z_1 = 0]$

The cartesian coordinates of the points $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$ located on the circumfrence of the circle obtained by the left side propelled helion-4 are as shown below.

$\Rightarrow$ The line $\overline{P_1P_2}$ is the diameter of the circle.



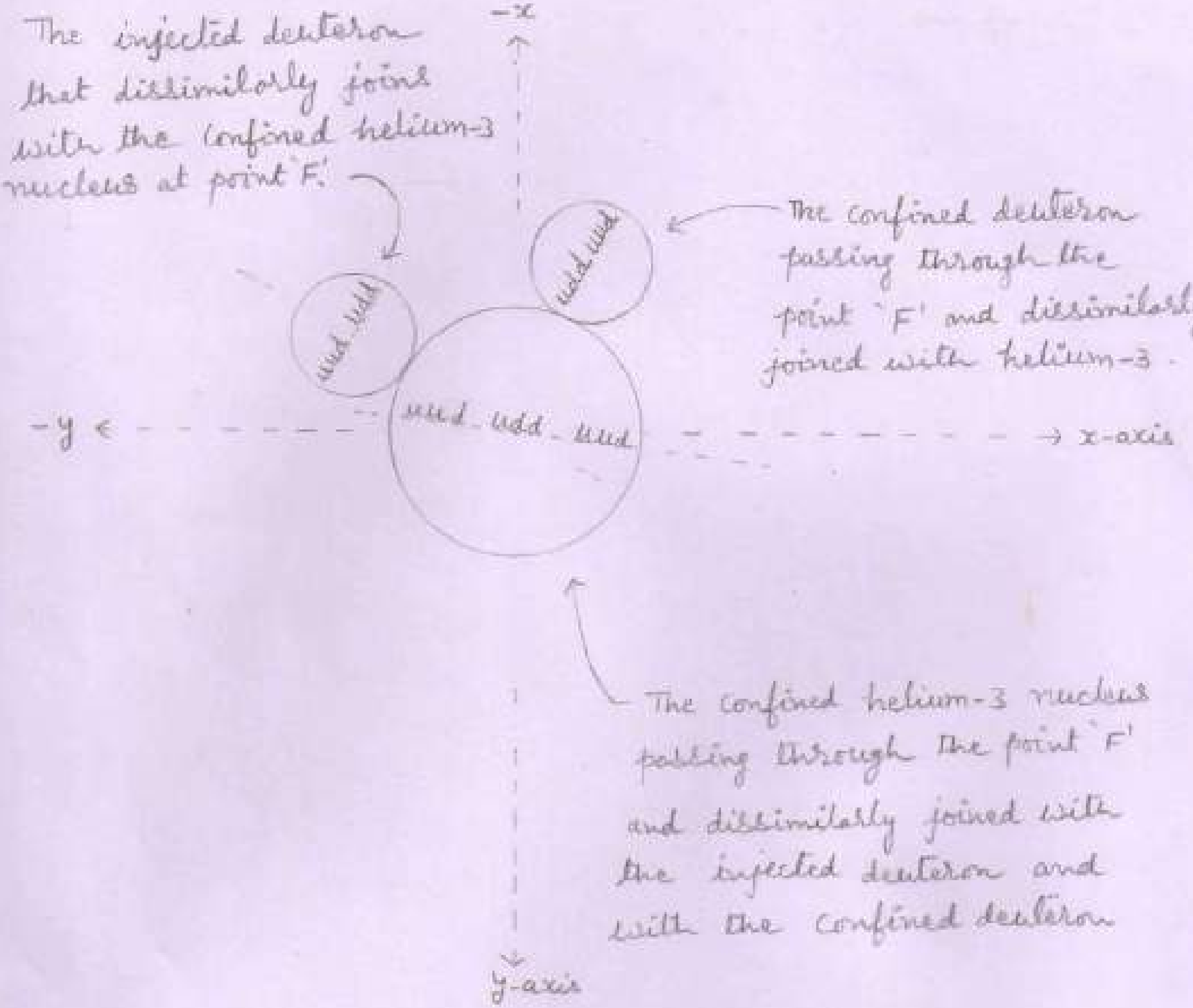
For fusion reaction (8) : ${}^{2}_{1}H + {}^{3}_{2}He + {}^{2}_{1}H \rightarrow {}^{7}_{4}Be + \gamma$ rays

1 Interaction of nuclei :-

As the injected deuteron reaches at point 'F', it interacts [experiences a repulsive force due to confined helium-3 nucleus and the confined deuteron passing through the point 'F'] with the confined helium-3 and the confined deuteron at point 'F'.

Similarly, as the confined deuteron reaches at point 'F', it interacts [experiences a repulsive force due to the injected deuteron reaching at point 'F' and the confined helium-3 nucleus passing through the point 'F'] with the injected deuteron reaching at point 'F' and the confined helium-3 nucleus passing through the point 'F'.

The injected deuteron and the confined deuteron overcomes the electrostatic repulsive force and thus all the three nuclei [the injected deuteron, the confined helium-3 nucleus and the confined deuteron] dissimilarly join with each other.

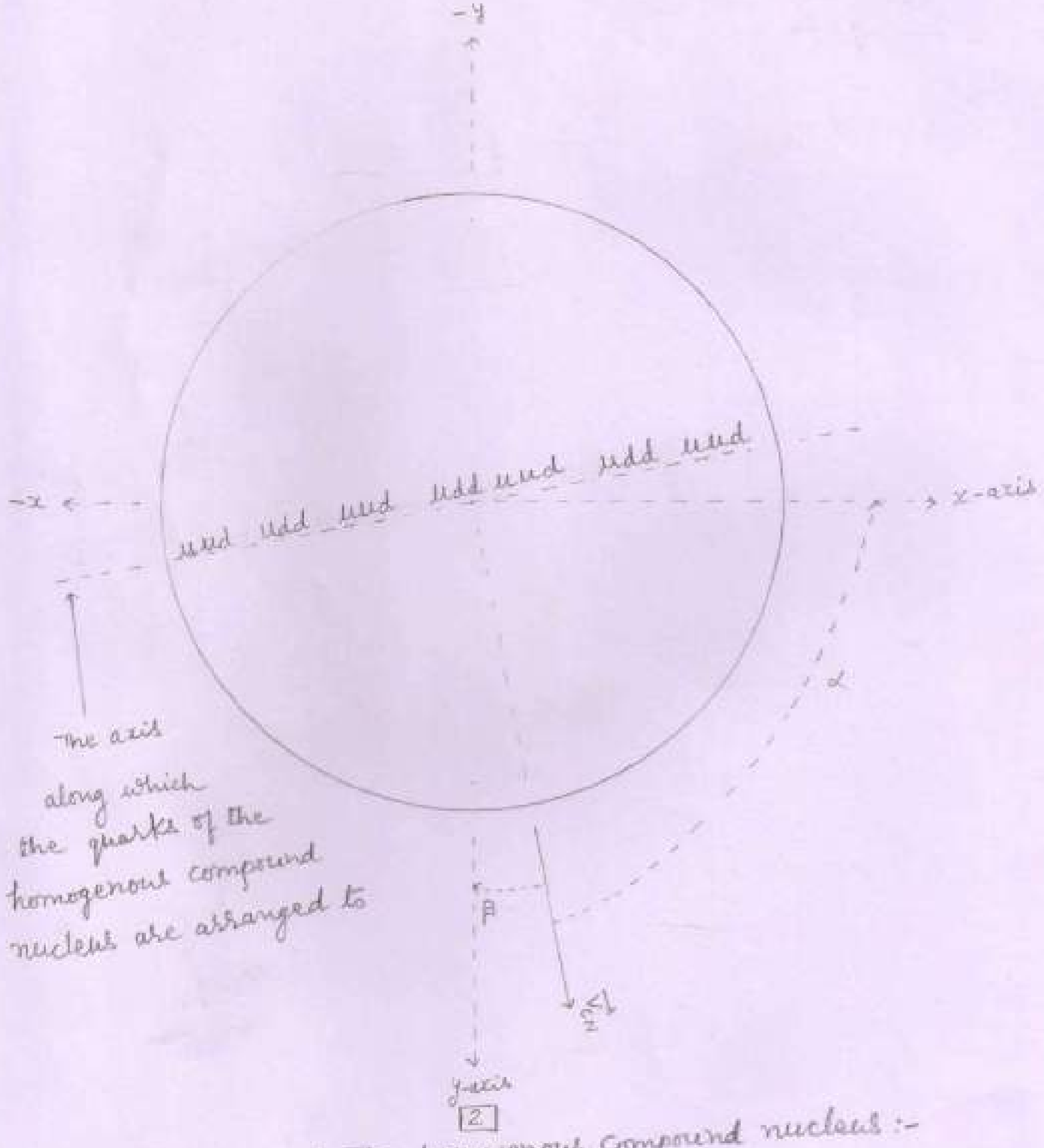


1

Interaction of nuclei

2. Formation of homogenous compound nucleus :-
The constituents (quarks and gluons) of the dissimilarly joined nuclei (the injected deuteron, the confined helium-3 nucleus and the confined deuteron) behave like a liquid and form the homogenous compound nucleus having similarly distributed groups of quarks with similarly distributed surrounding gluons.

Thus within the homogenous compound nucleus - each group of quarks is surrounded by the gluons in equal proportion. So, within the homogenous compound nucleus there are 7 groups of quarks surrounded by the gluons.



2

-: The homogenous compound nucleus :-

Where, $\alpha \simeq 79.4$ degree

$\beta \simeq 10.6$ degree

3. Formation of lobes within into the homogenous compound nucleus [$_{4}^{7}M$] or the transformation of the homogenous compound nucleus into the heterogenous compound nucleus :-

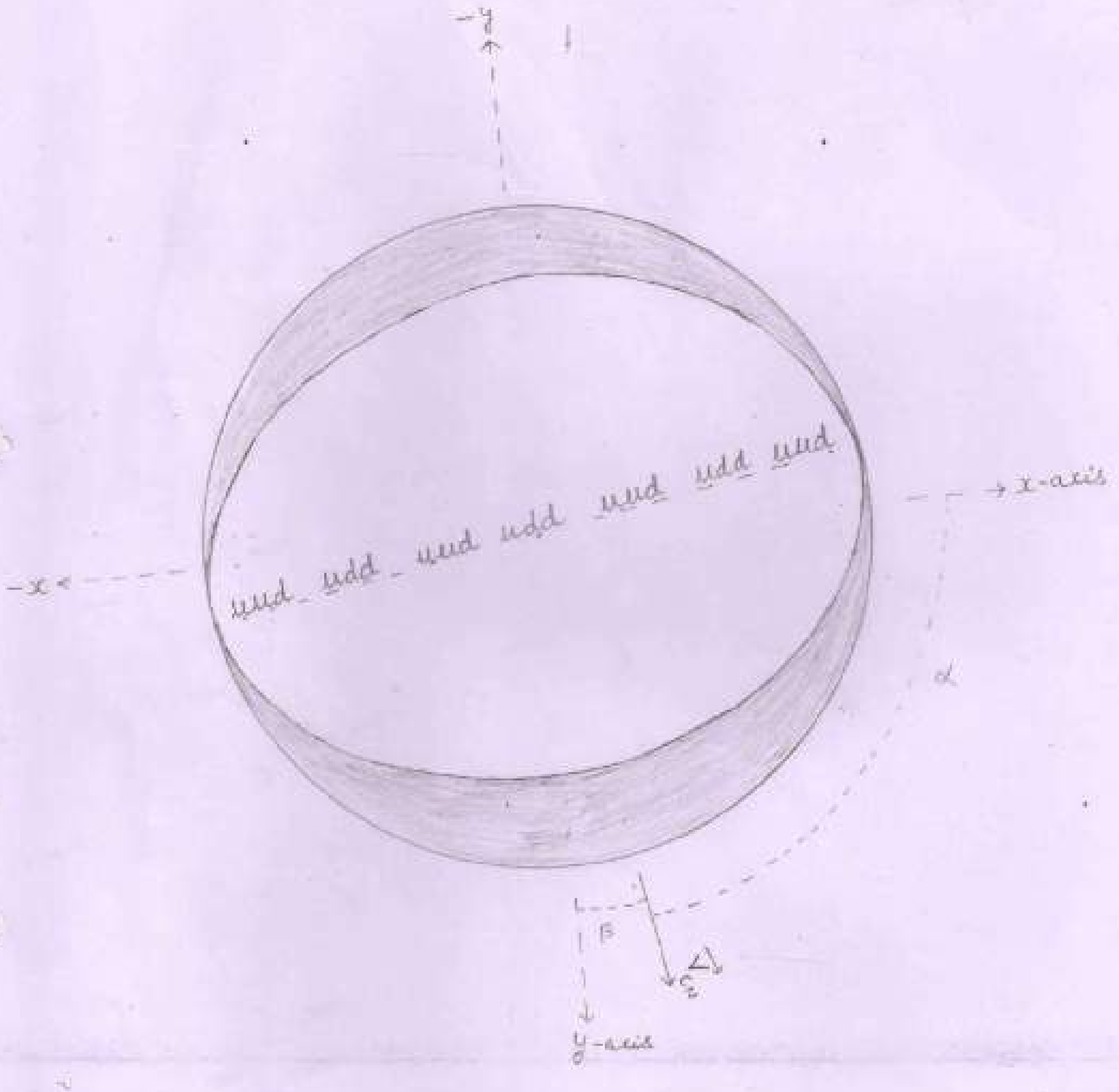
The homogenous compound nucleus [$_{4}^{7}M$] is unstable. So, for stability, the central group of quarks with its surrounding gluons to become a stable and the just lower nucleus (beryllium-7) than the homogenous one [$_{4}^{7}M$], includes the other 6 groups of quarks with their surrounding gluons and rearrange to form the 'A' lobe of the heterogenous compound nucleus.

While, the remaining gluons [the gluons (or the mass) that are not involved in the formation of the lobe 'A'] rearrange to form the 'B' lobe of the heterogenous compound nucleus.

Thus, due to formation of two lobes within into the homogenous compound nucleus, the homogenous compound nucleus transforms into the heterogenous compound nucleus.

* The homogenous compound nucleus [$_{4}^{7}M$] has more mass than the beryllium-7 nucleus.

The formation of lobes within into the homogenous compound nucleus :-

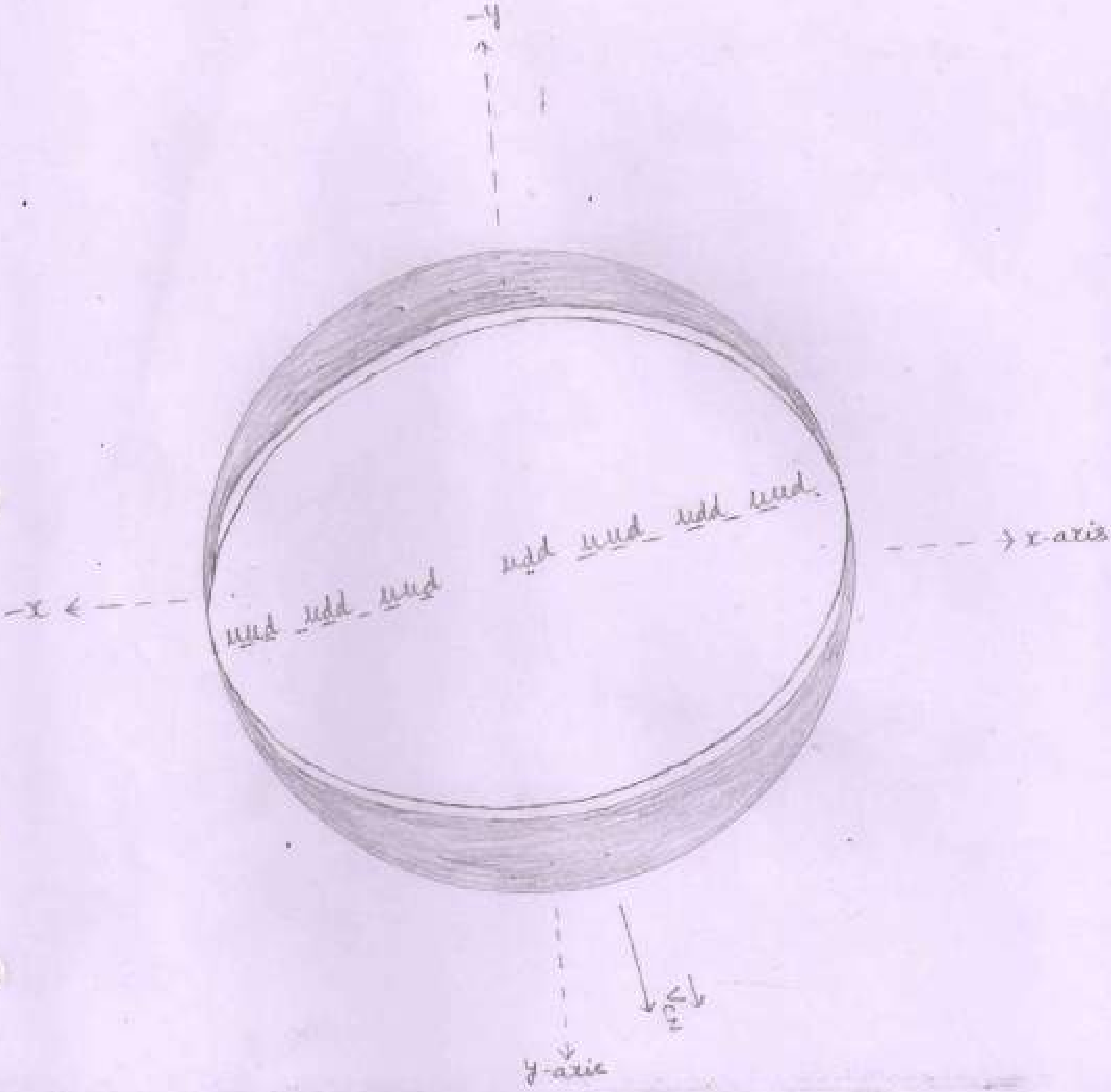


1. Where, $\alpha \simeq 79.4$ degree
   $\beta \simeq 10.6$ degree
2. Within into the compound nucleus, the inner one is the lobe 'A' while the outer one is the lobe 'B'
3. The lobe 'A' represents the beryllium-7 nucleus while the lobe 'B' represents the remaining gluons (or the reduced mass).

4. Final Stage of the heterogenous Compound nucleus :-

The Remaining gluons [that compose the 'B' lobe of the heterogenous compound nucleus] remains loosely bonded to the beryllium-7 nucleus [that compose the 'A' lobe of the heterogenous compound nucleus]. Thus, the heterogenous compound nucleus, finally, becomes like a coconut into which the outer shield is made up of remaining gluons while the inner part is made up of the beryllium-7 nucleus.

Final stage of the heterogenous compound nucleus :-



The fusion reaction is

$$^{2}_{1}H + ^{3}_{2}He + ^{2}_{1}H \longrightarrow ^{7}_{4}Be + \gamma \text{ rays}$$

[injected] [Confined]

1. The minimum kinetic energy required by the deuteron for the above described fusion reaction is -

$$E_m = E_{D-D} \times z_2^2$$

For fusion, a deuteron has to overcome the electrostatic repulsive force exerted by the other three positive charges. So,

$$z_2 = 3$$

$$E_{D-D} = 5.0622 \text{ kev}$$

$$\Rightarrow E_m = 5.0622 \text{ kev} \times (3)^2$$
$$= 5.0622 \times 9 \text{ kev}$$
$$= 45.5598 \text{ kev}$$

2. Kinetic energy of deuteron just before fusion :-

(i) Just before fusion, to overcome the electrostatic repulsive force, the deuteron has to loose energy equal to the minimum kinetic energy (E_m) required for fusion. That is just before fusion, the deuteron has to lose energy equal to 45.5598 kev.

(ii) So, just before fusion, the kinetic energy (E_b) of the deuteron is -

$$E_b = E_{injected} - E_{loss}$$

$$= [102.4] - [45.5598] \text{ kev}$$

$$= 56.8402 \text{ kev}$$

$$= 0.0568402 \text{ Mev}$$

3. Momentum (P_b) of the deuteron just before fusion :-

$$P_b = [2 m_d E_b]^{\frac{1}{2}}$$

$$E_b = 0.0568402 \text{ Mev}$$

$$\Rightarrow P_b = [2 \times 3.3434 \times 10^{-27} \times 0.0568402 \times 1.6 \times 10^{-13}]^{\frac{1}{2}} \text{ kg m/s}$$

$$\Rightarrow P_b = [0.60812647897 \times 10^{-40}]^{\frac{1}{2}} \text{ kg m/s}$$

$$\Rightarrow P_b = 0.7798 \times 10^{-20} \text{ kg m/s}$$

3. Just before fusion, the components of the momentum (P_b) of the deuteron (either it is injected or confined) :-

Either the deuteron is injected or confined, just before fusion, both reaches (or passes) with the same components of momentum ($\vec{P_b}$) at (or through) the point 'F' and fuse with each other and also with the helium-3 nucleus available (or passing through) at the point 'F'.

Now, the deuteron is injected making 30° angle with x-axis, 60° angle with y-axis and 90° angle with z-axis. So, the components of the momentum ($\vec{P_b}$) of the deuteron, just before fusion, are —

1. $\vec{P_x} = P_b \cos\alpha$

$\cos\alpha = \cos 30° = 0.866$

$\Rightarrow \vec{P_x} = 0.7798 \times 10^{-20} \times 0.866$ kgm/s
$= 0.6753 \times 10^{-20}$ kgm/s

2. $\vec{P_y} = P_b \cos\beta$

$\cos\beta = \cos 60° = 0.5$

$\Rightarrow \vec{P_y} = 0.7798 \times 10^{-20} \times 0.5$ kgm/s
$= 0.3899 \times 10^{-20}$ kgm/s

3. $\vec{P_z} = P_b \cos\gamma$

$\cos\gamma = \cos 90° = 0$

$\Rightarrow \vec{P_z} = 0.7798 \times 10^{-20} \times 0$ kgm/s
$= 0$ kgm/s

The components of the momentum of the Compound nucleus :-

According to	The components of the momentum of the injected deuteron, just before fusion.	The components of the momentum of the confined helium-3 nucleus	The components of the momentum of the confined deuteron, just before fusion.	The components of the momentum of the Compound nucleus
0	1	2	3	4 = 1+2+3
x-axis	$\vec{P}_x = 0.6753 \times 10^{-20}$ kg m/s	$\vec{P}_x = -0.4710 \times 10^{-20}$ kg m/s	$\vec{P}_x = 0.6753 \times 10^{-20}$ kg m/s	$\vec{P}_x = 0.8796 \times 10^{-20}$ kg m/s
y-axis	$\vec{P}_y = 0.3899 \times 10^{-20}$ kg m/s	$\vec{P}_y = 3.9094 \times 10^{-20}$ kg m/s	$\vec{P}_y = 0.3899 \times 10^{-20}$ kg m/s	$\vec{P}_y = 4.6892 \times 10^{-20}$ Kg m/s
z-axis	$\vec{P}_z = 0$ kg m/s	$\vec{P}_z = 0$ kg m/s	$\vec{P}_z = 0$ kg m/s	$\vec{P}_z = 0$ kg m/s

Mass of the Compound nucleus (M) :

$$M = [m_d + m_{he-3} + m_d]$$

$$M = [3.3434 \times 10^{-27} + 5.00629 \times 10^{-27} + 3.3434 \times 10^{-27}] \text{ kg}$$

$$M = 11.69309 \times 10^{-27} \text{ kg}$$

Components of the velocity of the compound nucleus ($\vec{V}_{CN}$) :-

1. $\vec{V}_x = V_{CN} \cos\alpha = \dfrac{\vec{P}_{CN} \cos\alpha}{M} = \dfrac{\vec{P}_x}{M}$

$\vec{P}_x = P_{CN} \cos\alpha = 0.8796 \times 10^{-20}$ kgm/s

$M = 11.69309 \times 10^{-27}$ kg

$\Rightarrow \vec{V}_x = V_{CN} \cos\alpha = \dfrac{0.8796 \times 10^{-20}}{11.69309 \times 10^{-27}} \dfrac{\text{kg m/s}}{\text{kg}}$

$\Rightarrow \vec{V}_x = V_{CN} \cos\alpha = 0.0752 \times 10^{7}$ m/s

2. $\vec{V}_y = V_{CN} \cos\beta = \dfrac{P_{CN} \cos\beta}{M} = \dfrac{\vec{P}_y}{M}$

$P_{CN} \cos\beta = \vec{P}_y = 4.6892 \times 10^{-20}$ kg m/s

$\Rightarrow \vec{V}_y = V_{CN} \cos\beta = \dfrac{4.6892 \times 10^{-20}}{11.69309 \times 10^{-27}} \dfrac{\text{kg m/s}}{\text{kg}}$

$\Rightarrow \vec{V}_y = V_{CN} \cos\beta = 0.4010 \times 10^{7}$ m/s

3. $\vec{V}_z = V_{CN} \cos\gamma = \dfrac{P_{CN} \cos\gamma}{M} = \dfrac{\vec{P}_z}{M}$

$\vec{P}_z = 0$ kgm/s

$\Rightarrow \vec{V}_z = V_{CN} \cos\gamma = \dfrac{0}{11.69309 \times 10^{-27}} \dfrac{\text{kg m/s}}{\text{kg}}$

$\Rightarrow \vec{V}_z = V_{CN} \cos\gamma = 0$ m/s

Velocity of the Compound nucleus (V_{CN}):

$$V_{CN}^2 = V_x^2 + V_y^2 + V_z^2$$

$$\vec{V}_x = V_{CN} \cos\alpha = 0.0752 \times 10^7 \text{ m/s}$$

$$\vec{V}_y = V_{CN} \cos\beta = 0.4010 \times 10^7 \text{ m/s}$$

$$\vec{V}_z = V_{CN} \cos\gamma = 0 \text{ m/s}$$

$$\Rightarrow V_{CN}^2 = (0.0752 \times 10^7)^2 + (0.4010 \times 10^7)^2 + (0)^2 \text{ m}^2/\text{s}^2$$

$$\Rightarrow V_{CN}^2 = (0.00565504 \times 10^{14}) + (0.160801 \times 10^{14}) + 0 \text{ m}^2/\text{s}^2$$

$$\Rightarrow V_{CN}^2 = 0.16645604 \times 10^{14} \text{ m}^2/\text{s}^2$$

$$\Rightarrow V_{CN} = 0.4079 \times 10^7 \text{ m/s}$$

Angles that make the velocity of the compound nucleus ($\vec{V}_{CN}$) with positive x, y and z-axes at point 'F'.

1. With x-axis

$$\cos\alpha = \frac{V_{CN}\cos\alpha}{V_{CN}} = \frac{\vec{V}_x}{V_{CN}}$$

$$\vec{V}_x = V_{CN}\cos\alpha = 0.0752 \times 10^7 \text{ m/s}$$

$$V_{CN} = 0.4079 \times 10^7 \text{ m/s}$$

$$\Rightarrow \cos\alpha = \frac{0.0752 \times 10^7}{0.4079 \times 10^7} \frac{\text{m/s}}{\text{m/s}} = 0.1843$$

$$\Rightarrow \alpha \simeq 79.4 \text{ degree} \quad [\because \cos(79.4) = 0.1839]$$

2. With y-axis

$$\cos\beta = \frac{V_{CN}\cos\beta}{V_{CN}} = \frac{\vec{V}_y}{V_{CN}}$$

$$\vec{V}_y = V_{CN}\cos\beta = 0.4010 \times 10^7 \text{ m/s}$$

$$\Rightarrow \cos\beta = \frac{0.4010 \times 10^7}{0.4079 \times 10^7} \frac{\text{m/s}}{\text{m/s}} = 0.9830$$

$$\Rightarrow \beta \simeq 10.6 \text{ degree} \quad [\because \cos(10.6) = 0.9829]$$

3. With z-axis

$$\cos\gamma = \frac{V_{CN}\cos\gamma}{V_{CN}} = \frac{\vec{V}_z}{V_{CN}}$$

$$\vec{V}_z = 0 \text{ m/s}$$

$$\Rightarrow \cos\gamma = \frac{0}{0.4079 \times 10^7} \frac{\text{m/s}}{\text{m/s}} = 0$$

The splitting of the heterogenous compound nucleus :-

⇒ The remaining gluons are loosely bonded to the beryllium-7 nucleus.

⇒ At the poles of the beryllium-7 nucleus, the remaining gluons are lesser in amount than at the equator.

⇒ So, during the rearrangement of the remaining gluons [or during the formation of the 'B' lobe of the heterogenous compound nucleus], the remaining gluons to be homogenously distributed all around, rush from the equator to the poles.

In this way, the loosely bonded remaining gluons separates from the beryllium-7 nucleus and also divides itself into two parts giving us three particles - the first one is the one-half of the reduced mass, second one is the beryllium-7 nucleus and the third one is the another one-half of the reduced mass.

⇒ Thus, the heterogenous compound nucleus, splits according to the lines parallel to the velocity of the compound nucleus into three particles – the first one is the one-half of the reduced mass ($\frac{\Delta m}{2}$), the second one is the beryllium-7 nucleus and the third one is the another one-half of the reduced mass ($\frac{\Delta m}{2}$).

