Chhatrapati Shahu Ji Maharaj
University, Kanpur

Answer Script Details
Barcode 11592270

Roll No. 24077000697
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Exam M.SC-III_ODD_EXAM_NOV_2025
Subject B010903T - Nuclear Physics-I

Question wise Mark Summary

Q.No	Mark	Q.No	Mark	Q.No	Mark	Q.No	Mark
1A	4/5						
1B	4/5						
1C	4/5						
1D	4/5						
1E	4/5						
1F	4/5						
1G	4/5						
1H	4/5						
1I	4/5						
2	0/15						
3	0/15						
4	0/15						
5	11/15						
6	0/15						
7	12/15						
8	0/15						
9	0/15						

Chhatrapati Shahu Ji Maharaj University
Kanpur, Uttar Pradesh

Date of Exam : 09/12/25 Shift : III Room No. 32
Paper Code B010903T Subject : NUCLEAR PHYSICS-I Year/Sem. II/III
Name of Candidate FARHEEN RAHMAN
Roll No. 2407700697

COE Facsimile
Signature of Invigilator
Signature of Candidate

PART-II

MARKS OBTAINED

Q.	1	2	3	4	5	6	7	8	9	10
(a)										
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Total										

Total Marks in Figures | Max. Marks
Total Marks in Words

B010903T
Paper Code

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Course M.Sc.
Session 2025-26 Year/Semester II / III
Subject NUCLEAR PHYSICS-I

Paper Code
B 0 1 0 9 0 3 T

Exam Date
0 9 / 1 2 / 2 5

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College Code
K N 0 4

परीक्षा केन्द्र का कोड
Exam Centre Code
K N 0 4

परीक्षा का प्रकार
Type of Exam
संस्थागत Regular ● | भूतपूर्व परीक्षार्थी Ex. Student ○
व्यक्तिगत Private ○ | बैक पेपर परीक्षा Back paper Exam ○

ANSWER BOOKLET NO.
11592270

B010903T
Paper Code

नामांकन संख्या
Enrollment Number
C S J M A 2 4 0 0 0 1 3 0 9 5 4

परीक्षार्थी अनुक्रमांक संख्या Candidate's Roll Number
2 4 0 7 7 0 0 0 6 9 7

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B 0 1 0 9 0 3 T

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नोट : 1. परीक्षार्थी को निर्देशित किया जाता है कि आवरण पन्ने के पृष्ठ भाग पर अंकित सभी निर्देशों को सावधानी पूर्वक पढ़ें। 2. बॉक्स में भरी जाने वाली प्रविष्टियाँ बायीं तरफ से शुरू की जायें। 3. गोलों को काले या नीले बॉलपेन से भरा जायें।

INSTRUCTIONS TO THE CANDIDATE FOR FILLING PART-I

1. Read the instructions carefully given on the answer script and admit card.
2. Write Date of Exam, Shift, Paper Code & Name of Subject Correctly.
3. Write Name & Roll No. Correctly.
4. Write Semester & Branch Correctly.

INSTRUCTIONS TO THE CANDIDATE FOR FILLING PART-III

1. Use blue or black ball point pen for writing alphabets & numerals in ☐ Boxes.
2. Carefully study the example before you start marking.
3. As shown in the example below blacken the circles completely.

Correct method	Incorrect method
① ● ③ ④	✓ ✗ ◉ ◉

4. Make no Stray marks on this sheet.
5. **DO NOT WRITE OR MARK ON THE BAR CODE.**

IN ORDER TO AVOID UFM (UNFAIR MEANS) :

1. The Roll No. and Answer Book no. found elsewhere or any other symbol found in the answer book will be treated as unfair means.
2. Any tempering of Bar Code and Booklet no shall be treated as Unfair Means.
3. Do Not bring the materials like slip of paper/mobile/digital diaries/ study material/ revision notes in examination hall. Possession of the mobiles/ digital diaries/ electronic watch and any other electronic gadget except memory less scientific calculator shall be considered as UFM case.
4. Do not keep or paste currency note in answer script it shall be consider as UFM.