⇒ By the law of inertia, each particle that has separated from the compound nucleus has an inhereted velocity ($\vec{V}_{inh}$) equal to the velocity of the compound nucleus ($\vec{V}_{CN}$).

⇒ So, for conservation of momentum

$$M\vec{V}_{CN} = \left(\frac{\Delta m}{2} + m_{Be-7} + \frac{\Delta m}{2}\right)\vec{V}_{CN}$$

Where,

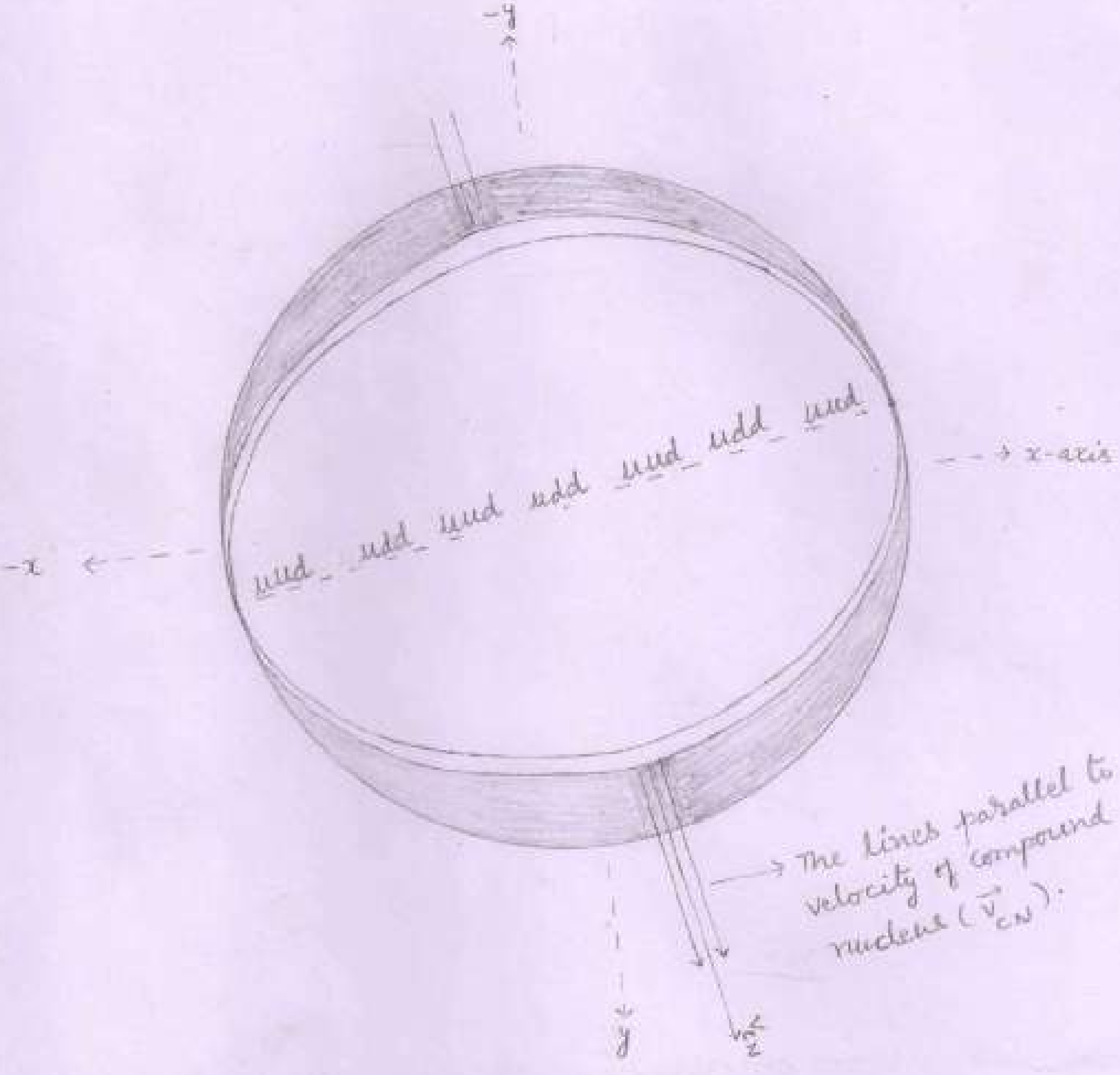
M = Mass of the compound nucleus

$\vec{V}_{CN}$ = Velocity of the compound nucleus

$\frac{\Delta m}{2}$ = A particle having a mass equal to one-half of the reduced mass.

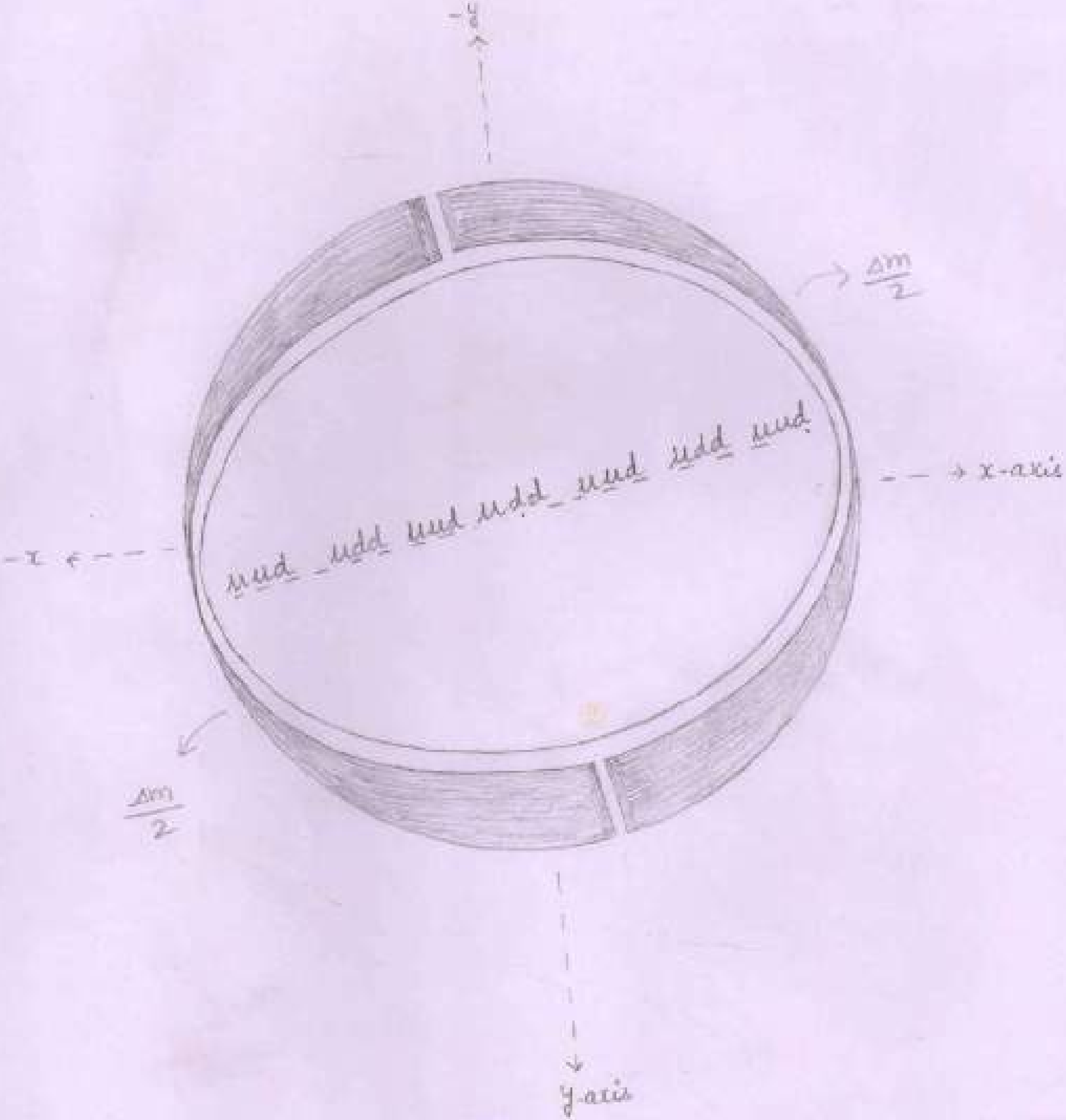
m_{Be-7} = Mass of the beryllium-7 nucleus

The Splitting of the heterogenous compound nucleus :-



Sp - 1

The splitting of the heterogenous compound nucleus :-



$\boxed{\text{Sp-2}}$

⇒ The heterogenous compound nucleus splits into three particles – (i) $\frac{\Delta m}{2}$ (ii) ${}^{7}_{4}Be$ (iii) $\frac{\Delta m}{2}$

Inhereted velocity ($\vec{V}_{inh}$) of the particles :-

Each particle that has separated from the compound nucleus has an inhereted velocity ($\vec{V}_{inh}$) equal to the velocity of the compound nucleus ($\vec{V}_{CN}$).

I. For the beryllium-7 nucleus

$$\vec{V}_{inh} = \vec{V}_{CN} = 0.4079 \times 10^{7} \text{ m/s}$$

Components of the inhereted velocity of the beryllium-7

1. $\vec{V}_x = V_{inh} \cos\alpha = V_{CN} \cos\alpha = 0.0752 \times 10^{7}$ m/s

2. $\vec{V}_y = V_{inh} \cos\beta = V_{CN} \cos\beta = 0.4010 \times 10^{7}$ m/s

3. $\vec{V}_z = V_{inh} \cos\gamma = V_{CN} \cos\gamma = 0$ m/s

II. For the one-half of the reduced mass ($\frac{\Delta m}{2}$) :-

$$\vec{V}_{inh} = \vec{V}_{CN} = 0.4079 \times 10^{7} \text{ m/s}$$

III. For the another one-half of the reduced mass ($\frac{\Delta m}{2}$)

$$\vec{V}_{inh} = \vec{V}_{CN} = 0.4079 \times 10^{7} \text{ m/s}$$

Propellation of the particle

1. Reduced mass (Δm) :

$$\Delta m = [m_d + m_{he-3} + m_d] - [m_{be-7}]$$

$$\Rightarrow \Delta m = [2.01355 + 3.014932 + 2.01355] - [7.01692]\ \text{amu}$$

$$\Rightarrow \Delta m = [7.042032] - [7.01692]\ \text{amu}$$

$$\Rightarrow \Delta m = 0.025112\ \text{amu}$$

$$\Rightarrow \Delta m = 0.025112 \times 1.6605 \times 10^{-27}\ \text{kg}$$

$$\Rightarrow \Delta m = 0.041698476 \times 10^{-27}\ \text{kg}$$

2. Inhereted kinetic energy (E_{inh}) of each one-half of the reduced mass ($\frac{\Delta m}{2}$) :-

$$E_{inh} = \frac{1}{2}\frac{\Delta m}{2} V_{inh}^2 = \frac{1}{2}\frac{\Delta m}{2} V_{CN}^2$$

3. Inhereted kinetic energy of the reduced mass (Δm):-

$$\Rightarrow E_{inh} = \frac{1}{2}\Delta m V_{inh}^2 = \frac{1}{2}\Delta m V_{CN}^2$$

$$V_{inh}^2 = V_{CN}^2 = 0.16645604 \times 10^{14}\ m^2/s^2$$

$$\Rightarrow E_{inh} = \frac{1}{2} \times 0.041698476 \times 10^{-27} \times 0.16645604 \times 10^{14}\ J$$

$$= 0.0034704815 9 \times 10^{-13}\ J$$

$$= 0.002169\ \text{Mev}$$

3. Released energy (E_R) :-

$E_R = \Delta m c^2$

$\Delta m = 0.025112$ amu

1 amu $= 931$ Mev

$\Rightarrow E_R = 0.025112 \times 931$ Mev

$= 23.379272$ Mev

4. Total energy (E_T) :-

$E_T = E_{Inhereted} + E_{Released}$

$\Rightarrow E_T = [0.002169] + [23.379272]$ Mev

$\Rightarrow E_T = 23.381441$ Mev

Propellation of the particle

⇒ The each one-half of the reduced mass ($sm/2$) converts into energy. So, the energy (E) carried by the produced pairs of gamma ray photons is –

$$E = \frac{E_T}{2}$$

$$E_T = 23.381441 \text{ MeV}$$

$$\Rightarrow E = \frac{23.381441}{2} \text{ MeV}$$

$$\Rightarrow E = 11.6907 \text{ MeV}$$

Number of pairs of gamma ray photons (N_γ) :-

⇒ When one-half of the reduced mass ($\Delta m/2$) converts into energy, the energy (E) carried by the pairs of gamma ray photons is 11.6907 Mev.

⇒ Each pair of gamma ray photon that carry a part of the energy (E) must have an energy equal to or more than 1.02 Mev.

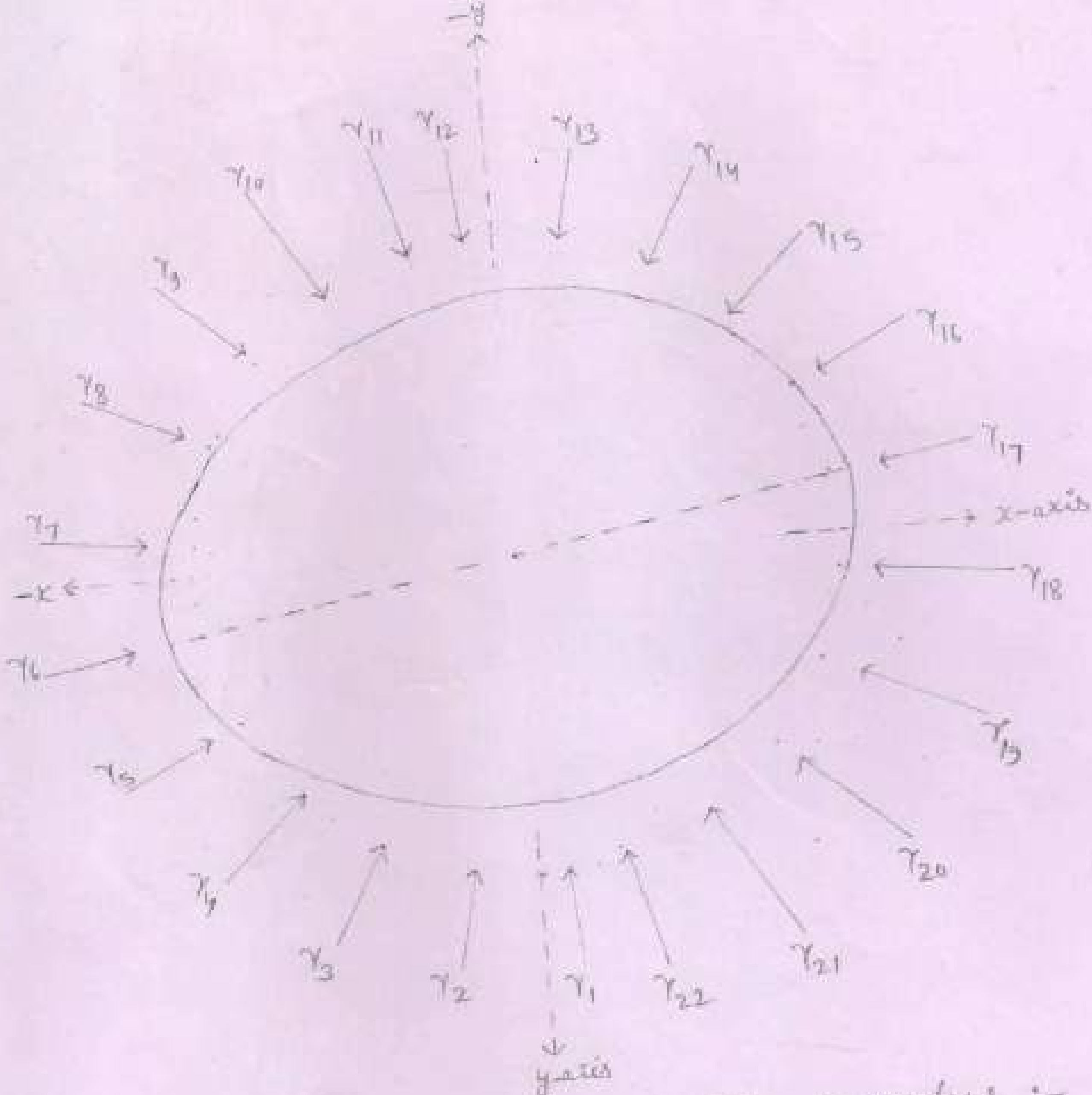
⇒ So,

$$\text{Number of pairs of gamma ray photons} = \frac{\text{Energy (E) produced due to } \Delta m/2}{\text{Energy that must carried by a pair of g.r. photon}}$$

$$\Rightarrow N_\gamma = \frac{11.6907 \text{ Mev}}{1.02 \text{ Mev}} = 11.4614$$

⇒ Taking the whole digit, we may say that there are the 11 pairs of gamma ray photons that carry the energy 11.6907 Mev

⇒ Thus, there are the 22 pairs of gamma ray photons that carry the total energy (E_T) equal to 23.381441 Mev.



— : Propellation of the beryllium-7 nucleus :-

⇒ Each gamma ray photon make a head-on collision with the beryllium-7 nucleus.

⇒ Each pair of gamma ray photon carry 1.0627 MeV energy

Page No.:
Date: / /

Energy carried by the each pair of gamma ray photon [E_γ]

⇒ Energy carried by the each pair of gamma ray photon is equal to the energy (E) produced due to the one-half of the reduced mass ($\Delta m/2$) divided by the total number of pairs of gamma ray photons that carry the energy (E).

$$\Rightarrow E_\gamma =$$

$$\Rightarrow E_\gamma = \frac{\text{Energy (E) produced due to } \Delta m/2}{\text{Total number of pairs of g.r. photons that carry energy (E)}}$$

$$\Rightarrow E_\gamma = \frac{E_T/2}{N_\gamma}$$

$$\Rightarrow E_\gamma = \frac{11.6907}{11} \text{ Mev}$$

$$\Rightarrow E_\gamma = 1.0627 \text{ Mev}$$

Conclusion : Each pair of gamma ray photon carry 1.0627 Mev.

Page No.:
Date : / /

Increased energy (E_{inc}) of the beryllium-7 nucleus :-

⇒ Each pair of gamma ray photon carry 1.0627 MeV energy.

⇒ Each pair of gamma ray photon by making a head-on collision with the beryllium-7 nucleus imparts its extra energy to the beryllium-7 nucleus.

⇒ Extra energy of the each pair of gamma ray photon is equal to the energy (E_γ) carried by a pair of gamma ray photon minus 1.02 MeV.

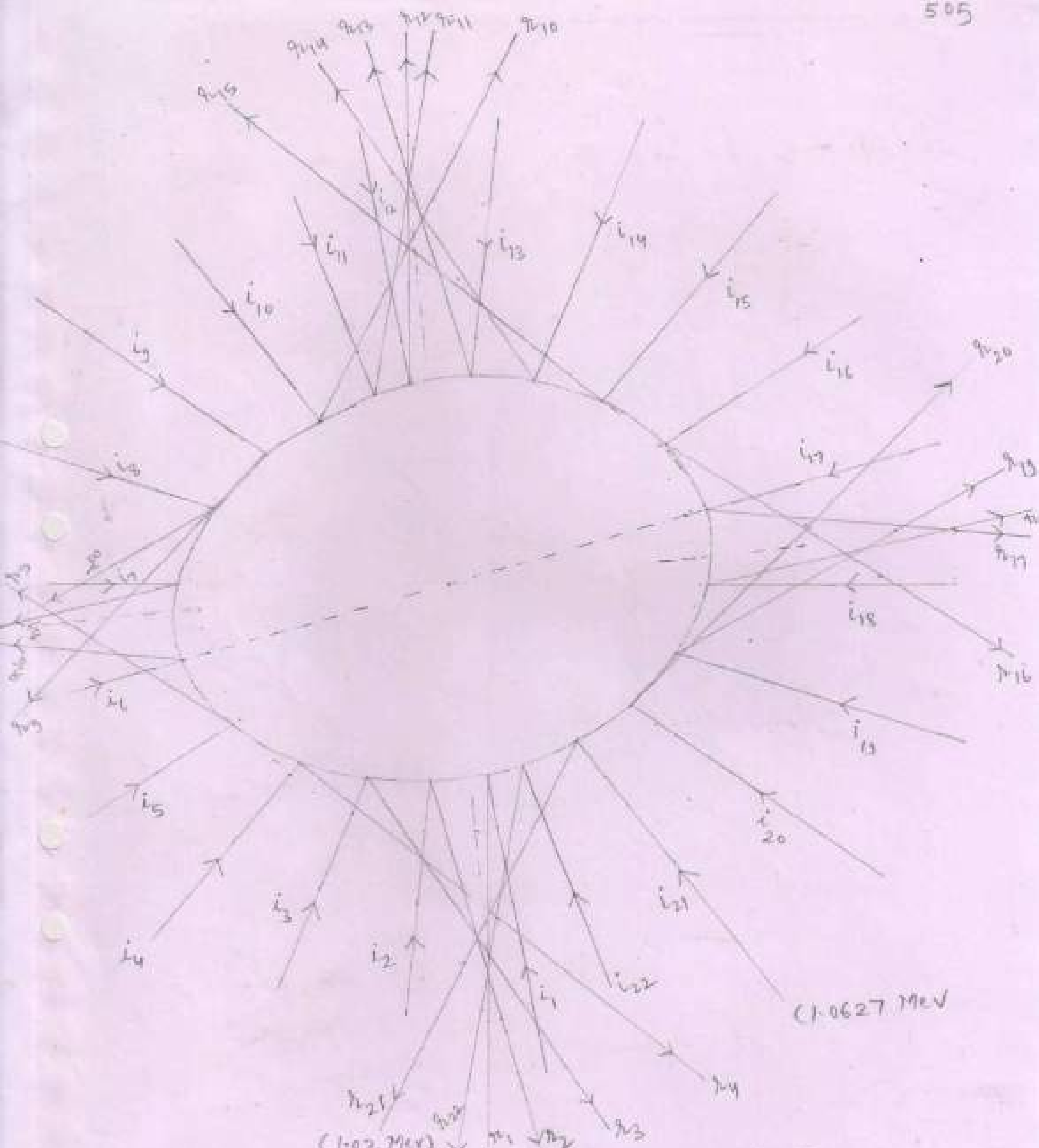
$$E_{extra} = E_\gamma - [m_{e^+}c^2 + m_{e^-}c^2]$$

$$\Rightarrow E_{extra} = 1.0627 - [1.02] \text{ MeV}$$
$$= 0.0427 \text{ MeV}$$

⇒ So, when 22 pairs of gamma ray photons strike to the beryllium-7 nucleus, the increased energy (E_{inc}) of the beryllium-7 nucleus is -

$$E_{inc} = E_{\text{Imparted by a pair of g.r. photon}} \times 22$$

$$\Rightarrow E_{inc} = 0.0427 \text{ MeV} \times 22$$
$$= 0.9394 \text{ MeV}$$



⇒ All the 22 pairs of gamma ray photons strike to the beryllium-7 nucleus and energise it by the 0.9394 MeV energy

⇒ The angle of reflection of each pair of gamma ray photon is equal to the angle of incidence of that pair of gamma ray photon.

⇒ Each pair of gamma ray photon imparts its extra energy to the beryllium-7.

Increased velocity (V_{inc}) of the beryllium-7 nucleus :-

$$V_{inc} = \left[\frac{2E_{inc}}{m_{be-7}} \right]^{\frac{1}{2}}$$

$E_{inc} = 0.9394 \times$

$m_{be-7} = 11.6515 \times 10^{-27}$ Kg

$$V_{inc} = \left[\frac{2 \times 0.9394 \times 1.6 \times 10^{-13}}{11.6515 \times 10^{-27}} \right]^{\frac{1}{2}} \text{ m/s}$$

$$V_{inc} = \left[\frac{3.00608 \quad \times 10^{14}}{11.6515} \right]^{\frac{1}{2}} \text{ m/s}$$

$$V_{inc} = \left[0.257999399 21 \times 10^{14} \right]^{\frac{1}{2}} \text{ m/s}$$

$$V_{inc} = 0.5079 \times 10^{7} \text{ m/s}$$

Components of the increased velocity (V_{inc}) of the beryllium-7 nucleus :-

1. We know that the beryllium-7 nucleus has separated from the compound nucleus with an inhereted velocity (V_{inh}) equal to the velocity of the compound nucleus ($\vec{V}_{CN}$). So, the inhereted velocity of the beryllium-7 makes angle 79.4 degree with x-axis, 10.6 degree angle with y-axis and 90° angle with z-axis.
2. The beryllium-7 nucleus and the gamma ray photons are produced at point 'F'. The gamma ray photons that are produced with the beryllium-7, heats the beryllium-7 and increase its energy by 0.9394 MeV.
3. So, we may say that the beryllium-7 nucleus that has a velocity that makes angle 79.4 degree with x-axis, 10.6 degree angle with y-axis and 90° with z-axis is again excited by 0.9394 MeV energy due to head-on collision between the gamma ray photon(s) and the beryllium-7 nucleus.
4. So, the increased velocity ($\vec{V}_{inc}$) of the beryllium-7 nucleus also makes 79.4 degree angle with the x-axis, 10.6 degree angle with y-axis and 90° angle with z-axis.