अनुचित साधन से बचने हेतु:

1. उत्तर पुस्तिका के निर्देशित स्थान को छोड़कर अनुक्रमांक एवं उत्तरपुस्तिका का क्रमांक कहीं और न लिखे तथा कोई भी चिन्ह न बनायें क्योंकि यह अनुचित साधन प्रयोग की परिधि में आता है।
2. उत्तर पुस्तिका के बारकोड अथवा उत्तर पुस्तिका संख्या पर छेड़ करने पर अनुचित साधन प्रयोग माना जायेगा।
3. परीक्षा कक्ष में निम्न वस्तुएं साथ न लाये, जैसे लिखे हुए कागज के टुकड़े, मोबाईल, डिजिटल डायरी, कॉपी, पुस्तक यह सभी वस्तुएं जो अनुचित साधन के अन्तर्गत आती है। केवल संबंधित प्रश्नपत्र में ही मेमोरी लैस साइंटफिक केल्कुलेटर ले जाने की अनुमन्यता होगी।
4. उत्तर पुस्तिकाओं में रूपये न रखे न ही उत्तर पुस्तिका में चिपकायें। ऐसा करना अनुचित साधन प्रयोग की परिधि में आता है।

परीक्षार्थी के लिए नि[र्दे]श

1. प्रवेश पत्र एवं उत्तरपुस्तिका पर दिये गये [नि]र्देशों को ध्यान से पढ़ें।
2. कवर पृष्ठ के दूसरी तरफ कुछ न लिखें।
3. उत्तर पुस्तिका के पृष्ठों पर दोनों तरफ लि[खें]।
4. प्रश्न पत्र पर अपने अनुक्रमांक के अतिरि[क्त] कुछ न लिखें।
5. प्रश्न पत्र कोड एवं प्रश्न पत्र कोड सावधा[नी]पूर्वक लिखें।
6. अपनी स्थिति स्पष्ट लिखें।
7. उत्तर पुस्तिका के पृष्ठों की संख्या देखें [अ]गर उत्तर पुस्तिका में पृ (1–24) से कम है या फटे हुए है, तो परी[क्षा] शुरु होने के पूर्व दूसरी उत्त पुस्तिका ले लें।
8. प्रश्नपत्र को देख, यदि प्रश्नपत्र के विषय [को]ड, विषय का नाम तथा प्रश् में कोई त्रुटि है तो उसके परीक्षा शुरू हो[ने] के 30 मिनट के अन्दर क निरीक्षक को तत्काल सूचित करें, उसके [बा]द विश्वविद्यालय द्वारा को कार्यवाही नहीं की जायेगी।
9. प्रश्नों के उत्तर लिखने के लिये पैंसिल का [प्र]योग न करें।
10. B कॉपी या अतिरिक्त ग्राफ नहीं दिया जा[येगा]।

INSTRUCTIONS TO THE CANDIDATE

1. Read the instructions carefully giv[en] on the Question Pape Admit Card & Answer Script.
2. Do not write anything on back side of [th]e cover page.
3. Write on both sides of pages of answ[er] book.
4. Do not write anything on question pa[pe]r except Roll Number.
5. Write Paper Code & Question Paper [..] carefully.
6. CHECK the number of pages (1-32) [&] any other kind of damag in your answer script, if found tha[t c]hange the answer scrip immediately before the commencem[en]t of examination.
7. CHECK the Question Paper for a[ny] kind of discrepancy e.g Subject Code, Subject Name and [Q]uestion of the Questio Paper during first THIRTY MINUTE[S] of the commencement o the exam, so that it can be corre[cte]d in TIME. After that no corrections shall be entertained by th[e U]niversity.
8. Do not use pencil for answering the q[ue]stion.
9. Write status correctly e.g. those app[ea]ring in carry over paper should fill in status as Carry Ove[r.] Those appearing as Ex Students should fill in status as ex.
10. No supplementary answer book & gr[ap]h paper will be provided.

INSTRUCTIONS TO THE CANDIDATE FOR FILLING PART-IV

1. Use blue or black ball point pen for wri[tin]g alphabets & numberals in ☐ Boxes.
2. Use blue or black ball point pen for filli[ng t]he circles.

	1	8	1	5	4	3	[illegible]	1	6	9

Note - If your Roll No. is of 10 digits. Pleas[e l]eave first three column

Section-A

Short Answer Type Questions

Answer no. 1 (A)

Mass Defect → When nucleons are come together to forms a nucleus. here the some mass are losses during this process. It has been observed that total mass of the individual nucleons is greater than the complete mass of the nucleus.

So, "Mass defect is the difference betweem total mass of individual nucleons and actual mass of the nucleus."

It is represented by Δm.

$$\Delta m = (Zm_p + Nm_n) - M_n(A,Z)$$

where

Z = Number of protons
m_p = mass of proton
N = Number of neutrons
m_n = Mass of neutron
M_n = Actual mass of nucleus.

Packing Fraction → Packing fraction is defined as the ratio of mass defect into the nuclear mass number (A) is called as packing fraction.

Paper Code: B O 1 O 9 O 3 T

It is represented by 'f'

$$f = \frac{\Delta m}{A}$$

by the packing fraction equation

$$(1+f)A = \Delta m$$

by using this equation, we get

$$f = \frac{\Delta m}{A} - 1$$

$$\boxed{f = \frac{\Delta M(A,Z)}{A} - 1}$$

where,

ΔM = mass defect

A = mass number

Answer no. 1 (B)

given,

radius of $^{64}_{29}Cu = 4.8 \times 10^{-13} cm$

Let radius of $^{27}_{13}Mn = x$

we know that

nuclear radius,

$$r = r_0 A^{1/3}$$

So, from given data.

$$\frac{R_1}{R_2} = \frac{A_1^{1/3}}{A_2^{1/3}}$$

put values on above

$$\frac{4.8 \times 10^{-13}}{x} = \frac{(64)^{1/3}}{(27)^{1/3}}$$

$$\frac{4.8 \times 10^{-13}}{x} = \frac{4^{3 \times \frac{1}{3}}}{3^{3 \times \frac{1}{3}}}$$

$$\frac{1.2 \times 10^{-13}}{x} = \frac{1}{3}$$

$x = 3 \times 1.2 \times 10^{-13}$ cm

$x = 3.6 \times 10^{-13}$ cm

Hence,

The Radius of ${}^{27}_{12}Mn$ having mass number 27 is 3.6×10^{-13} cm

radius of Cu = 4.8×10^{-13} cm

and

radius of Mn = 3.6×10^{-13} cm

Answer no. 1(c)

given that,

Mass number of the nucleus = 240

decay by α-emission to ground state of its daughter nucleus

Do Not Write anything in this Portion

Paper Code: B01 0903 T

mass number of daughter nucleus = A-4
and
Q-value = 5.26 MeV

Let α-particle having energy T_α

by the equation of Q-value.

$$T_\alpha = \left(\frac{A-4}{A}\right)Q \quad -①$$

A = 240
A-4 = 240-4
= 236
Q = 5.26 MeV

Substituting values in eq. ①

$$T_\alpha = \left(\frac{240-4}{240}\right) \times 5.26$$

$$T_\alpha = \frac{236}{240} \times \frac{526}{100}$$

$$T_\alpha = \frac{59 \times 263}{80 \times 100}$$

$$T_\alpha = \frac{15517}{3 \times 10^3}$$

$$T_\alpha = 5172.3 \times 10^{-3}$$

rough
$\frac{59}{60} \times \frac{263}{100}$
59×263
30 100
263
×59
2367
1315
3)15517(5172
15
5
3
21
21
×

$T_\alpha = 5.1723$ MeV

Energy of α-particle is 5.1723 MeV

Answer no. 1 (D)

Curie Plot → When β-emission occur then a β-particle emits which is positive as well negative. And this β-particle spectrom well described by 'Fermi' Theory of β-decay. by it a curie plot draw for the emitting β-particle is known as 'Curie plot'.

from transition probability of β-decay a correction factor $f(A,Z)$ is introduce which defined as.

$$\frac{P(p)dp}{f(A,Z)} \propto E$$

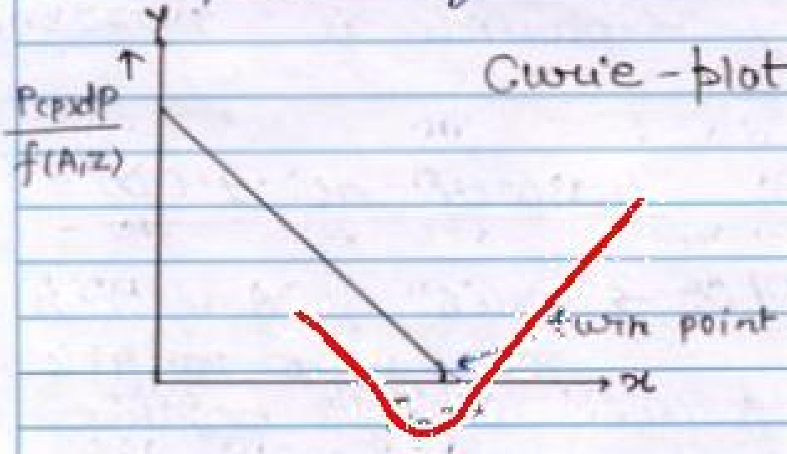
where,

$P(p)dp$ = transition probability for β-decay

E_β = Energy of β-particle

$f(A,Z)$ = Correction factor

when we draw a graph between E_β and $\frac{P(p)dp}{f(A,Z)}$ we get a twin point not the straight line this turn point not straight line is explain by Curie plot.