So, the components of the increased velocity ($\vec{V}_{inc}$) of the beryllium-7 nucleus are —

(i) $\vec{v}_x = v_{inc} \cos\alpha$

$v_{inc} = 0.5079 \times 10^7$ m/s

$\cos\alpha = \cos(79.4) = 0.18$

$\Rightarrow c\ \vec{v}_x = 0.5079 \times 10^7 \times 0.18$ m/s

$= 0.0914 \times 10^7$ m/s

(ii) $\vec{v}_y = v_{inc} \cos\beta$

$\cos\beta = \cos(10.6) = 0.98$

$\Rightarrow \vec{v}_y = 0.5079 \times 10^7 \times 0.98$ m/s

$= 0.4977 \times 10^7$ m/s

(iii) $\vec{v}_z = v_{inc} \cos\gamma$

$\cos\gamma = \cos 90^\circ = 0$

$\Rightarrow \vec{v}_z = 0.5079 \times 10^7 \times 0$ m/s

$=$

$\Rightarrow \vec{v}_z = 0$ m/s

Final velocity ($\vec{V}_f$) of the beryllium-7 nucleus

According to	Inhereted velocity ($\vec{V}_{inh}$)	Increased velocity ($\vec{V}_{inc}$)	Final velocity ($\vec{V}_f$) $\vec{V}_f = \vec{V}_{inh} + \vec{V}_{inc}$
x-axis	$\vec{V}_x = 0.0752 \times 10^7$ m/s	$\vec{V}_x = 0.0914 \times 10^7$ m/s	$\vec{V}_x = 0.1666 \times 10^7$ m/s
y-axis	$\vec{V}_y = 0.4010 \times 10^7$ m/s	$\vec{V}_y = 0.4977 \times 10^7$ m/s	$\vec{V}_y = 0.8987 \times 10^7$ m/s
z-axis	$\vec{V}_z = 0$ m/s	$\vec{V}_z = 0$ m/s	$\vec{V}_z = 0$ m/s

Final velocity (v_f) of the beryllium-7

$$v_f^2 = v_x^2 + v_y^2 + v_z^2$$

$v_x = 0.1666 \times 10^7$ m/s
$v_y = 0.8987 \times 10^7$ m/s
$v_z = 0$ m/s

$$\Rightarrow v_f^2 = (0.1666 \times 10^7)^2 + (0.8987 \times 10^7)^2 + (0)^2 \quad m^2/s^2$$

$$\Rightarrow v_f^2 = (0.02775556 \times 10^{14}) + (0.80766169 \times 10^{14}) + (0) \quad m^2/s^2$$

$$\Rightarrow v_f^2 = 0.83541725 \times 10^{14} \quad m^2/s^2$$

$$\Rightarrow v_f = 0.9140 \times 10^7 \quad m/s$$

Final kinetic energy of the beryllium-7

$$E = \frac{1}{2} m_{Be-7} \times v_f^2$$

$v_f^2 = 0.83541725 \times 10^{14}$ m^2/s^2

$$\Rightarrow E = \frac{1}{2} \times 11.6515 \times 10^{-27} \times 0.83541725 \times 10^{14} \quad J$$

$$= 4.866932044\,18 \times 10^{-13} \quad J$$

$$= 3.0418 \quad MeV$$

$$\Rightarrow m_{Be-7} v_f^2 = 11.6515 \times 10^{-27} \times 0.83541725 \times 10^{14} \quad J$$

$$= 9.7338 \times 10^{-13} \quad J$$

Forces acting on the beryllium-7 nucleus :-

1. $F_y = q V_x B_z \sin\theta$

$\vec{V}_x = 0.1666 \times 10^{7}$ m/s

$\vec{B}_z = -1$ Tesla

$q = 4 \times 1.6 \times 10^{-19}$ C

$\sin\theta = \sin 90^\circ = 1$

$\Rightarrow F_y = 4 \times 1.6 \times 10^{-19} \times 0.1666 \times 10^{7} \times 1 \times 1$ N

$= 1.0662 \times 10^{-12}$ N

From the right hand palm rule, the direction of force $\vec{F}_y$ is according to negative y-axis. So,

$\vec{F}_y = -1.0662 \times 10^{-12}$ N

2. $F_z = q V_x B_y \sin\theta$

$\vec{B}_y = 1$ Tesla

$\sin\theta = \sin 90^\circ = 1$

$\Rightarrow F_z = 4 \times 1.6 \times 10^{-19} \times 0.1666 \times 10^{7} \times 1 \times 1$ N

$= 1.0662 \times 10^{-12}$ N

From the right hand palm rule, the direction of force $\vec{F}_z$ is according to negative z-axis. So,

$\vec{F}_z = -1.0662 \times 10^{-12}$ N

3. $F_x = q V_y B_z \sin\theta$

$\vec{V}_y = 0.8987 \times 10^{7}$ m/s

$\sin\theta = \sin 90^\circ = 1$

$\Rightarrow F_x = 4 \times 1.6 \times 10^{-19} \times 0.8987 \times 10^{7} \times 1 \times 1$ N

$= 5.7516 \times 10^{-12}$ N

From the right hand palm rule, the direction of force $\vec{F}_x$ is according to ~~negaliv~~ positive x-axis. So,

$\vec{F}_x = 5.7516 \times 10^{-12}$ N

4. Resultant force (F_R) acting on the beryllium-7 :-

$$F_R^2 = F_x^2 + F_y^2 + F_z^2$$

$$F_x = 5.7516 \times 10^{-12} \text{ N}$$

$$F = F_y = F_z = 1.0662 \times 10^{-12} \text{ N}$$

$$\Rightarrow F_R^2 = F_x^2 + 2F^2$$

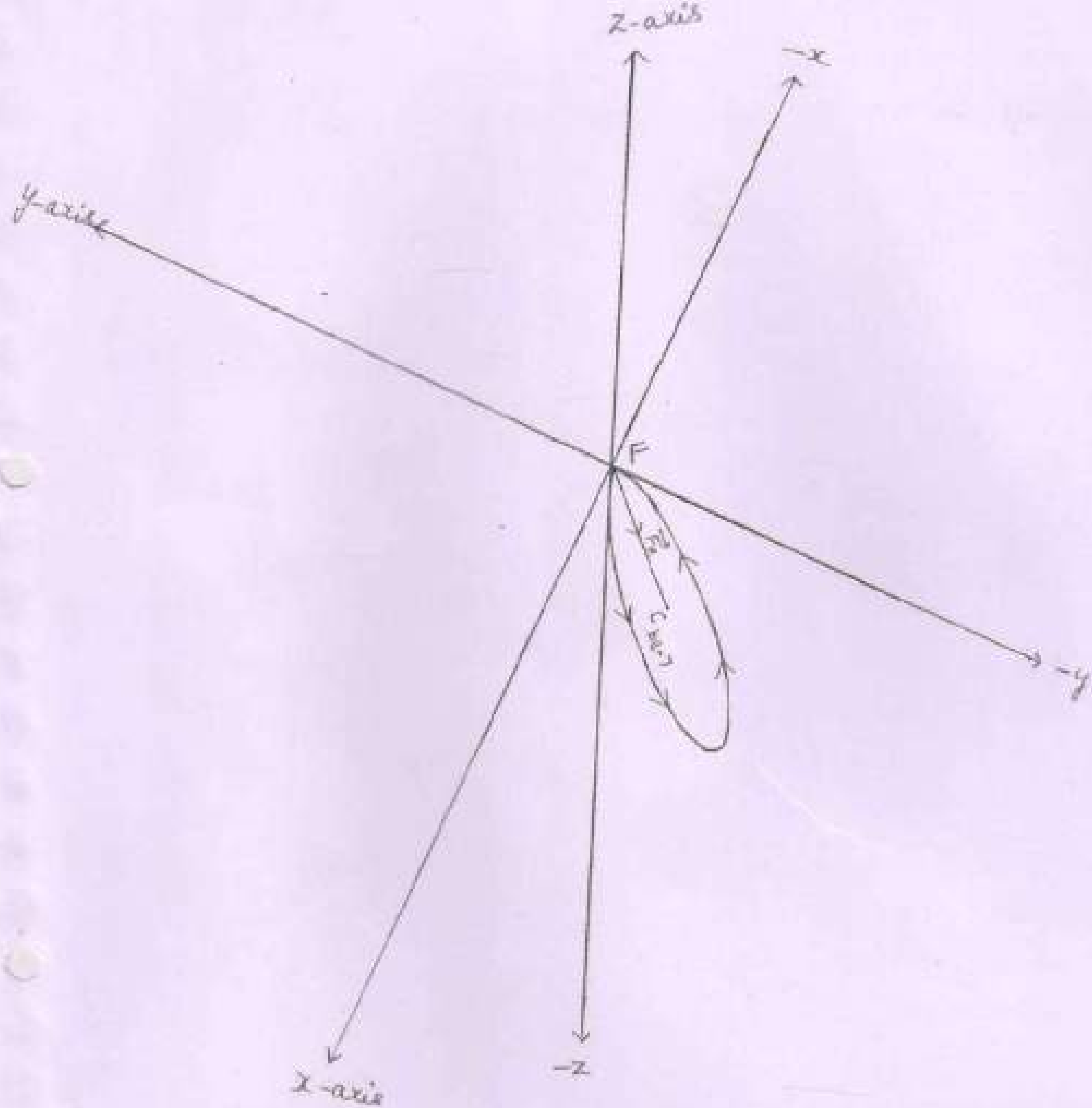
$$\Rightarrow F_R^2 = (5.7516 \times 10^{-12})^2 + 2(1.0662 \times 10^{-12})^2 \text{ N}^2$$

$$\Rightarrow F_R^2 = (33.08090256 \times 10^{-24}) + 2(1.13678244 \times 10^{-24}) \text{ N}^2$$

$$\Rightarrow F_R^2 = (33.08090256 \times 10^{-24}) + (2.27356488 \times 10^{-24}) \text{ N}^2$$

$$\Rightarrow F_R^2 = 35.35446744 \times 10^{-24} \text{ N}^2$$

$$\Rightarrow F_R^2 = 5.9459 \times 10^{-12} \text{ N}$$



⇒ The circular orbit to be followed by the beryllium-7 nucleus lies in the plane made up of positive x-axis, negative y-axis and the negative z-axis.

⇒ C_{Be-7} = center of the circular orbit to be followed by the beryllium-7 nucleus

⇒ $\vec{F}_R$ = The resultant force ($\vec{F}_R$) acting on the Be-7 when the Be-7 is at point 'F'.

Radius of the circular orbit to be followed by the beryllium-7 nucleus :-

$$r = \frac{mv^2}{F_R}$$

$$mv^2 = 9.7338 \times 10^{-13} \text{ J}$$
$$F_R = 5.9459 \times 10^{-12} \text{ N}$$

$$\Rightarrow r = \frac{9.7338 \times 10^{-13}}{5.9459 \times 10^{-12}} \quad \frac{J}{N}$$

$$\Rightarrow r = 1.63706 \times 10^{-1} \quad m$$
$$\Rightarrow r = 16.3706 \times 10^{-2} \quad m$$

Page No.:
Date: / /

Angles that make the resultant force ($\vec{F_R}$) acting on the particle at point F with respect to positive x, y and z-axes.

1. With x-axis

$$\cos\alpha = \frac{F_R \cos\alpha}{F_R} = \frac{\vec{F_x}}{F_R} = \frac{5.7516 \times 10^{-12}}{5.9459 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\alpha = 0.9673$

$\Rightarrow \alpha \simeq 14.7$ degree $[\because \cos(14.7) = 0.9672]$

2. With y-axis

$$\cos\beta = \frac{F_R \cos\beta}{F_R} = \frac{\vec{F_y}}{F_R} = \frac{-1.0662 \times 10^{-12}}{5.9459 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\beta = -0.1793$

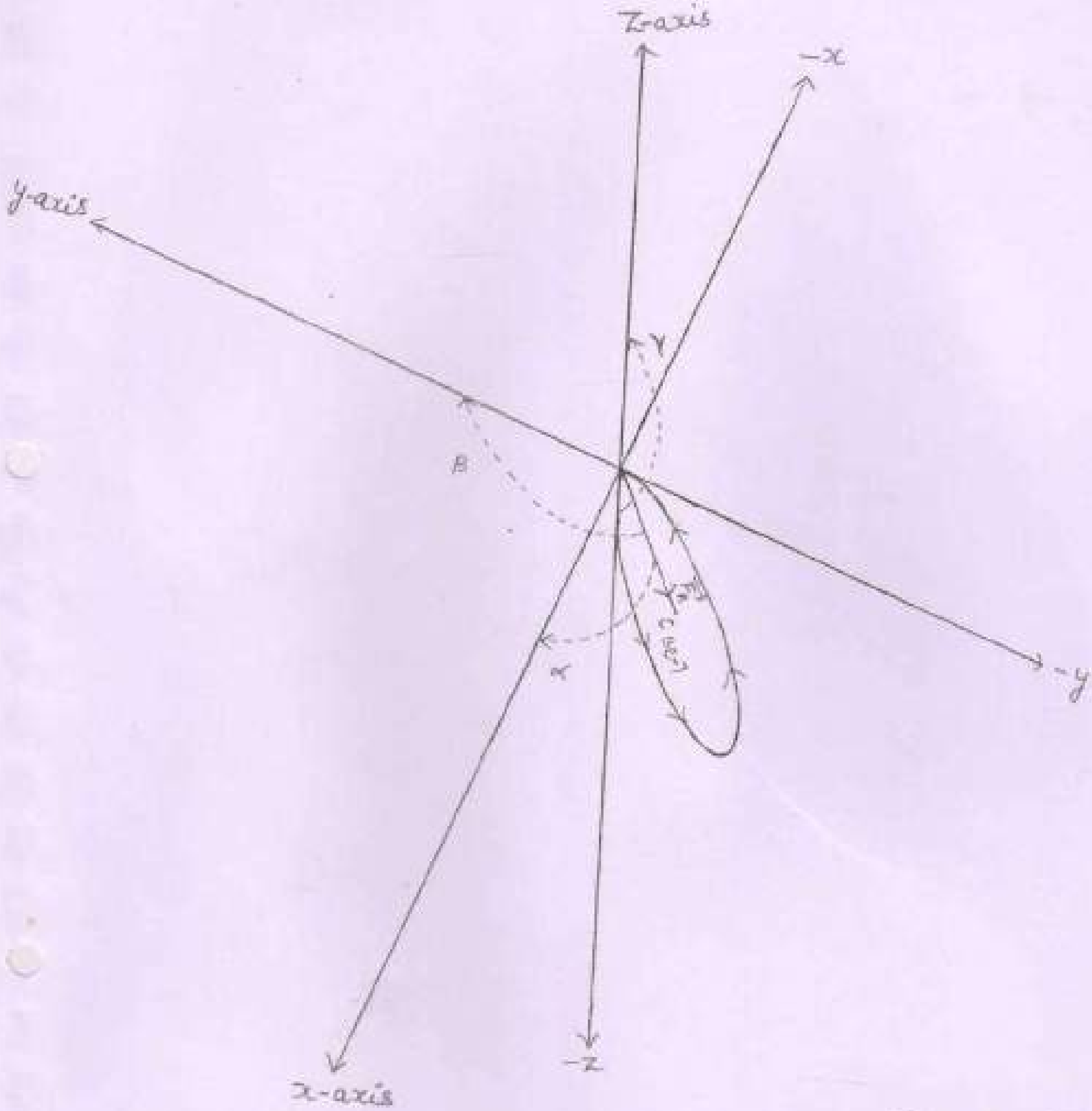
$\Rightarrow \beta \simeq 100.3$ degree $[\because \cos(100.3) = -0.1788]$

3. With z-axis

$$\cos\gamma = \frac{F_R \cos\gamma}{F_R} = \frac{\vec{F_z}}{F_R} = \frac{-1.0662 \times 10^{-12}}{5.9459 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\gamma = -0.1793$

$\Rightarrow \gamma \simeq 100.3$ degree



⇒ The angles that make the resultant force ($\vec{F}_R$) [acting on the beryllium-7, when the be-7 is at point 'F'] with positive x, y and z-axes respectively are :-

1. $\alpha \simeq 14.7$ degree
2. $\beta \simeq 100.3$ degree
3. $\gamma \simeq 100.3$ degree

The cartesian coordinates of the points $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$ located on the circumfrence of the circle to be obtained by the beryllium-7 :-

1. $\cos\alpha = \dfrac{x_2 - x_1}{d}$

$$\cos\alpha = 0.9673$$
$$d = 2 \times r$$
$$= 2 \times 16.3706 \times 10^{-2} \text{ m}$$
$$= 32.7412 \times 10^{-2} \text{ m}$$

$\Rightarrow x_2 - x_1 = d \times \cos\alpha$

$\Rightarrow x_2 - x_1 = 32.7412 \times 10^{-2} \times 0.9673$ m

$\Rightarrow x_2 - x_1 = 31.6705 \times 10^{-2}$ m

$\Rightarrow x_2 = 31.6705 \times 10^{-2}$ m $\quad [\because x_1 = 0]$

2. $\cos\beta = \dfrac{y_2 - y_1}{d}$

$$\cos\beta = -0.1793$$

$\Rightarrow y_2 - y_1 = d \times \cos\beta$

$\Rightarrow y_2 - y_1 = 32.7412 \times 10^{-2} \times (-0.1793)$ m

$\Rightarrow y_2 - y_1 = -5.8704 \times 10^{-2}$ m

$\Rightarrow y_2 = -5.8704 \times 10^{-2}$ m $\quad [\because y_1 = 0]$

3. $\cos\gamma = \dfrac{z_2 - z_1}{d}$

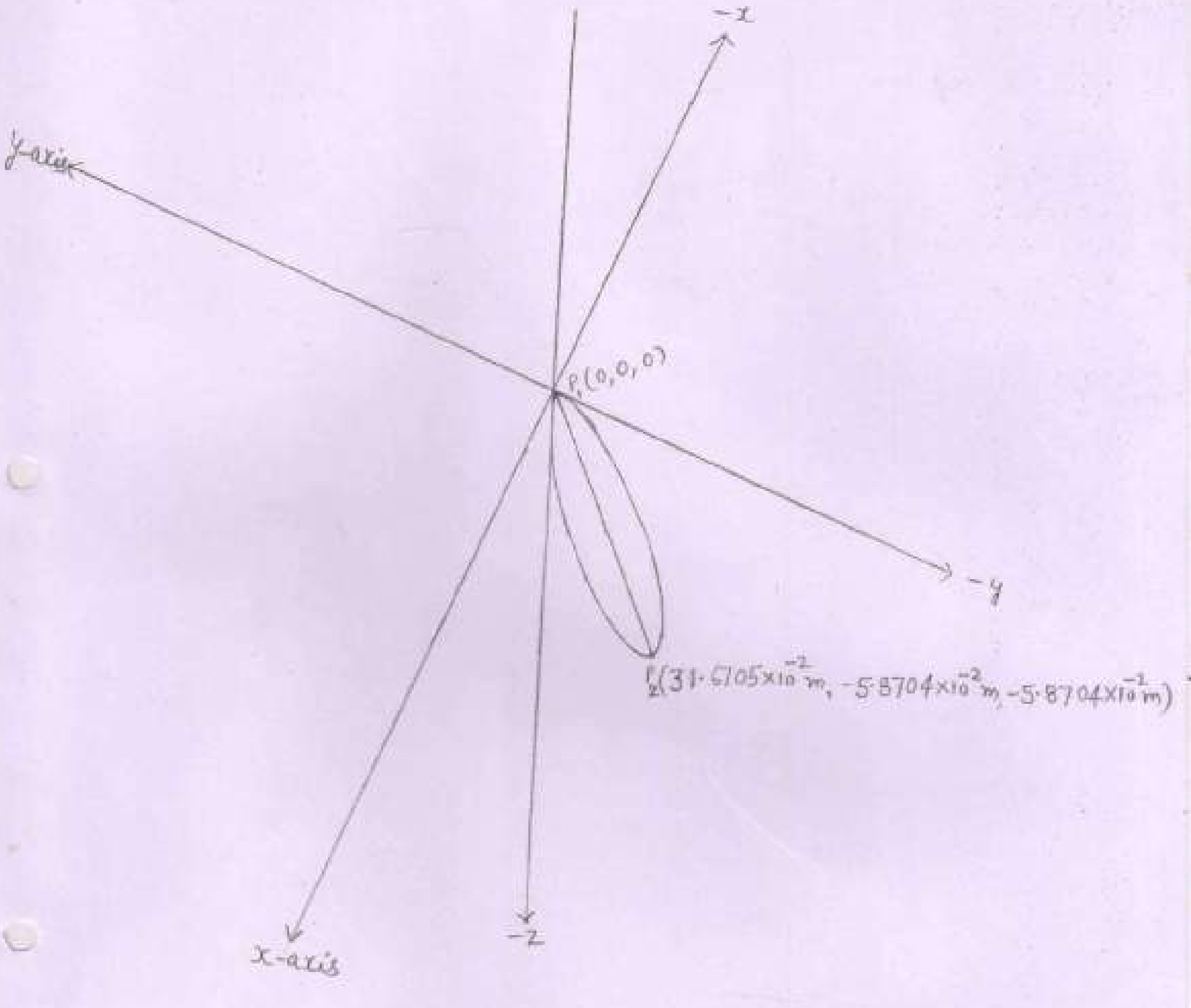
$$\cos\gamma = -0.1793$$

$\Rightarrow z_2 - z_1 = d \times \cos\gamma$

$\Rightarrow z_2 - z_1 = 32.7412 \times 10^{-2} \times (-0.1793)$ m

$\Rightarrow z_2 - z_1 = -5.8704 \times 10^{-2}$ m

$\Rightarrow z_2 = -5.8704 \times 10^{-2}$ m $\quad [\because z_1 = 0]$



$\Rightarrow$ The cartesian coordinates of the points $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$ located on the circumfrence of the circle to be obtained by the beryllium-7 nucleus.

For fusion reaction (9) : $^{2}_{1}H + ^{3}_{1}H + ^{2}_{1}H \rightarrow ^{7}_{3}Li + \gamma$ rays

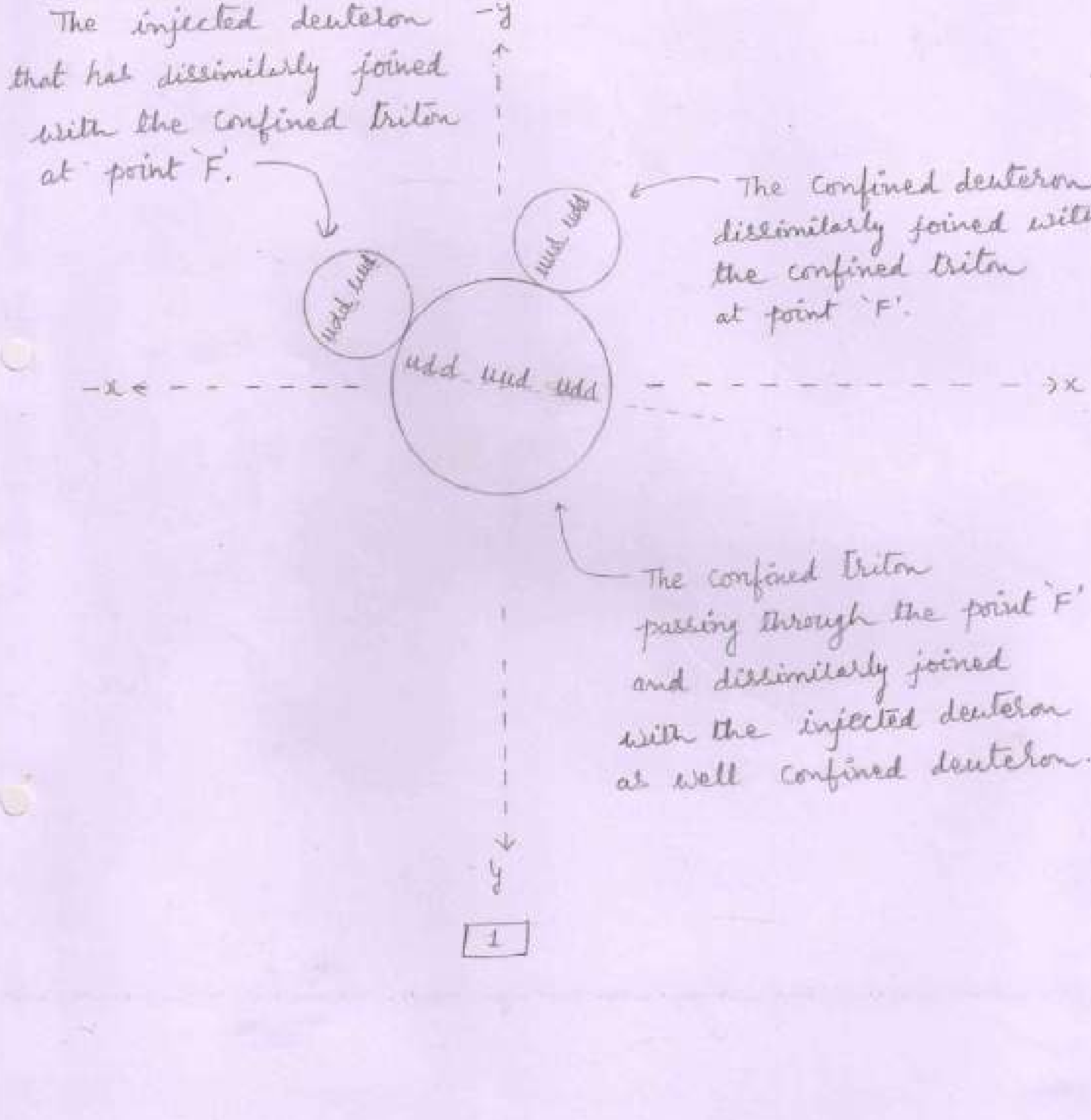
1. Interaction of nuclei :-

As the injected deuteron reaches at point 'F', it interacts [experiences a repulsive force due to the confined triton and the confined deuteron passing through the point 'F'] with the confined triton and the confined deuteron at point 'F'.

Similarly, as the confined deuteron reaches at point 'F', it interacts [experiences a repulsive force due to the injected deuteron reaching at point 'F' and the confined triton passing through the point 'F'] with the injected deuteron and the confined triton passing through the point 'F'.

The injected deuteron and the confined deuteron overcomes the electrostatic repulsive force and thus all the three nuclei [the injected deuteron, the confined triton and the confined deuteron] dissimilarly join with each other.

The interaction of nuclei :-



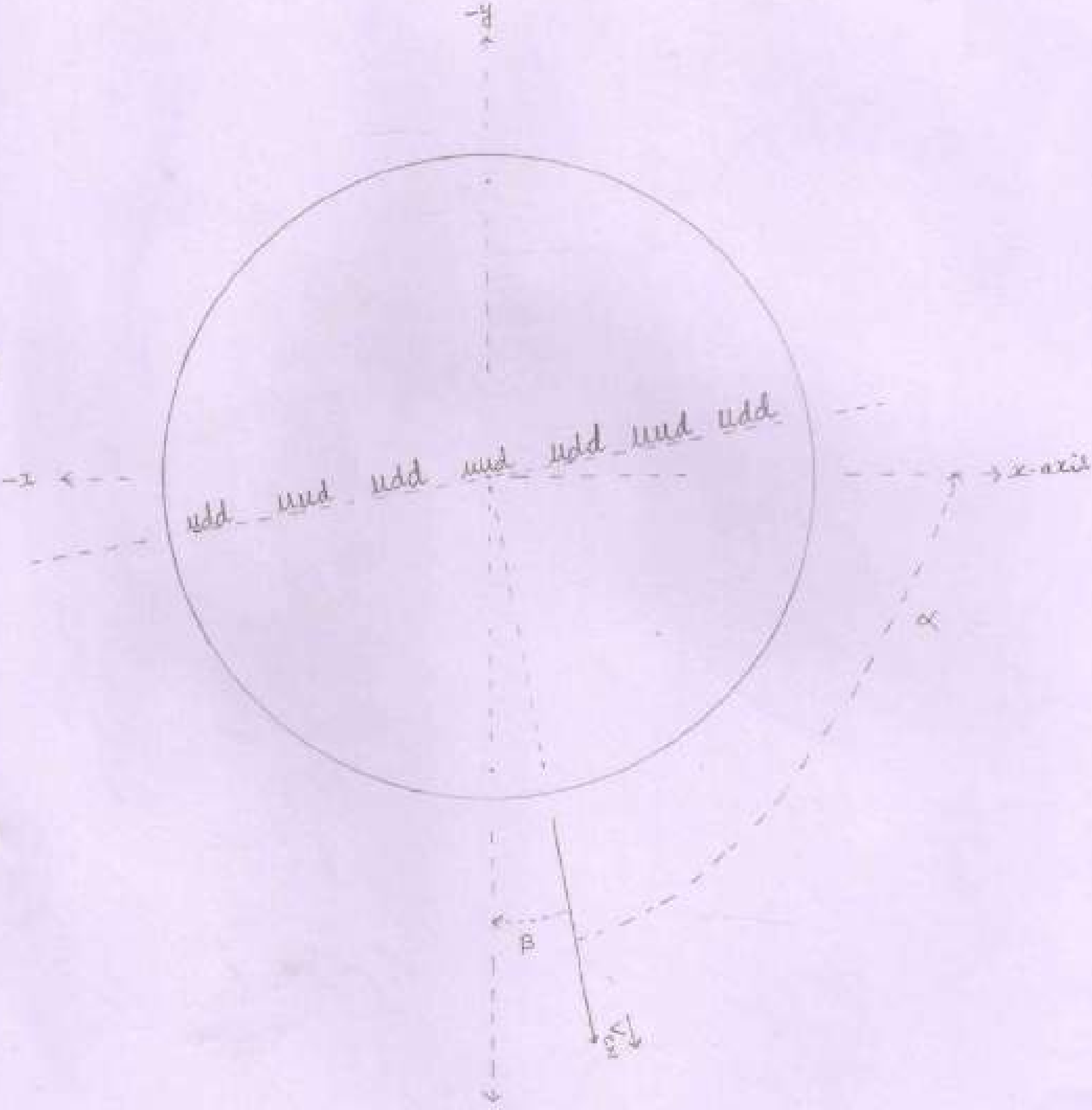
1

2. Formation of homogenous compound nucleus :-

The constituents (quarks and gluons) of the dissimilarly joined nuclei (the injected deuteron, the confined triton and the confined deuteron) behave like a liquid and form the homogenous compound nucleus having similarly distributed groups of quarks with similarly distributed surrounding gluons.

Thus, within the homogenous compound nucleus - each group of quarks is surrounded by the gluons in equal proportion. So, within the homogenous compound nucleus there are 7 groups of quarks surrounded by the gluons.