<u>Use in β-decay</u> - 1) From the graph of curie plot we see we get not straight line for non-relativistic case.

2) In this β-transition is forbidden

3) Mass of the neutron is not zero

4) It helps to estimate the β-decay process during emission.

5) Curie showed that only allowed transition occur for straight line

6) Forbidden transition occur for curve bend point.

B O 1 0 9 0 3 T 07

Answer no. 1 (E)

Internal conversion - Internal conversion is a process in which when the excited nucleus falls down to lower energy state from the excited state then the transition energy (ΔE) is directly transfered to the bound electrons. Such electrons are knocked out from the nucleus.

And these electrons called as conversion electron and the process is called as 'Internal conversion.

Differ from γ-decay - 1) In γ-emission, atomic number and mass number will not changes after decay but energy state will be change but in internal conversion transition energy transfer directly to the bound electrons.

2) There is no excess energy after the emission of γ-decay.

3) Here γ-emits more successfully than the other pairing conversion and β-emission.

Do Not Write anything in this Portion

Paper Code B01 69 03 T

Answer no. 1 (F)

Nuclear Isomerism - There are some nuclei having same mass number and the same atomic number but differ in their nuclear energy state for their different re-arrangement of nuclei.

These isom nuclei are called as 'Isomers' and the process is known as the 'Nuclear Isomerism'.

i.e,

$$^{99m}Ta^{*} \longrightarrow {}^{99}Ta + \gamma$$

$$^{100m}Tc^{*} \longrightarrow {}^{100}Tc + \gamma$$

Physical Significance of Nuclear Isomerism -

1) The life time of excited nuclear is long as compared to the other nucleus having same mass number.
2) This long life state is known as metastable state.
3) After nucleus falling down to lower energy state, γ-photon emits by the excited nucleus.
4) Nuclear isomerism is benificial for most of the projectile decay.

Answer no. 1 (G)

Q-value of Nuclear Reaction-

The total energy released or absorbed during the nuclear reaction is known as 'Q-value' of the given reaction.

Consider the reaction,

$$X + a \rightarrow Y + b \quad -①$$

i.e,

$$^{235}_{92}U + {}^{1}n_0 \longrightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3\,{}^{1}n_0 + Q \quad -②$$

Here,

$^{235}_{92}U$ = Parent Nuclei
Ba & Kr = Daughter Nuclei
n = Neutrons
Q = Released energy (which is Q-value of Reaction)

Q-value is defined as-

Q-value = kinetic energy of Product − Kinetic energy of reactant

So, Q-value in terms of mass energy is

$$Q = [(m_b + m_Y) - (m_a + m_X)]c^2 \quad -③$$

also,
Q-value in terms of kinetic energy

$$Q = (E_y + E_b) - E_a \quad —(1)$$

From the analysis the reaction the final expression for Q-value of non-relativistic case is

$$Q = E_b\left(1+\frac{m_b}{m_y}\right) - E_a\left(1-\frac{m_a}{m_y}\right) - 2\sqrt{\left(\frac{m_a}{m_y}\right)E_a\left(\frac{m_b}{m_y}\right)E_b}\cos\theta$$

Q-value tells the reaction whether endogic reaction or exorgic reaction.

Answer no. 1 (H)

Controlled Nuclear Fission -

In a single fission mostly two or three electrons are liberated. If an an average neutron y one another fission take places during reaction.

One neutron is goes to fission only by one neutron during the reaction. If fission rate is contraint constant reaction and situation is not out of hand then the reaction is said to be Nuclear controlled chain reaction.

Principle- Nuclear Controlled fission chain reaction is based on the principle of 'Nuclear Reactor'.

The nuclear controlled chain reaction may be write as

$$^{235}_{92}U + {}^{1}n_0 \longrightarrow {}^{144}_{56}Ba + {}^{81}_{36}Kr + Q + {}^{3}n_0$$

Here the energy and neutron are controlled by nuclear reactor.

Nuclear corrector factor is

$$K = \frac{P}{L+A}$$

or

$$\boxed{K = \frac{nF/A}{\frac{L}{A}+1}}$$

where,

P = rate of production of neutrons
L = rate of leakage of neutrons
A = rate of absorption of neutrons
nF = rate of neutron per fission

Do Not Write anything in this Portion

Paper Code: B01090 3T

Answer no. 1 (I)

Significance of Breit-Wigner Single level formula—

when projectile energy is interact with nucleus energy then it is absorbed and a new nucleus formed which is compound nucleus.
This is done by the energy of radiation Er from this we get a absorption cross-section which have a sharp peak.
This is known as resonance and this process is explained by the Breit-Wigner's formula.

$$\sigma(E) = \frac{\pi}{K^2} \frac{T_{in} T_{out}}{(E-E_r)^2 + \left(\frac{T}{2}\right)^2}$$

Breit-wigner's formula gives the cross-section having sharp peaks where,

$\sigma(E)$ = transition cross-section
K = wave no. of incident particle
T_{in} = Partial width for formation
T_{out} = partial width for decay
E_r = Energy of radiation

Do Not Write anything in this Portion

Paper Code: 8 0 1 0 9 0 3 T

Section - B

Long Answer Type Question

Answer no. 5

Quantum Theory Of Alpha Decay

Alpha decay can be explained by the quantum theory which is 'Quantum Tunneling Effect' by the help of the Gamow Theory in which particle inside the nucleus considered as wave.

Existance of particle in the nucleus - In the excited nucleus an alpha particle already exist in the nucleus having energy 3-4 MeV according to classical theory.

Potential Barrier - Alpha particle have no enough energy to escape potential (Coulomb) barrier having very high potential.

$$V(r) = \frac{1}{4\pi\epsilon_0} \frac{2Ze^2}{r} \quad \text{—(1)}$$

$$V(r) = \frac{1}{4\pi\epsilon_0} \cdot \frac{(Z-1)2e^2}{r_0 A^{1/3}}$$

$$V(r) = \frac{9\times10^9 \times 82\times1.6\times10^{-19}}{1.4\times10^{-15}\times A^{1/3}}$$

Paper Code B 0 1 0 9 0 3 T

$$V(r) \simeq 30.05 \text{ MeV}$$

this energy is very large a compared to the alpha energy

$$E_\alpha << V(r)$$

Quantum Tunnelling— particle can be escape from the nucleus through potential barrier o even $E < V(r)$ by the quantum tunnelling where partide treats as a wave.

Penetration Probability— Gamow uses the WKB approximation for the penetration probability.

$$P \simeq e^{-\int 2k(r)dr} \quad -②$$

where,

$$k(r) = \sqrt{\frac{2m(V(r)-E)}{\hbar^2}}$$

$$P \simeq e^{-\int \frac{2}{\hbar}\sqrt{2m(V(r)-E)}\,dr}$$

on solving this probability we get a decay factor λ.

$$\lambda = P \times f \quad -③$$

$\therefore f =$ frequency

decay factor is λ

$$P = e^{-\frac{4\pi}{\hbar v} Ze^2}$$

$$\lambda = Pf$$

$$\boxed{\lambda = f e^{-\frac{4\pi}{\hbar v} Ze^2}} \quad -④$$

Geiger- Nuttal Relation – It is the empirical relation between half-life of emitted radioactive nucleus and energy of the alpha particle which relates with gamow theory -

Mathematically,

$$T_{1/2} = a + \frac{b}{\sqrt{Q}} \quad ⑤$$

where,

Q = energy of alpha particle
a & b = radioactive series constant.

Relation between Geiger- Nuttal and Decay constant -

Geiger - Nuttal law can be derived from the Gamow theory of alpha decay in this ~~pro~~ expression $T_{1/2}$ and λ varies exponentially with energy of alpha - particle.

proof – potential of barrier is

$$V(r) = \frac{1}{4\pi\epsilon_0} \frac{2Ze^2}{r} \quad -⑥$$

and the penetration probability is

$$P = \exp[-2\int K(r)dr] \quad ⑦$$

$$P = \exp\left[-2\int \sqrt{\frac{2m}{\hbar^2}(V(r)-E)}\right]dr$$

V = velocity of α-particle
$V^2 = \frac{2E}{m}$ ~~2m~~

and decay constant becomes.