The homogenous compound nucleus :-



2

Where,

$\alpha \simeq 79.9$ degree

$\beta \simeq 10.1$ degree

3. Formation of lobes within into the homogenous compound nucleus [$^{7}_{3}M$] or the transformation of the homogenous compound nucleus into the heterogenous compound nucleus:-

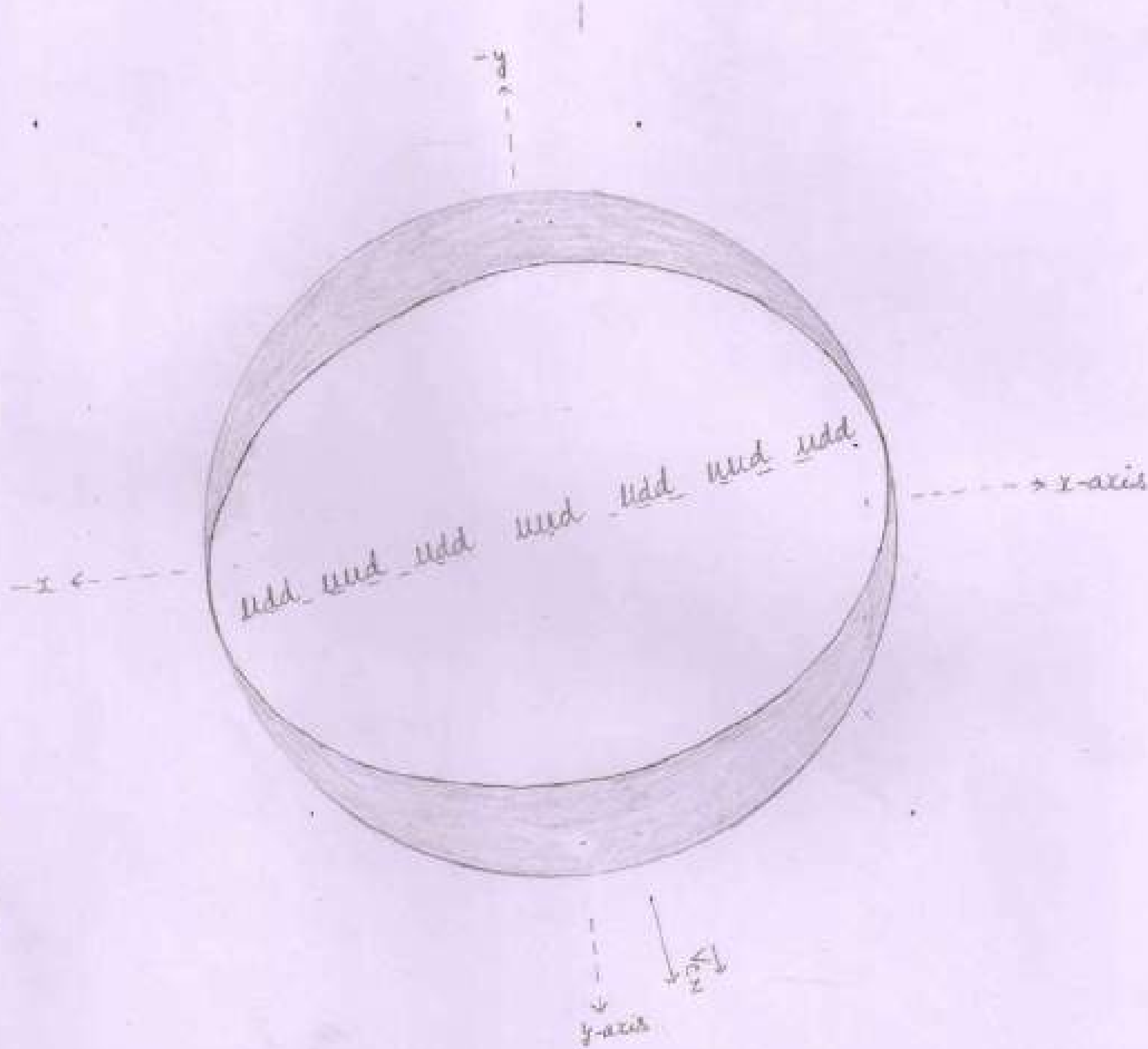
The homogenous compound nucleus [$^{7}_{3}M$] is unstable. So, for stability, the central group of quarks with its surrounding gluons to become a stable and the just lower nucleus (the lithium-7) than the homogenous one [$^{7}_{3}M$], includes the other 6 groups of quarks with their surrounding gluons and rearrange to form the 'A' lobe of the heterogenous compound nucleus.

While the remaining gluons [the gluons (or the mass) that are not involved in the formation of the lobe 'A'] rearrange to form the 'B' lobe of the heterogenous compound nucleus.

Thus, due to formation of two lobes within into the homogenous compound nucleus, the homogenous compound nucleus transforms into the heterogenous compound nucleus.

* The homogenous compound nucleus [$^{7}_{3}M$] has more mass than the lithium-7 nucleus.

Formation of lobes within into the heterogenous compound nucleus :-



3

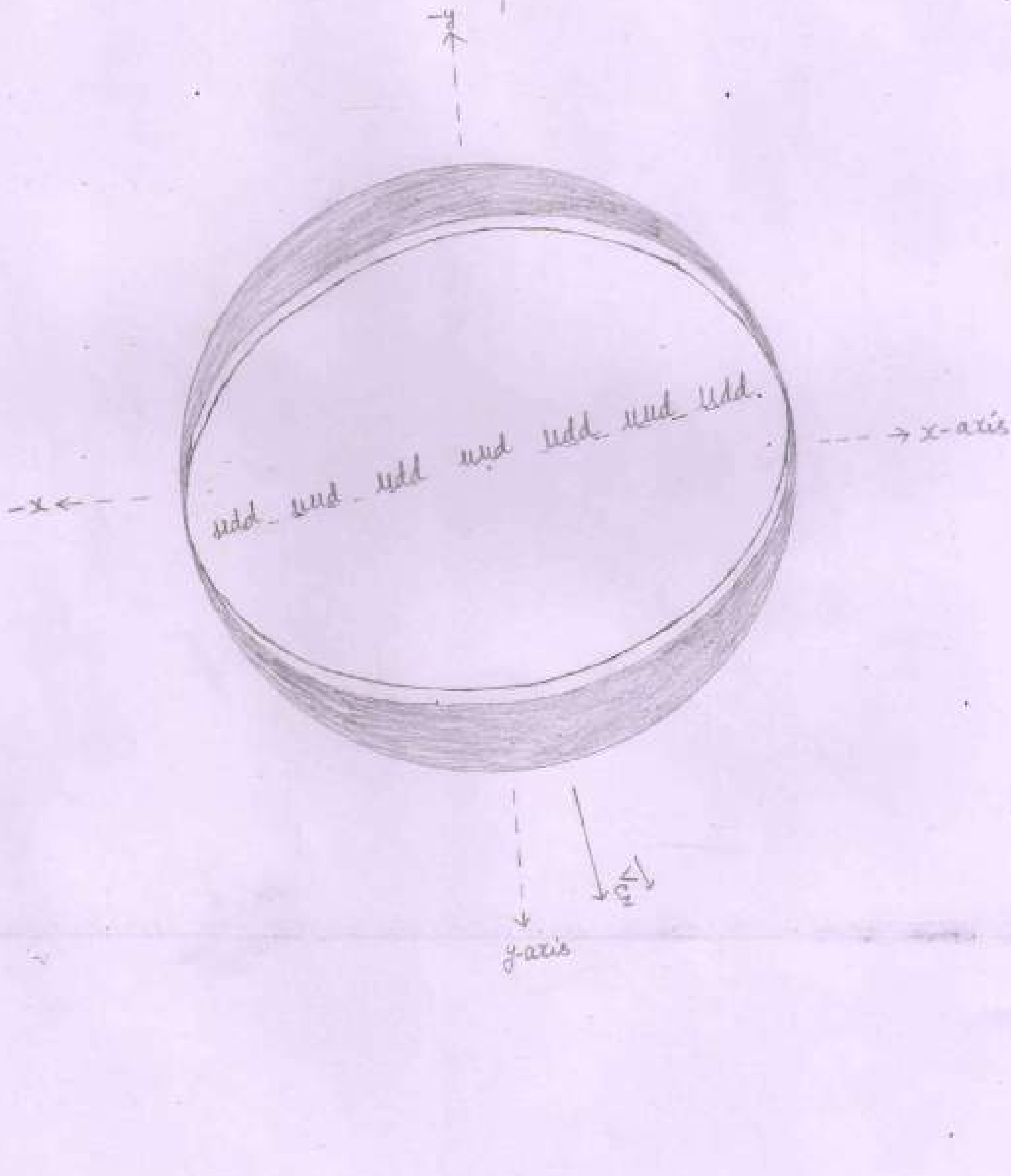
⇒ Where,

1. Inner side - the lobe 'A' is formed [That is the lithium-7 nucleus is formed]

2. outer side - the lobe 'B' is formed [That is the remaining gluons (or the reduced mass) represents the lobe 'B']

4. Final stage of the heterogenous compound nucleus:- The remaining gluons [that compose the `B' lobe of the heterogenous compound nucleus ] remains loosely bonded to the lithium-7 nucleus [ that compose the `A' lobe of the heterogenous compound nucleus]. Thus, the heterogenous compound nucleus, finally, becomes like a coconut into which the outer shield is made up of the remaining gluons while the inner part is made up of lithium-7 nucleus.

Final stage of the heterogenous compound nucleus :-



For fusion reaction

$$^{2}_{1}H + ^{3}_{1}H + ^{2}_{1}H \longrightarrow ^{7}_{3}Li + \gamma \text{ rays}$$

[injected] [confined]

1. The minimum kinetic energy (E_m) required by the deuteron for the above described fusion reaction is –

$$E_m = E_{D-D} \times Z_2^2$$

For fusion, a deuteron has to overcome the electrostatic repulsive force exerted by the other two positive charges. So,

$Z_2 = 2$

$E_{D-D} = 5.0622$ kev

$$\Rightarrow E_m = 5.0622 \text{ kev} \times (2)^2$$

$$\Rightarrow E_m = 20.2488 \text{ kev}$$

2. Just before fusion, the kinetic energy (E_b) of the deuteron (either it is injected or confined) :-

Just before fusion, the deuteron [either it is injected or confined], to overcome the electrostatic repulsive force, loses 20.2488 kev energy. So, just before fusion, the kinetic energy of the deuteron (either is injected or confined) is –

$$E = [102.4 \text{ kev} - 20.2488 \text{ kev}]$$

3. Just before fusion, the momentum (P_b) of the deuteron [either it is injected or confined] :-

$$P_b = [2 m_d E_b]^{\frac{1}{2}}$$

$$\Rightarrow P_b = [2 \times 3.3434 \times 10^{-27} \times 0.0821512 \times 1.6 \times 10^{-13}]^{\frac{1}{2}} \text{ kg m/s}$$

$$\Rightarrow P_b = [0.87892583065 \times 10^{-40}]^{\frac{1}{2}} \text{ kg m/s}$$

$$\Rightarrow P_b = 0.9375 \times 10^{-20} \text{ kg m/s}$$

4. Components of momentum of the deuteron [either it is injected or confined] :-

The confined deuteron reaches at point 'F' with the same momentum with which it is injected to point 'F'.

The each deuteron is injected making angle 30° with x-axis, 60° angle with y-axis and 90° angle with z-axis. So,

1. $\vec{P}_x = P_b \cos\alpha$

$\cos\alpha = \cos 30° = 0.866$

$P_b = 0.9375 \times 10^{-20}$ kgm/s

$\Rightarrow \vec{P}_x = 0.9375 \times 10^{-20} \times 0.866$ kgm/s

$= 0.8118 \times 10^{-20}$ kgm/s

2. $\vec{P}_y = P_b \cos\beta$

$\cos\beta = \cos 60° = 0.5$

$\Rightarrow \vec{P}_y = 0.9375 \times 10^{-20} \times 0.5$ kgm/s

$= 0.4687 \times 10^{-20}$ kgm/s

3. $\vec{P}_z = P_b \cos\gamma$

$\cos\gamma = \cos 90° = 0$

$\Rightarrow \vec{P}_z = 0.9375 \times 10^{-20} \times 0$ kgm/s

$\Rightarrow \vec{P}_z = 0$ kgm/s

The components of the momentum of the Compound nucleus :-

According to	Just before fusion, the Components of the momentum $(\vec{P}_b)$ of the injected deuteron	The components of the momentum of the confined triton	Just before fusion, the components of the momentum $(\vec{P}_b)$ of the confined deuteron	The Components of the momentum of the compound nucleus formed due to fusion at point 'F'.
0	1	2	3	4 = 1+2+3
x-axis	$\vec{P}_x = 0.8118 \times 10^{-20}$ Kgm/s	$\vec{P}_x = -0.7005 \times 10^{-20}$ Kgm/s	$\vec{P}_x = 0.8118 \times 10^{-20}$ Kgm/s	$\vec{P}_x = 0.9231 \times 10^{-20}$ Kgm/s
y-axis	$\vec{P}_y = 0.4687 \times 10^{-20}$ Kgm/s	$\vec{P}_y = 4.2556 \times 10^{-20}$ Kgm/s	$\vec{P}_y = 0.4687 \times 10^{-20}$ Kgm/s	$\vec{P}_y = 5.193 \times 10^{-20}$ Kgm/s
z-axis	$\vec{P}_z = 0$ Kgm/s	$\vec{P}_z = 0$ Kgm/s	$\vec{P}_z = 0$ Kgm/s	$\vec{P}_z = 0$ Kgm/s

Mass of the Compound nucleus (M):-

$M = (m_d + m_t + m_d)$

$= [3.3434 \times 10^{-27} + 5.0072 \times 10^{-27} + 3.3434 \times 10^{-27}]$ Kg

The components of the velocity ($\vec{v}_{CN}$) of the compound nucleus :-

1. $\vec{V}_x = V_{CN} \cos\alpha = \frac{M V_{CN} \cos\alpha}{M} = \frac{\vec{P_x}}{M}$

$\vec{P}_x = 0.9231 \times 10^{-20}$ kgm/s

$M = 11.694 \times 10^{-27}$ kg

$\Rightarrow \vec{V}_x = V_{CN} \cos\alpha = \frac{0.9231 \times 10^{-20}}{11.694 \times 10^{-27}} \frac{kgm/s}{kg}$

$\Rightarrow \vec{V}_x = V_{CN} \cos\alpha = 0.0789 \times 10^{7}$ m/s

2. $\vec{V}_y = V_{CN} \cos\beta = \frac{M V_{CN} \cos\beta}{M} = \frac{\vec{P_y}}{M}$

$\vec{P}_y = 5.193 \times 10^{-20}$ kgm/s

$\Rightarrow \vec{V}_y = V_{CN} \cos\beta = \frac{5.193 \times 10^{-20}}{11.694 \times 10^{-27}} \frac{kgm/s}{kg}$

$\Rightarrow \vec{V}_y = V_{CN} \cos\beta = 0.4440 \times 10^{7}$ m/s

3. $\vec{V}_z = V_{CN} \cos\gamma = \frac{M V_{CN} \cos\gamma}{M} = \frac{\vec{P_z}}{M}$

$\vec{P}_z = 0$ kgm/s

$\Rightarrow \vec{V}_z = V_{CN} \cos\gamma = \frac{0}{11.694 \times 10^{-27}} \frac{kgm/s}{kg}$

$\Rightarrow \vec{V}_z = 0$ m/s

Velocity of the compound nucleus (V_{CN}) :-

$$V_{CN}^2 = V_x^2 + V_y^2 + V_z^2$$

$$\vec{V}_x = V_{CN} \cos\alpha = 0.0789 \times 10^7 \ m/s$$

$$\vec{V}_y = V_{CN} \cos\beta = 0.4440 \times 10^7 \ m/s$$

$$\vec{V}_z = 0 \quad m/s$$

$$\Rightarrow V_{CN}^2 = (0.0789 \times 10^7)^2 + (0.4440 \times 10^7)^2 + (0)^2 \ m^2/s^2$$

$$\Rightarrow V_{CN}^2 = (0.00622521 \times 10^{14}) + (0.197136 \times 10^{14}) + (0) \ m^2/s^2$$

$$\Rightarrow V_{CN}^2 = 0.20336121 \times 10^{14} \quad m^2/s^2$$

$$\Rightarrow V_{CN} = 0.4509 \times 10^7 \quad m/s$$

Angles that make the velocity of the compound nucleus ($\vec{V}_{CN}$) with respect to positive x, y and z-axes.

1. With x-axis

$$\cos\alpha = \frac{V_{CN}\cos\alpha}{V_{CN}} = \frac{\vec{V_x}}{V_{CN}}$$

$$V_{CN}\cos\alpha = \vec{V}_x = 0.0789\times10^7 \text{ m/s}$$

$$V_{CN} = 0.4509\times10^7 \text{ m/s}$$

$$\Rightarrow \cos\alpha = \frac{0.0789\times10^7}{0.4509\times10^7}\ \frac{\text{m/s}}{\text{m/s}}$$

$$\Rightarrow \cos\alpha = 0.1749$$

$$\Rightarrow \alpha \simeq 79.9 \text{ degree} \qquad [\because \cos(79.9) = 0.1753]$$

2. With y-axis

$$\cos\beta = \frac{V_{CN}\cos\beta}{V_{CN}} = \frac{\vec{V_y}}{V_{CN}}$$

$$V_{CN}\cos\beta = \vec{V}_y = 0.4440\times10^7 \text{ m/s}$$

$$\Rightarrow \cos\beta = \frac{0.4440\times10^7}{0.4509\times10^7}\ \frac{\text{m/s}}{\text{m/s}} = 0.9846$$

$$\Rightarrow \beta \simeq 10.1 \text{ degree} \qquad [\because \cos(10.1) = 0.9845$$

3. With z-axis

$$\cos\gamma = \frac{V_{CN}\cos\gamma}{V_{CN}} = \frac{\vec{V_z}}{V_{CN}}$$

$$V_{CN}\cos\gamma = \vec{V}_z = 0 \text{ m/s}$$

$$\Rightarrow \cos\gamma = \frac{0}{0.4509\times10^7}\ \frac{\text{m/s}}{\text{m/s}} = 0$$

$$\Rightarrow \gamma = 90^\circ$$

The Splitting of the heterogenous Compound nucleus :-

⇒ The remaining gluons are loosely bonded to the lithium -7 nucleus.

⇒ At the poles of the lithium -7 nucleus, the remaining gluons are lesser in amount than at the equator.

⇒ So, during the rearrangement of the remaining gluons [or during the formation of the 'B' lobe of the heterogenous compound nucleus], the remaining gluons to be homogenously distributed all around, rush from the equator to the poles.

In this way, the loosely bonded remaining gluons separates from the lithium -7 nucleus and also divides itself into two parts giving us three particles - the first one is the one-half of the reduced mass, Second one is the lithium -7 nucleus and the third one is the another one-half of the reduced mass.

⇒ Thus, the heterogenous compound nucleus splits according to the lines parallel to the velocity of the compound nucleus into three particles - the first one is the one-half of the reduced mass ($\frac{\Delta m}{2}$), the second one is the lithium-7 nucleus, and the third one is the another one-half of the reduced mass ($\frac{\Delta m}{2}$).

⇒ By the law of inertia, each particle that has separated from the compound nucleus has an inhereted velocity ($\vec{V}_{inh}$) equal to the velocity of the compound nucleus ($\vec{V}_{CN}$).

⇒ So, for conservation of momentum

$$M\vec{V}_{CN} = \left(\frac{\Delta m}{2} + m_{Li-7} + \frac{\Delta m}{2}\right)\vec{V}_{CN}$$

Where,

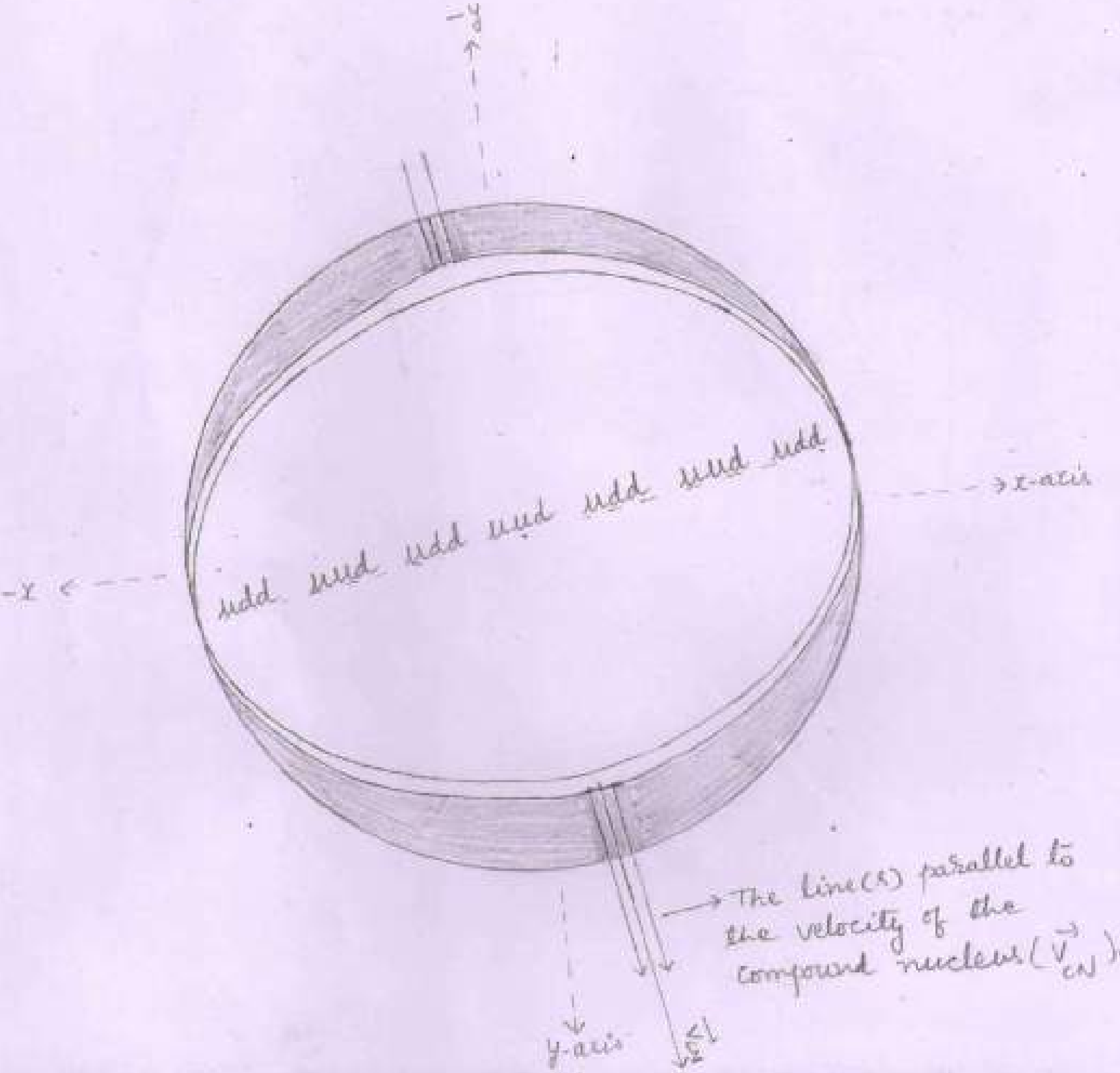
M = Mass of the compound nucleus

$\vec{V}_{CN}$ = Velocity of the compound nucleus

$\frac{\Delta m}{2}$ = A particle having a mass equal to one-half of the reduced mass.

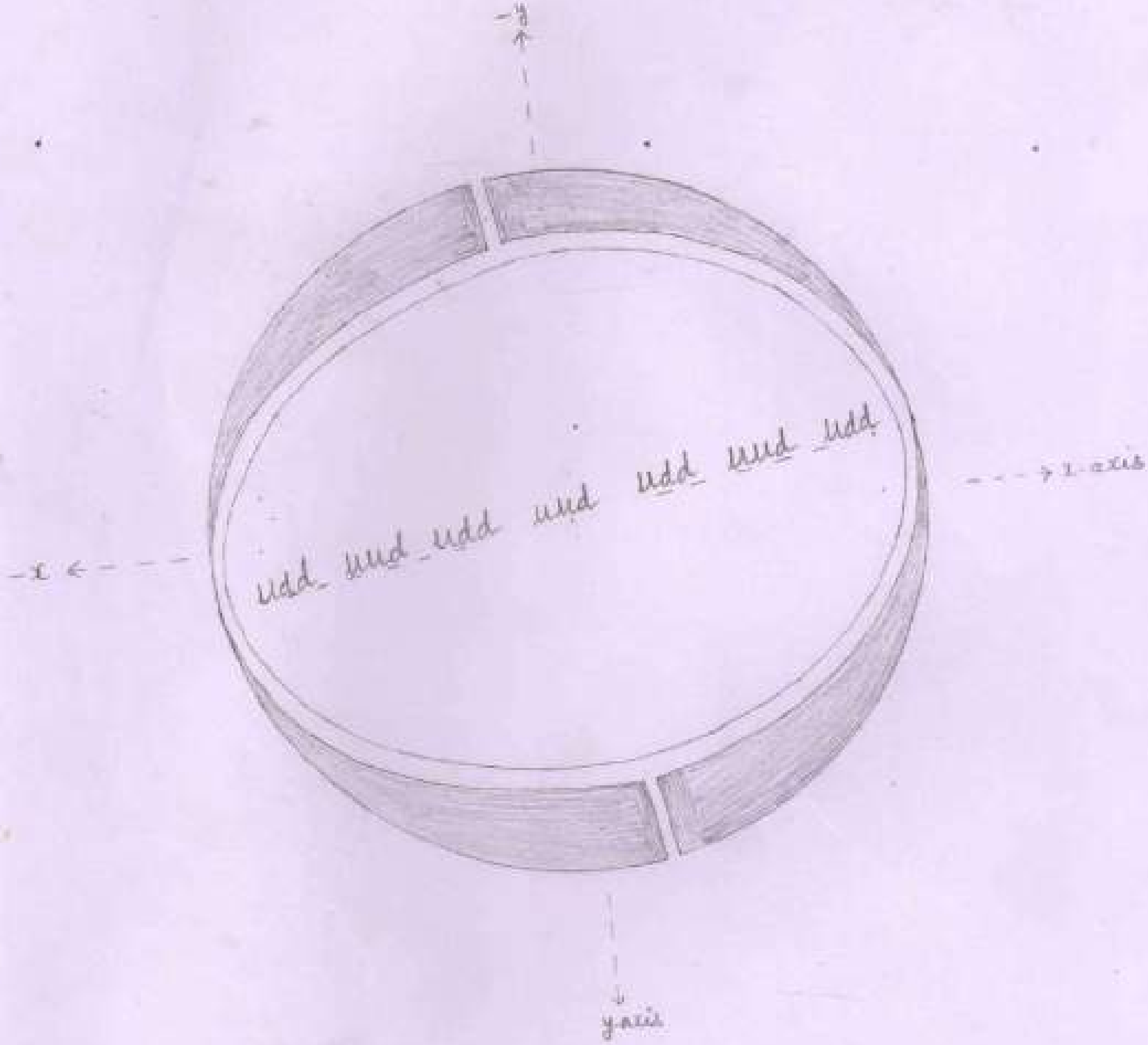
m_{Li-7} = mass of the lithium-7 nucleus.

The splitting of the heterogenous compound nucleus :-



Sp - 1

The splitting of the heterogenous compound nucleus :-



$\boxed{5p-2}$

⇒ The heterogenous compound nucleus splits into three particles -

(1) $\frac{\Delta m}{2}$ (2) $^{7}_{3}Li$ (3) $\frac{\Delta m}{2}$

Inhereted velocity ($\vec{V}_{inh}$) of the particles

Each particle that has separated from the compound nucleus has an inhereted velocity ($\vec{V}_{inh}$) equal to the velocity of the compound nucleus ($\vec{V}_{CN}$).

I. Inhereted velocity ($\vec{V}_{inh}$) of the lithium-7

$$\vec{V}_{inh} = \vec{V}_{CN} = 0.4509 \times 10^{7} \ m/s$$

Components of the inhereted velocity of lithium-7

1. $\vec{V}_x = V_{inh} \cos\alpha = V_{CN} \cos\alpha = 0.0789 \times 10^{7} \ m/s$

2. $\vec{V}_y = V_{inh} \cos\beta = V_{CN} \cos\beta = 0.4440 \times 10^{7} \ m/s$

3. $\vec{V}_z = V_{inh} \cos\gamma = V_{CN} \cos\gamma = 0 \ m/s$

II. Inhereted velocity of the one-half of the reduced mass ($\frac{\Delta m}{2}$) :-

$$\vec{V}_{inh} = \vec{V}_{CN} = 0.4509 \times 10^{7} \ m/s$$

III. Inhereted velocity of the another one-half of the reduced mass ($\frac{\Delta m}{2}$) :-

$$\vec{V}_{inh} = \vec{V}_{CN} = 0.4509 \times 10^{7} \ m/s$$

Propellation of the particles

1. Reduced mass :

$\Rightarrow \Delta m = [m_d + m_t + m_d] - [m_{Li-7}]$

$\Rightarrow \Delta m = [2m_d + m_t] - [m_{Li-7}]$

$\Rightarrow \Delta m = [2 \times 2.01355 + 3.0155] - [7.01600]$ amu

$\Rightarrow \Delta m = [7.0426] - [7.01600]$ amu

$\Rightarrow \Delta m = 0.0266$ amu

$\Rightarrow \Delta m = 0.0266 \times 1.6605 \times 10^{-27}$ Kg

$\Rightarrow \Delta m = 0.0441693 \times 10^{-27}$ Kg

2. Inhereted kinetic energy (E_{inh}) of the reduced mass (Δm):

$\Rightarrow E_{inh} = \frac{1}{2} \Delta m V_{inh}^2$

$$\Rightarrow E_{inh} = \frac{1}{2} \Delta m \, v_{CN}^2 \qquad [\because \vec{v}_{inh} = \vec{v}_{CN}]$$

$v_{CN}^2 = 0.20336121 \times 10^{14} \ m^2/s^2$

$\Delta m = 0.0441693 \times 10^{-27}$ kg

$$\Rightarrow E_{inh} = \frac{1}{2} \times 0.0441693 \times 10^{-27} \times 0.20336121 \times 10^{14} \ J$$

$$= 0.0044911614 \times 10^{-13} \ J$$

$$= 0.0028 \ Mev$$

3. Released energy (E_R) :-

$$E_R = \Delta m c^2$$

$\Delta m = 0.0266$ amu

1 amu $= 931$ Mev

$$\Rightarrow E_R = 0.0266 \times 931 \ Mev$$

$$= 24.7646 \ Mev$$

4. Total energy (E_T) :-

$$E_T = E_{Inhereted} + E_{Released}$$

$$\Rightarrow E_T = [0.0028] + [24.7646] \ Mev$$

$$\Rightarrow E_T = 24.7674 \ Mev$$

Propellation of the particle

⇒ The each one-half of the reduced mass ($\Delta m/2$) converts into energy. So, the energy (E) carried by the produced pairs of gamma ray photons is —

$$E = \frac{E_T}{2}$$

$$E_T = 24.7674 \text{ Mev}$$

⇒ $$E = \frac{24.7674}{2} \text{ Mev}$$

⇒ $$E = 12.3837 \text{ Mev}$$

Page No.:
Date: / /

Number of pairs of gamma ray photons (N_γ) :-

⇒ When one-half of the reduced mass (rm/2) converts into energy, the energy (E) carried by the pairs of gamma ray photons is 12.3837 Mev.

⇒ Each pair of gamma ray photon that carry a part of the energy (E) must have an energy equal to or more than 1.02 Mev.

⇒ so,

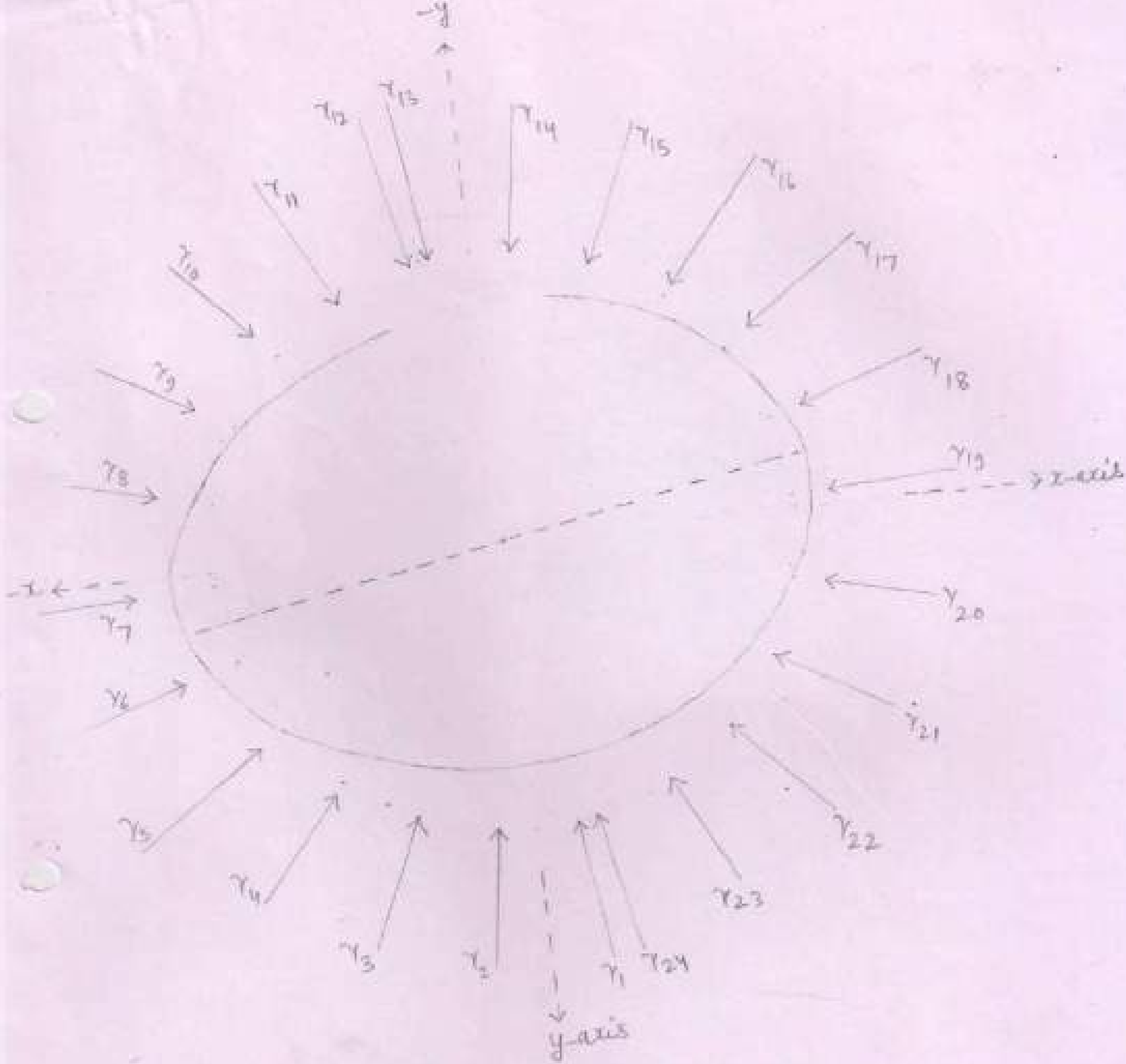
Number of pairs of gamma ray photons = $\dfrac{\text{Energy (E) produced due to rm/2}}{\text{Energy that must carried by a pair of g.r. photon}}$

⇒ $N_\gamma = \dfrac{12.3837}{1.02} \dfrac{\text{Mev}}{\text{Mev}}$

⇒ $N_\gamma = 12.1408$

⇒ Taking the whole digit, we may say that there are the 12 pairs of gamma ray photons that carry the energy 12.3837 Mev.

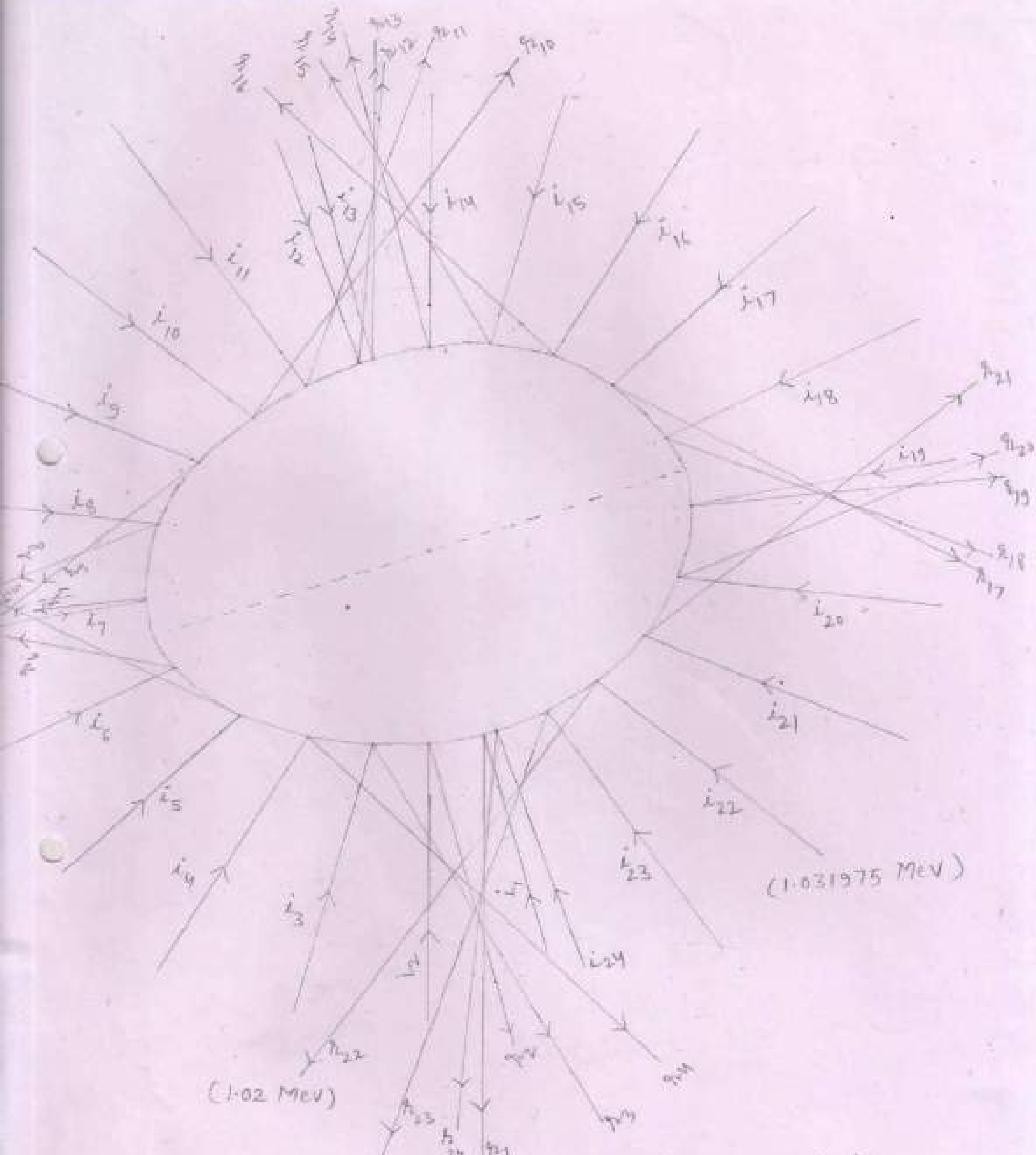
⇒ Thus, there are the 24 pairs of gamma ray photons that carry the total energy (E_T) equal to 24.7674 Mev.



:- Propellation of the lithion-7 :-

⇒ Each pair of gamma ray photon make a head-on collision with the lithium-7 nucleus.

⇒ There are the 24 pairs of gamma ray photons that strike to the lithium-7 nucleus.



⇒ Each pair of gamma ray photon imparts its extra energy to the lithium-7 nucleus.

⇒ The 24 pairs of gamma ray photon strike to the lithium-7 nucleus and energise it by the 0.2874 MeV.

⇒ The angle of reflection of each pair of gamma ray photon is equal to the angle of incidence of that pair of gamma ray photon.

Energy carried by the each gamma ray photon [E_γ]:-

$\Rightarrow$ $E_\gamma = \dfrac{\text{The energy (E) produced due to } \Delta m/2}{\text{Total number of pairs of gamma ray photons}}$

$\Rightarrow$ $E_\gamma = \dfrac{E}{N_\gamma} = \dfrac{12.3837}{12} = 1.031975$ Mev

$\Rightarrow$ Conclusion : each pair of gamma ray photon carry 1.031975 Mev.

Increased energy (E_{inc}) of the lithium -7

$\Rightarrow$ Each gamma ray photon by making a head-on collision with the lithium -7 imparts its extra energy to the lithium -7 nucleus.

$\Rightarrow$ Extra energy of a pair of gamma ray photon is equal to the total energy carried by a pair of gamma ray photon minus 1.02 Mev

$$E_{extra} = E_\gamma - [m_{e^+}c^2 + m_{e^-}c^2]$$

$\Rightarrow$ E_{extra} = [1.031975 Mev] - [1.02 Mev]
= 0.011975 Mev

$\Rightarrow$ So, when 24 pairs of gamma ray photons strike to the lithium -7, the increased energy (E_{inc}) of the lithium -7 is -

$E_{inc} = E_{\text{Imparted by a pair of g.r. photon}} \times 24$

$\Rightarrow$ $E_{inc} = E_{extra} \times 24$

$\Rightarrow$ E_{inc} = 0.011975 Mev × 24
= 0.2874 Mev

Increased velocity (v_{inc}) of the lithium-7

$$v_{inc} = \left[\frac{2 E_{inc}}{m_{Li-7}} \right]^{\frac{1}{2}}$$

$$\Rightarrow v_{inc} = \left[\frac{2 \times 0.2874 \times 1.6 \times 10^{-13}}{11.6500 \times 10^{-27}} \right]^{\frac{1}{2}} \text{ m/s}$$

$$\Rightarrow v_{inc} = \left[\frac{0.91968}{11.6500} \times 10^{14} \right]^{\frac{1}{2}} \text{ m/s}$$

$$\Rightarrow v_{inc} = \left[0.0789424892 7 \times 10^{14} \right]^{\frac{1}{2}} \text{ m/s}$$

$$\Rightarrow v_{inc} = 0.2809 \times 10^{7} \text{ m/s}$$

Components of the final velocity ($\vec{v}_f$) of lithium-7

According to	Inhereted velocity ($\vec{v}_{inh}$)	Increased velocity ($\vec{v}_{inc}$)	Final velocity ($\vec{v}_f$) $\vec{v}_f = \vec{v}_{inh} + \vec{v}_{inc}$
x-axis	$\vec{v}_x = 0.0789 \times 10^7$ m/s	$\vec{v}_x = 0.0477 \times 10^7$ m/s	$\vec{v}_x = 0.1266 \times 10^7$ m/s
y-axis	$\vec{v}_y = 0.4440 \times 10^7$ m/s	$\vec{v}_y = 0.2752 \times 10^7$ m/s	$\vec{v}_y = 0.7192 \times 10^7$ m/s
z-axis	$\vec{v}_z = 0$ m/s	$\vec{v}_z = 0$ m/s	$\vec{v}_z = 0$ m/s

Components of the increased velocity (v_{inc}) of the lithium-7 :-

At point 'F', the lithium-7 nucleus moving in a direction that make angle 79.9 degree with x-axis, 10.1 degree angle with y-axis and 90° angle with z-axis is excited by 0.2874 MeV energy due to head-on collision between gamma ray photons and the lithium-7 nucleus.

So, the increased velocity ($\vec{v}_{inc}$) of the lithium-7 make angle

1. $\alpha \simeq$ 79.9 degree
2. $\beta \simeq$ 10.1 degree
3. $\gamma = 90^\circ$

with positive x, y and z-axes respectively.

So, the components of the increased velocity of the lithium-7 are-

1. $\vec{v}_x = v_{inc} \cos\alpha$

$v_{inc} = 0.2809 \times 10^7$ m/s

$\cos\alpha = \cos(79.9) = 0.17$

$\Rightarrow \vec{v}_x = 0.2809 \times 10^7 \times 0.17$ m/s

$= 0.0477 \times 10^7$ m/s

2. $\vec{v}_y = v_{inc} \cos\beta$

$\cos\beta = \cos(10.1) = 0.98$

$\Rightarrow \vec{v}_y = 0.2809 \times 10^7 \times 0.98$ m/s

$= 0.2752 \times 10^7$ m/s

3. $\vec{v}_z = v_{inc} \cos\gamma$

$\cos\gamma = \cos 90^\circ = 0$

$\Rightarrow \vec{v}_z = 0.2809 \times 10^7 \times 0$ m/s

$= 0$ m/s

Final velocity (v_f) of the lithium -7

$$v_f^2 = v_x^2 + v_y^2 + v_z^2$$

$\vec{v}_x = 0.1266 \times 10^7$ m/s
$\vec{v}_y = 0.7192 \times 10^7$ m/s
$\vec{v}_z = 0$ m/s

$$\Rightarrow v_f^2 = (0.1266 \times 10^7)^2 + (0.7192 \times 10^7)^2 + (0)^2 \ m^2/s^2$$

$$\Rightarrow v_f^2 = (0.01602756 \times 10^{14}) + (0.51724864 \times 10^{14}) + (0)^2 \ m^2/s^2$$

$$\Rightarrow v_f^2 = 0.5332762 \times 10^{14} \ m^2/s^2$$

$$\Rightarrow v_f = 0.7302 \times 10^7 \ m/s$$

Final kinetic energy of the lithium -7

$$E = \frac{1}{2} m_{Li-7} \times v_f^2$$

$m_{Li-7} = 11.6500 \times 10^{-27}$ Kg

$v_f^2 = 0.5332762 \times 10^{14}$ m²/s²

$$\Rightarrow E = \frac{1}{2} \times 11.6500 \times 10^{-27} \times 0.5332762 \times 10^{14} \ J$$

$$= 3.106333865 \times 10^{-13} \ J$$

$$= 1.9414 \ Mev$$

$$\Rightarrow m_{Li-7} v_f^2 = 11.6500 \times 10^{-27} \times 0.5332762 \times 10^{14} \ J$$

$$= 6.2126 \times 10^{-13} \ J$$

The forces acting on the lithium-7

1. $F_y = q V_x B_z \sin\theta$

$q = 3 \times 1.6 \times 10^{-19}$ C

$\vec{V_x} = 0.1266 \times 10^{7}$ m/s

$\vec{B_z} = -1$ Tesla

$\sin\theta = \sin 90^\circ = 1$

$\Rightarrow F_y = 3 \times 1.6 \times 10^{-19} \times 0.1266 \times 10^{7} \times 1 \times 1$ N

$= 0.6076 \times 10^{-12}$ N

From the right hand palm rule, the direction of force $\vec{F_y}$ is according to negative y-axis. So,

$\vec{F_y} = -0.6076 \times 10^{-12}$ N

2. $F_z = q V_x B_y \sin\theta$

$\vec{B_y} = 1$ Tesla

$\sin\theta = \sin 90^\circ = 1$

$\Rightarrow F_z = 3 \times 1.6 \times 10^{-19} \times 0.1266 \times 10^{7} \times 1 \times 1$ N

$= 0.6076 \times 10^{-12}$ N

From the right hand palm rule, the direction of force $\vec{F_z}$ is according to negative z-axis. So,

$\vec{F_z} = -0.6076 \times 10^{-12}$ N

3. $F_x = q V_y B_z \sin\theta$

$\vec{V_y} = 0.7192 \times 10^{7}$ m/s

$\vec{B_z} = -1$ Tesla

$\sin\theta = \sin 90^\circ = 1$

$\Rightarrow F_x = 3 \times 1.6 \times 10^{-19} \times 0.7192 \times 10^{7} \times 1 \times 1$ N

$= 3.4521 \times 10^{-12}$ N

$\Rightarrow$ From the right hand palm rule, the direction of force $\vec{F}$ is according to positive x-axis. So,

4. Resultant force ($\vec{F_R}$) :-

$$F_R^2 = F_x^2 + F_y^2 + F_z^2$$

$$F_x = 3.4521 \times 10^{-12}\ N$$

$$F = F_y = F_z = 0.6076 \times 10^{-12}\ N$$

$$\Rightarrow F_R^2 = F_x^2 + 2F^2$$

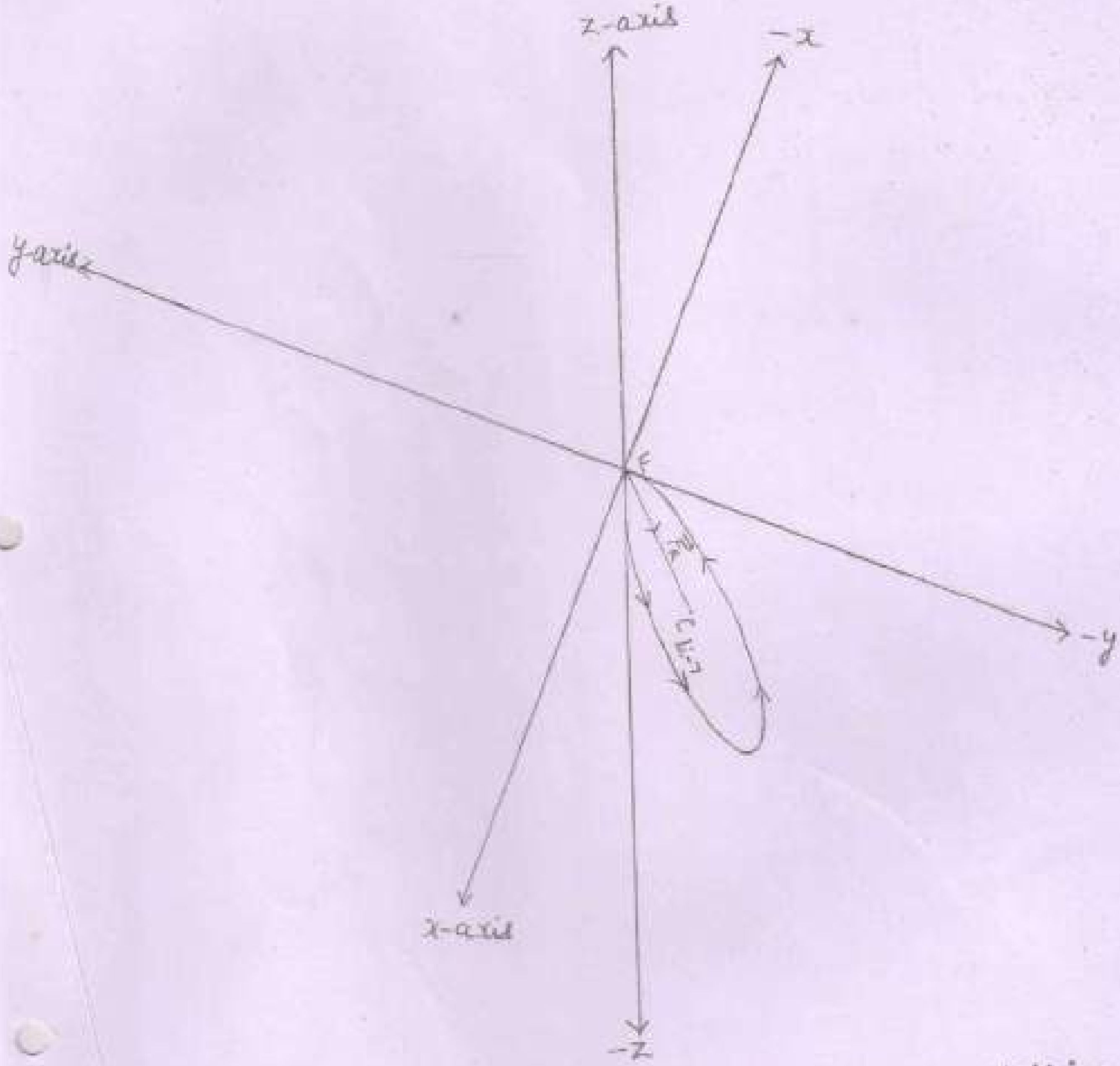
$$\Rightarrow F_R^2 = (3.4521 \times 10^{-12})^2 + 2(0.6076 \times 10^{-12})^2\ N^2$$

$$\Rightarrow F_R^2 = (11.91699441 \times 10^{-24}) + 2(0.36917776 \times 10^{-24})\ N^2$$

$$\Rightarrow F_R^2 = (11.91699441 \times 10^{-24}) + (0.73835552 \times 10^{-24})\ N^2$$

$$\Rightarrow F_R^2 = 12.65534993 \times 10^{-24}\ N^2$$

$$\Rightarrow F_R = 3.5574 \times 10^{-12}\ N$$



⇒ The circular orbit to be followed by the lithium-7 nucleus lies in the plane made up of positive x-axis, negative y-axis and negative z-axis.

⇒ Where, (1). C_{Li-7} = center of the circular orbit to be followed by the lithium-7 nucleus.

(2) $\overrightarrow{F_R}$ = The direction of the resultant force ($\overrightarrow{F_R}$) acting on the lithium-7 when the lithium-7 starts its circular motion from point 'F' or the point $P_1(0, 0, 0)$.

Angles that make the resultant force ($\vec{F}_R$) [acting on the lithium-7 at point 'F'] with respect to positive x, y and z axes.

1. With x-axis

$$\cos\alpha = \frac{F_R \cos\alpha}{F_R} = \frac{\vec{F_x}}{F_R} = \frac{3.4521 \times 10^{-12}}{3.5574 \times 10^{-12}} \frac{N}{N}$$

$$\Rightarrow \cos\alpha = 0.9703$$

$$\Rightarrow \alpha \simeq 14 \text{ degree} \quad [\because \cos(14) = 0.9702]$$

2. With y-axis

$$\cos\beta = \frac{F_R \cos\beta}{F_R} = \frac{\vec{F_y}}{F_R} = \frac{-0.6076 \times 10^{-12}}{3.5574 \times 10^{-12}} \frac{N}{N}$$

$$\Rightarrow \cos\beta = -0.1707$$

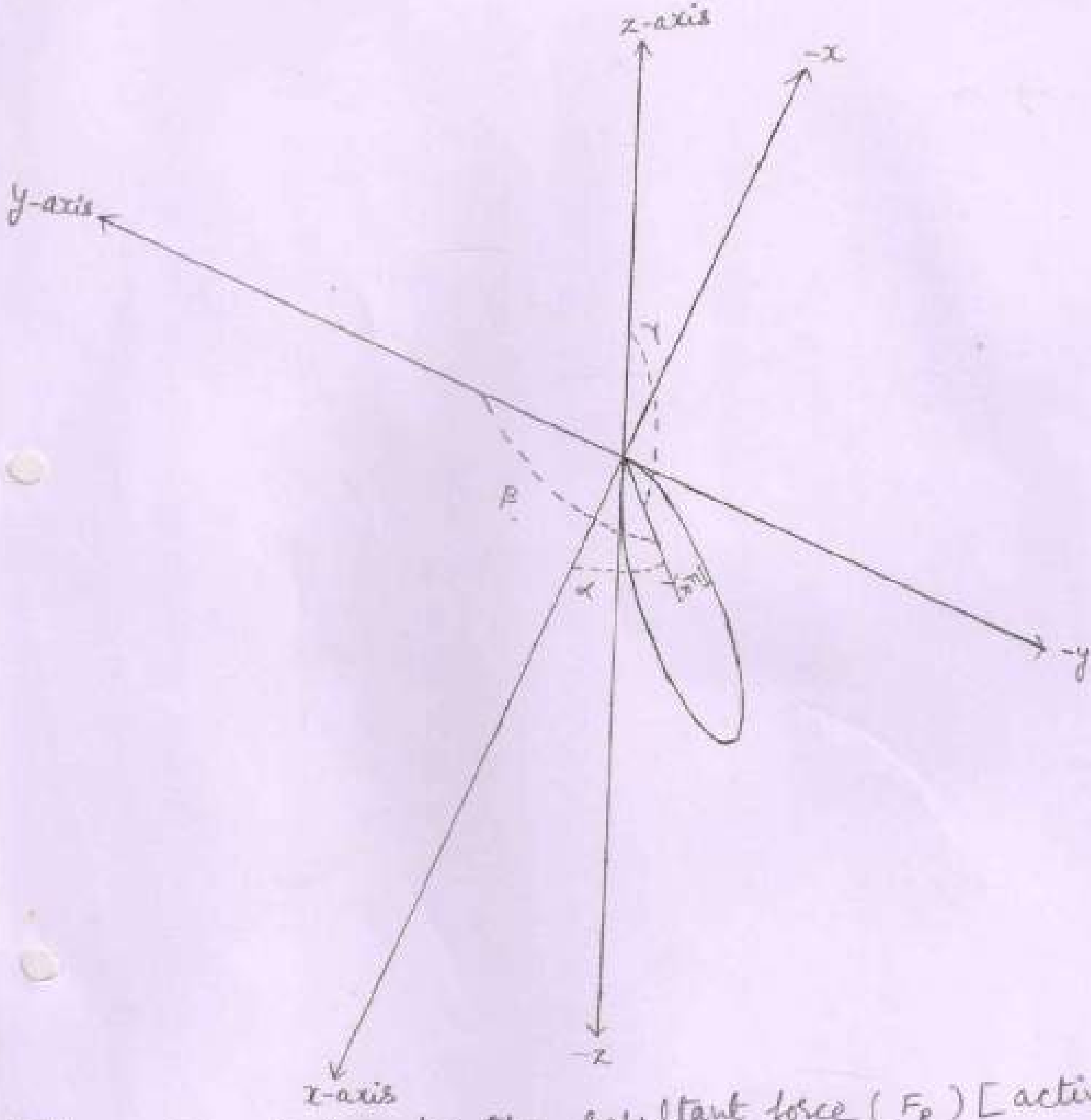
$$\Rightarrow \beta \simeq 99.8 \text{ degree} \quad [\because \cos(99.8) = -0.1702]$$

3. With z-axis

$$\cos\gamma = \frac{F_R \cos\gamma}{F_R} = \frac{\vec{F_z}}{F_R} = \frac{-0.6076 \times 10^{-12}}{3.5574 \times 10^{-12}} \frac{N}{N}$$

$$\Rightarrow \cos\gamma = -0.1707$$

$$\Rightarrow \gamma \simeq 99.8 \text{ degree} \quad [\because \cos(99.8) = -0.1702]$$



⇒ The angles that make the resultant force (F_R) [acting on the lithium-7 when the lithium-7 is at point 'F'] with the positive x, y and z-axes respectively are :-

1. $\alpha \simeq$ 14 degree
2. $\beta \simeq$ 99.8 degree
3. $\gamma \simeq$ 99.8 degree

Radius of the circular orbit to be followed by the lithium-7 :-

$$r = \frac{mv^2}{F_R}$$

$mv^2 = 6.2126 \times 10^{-13}$ J

$F_R = 3.5574 \times 10^{-12}$ N

$$\Rightarrow r = \frac{6.2126 \times 10^{-13}}{3.5574 \times 10^{-12}} \frac{J}{N}$$

$$\Rightarrow r = 1.74638 \times 10^{-1} \text{ m}$$

$$\Rightarrow r = 17.4638 \times 10^{-2} \text{ m}$$

The cartesian coordinates of the points $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$ located on the circumfrence of the circle to be obtained by the lithium-7 :-

1. $\cos\alpha = \dfrac{x_2 - x_1}{d}$

$$d = 2 \times r$$
$$= 2 \times 17.4638 \times 10^{-2}\ m$$
$$= 34.9276 \times 10^{-2}\ m$$
$$\cos\alpha = 0.97$$