$$\lambda = Pf \quad ⑧$$

$$P = \exp\left[\frac{-4\pi}{\hbar v} Ze^2\right]$$

putting $V = \sqrt{\frac{2E}{m}}$

$$P = \exp\left[-\frac{4\pi Ze^2}{\hbar}\sqrt{\frac{m}{2E}}\right] \quad ⑨$$

$$\lambda = P \times f$$

Substituting value of P

$$\lambda = f \exp\left[\frac{-4\pi Ze^2}{\hbar}\sqrt{\frac{m}{2E}}\right]$$

taking log on both sides.

$$\log \lambda = \log f - \frac{4\pi z e^2}{\hbar\sqrt{2}} \frac{\sqrt{m}}{\sqrt{E}}$$

or

$$\log_{10} \lambda = A + \frac{B}{\sqrt{Q}} \quad \therefore E = Q$$

or

$$\boxed{\log \tau_{1/2} = a - \frac{b}{\sqrt{Q}}} \quad \text{—(10)}$$

This is the required Geiger-Nuttal relation from Gamow theory.

where, $\boxed{T_\alpha = \left(\frac{A-4}{A}\right) Q}$ is the energy emitted by the alpha-particle

This shows that $\tau_{1/2}$ and λ varies exponentially with energy of α-particle.

This gives the Binding energy curve and explain nuclear stability.

Paper Code B D 1 0 9 0 3 T

Do Not Write anything in this Portion

Section-C

Long Answer Type Questions.

Answer no. (7)

Angular Correlation – In γ-transition the two radiation are emitted and the second radiation's direction depend on the first one not the random due to the conservation of angular momentum.

This direction dependency of radiation on each other due to the angular momentum is called an angular correlation.

In γ-transition, we use this concept for measuring parity, multipolarity and stability of the nucleus.

Used In the study of Nuclear spin –

To find and study the nuclear spin we used angular correlation concept.

Nuclear spin is the total intrinsic angular momentum arises due to the orbital and spin motion of nucleons.
So it can write as

$$I = \Sigma(S_p + l_p) + \Sigma(S_n + l_n)$$

It is represented by I

having magnitude $\vec{I} = \vec{L} + \vec{S}$

$$|\vec{I}| = \sqrt{I(I+1)}\hbar$$

If nucleons has $l_1, l_2 \ldots$ & S_1 & S_2 spin and orbital angular momentum then nuclear spin is

$$\vec{J} = \vec{S} + \vec{L}$$

If nucleons are even then spin will be
$S = \hbar, 2\hbar, 3\hbar$

If nucleons are odd then spin will be
$S = \frac{\hbar}{2}, \frac{3\hbar}{2} \ldots$

This relates angular correction with the nuclear spin
To find nuclear state spin can used the correction concept

Used as Transition Multipolarity

If excited nucleus depend on spin and anglar momentum then multipolarity aries which give probability per second

$$\lambda(\pi L) = \frac{T(\pi L)}{\hbar} = \frac{8\pi(L+1)}{L[(2L+1)!!]^2}\left(\frac{E_\gamma}{\hbar c}\right)^{2L+1}\frac{B(\pi L)}{\hbar}$$

where,

T(πL) = transition probability

L = multipolarity

B(πL) = reduced probability

For Electric Transition - Due to the charge distribution in nucleus.

$$\lambda_0(EL) = \frac{1}{4\pi}\left(\frac{L}{3+L}\right)^{2L}(r_0 A^{1/3})^{2L} e^2 fm^{2}$$

in nuclear unit = $e^2 \, fm^2$

∴ nucleus radius = $r_0 A^{1/3}$

For magnetic Transition -

$$\lambda_0(ML) = \frac{10}{4\pi}\left(\frac{L}{3+L}\right)^{2L-2}\mu_N^2 \, fm^2 (r_0 A^{1/3})^{2L-2}$$

It arises due to the current

Paper Code: B 0 1 0 9 0 3 T

21

distribution in the nuclear nucleus.

for $A = 100$
$E = 1 MeV$

for E:

$\lambda(E1) = 2.46$ MeV
$\lambda(E2) = 74.6$ MeV

(E1) $T_{1/2} = 10^{14}$ /Sec
(E2) $T_{1/2} = 10^{36}$ /Sec

for ML

$\lambda(M1) = 79.6$ MeV
$\lambda(M2) = 24.4$ MeV

(M1) $T_{1/2} = 10^{12}$ /sec
(M2) $T_{1/2} = 10^{36}$ /sec

we see that E1 transition is the strongest than M1 and so on this is get by the angular correlation factor.

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