$\Rightarrow x_2 - x_1 = d \times \cos\alpha$

$\Rightarrow x_2 - x_1 = 34.9276 \times 10^{-2} \times 0.97\ m$

$\Rightarrow x_2 - x_1 = 33.8797 \times 10^{-2}\ m$

$\Rightarrow x_2 = 33.8797 \times 10^{-2}\ m$ [$\because x_1 = 0$]

2. $\cos\beta = \dfrac{y_2 - y_1}{d}$

$$\cos\beta = -0.17$$

$\Rightarrow y_2 - y_1 = d \times \cos\beta$

$\Rightarrow y_2 - y_1 = 34.9276 \times 10^{-2} \times (-0.17)\ m$

$\Rightarrow y_2 - y_1 = -5.9376 \times 10^{-2}\ m$

$\Rightarrow y_2 = -5.9376 \times 10^{-2}\ m$ [$\because y_1 = 0$]

3. $\cos\gamma = \dfrac{z_2 - z_1}{d}$

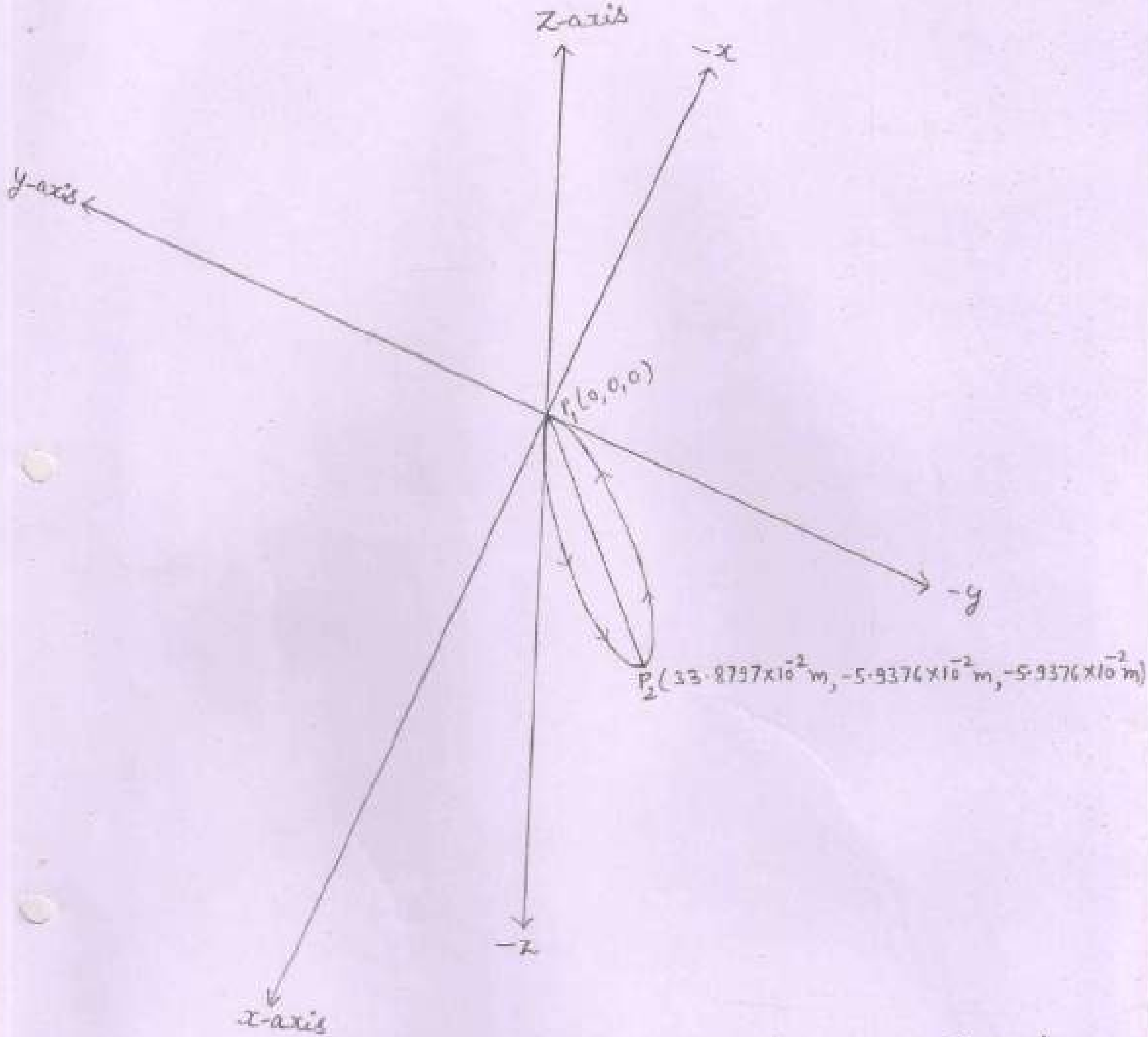
$$\cos\gamma = -0.17$$

$\Rightarrow z_2 - z_1 = d \times \cos\gamma$

$\Rightarrow z_2 - z_1 = 34.9276 \times 10^{-2} \times (-0.17)\ m$

$\Rightarrow z_2 - z_1 = -5.9376 \times 10^{-2}\ m$

$\Rightarrow z_2 = -5.9376 \times 10^{-2}\ m$ [$\because z_1 = 0$]



⇒ The cartesian coordinates of the points $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$ located on the circumfrence of the circle to be obtained by the lithium-7 nucleus.

For fusion reaction (10) : ${}^{2}_{1}H + {}^{3}_{2}He + {}^{3}_{1}H + {}^{2}_{1}H \rightarrow {}_{5}B + \gamma$ rays

1. Interaction of nuclei :-

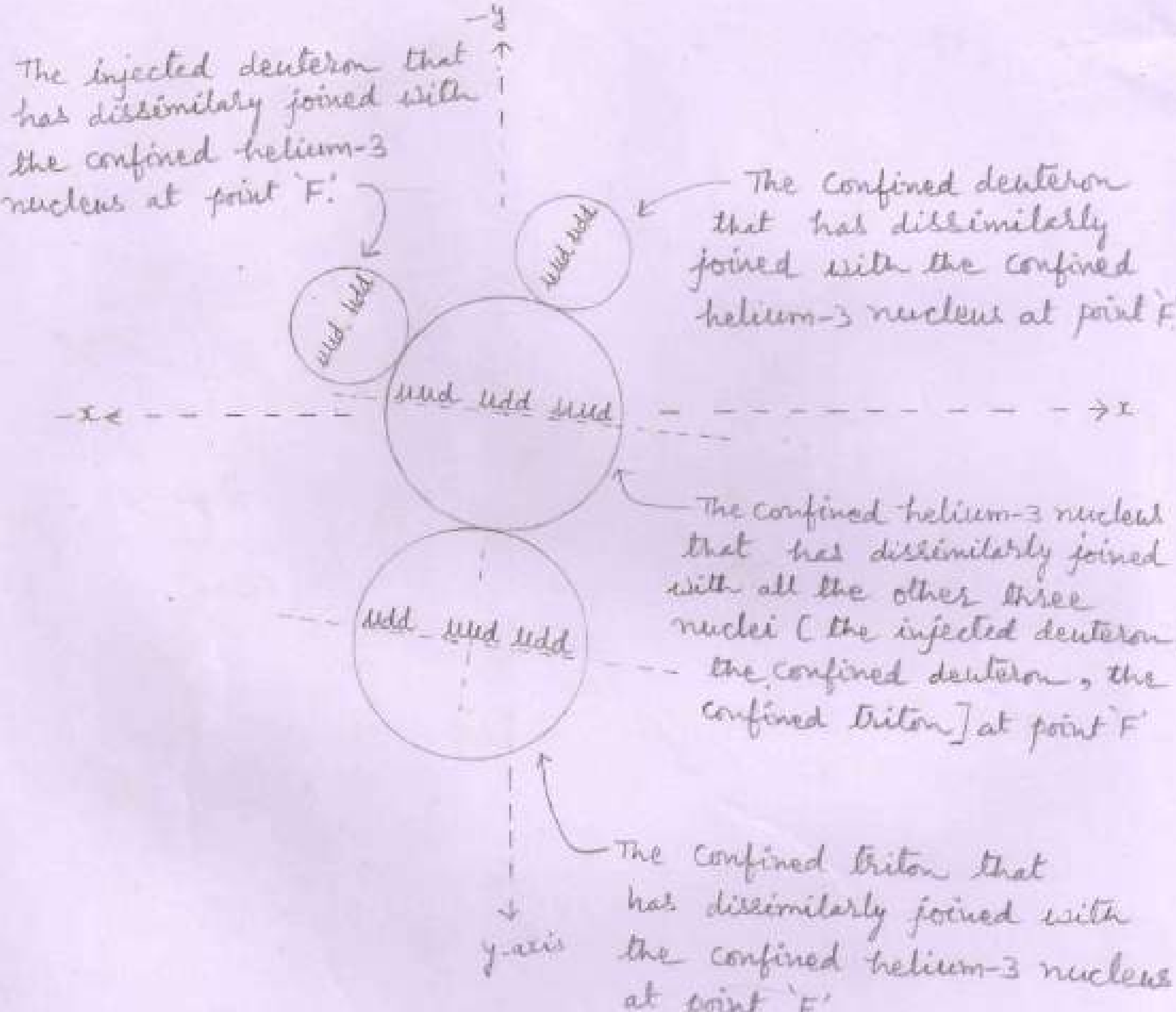
As the injected deuteron reaches at point 'F', it interacts [experiences a repulsive force due to confined helium-3, due to the confined triton and also due to the confined deuteron passing through the point 'F'] with the confined helium-3, confined triton and with confined deuteron at point 'F'.

Similarly, as the confined triton reaches at point 'F', it interacts [experiences a repulsive force due to the injected deuteron reaching at point 'F', due to the confined helium-3 nucleus passing through the point 'F' and also due to the confined deuteron passing through the point 'F'] with the injected deuteron reaching at point 'F' and with the confined helium-3 and with the confined deuteron passing through the point 'F'.

Similarly, as the confined deuteron reaches at point 'F', it interacts [experiences a repulsive force due to the injected deuteron reaching at point 'F', due to the confined helium-3 nucleus, due to the confined triton passing through the point 'F'] with the injected deuteron reaching at point 'F', with the confined helium-3, confined triton and confined deuteron passing through the point 'F'.

The injected deuteron, the confined triton and the confined deuteron - all these overcomes the electrostatic repulsive force and thus all the four nuclei [the injected deuteron, the confined helium-3, the confined

Interaction of nuclei :-

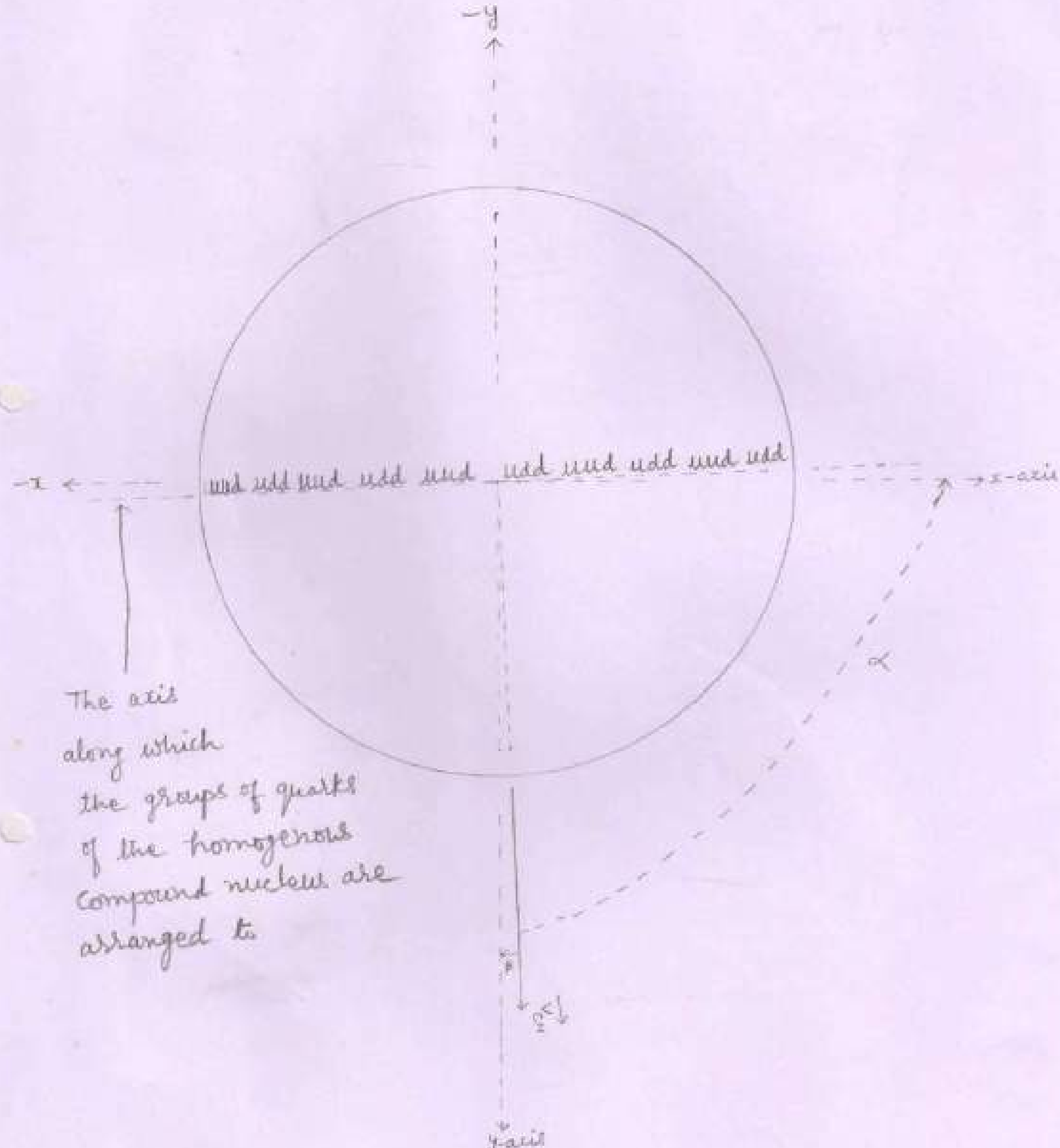


1

2. Formation of homogenous compound nucleus :-
The constituents (quarks and gluons) of the dissimilarly joined nuclei (the injected deuteron, the confined helium-3, the confined triton and the confined deuteron) behave like a liquid and form the homogenous compound nucleus having similarly distributed groups of quarks with similarly distributed surrounding gluons.

Thus, within the homogenous compound nucleus - each group of quarks is surrounded by the gluons in equal proportion. So, within the homogenous compound nucleus there are 10 groups of quarks surrounded by the gluons.

The homogenous compound nucleus :-



2

1. Where,

$\alpha \simeq 88.25$ degree

$\beta \simeq 1.75$ degree

2. The velocity of Compound nucleus ($\vec{V}_{CN}$) is perpendicular to the

3. Formation of lobes within into the homogenous compound nucleus [$^{10}_{5}M$] or the transformation of the homogenous compound nucleus into the heterogenous compound nucleus:-

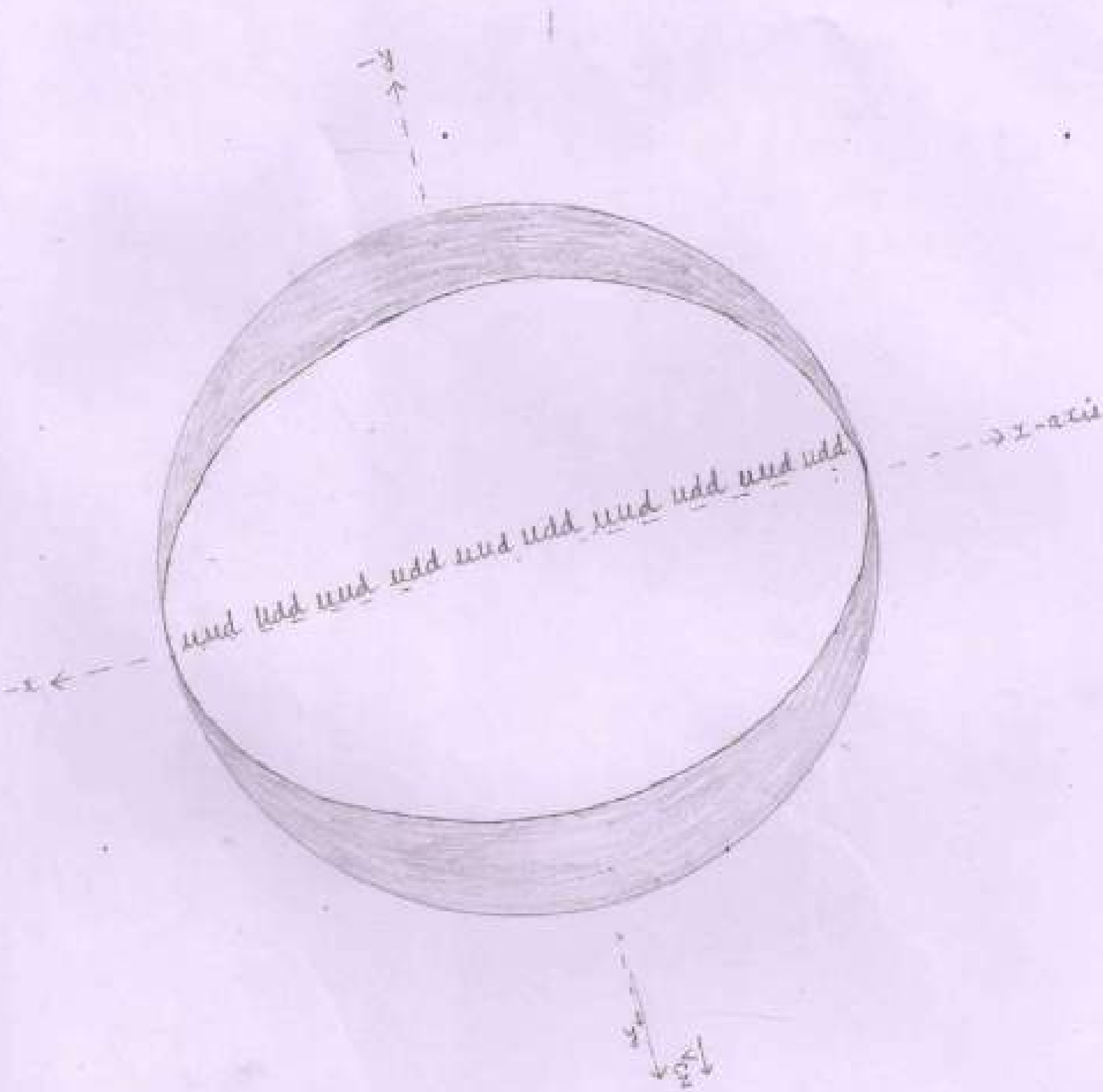
The homogenous compound nucleus [$^{10}_{5}M$] is unstable. So, for stability, the central group of quarks with its surrounding gluons to become a stable and the just lower nucleus (the boron-10) than the homogenous one [$^{10}_{5}M$], includes the other 9 groups of quarks with their surrounding gluons and rearrange to form the 'A' lobe of the heterogenous compound nucleus.

While the remaining gluons [the gluons (or the mass) that are not involved in the formation of the lobe 'A'] rearrange to form the 'B' lobe of the heterogenous compound nucleus.

Thus, due to formation of two lobes within into the homogenous compound nucleus, the homogenous compound nucleus transforms into the heterogenous compound nucleus.

* The homogenous compound nucleus [$^{10}_{5}M$] has more mass than the boron-10 nucleus.

Formation of lobes within into the homogenous compound nucleus :-



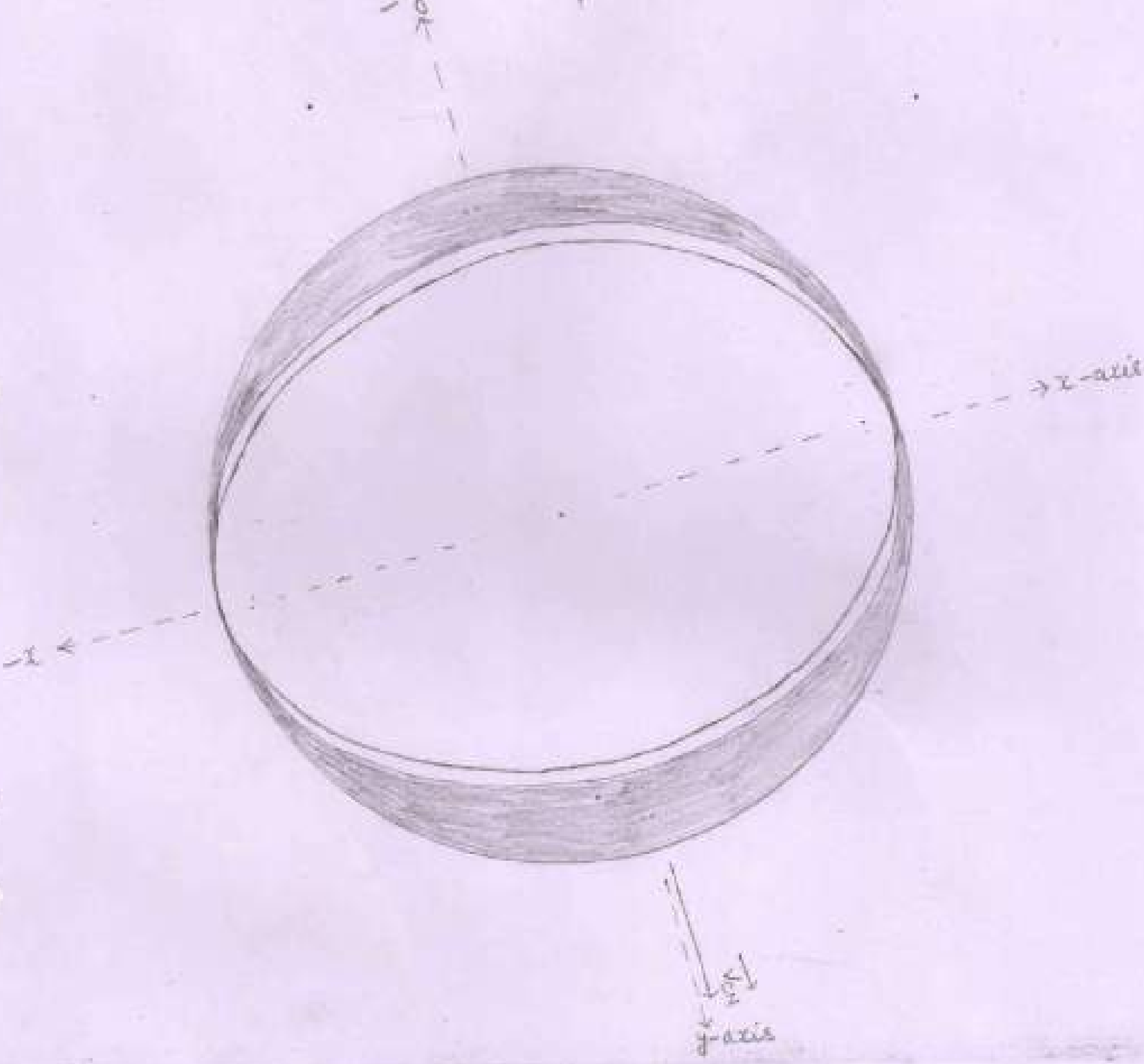
⇒ Where,

1. Inner side - the lobe 'A' is formed [that is the boron-10 nucleus is formed]
2. Outer side - the lobe 'B' is formed [That is the remaining gluons (or the reduced mass) represents the lobe 'B']

4. Final stage of the heterogenous compound nucleus :-

The remaining gluons [that compose the 'B' lobe of the heterogenous compound nucleus] remains loosely bonded to the boron-10 nucleus [that compose the 'A' lobe of the heterogenous compound nucleus]. Thus, the heterogenous compound nucleus, finally, becomes like a coconut into which the remaining gluons represents the outer shield of the coconut while the boron-10 nucleus represents the inner-part of the coconut.

The final Stage of the heterogenous compound nucleus:-



The fusion Reaction is -

$$ {}_{1}^{2}H + {}_{2}^{3}He + {}_{1}^{3}H + {}_{1}^{2}H \longrightarrow {}_{5}^{10}B + \gamma \text{ rays} $$

[injected] [Confined]

1. Minimum kinetic energy (E_m) required by the deuteron :-

For the above fusion reaction, the deuteron [either it is injected or confined] has to overcome the electrostatic repulsive force exerted by the four positive charges. So,

$$ E_m = E_{D-D} \times Z_2^2 $$

$Z_2 = 4$

$E_{D-D} = 5.0622$ kev

$$ \Rightarrow E_m = 5.0622 \text{ kev} \times (4)^2 $$

$$ \Rightarrow E_m = 80.9952 \text{ kev} $$

$$ \Rightarrow E_m = 0.0809952 \text{ MeV} $$

2. Just before fusion, the kinetic energy (E_b) of the deuteron [either it is injected or confined] :-

(i) Just before fusion, to overcome the electrostatic repulsive force, the deuteron has to loose the energy equal to minimum kinetic energy (E_m) required for fusion. That is, just before fusion, the deuteron loses energy -

$$E_{loss} = E_m = 80.9952 \text{ kev}.$$

(ii) So, just before fusion, the kinetic energy (E_b) of the deuteron [either it is injected or confined] is —

$$E_b = E_{injected} - E_{loss}$$

$$\Rightarrow E_b = [102.4 \text{ kev}] - [80.9952 \text{ kev}]$$

$$\Rightarrow E_b = 21.4048 \text{ kev}$$

$$\Rightarrow E_b = 0.0214048 \text{ Mev}$$

3. Just before fusion, the momentum (P_b) of the deuteron [either it is injected or confined] :-

$$P_b = \left[2 \, m_d \, E_b \right]^{\frac{1}{2}}$$

$E_b = 0.0214048$ MeV

1 MeV $= 1.6 \times 10^{-13}$ J

$$\Rightarrow P_b = \left[2 \times 3.3434 \times 10^{-27} \times 0.0214048 \times 1.6 \times 10^{-13} \right]^{\frac{1}{2}} \text{ Kgm/s}$$

$$\Rightarrow P_b = \left[0.22900738662 \times 10^{-40} \right]^{\frac{1}{2}} \text{ Kgm/s}$$

$$\Rightarrow P_b = 0.4785 \times 10^{-20} \text{ Kgm/s}$$

4. Just before fusion, the components of momentum ($\vec{P}_b$) of the deuteron [either it is injected or confined] :-

The deuteron [either it is injected or confined] reaches at point 'F' making angles

$$\alpha = 30^\circ$$
$$\beta = 60^\circ$$
$$\gamma = 90^\circ$$

with positive x, y and z axes respectively.

So, just before fusion, the components of the momentum ($\vec{P}_b$) of the deuteron are -

1. $\vec{P}_x = P_b \cos\alpha$

$\cos\alpha = \cos 30^\circ = 0.866$

$P_b = 0.4785 \times 10^{-20}$ Kgm/s

$\Rightarrow \vec{P}_x = 0.4785 \times 10^{-20} \times 0.866$ Kgm/s

$\Rightarrow \vec{P}_x = 0.4143 \times 10^{-20}$ Kgm/s

2. $\vec{P}_y = P_b \cos\beta$

$\cos\beta = \cos 60^\circ = 0.5$

$\Rightarrow \vec{P}_y = 0.4785 \times 10^{-20} \times 0.5$ Kgm/s

$\Rightarrow \vec{P}_y = 0.2392 \times 10^{-20}$ Kgm/s

3. $\vec{P}_z = P_b \cos\gamma$

$\cos\gamma = \cos 90^\circ = 0$

$\Rightarrow \vec{P}_z = 0.4785 \times 10^{-20} \times 0$ Kgm/s

$\Rightarrow \vec{P} = 0$ Kgm/s

II. For triton

1 Minimum kinetic energy (E_m) required by the triton :

For the described fusion reaction, the triton has to overcome the electrostatic repulsive force exerted by the other four positive charges. So,

$$E_m = \frac{2 k^2 z_1^2 z_2^2 q^4 m_t}{h^2}$$

$z_1 = 1$
$z_2 = 4$

$$\Rightarrow E_m = \frac{2 \times (9 \times 10^9)^2 \times 1^2 \times 4^2 \times (1.6 \times 10^{-19})^4 \times 5.0072 \times 10^{-27}}{(6.62 \times 10^{-34})^2} \text{ J}$$

$$\Rightarrow E_m = \frac{85056.9619046 \times 10^{18} \times 10^{-76} \times 10^{-27}}{43.8244 \times 10^{-68}} \text{ J}$$

$$\Rightarrow E_m = 1940.85856063 \times 10^{-17} \text{ J}$$

$$\Rightarrow E_m = 1213.0366003 9 \times 10^2 \text{ eV}$$

$$\Rightarrow E_m = 121.3036 \text{ KeV}$$

$$\Rightarrow E_m = 0.1213036 \text{ MeV}$$

$$\Rightarrow E_m \approx 0.1213 \text{ MeV}$$

2. Just before fusion, the kinetic energy (E_b) of the triton :-

Just before fusion, to overcome the electrostatic repulsive force, the triton has to lose energy equal to the minimum kinetic energy (E_m). That is the triton loses energy equal to 0.1213 Mev.

$$E_b = E_{injected} - E_{lose}$$

$$\Rightarrow E_b = [1.1583 \text{ Mev}] - [0.1213 \text{ Mev}]$$

$$\Rightarrow E_b = 1.037 \text{ Mev}$$

⇒ At point 'F', the triton is produced or carries the 1.1583 Mev energy. So, when the triton passes through the point 'F' again, it has the same velocity and the energy with which it was produced.

3. Just before fusion, the momentum of the triton :-

$$P_b = \left[2 m_t E_b \right]^{\frac{1}{2}}$$

$$\Rightarrow P_b = \left[2 \times 5.0072 \times 10^{-27} \times 1.037 \times 1.6 \times 10^{-13}\right]^{\frac{1}{2}} \text{ Kgm/s}$$

$$\Rightarrow P_b = \left[16.61589248 \times 10^{-40}\right]^{\frac{1}{2}} \text{ Kgm/s}$$

$$\Rightarrow P_b = 4.0762 \times 10^{-20} \text{ Kgm/s}$$

4. Just before fusion, the Components of momentum ($\vec{P}_b$) of the triton :-

The triton is produced at point 'F' where the velocity of the triton make angles α, β and γ with positive x, y and z axes respectively. Where, $\alpha \simeq 99^\circ$

$\beta \simeq 9^\circ$

$\gamma = 90^\circ$

(i) $\vec{P}_x = P_b \cos\alpha$

$\cos\alpha \simeq \cos 99^\circ \simeq -0.15$

$$\Rightarrow \vec{P}_x = 4.0762 \times 10^{-20} \text{ Kgm/s} \times (-0.15)$$
$$= -0.6114 \times 10^{-20} \text{ Kgm/s}$$

(ii) $\vec{P}_y = P_b \cos\beta$

$\cos\beta \simeq \cos 9^\circ \simeq 0.98$

$$\Rightarrow \vec{P}_y = 4.0762 \times 10^{-20} \times 0.98 \text{ Kgm/s}$$
$$= 3.9946 \times 10^{-20} \text{ Kgm/s}$$

(iii) $\vec{P}_z = P_b \cos\gamma$

$\cos\gamma = \cos 90^\circ = 0$

$$\Rightarrow \vec{P}_z = 4.0762 \times 10^{-20} \times 0 \text{ Kgm/s}$$
$$= 0 \text{ Kgm/s}$$

The components of the momentum of the compound nucleus :-

According to	At point `F' just before fusion, the components of momentum of the injected deuteron	At point `F' the components of momentum of the confined helium-3 with which it was produced	At point `F', just before fusion, the components of momentum of the confined triton	At point `F', just before fusion, the components of momentum of the confined deuteron	At point `F', After fusion, the components of momentum of the compound nucleus
0	1	2	3	4	5=1+2+3+4
x-axis	$\vec{P}_x =$ 0.4143×10^{-20} kg m/s	$\vec{P}_x =$ -0.4710×10^{-20} kg m/s	$\vec{P}_x =$ -0.6114×10^{-20} kg m/s	$\vec{P}_x =$ 0.4143×10^{-20} kg m/s	$\vec{P}_x =$ 0.2538×10^{-20} kg m/s
y-axis	$\vec{P}_y =$ 0.2392×10^{-20} kg m/s	$\vec{P}_y =$ 3.9094×10^{-20} kg m/s	$\vec{P}_y =$ 3.9946×10^{-20} kg m/s	$\vec{P}_y =$ 0.2392×10^{-20} kg m/s	$\vec{P}_y =$ 8.3824×10^{-20} kg m/s
z-axis	$\vec{P}_z = 0$ kg m/s	$\vec{P}_z = 0$ kg m/s	$\vec{P}_z = 0$ kg m/s	$\vec{P}_z = 0$ kg m/s	$\vec{P}_z = 0$ kg m/s

Mass of the compound nucleus (M) :-

$$M = (m_d + m_{he-3} + m_t + m_d)$$

$$M = (3.3434\times10^{-27} + 5.00629\times10^{-27} + 5.0072\times10^{-27} + 3.3434\times10^{-27})\,kg$$

The components of the velocity of the compound nucleus ($\vec{V}_{CN}$) :-

1. X-component of velocity of compound nucleus :-

$$\vec{V}_x = V_{CN} \cos\alpha = \frac{M V_{CN} \cos\alpha}{M} = \frac{\vec{P_x}}{M}$$

$$\vec{P}_x = M V_{CN} \cos\alpha = 0.2538 \times 10^{-20} \text{ Kgm/s}$$

$$M = 16.70029 \times 10^{-27} \text{ kg}$$

$$\Rightarrow \vec{V}_x = V_{CN} \cos\alpha = \frac{0.2538 \times 10^{-20}}{16.70029 \times 10^{-27}} \frac{\text{kg m/s}}{\text{kg}}$$

$$\Rightarrow \vec{V}_x = V_{CN} \cos\alpha = 0.0151 \times 10^{7} \text{ m/s}$$

2. Y-component of velocity of compound nucleus

$$\vec{V}_y = V_{CN} \cos\beta = \frac{M V_{CN} \cos\beta}{M} = \frac{\vec{P_y}}{M}$$

$$\vec{P}_y = M V_{CN} \cos\beta = 8.3824 \times 10^{-20} \text{ kgm/s}$$

$$\Rightarrow \vec{V}_y = V_{CN} \cos\beta = \frac{8.3824 \times 10^{-20}}{16.70029 \times 10^{-27}} \frac{\text{kg m/s}}{\text{kg}}$$

$$\Rightarrow \vec{V}_y = V_{CN} \cos\beta = 0.5019 \times 10^{7} \text{ m/s}$$

3. Z-component of velocity of compound nucleus

$$\vec{V}_z = V_{CN} \cos\gamma = \frac{M V_{CN} \cos\gamma}{M} = \frac{\vec{P_z}}{M}$$

$$\vec{P}_z = M V_{CN} \cos\gamma = 0 \text{ Kgm/s}$$

$$\Rightarrow \vec{V}_z = V_{CN} \cos\gamma = \frac{0}{16.70029 \times 10^{-27}} \frac{\text{Kg m/s}}{\text{kg}}$$

$$\Rightarrow \vec{V}_z = V_{CN} \cos\gamma = 0 \text{ m/s}$$

velocity of the compound nucleus (V_{CN}) :-

$$V_{CN}^2 = V_x^2 + V_y^2 + V_z^2$$

$$\vec{V}_x = V_{CN} \cos\alpha = 0.0151 \times 10^7 \text{ m/s}$$

$$\vec{V}_y = V_{CN} \cos\beta = 0.5019 \times 10^7 \text{ m/s}$$

$$\vec{V}_z = V_{CN} \cos\gamma = 0 \text{ m/s}$$

$$\Rightarrow V_{CN}^2 = (0.0151 \times 10^7)^2 + (0.5019 \times 10^7)^2 + (0)^2 \text{ m}^2/\text{s}^2$$

$$\Rightarrow V_{CN}^2 = (0.00022801 \times 10^{14}) + (0.25190361 \times 10^{14}) + (0) \text{ m}^2/\text{s}^2$$

$$\Rightarrow V_{CN}^2 = 0.25213162 \times 10^{14} \text{ m}^2/\text{s}^2$$

$$\Rightarrow V_{CN} = 0.5021 \times 10^7 \text{ m/s}$$

Angles that make the velocity of compound nucleus ($\vec{V}_{CN}$) with positive x, y and z-axes. :-

1. With x-axis

$$\cos\alpha = \frac{V_{CN}\cos\alpha}{V_{CN}} = \frac{\vec{V_x}}{V_{CN}}$$

$$\vec{V}_x = V_{CN}\cos\alpha = 0.0151\times10^7 \text{ m/s}$$

$$V_{CN} = 0.5021\times10^7 \text{ m/s}$$

$$\Rightarrow \cos\alpha = \frac{0.0151\times10^7}{0.5021\times10^7}\ \frac{\text{m/s}}{\text{m/s}} = 0.0300$$

$\Rightarrow \alpha \simeq 88.25$ degree $\quad [\because \cos(88.25) = 0.030]$

2. With y-axis

$$\cos\beta = \frac{V_{CN}\cos\beta}{V_{CN}} = \frac{\vec{V_y}}{V_{CN}}$$

$$\vec{V}_y = V_{CN}\cos\beta = 0.5019\times10^7 \text{ m/s}$$

$$\Rightarrow \cos\beta = \frac{0.5019\times10^7}{0.5021\times10^7}\ \frac{\text{m/s}}{\text{m/s}} = 0.9996$$

$\Rightarrow \beta \simeq 1.75$ degree $\quad [\because \cos(1.75) = 0.999]$

3. With z-axis

$$\cos\gamma = \frac{V_{CN}\cos\gamma}{V_{CN}} = \frac{\vec{V_z}}{V_{CN}}$$

$$\vec{V_z} = 0 \text{ m/s}$$

$$\Rightarrow \cos\gamma = \frac{0}{0.5021\times10^7}\ \frac{\text{m/s}}{\text{m/s}} = 0$$

$\Rightarrow \gamma = 90^\circ$

The splitting of the heterogenous compound nucleus :-

⇒ The remaining gluons are loosely bonded to the boron-10 nucleus.

⇒ At the poles of the boron-10 nucleus, the remaining gluons are lesser in amount than at the equator.

⇒ So, during the rearrangement of the remaining gluons [or during the formation of the 'B' lobe of the heterogenous compound nucleus], the remaining gluons to be homogenously distributed all around, rush from the equator to the poles.

In this way, the loosely bonded remaining gluons separates from the boron-10 nucleus and also divides itself into two parts giving us three particles – the first one is the one-half of the reduced mass, second one is the boron-10 nucleus and the third one is the another one-half of the reduced mass.

⇒ Thus, the heterogenous compound nucleus splits according to the lines parallel to the velocity of the compound nucleus into three particles — the first one is the one-half of the reduced mass ($\frac{\Delta m}{2}$), the second one is the boron-10 nucleus and the third one is the another one-half of the reduced mass ($\frac{\Delta m}{2}$).

⇒ By the law of inertia, each particle that has separated from the compound nucleus has an inhereted velocity ($\vec{V}_{inh}$) equal to the velocity of the compound nucleus ($\vec{V}_{CN}$).

⇒ So, for conservation of momentum

$$M\vec{V}_{CN} = \left(\frac{\Delta m}{2} + m_{B\text{-}10} + \frac{\Delta m}{2}\right)\vec{V}_{CN}$$

Where,

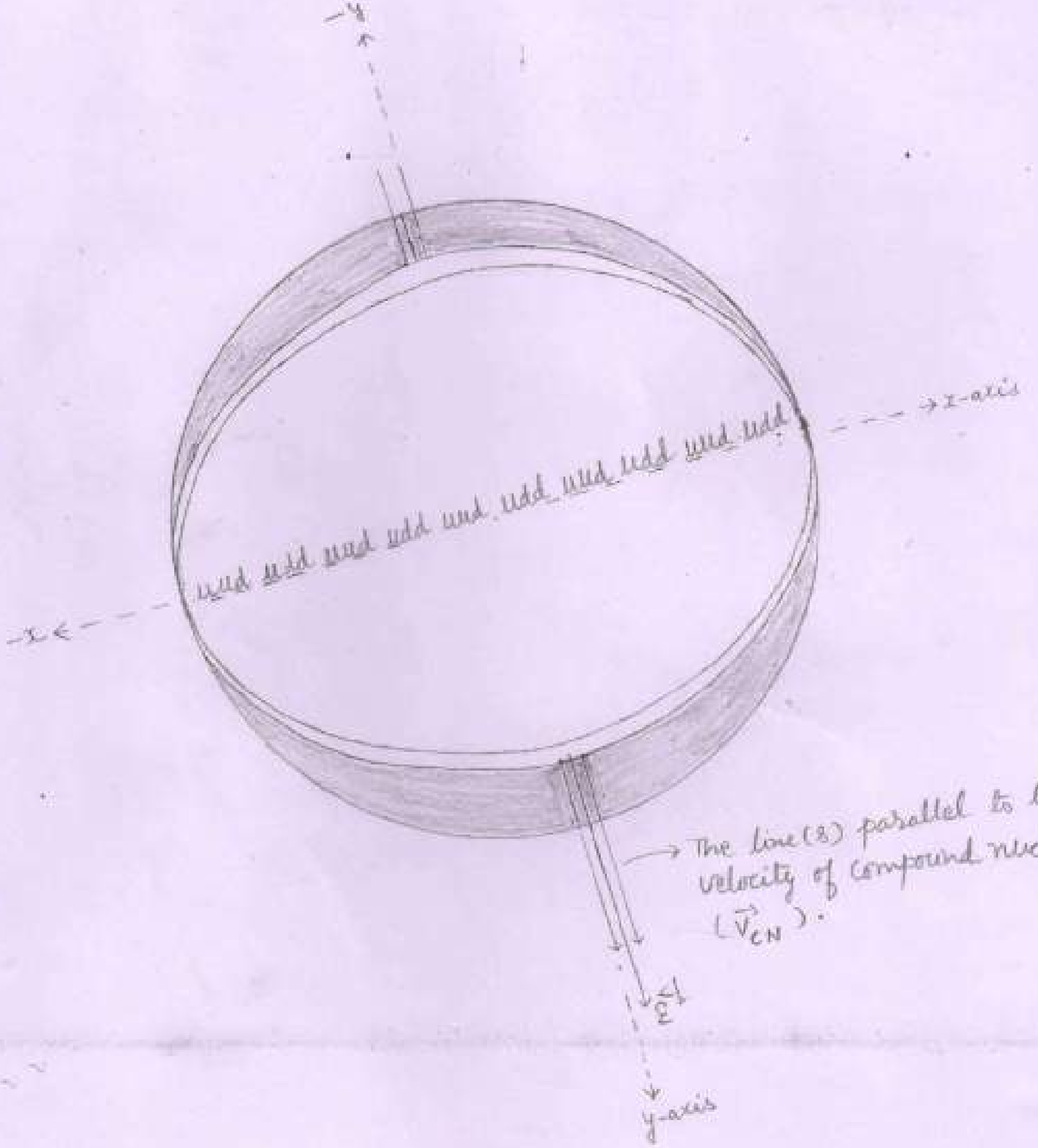
M = Mass of the compound nucleus

$\vec{V}_{CN}$ = velocity of the compound nucleus

$\frac{\Delta m}{2}$ = A particle having a mass equal to the one-half of the reduced mass.

$m_{B\text{-}10}$ = mass of the boron-10 nucleus.

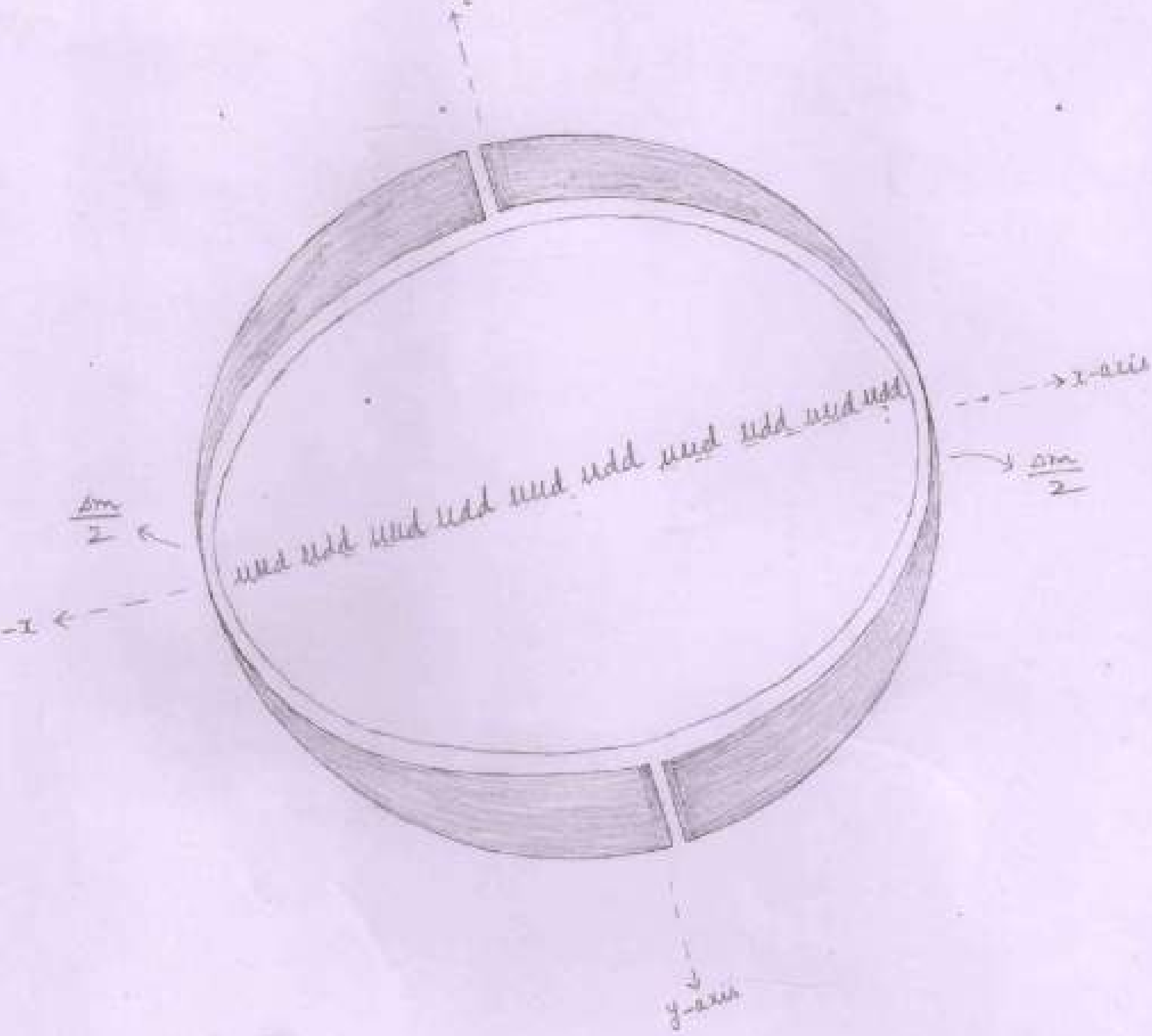
The Splitting of the heterogenous compound nucleus :-



The line(s) parallel to the velocity of compound nucleus ($\vec{V}_{CN}$).

SP-1

The splitting of the heterogenous compound nucleus :-



$\boxed{\text{Sp-2}}$

⇒ The heterogenous compound nucleus splits into three particles —

(1) $\frac{\Delta m}{2}$ (2) $^{10}_{5}B$ (3) $\frac{\Delta m}{2}$

The inhereted velocity ($\vec{V}_{inh}$) of the particles

$\Rightarrow$ Each particle that has separated from the compound nucleus has an inhereted velocity ($\vec{V}_{inh}$) equal to the velocity of the compound nucleus ($\vec{V}_{CN}$).

I. The inhereted velocity ($\vec{V}_{inh}$) of the boron-10

$$\vec{V}_{inh} = \vec{V}_{CN} = 0.5021 \times 10^{7} \text{ m/s}$$

The components of inhereted velocity ($\vec{V}_{inh}$) of boron-10

1. $\vec{V}_{x} = V_{inh} \cos\alpha = V_{CN} \cos\alpha = 0.0151 \times 10^{7}$ m/s

2. $\vec{V}_{y} = V_{inh} \cos\beta = V_{CN} \cos\beta = 0.5019 \times 10^{7}$ m/s

3. $\vec{V}_{z} = V_{inh} \cos\gamma = V_{CN} \cos\gamma = 0$ m/s

II. The inhereted velocity ($\vec{V}_{inh}$) of the each one-half of the reduced mass :-

$$\vec{V}_{inh} = \vec{V}_{CN} = 0.5021 \times 10^{7} \text{ m/s}$$

Propellation of the particle

1. Reduced mass (Δm) :-

$$\Delta m = [m_d + m_{he\text{-}3} + m_t + m_d] - [m_{B\text{-}10}]$$

$$\Delta m = [2.01355 + 3.014932 + 3.0155 + 2.01355] - [10.01293] \text{ amu}$$

$$\Delta m = [\ 10.057532\ ] - [\ 10.01293\ ] \text{ amu}$$

$$\Delta m = 0.044602 \text{ amu}$$

$$\Delta m = 0.044602 \times 1.6605 \times 10^{-27} \text{ Kg}$$

$$\Delta m = 0.074061621 \times 10^{-27} \text{ Kg}$$

2. Inhereted kinetic energy (E_{inh}) of the reduced mass (Δm)

$$\Rightarrow E_{inh} = \frac{1}{2} \Delta m V_{inh}^2$$

$\Rightarrow E_{inh} = \frac{1}{2} \Delta m \, v_{CN}^2$

$\Delta m = 0.074061621 \times 10^{-27}$ kg

$v_{CN}^2 = 0.25213162 \times 10^{14}$ m²/s²

$\Rightarrow E_{inh} = \frac{1}{2} \times 0.074061621 \times 10^{-27} \times 0.25213162 \times 10^{14}$ J

$\Rightarrow E_{inh} = 0.0093366 3824 \times 10^{-13}$ J

$\Rightarrow E_{inh} = 0.005835$ Mev

3. Released energy (E_R) :-

$E_R = \Delta m \, c^2$

$\Delta m = 0.044602$ amu

1 amu $= 931$ Mev

$\Rightarrow E_R = 0.044602 \times 931$ Mev

$= 41.524462$ Mev

4. Total energy (E_T) :-

$E_T = E_{Inhereted} + E_{Released}$

$\Rightarrow E_T = [0.005835 + 41.524462]$ Mev

$\Rightarrow E_T = 41.530297$ Mev

$\Rightarrow E_T = 41.5302$ Mev

Propellation of the particle

⇒ The each one-half of the reduced mass ($\Delta m/2$) converts into energy. So, the energy (E) carried by the produced pairs of gamma ray photons is -

$$E = \frac{E_T}{2}$$

$$E_T = 41.5302 \text{ Mev}$$

$$\Rightarrow E = \frac{41.5302}{2} \text{ Mev}$$

$$\Rightarrow E = 20.7651 \text{ Mev}$$

Number of pairs of gamma ray photons (N_γ) :-

⇒ When one-half of the reduced mass ($\Delta m/2$) converts into energy, the energy (E) carried by the pairs of gamma ray photons is 20.7651 Mev.

⇒ Each pair of gamma ray photon that carry a part of energy (E) must have an energy equal to or more than 1.02 Mev.

⇒ So,

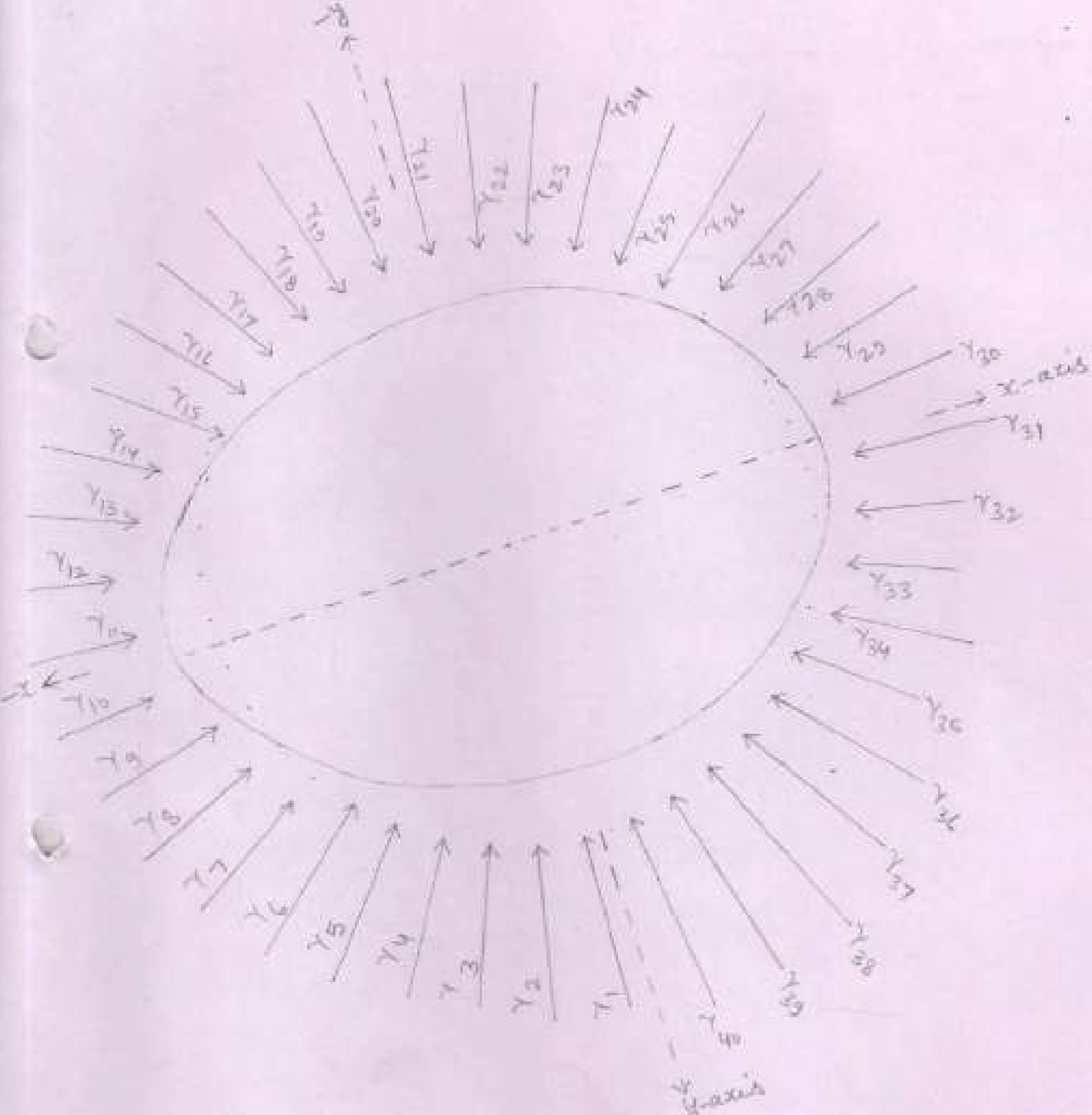
Number of pairs of gamma ray photons = $\frac{\text{Energy (E) produced due to } \Delta m/2}{\text{Energy that must carried by a } \gamma \text{ pair of g.r. photon}}$

$$\Rightarrow N_\gamma = \frac{20.7651}{1.02} \frac{Mev}{Mev}$$

$$\Rightarrow N_\gamma = 20.35$$

⇒ Taking the whole digit, we may say that there are 20 pairs of gamma ray photons that carry the energy 20.7651 Mev

⇒ Thus, there are the 40 pairs of gamma ray photons that carry the total energy (E_T) equal to ~~41.~~ 41.5302 Mev.



-: Propellation of the boron-10 nucleus :-

⇒ Each pair of gamma ray photon make a head-on collision with the boron-10 nucleus.

⇒ Total 40 pairs of gamma ray photons strike to the boron-10 nucleus and energise it by the

Energy carried by the each pair of gamma ray photon [E_γ] :-

$$E_\gamma = \frac{\text{Energy (E) produced due to } \Delta m/2}{\text{Total number of pairs of gamma ray photons that carry energy (E)}}$$

$$\Rightarrow E_\gamma = \frac{E_T/2}{N_\gamma}$$

$$\Rightarrow E_\gamma = \frac{20.7651}{20} \text{ Mev}$$

$$\Rightarrow E_\gamma = 1.03825 \text{ Mev}$$

Conclusion : each pair of gamma ray photon carry 1.03825 MeV.

Increased energy (E_{inc}) of the boron-10 nucleus :-

⇒ Each pair of gamma ray photon by making a head-on collision with boron-10 nucleus imparts its extra energy to the boron-10 nucleus.

⇒ Extra energy of the each pair of gamma ray photon is energy (E_{γ}) carried by the each pair of gamma ray photon minus 1.02 Mev
That is

$$E_{extra} = [E_{\gamma}] - [m_{e^+}c^2 + m_{e^-}c^2]$$

$$\Rightarrow E_{extra} = [1.03825 \text{ Mev}] - [1.02 \text{ Mev}]$$

$$\Rightarrow E_{extra} = 0.01825 \text{ Mev}$$

⇒ So, when 40 pairs of gamma ray photons strike to the boron-10 nucleus, the increased energy (E_{inc}) of the boron-10 nucleus is -

$$E_{inc} = E_{\text{imparted by each pair of g.r. photon}} \times 40$$

$$\Rightarrow E_{inc} = E_{extra} \times 40$$

$$\Rightarrow E_{inc} = 0.01825 \text{ Mev} \times 40$$

$$= 0.73 \text{ Mev}$$

Increased energy (E_{inc}) of the boron-10 nucleus :-

⇒ Each pair of gamma ray photon by making a head-on collision with boron-10 nucleus imparts its extra energy to the boron-10 nucleus.

⇒ Extra energy of the each pair of gamma ray photon is energy (E_γ) carried by the each pair of gamma ray photon minus 1.02 Mev
That is

$$E_{extra} = [E_\gamma] - [m_{e^+}c^2 + m_{e^-}c^2]$$

⇒ E

$$\Rightarrow E_{extra} = [1.03825 \text{ Mev}] - [1.02 \text{ Mev}]$$

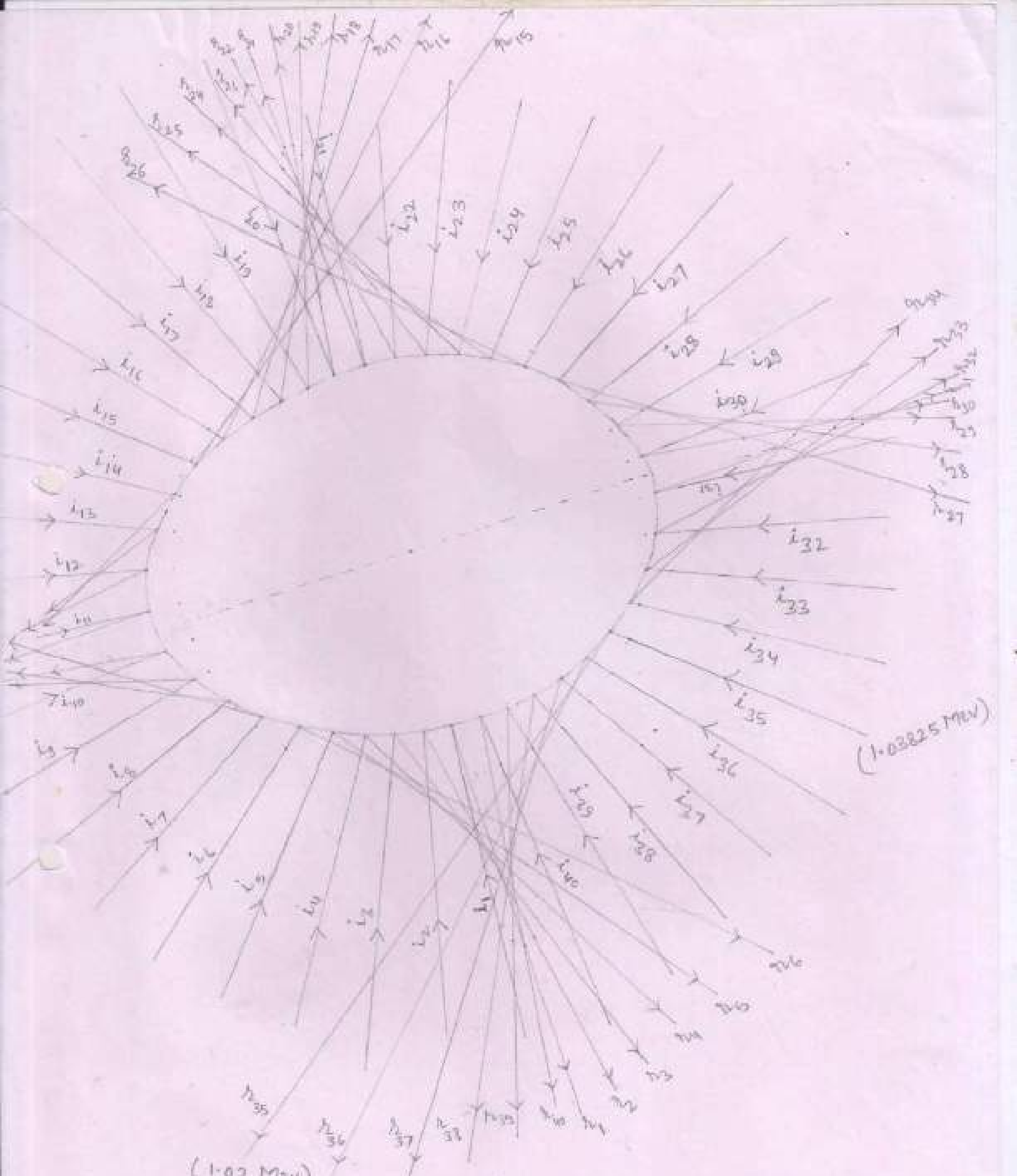
$$\Rightarrow E_{extra} = 0.01825 \text{ Mev}$$

⇒ So, when 40 pairs of gamma ray photons strike to the boron-10 nucleus, the increased energy (E_{inc}) of the boron-10 nucleus is —

$$E_{inc} = E_{\text{imparted by each pair of g. r. photon}} \times 40$$

$$\Rightarrow E_{inc} = E_{extra} \times 40$$

$$\Rightarrow E_{inc} = 0.01825 \text{ Mev} \times 40$$
$$= 0.73 \text{ Mev}$$



→ Each pair of gamma ray photon imparts its extra energy to the boron-10 nucleus.

→ Total 40 pairs of gamma ray photons strike to the boron-10

Increased velocity (V_{inc}) of the Boron-10 nucleus :-

$$V_{inc} = \left[\frac{2\,E_{inc}}{m_{B-10}}\right]^{\frac{1}{2}}$$

$E_{inc} = 0.73$ MeV

$m_{B-10} = 16.6264 \times 10^{-27}$ kg

$$\Rightarrow V_{inc} = \left[\frac{2 \times 0.73 \times 1.6 \times 10^{-13}}{16.6264 \times 10^{-27}} \; \frac{J}{kg}\right]^{\frac{1}{2}}$$

$$\Rightarrow V_{inc} = \left[\frac{2.336}{16.6264} \times 10^{14}\right]^{\frac{1}{2}} \; m/s$$

$$\Rightarrow V_{inc} = \left[0.14049944666 \times 10^{14}\right]^{\frac{1}{2}} \; m/s$$

$$\Rightarrow V_{inc} = 0.3748 \times 10^{7} \; m/s$$

Components of increased velocity (V_{inc}) of Boron-10 nucleus :-

1. We know that the at point 'F', the Boron-10 nucleus has separated from the compound nucleus with an inhereted velocity ($\vec{V}_{inh}$) equal to the velocity of the compound nucleus ($\vec{V}_{CN}$). So, the inhereted velocity makes angle

$\alpha \simeq$ 88.25 degree

$\beta \simeq$ 1.75 degree

$\gamma \simeq$ 90°

with positive x, y and z-axes respectively.

2 At point 'F', the boron-10 nucleus and the gamma ray photons are produced at once. The gamma ray photons that are produced with the boron-10 nucleus again heat [collide with] the boron-10 nucleus and increase its energy (tempreture) by 0.73 Mev.

3. So, we may say that at point 'F', the boron-10 nucleus moving in a direction that make angles 88.25 degree with x-axis, 1.75 degree with y-axis and 90 degree with z-axis is again energised by the 0.73 Mev energy. due to head-on collision between the gamma ray photon(s) and the boron-10 nucleus.

4. So, the increased velocity (v_{inc}) of the boron-10 nucleus also make angles

$\alpha \simeq$ 88.25 degree

$\beta \simeq$ 1.75 degree

$\gamma = 90^\circ$

with positive x, y and z-axes respectively.

$\Rightarrow$ So, the components of the increased velocity (v_{inc}) of the boron-10 nucleus are -

(i) $\vec{v}_x = v_{inc} \cos\alpha$

$v_{inc} = 0.3748 \times 10^7$ m/s

$\cos\alpha = \cos(88.25) = 0.03$

$\Rightarrow \vec{v}_x = 0.3748 \times 10^7 \times 0.03$ m/s

$= 0.0112 \times 10^7$ m/s

(ii) $\vec{v}_y = v_{inc} \cos\beta$

$\cos\beta = \cos(1.75) \simeq 0.99$

$\Rightarrow \vec{v}_y = 0.3748 \times 10^7 \times 0.99$ m/s

$= 0.3710 \times 10^7$ m/s

(iii) $\vec{v}_z = v_{inc} \cos\gamma$

$\cos\gamma = \cos 90^\circ = 0$

$\Rightarrow \vec{v}_z = 0.3748 \times 10^7 \times 0$ m/s

$= 0$ m/s

components of final velocity (v_f) of the boron-10 nucleus :-

According to	Inhereted velocity ($\vec{v}_{inh}$)	Increased velocity ($\vec{v}_{inc}$)	Final velocity ($\vec{v}_f$) $\vec{v}_f = \vec{v}_{inh} + \vec{v}_{inc}$
x-axis	$\vec{v}_x = 0.0151 \times 10^7$ m/s	$\vec{v}_x = 0.0112 \times 10^7$ m/s	$\vec{v}_x = 0.0263 \times 10^7$ m/s
y-axis	$\vec{v}_y = 0.5019 \times 10^7$ m/s	$\vec{v}_y = 0.3710 \times 10^7$ m/s	$\vec{v}_y = 0.8729 \times 10^7$ m/s
z-axis	$\vec{v}_z = 0$ m/s	$\vec{v}_z = 0$ m/s	$\vec{v}_z = 0$ m/s

Final velocity ($\vec{v}_f$) of the boron-10 nucleus :-

$$v_f^2 = v_x^2 + v_y^2 + v_z^2$$

$\vec{v}_x = 0.0263 \times 10^7$ m/s

$\vec{v}_y = 0.8729 \times 10^7$ m/s

$\vec{v}_z = 0$ m/s

$$\Rightarrow v_f^2 = (0.0263 \times 10^7)^2 + (0.8729 \times 10^7)^2 + (0)^2 \quad m^2/s^2$$

$$\Rightarrow v_f^2 = (0.00069169 \times 10^{14}) + (0.76195441 \times 10^{14}) + (0) \quad m^2/s^2$$

$$\Rightarrow v_f^2 = 0.7626461 \times 10^{14} \quad m^2/s^2$$

$$\Rightarrow v_f = 0.8732 \times 10^7 \quad m/s$$

Final kinetic energy of the boron-10 nucleus :-

$$E = \frac{1}{2} m_{B-10} \cdot v_f^2$$

$v_f^2 = 0.7626461 \times 10^{14}$ m²/s²

$m_{B-10} = 16.6264 \times 10^{-27}$ Kg

$$\Rightarrow E = \frac{1}{2} \times 16.6264 \times 10^{-27} \times 0.7626461 \times 10^{14} \quad J$$

$$= 6.3400285585 \times 10^{-13} \quad J$$

$$= 3.9625 \quad MeV$$

$$\Rightarrow m_{B-10} v_f^2 = 16.6264 \times 10^{-27} \times 0.7626461 \times 10^{14} \quad J$$

$$= 12.6800 \times 10^{-15} \quad J$$

The forces acting on the boron-10 nucleus

1. $F_y = q v_x B_z \sin\theta$

$\vec{v}_x = 0.0263 \times 10^7$ m/s

$\vec{B}_z = -1$ Tesla

$q = 5 \times 1.6 \times 10^{-19}$ C

$\sin\theta = \sin 90° = 1$

$\Rightarrow F_y = 5 \times 1.6 \times 10^{-19} \times 0.0263 \times 10^7 \times 1 \times 1$ N

$= 0.2104 \times 10^{-12}$ N

From the right hand palm rule, the direction of force $\vec{F}_y$ is according to negative y-axis. So,

$$\vec{F}_y = -0.2104 \times 10^{-12} \text{ N}$$

2. $F_z = q V_x B_y \sin\theta$

$\vec{B}_y = 1$ Tesla

$\sin\theta = \sin 90° = 1$

$\Rightarrow F_z = 5 \times 1.6 \times 10^{-19} \times 0.0263 \times 10^7 \times 1 \times 1$ N

$= 0.2104 \times 10^{-12}$ N

From the right hand palm rule, the direction of force $\vec{F}_z$ is according to negative z-axis. So,

$$\vec{F}_z = -0.2104 \times 10^{-12} \text{ N}$$

3. $F_x = q V_y B_z \sin\theta$

$\vec{V}_y = 0.8729 \times 10^7$ m/s

$\vec{B}_z = -1$ Tesla

$\sin\theta = \sin 90° = 1$

$\Rightarrow F_x = 5 \times 1.6 \times 10^{-19} \times 0.8729 \times 10^7 \times 1 \times 1$ N

$= 6.9832 \times 10^{-12}$ N

From the right hand palm rule, the direction of force $\vec{F}_x$ is according to positive x-axis. So,

$$\vec{F}_x = 6.9832 \times 10^{-12} \text{ N}$$

4. Resultant force (F_R) :-

$$F_R^2 = F_x^2 + F_y^2 + F_z^2$$

$$F_x = 6.9832 \times 10^{-12} \text{ N}$$

$$F = F_y = F_z = 0.2104 \times 10^{-12} \text{ N}$$

$$\Rightarrow F_R^2 = F_x^2 + 2F^2$$

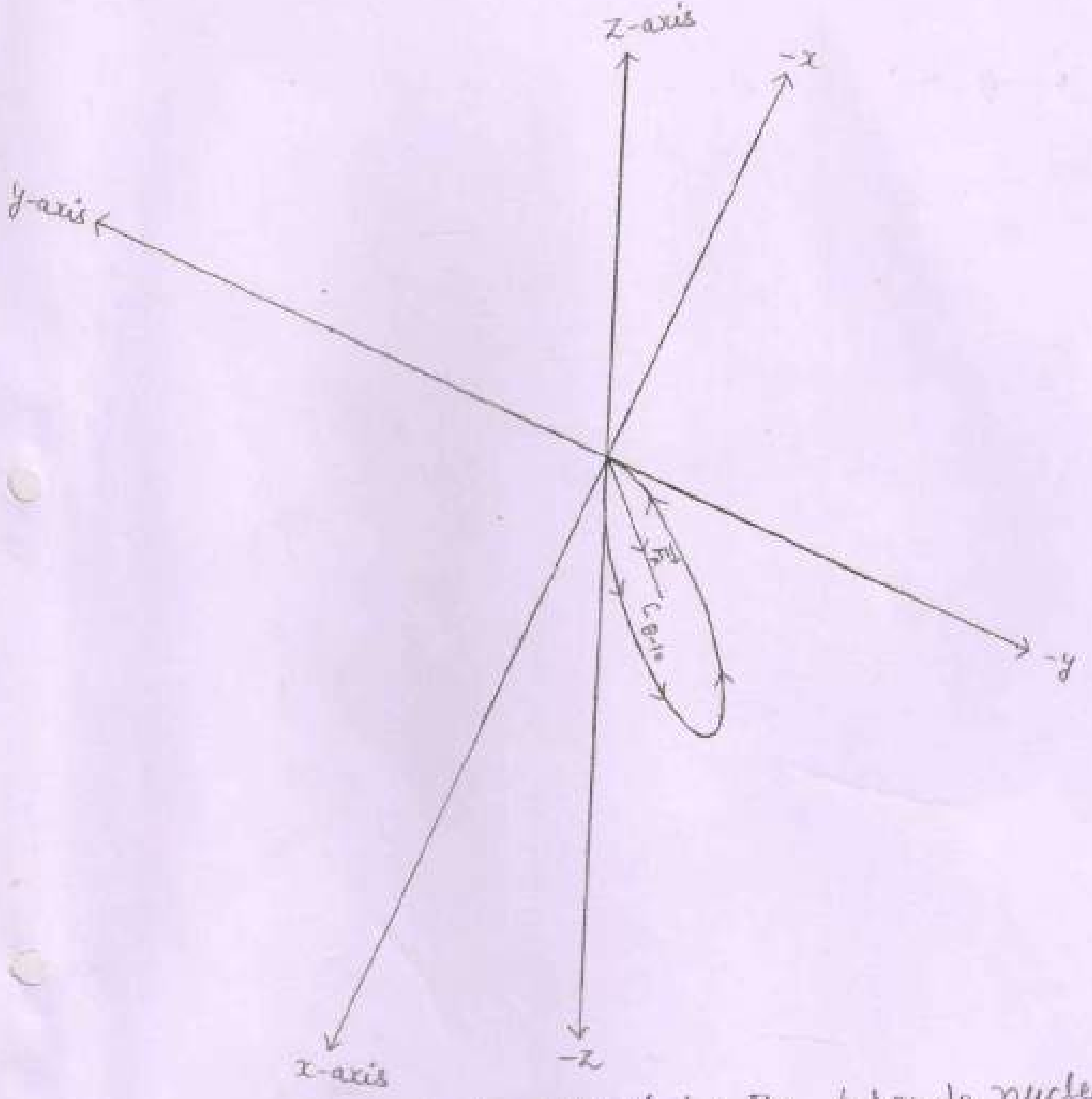
$$\Rightarrow F_R^2 = (6.9832 \times 10^{-12})^2 + 2(0.2104 \times 10^{-12})^2 \text{ N}^2$$

$$\Rightarrow F_R^2 = (48.76508224 \times 10^{-24}) + 2(0.04426816 \times 10^{-24}) \text{ N}^2$$

$$\Rightarrow F_R^2 = (48.76508224 \times 10^{-24}) + (0.08853632 \times 10^{-24}) \text{ N}^2$$

$$\Rightarrow F_R^2 = 48.85361856 \times 10^{-24} \text{ N}^2$$

$$\Rightarrow F_R = 6.9895 \times 10^{-12} \text{ N}$$



⇒ The circular orbit to be followed by the boron-10 nucleus lies in the plane made up of positive x-axis, negative y-axis and the negative z-axis.

⇒ Where, 1. $c_{B\text{-}10}$ = center of the circular orbit to be followed by the boron-10 nucleus

2. $\vec{F}_R$ = The direction of the resultant force acting on the boron-10 when the boron-10 starts its circular motion from the point 'F' or point $P_1(0,0,0)$

Angles that make the resultant force ($\vec{F_R}$) [acting on the boron-10 nucleus at point 'F'] with positive x, y and z-axes. :-

1. With x-axis

$$\cos\alpha = \frac{F_R \cos\alpha}{F_R} = \frac{\vec{F_x}}{F_R} = \frac{6.9832 \times 10^{-12}}{6.9895 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\alpha = 0.9990$

$\Rightarrow \alpha \simeq 2^\circ$ $\quad$ [$\because \cos(2) = 0.9993$]

2. With y-axis

$$\cos\beta = \frac{F_R \cos\beta}{F_R} = \frac{\vec{F_y}}{F_R} = \frac{-0.2104 \times 10^{-12}}{6.9895 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\beta = -0.0301$

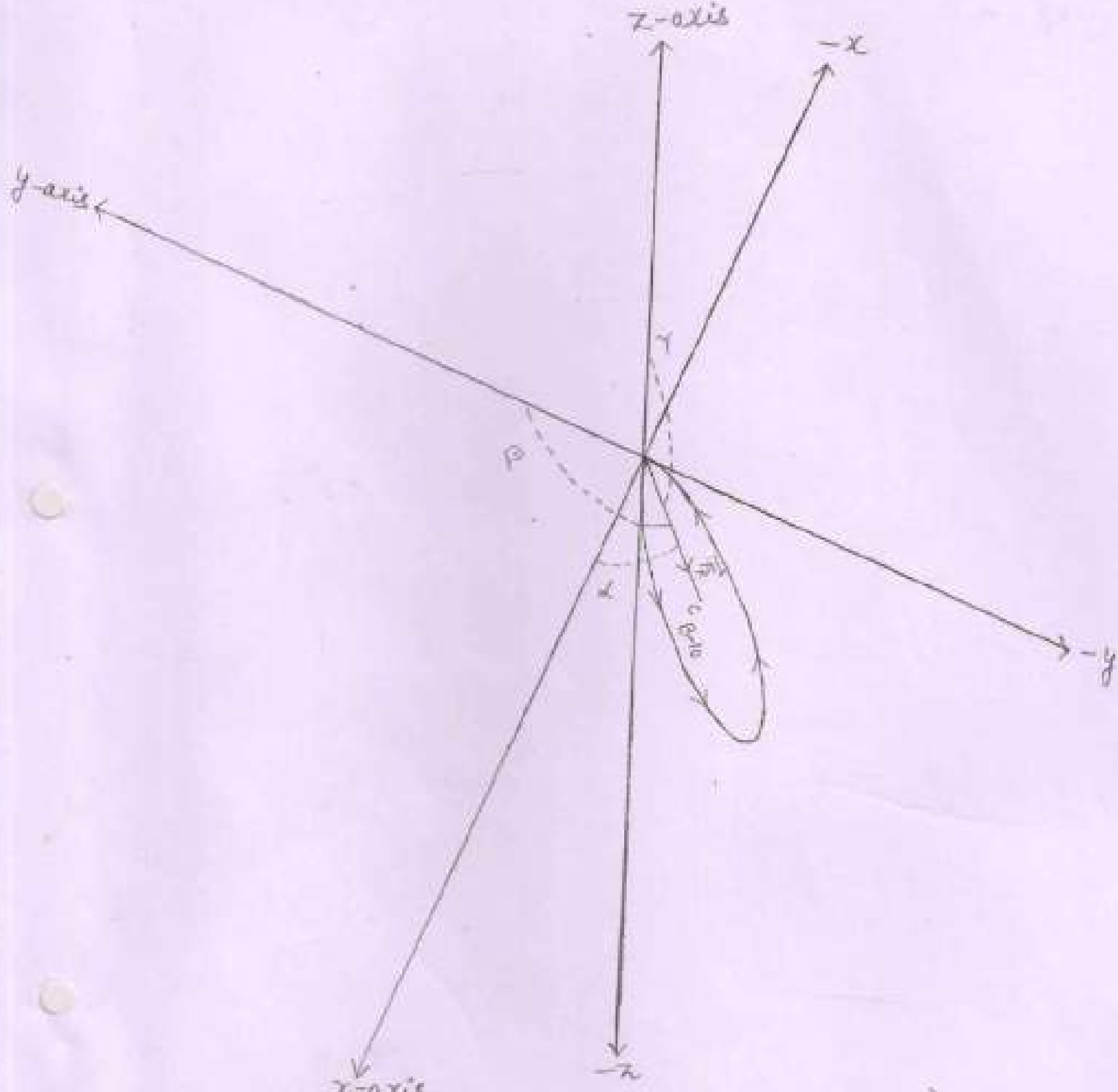
$\Rightarrow \beta \simeq 91.75$ $\quad$ [$\because \cos(91.75) = -0.0305$]

3. With z-axis

$$\cos\gamma = \frac{F_R \cos\gamma}{F_R} = \frac{\vec{F_z}}{F_R} = \frac{-0.2104 \times 10^{-12}}{6.9895 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\gamma = -0.0301$ $\quad$ [$\because \cos(91.75) = -0.0305$]

$\Rightarrow \gamma \simeq 91.75$



→ The angles that make the resultant force ($\vec{F}_R$) [acting on the boron-10 when the boron-10 is at point 'F'] with positive x, y and z-axes respectively are :-

1. $\alpha \simeq 2^\circ$
2. $\beta \simeq 91.75$ degree
3. $\gamma \simeq 91.75$ degree

Radius of the circular orbit to be followed by the boron-10 nucleus :-

$$r = \frac{mv^2}{F_R}$$

$mv^2 = 12.6800 \times 10^{-13}$ J
$F_R = 6.9895 \times 10^{-12}$ N

$$\Rightarrow r = \frac{12.6800 \times 10^{-13}}{6.9895 \times 10^{-12}} \frac{J}{N}$$

$$\Rightarrow r = 1.81414 \times 10^{-1} \text{ m}$$

$$\Rightarrow r = 18.1414 \times 10^{-2} \text{ m}$$

The cartesian coordinates of the points $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$ located on the circumfrence of the circle to be followed by the boron-10 nucleus :-

1. $\cos\alpha = \dfrac{x_2 - x_1}{d}$

$d = 2 \times r$

$d = 2 \times 18.1414 \times 10^{-2}$ m

$d = 36.2828 \times 10^{-2}$ m

$\cos\alpha = 0.99$

$\Rightarrow x_2 - x_1 = d \times \cos\alpha$

$\Rightarrow x_2 - x_1 = 36.2828 \times 10^{-2} \times 0.99$ m

$\Rightarrow x_2 - x_1 = 35.9199 \times 10^{-2}$ m

$\Rightarrow x_2 = 35.9199 \times 10^{-2}$ m $[\because x_1 = 0]$

2. $\cos\beta = \dfrac{y_2 - y_1}{d}$

$\cos\beta = -0.03$

$\Rightarrow y_2 - y_1 = d \times \cos\beta$

$\Rightarrow y_2 - y_1 = 36.2828 \times 10^{-2} \times (-0.03)$ m

$\Rightarrow y_2 - y_1 = -1.0884 \times 10^{-2}$ m

$\Rightarrow y_2 = -1.0884 \times 10^{-2}$ m $[\because y_1 = 0]$

3. $\cos\gamma = \dfrac{z_2 - z_1}{d}$

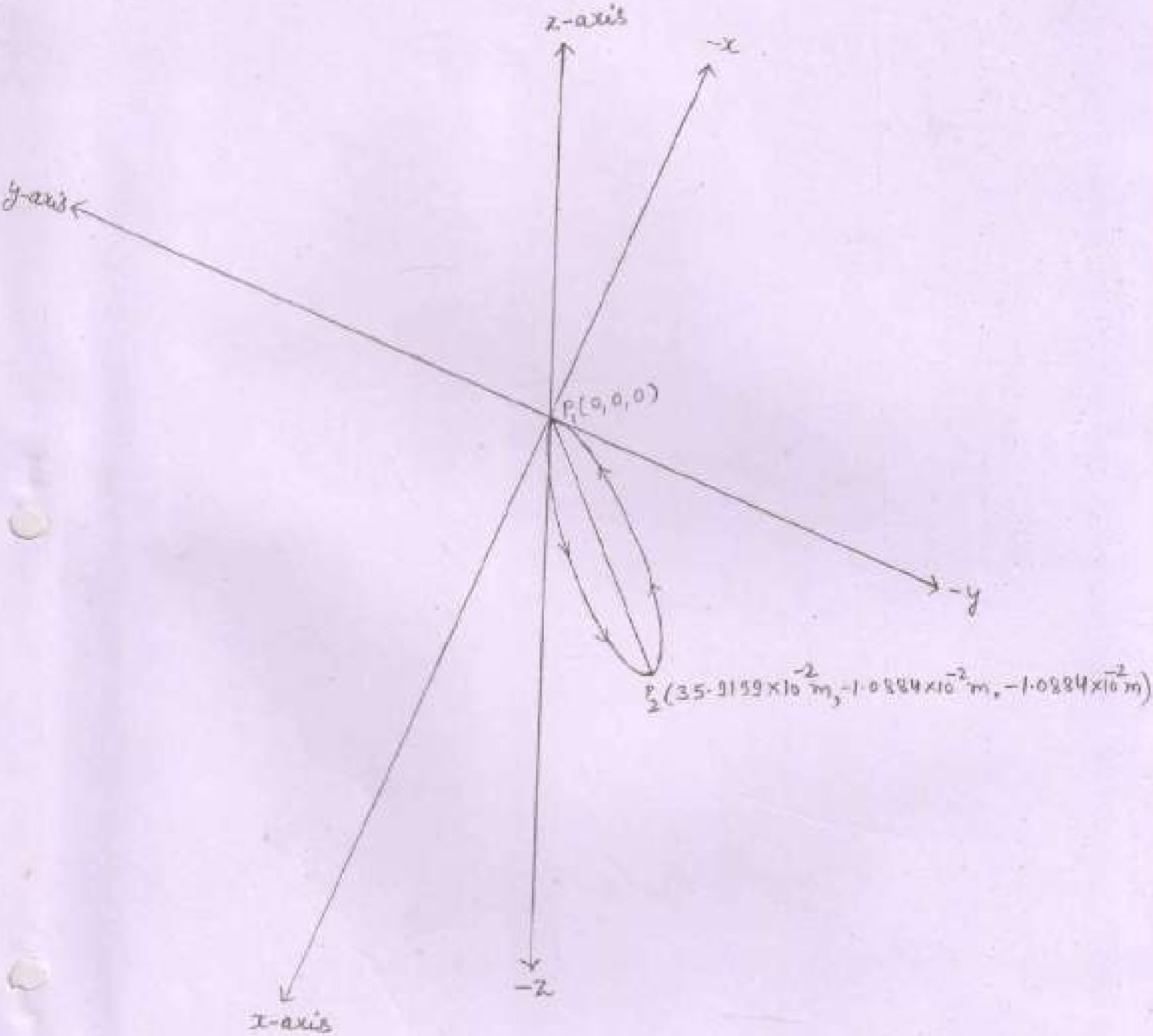
$\cos\gamma = -0.03$

$\Rightarrow z_2 - z_1 = d \times \cos\gamma$

$\Rightarrow z_2 - z_1 = 36.2828 \times 10^{-2} (-0.03)$ m

$\Rightarrow z_2 - z_1 = -1.0884 \times 10^{-2}$ m

$\Rightarrow z_2 = -1.0884 \times 10^{-2}$ m $[\because z_1 = 0]$



⇒ The cartesian coordinates of the points $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$ located on the circumfrence of the circle to be obtained by the boron-10 nucleus.