

INVESTIGATION OF NUCLEAR STATES OF SOME NEUTRON - RICH NUCLEI

THESIS

Submitted for the Degree of

DOCTOR OF PHILOSOPHY

in

NUCLEAR PHYSICS

By

Nadia El Sayed Walley El-Dine Fouad

Department of Physics

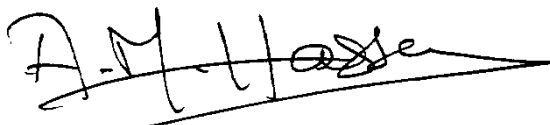
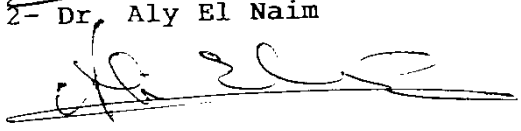
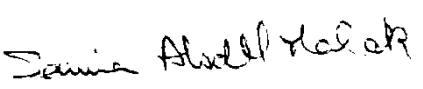
Faculty of Women

Ain Shams University

1986

INVESTIGATION OF NUCLEAR STATES

OF SOME NEUTRON RICH NUCLEI

<u>Supervisor</u>	<u>Position</u>
1- Dr. A. M. HASSAN 	Profressor in Reactor and Neutron Physics Depart- ment.
2- Dr. Aly El Naim 	Assistant Proffessor, Physics Department Faculty of Women Ain-Shams UNIVERSITY.
3- Dr. Samia Abdel Malak 	Assistant Proffessor Physics Department Faculty of Women Ain-Shams UNIVERSITY.

HEAD OF PHYSICS DEPARTMENT





ACKNOWLEDGEMENT

I would like to assert that without the research project between the physics departments in faculties of Women and Education supported by Ain Shams University, this work could not be completed.

The author wishes to express her appreciation and sincere gratitude to prof. Dr. A. M. Hassan, Reactor and Neutron Physics Department, Nuclear Research Center, Atomic Energy Authority, for his kind encouragements, and valuable supervision during this work.

Deep thanks and appreciation are also extended to Dr. A. El-Naim and Dr. S. Abdel Malak, for their guidance, continuous help, valuable discussions and supervision during this work.

I also would like to express great gratitude to Dr. S. Darwish Physics Department, Faculty of Science Cairo University and Dr. M. Abou Leila Faculty of Education for their great help and guidance during the coarse of this work.

My sincere gratitude to Dr. A. T. Sroor, Dr. A. M. El-Shershaby and Dr. N. Abdel Basset for their guidance and help.

I would like to thank all members of the Nuclear
Physics Laboratory.

Also, I wish to express my deep thanks to the Heads
of the Physics Department, Faculty of Women and Education ,
Ain-Shams University.

CONTENTS

	Page
ACKNOWLEDGMENT	
ABSTRACT	i
INTRODUCTION	1

CHAPTER I

Nuclear Disintegration Studies of Gamma-Ray Transitions	5
I.1. Analysis of Gamma-Ray Transitions	5
1.1. Interaction of Gamma Radiation with Matter	5
1.2. Selection Rules for Gamma-Ray Transitions	6
1.3. Gamma-Decay Transition Probabilities	9
1.4. Gamma-Rays Relative Intensities	12
1.5. Total Attenuation Coefficients.	14
1.6. Internal Conversion	17
1.7. Log ft Values.	19
I.2. Gamma-Gamma Coincidence Studies	23
I.3. Gamma-Gamma Angular Correlation Analysis	25
3.1. Basis of Calculation and Data Analysis of the γ - γ angular Correlation.	25
3.2. Graphical Representation of angular Correlation	35

CHAPTER II

Spectrometer Arrangements and Experimental Techniques	37
I.1. The Gamma-Ray Singles Spectrometer	37
1.1. Introduction.	37

1.2. Experimental Arrangement	39
1.3. Steps of Measuring the Gamma-Ray Singles Spectra ..	44
II.2. The Gamma-Gamma Coincidence Spectrometer	52
2.1. Experimental Arrangement	52
2.1. Measurement of Gamma-Gamma Coincidence spectra	58
II.3. The Gamma-Gamma Angular Correlation Spectrometer	60
3.1. Steps of Measuring the Gamma-Gamma Directional Angular Correlation Coefficient.	60

CHAPTER III

Intensity Measurement* and Spins and Mixing** Ratios in ^{153}Eu following the β^- - Decay of ^{153}Sm	65
III.1. Introduction	65
III.2. Source Preparation	66
III.3. Gamma-Ray Singles Measurements	67
III.4. Gamma-Ray Coincidence Measurements	76
4.1. The Results of γ - γ Coincidence Measurements	76
4.2. Data Interpretation and Discussion	81
III.5. Gamma-Gamma Angular Correlation Measurements	85
5.1. Introduction	85
5.2. Results and Discussion of γ - γ Angular Correlation Measurements	85

CHAPTER IV

	Page
Gamma-Gamma Angular Correlation and Intensity ^{***} Measurements of Gamma-Rays In the Decay of ^{103}Ru	96
IV.1. Introduction	96
IV.2. γ -ray Singles Measurements	96
IV.3. γ - γ Coincidence Measurements and discussion	104
IV.4. γ - γ Angular Correlation Measurements and Discussion..	111
REFERENCES	118
List of Publications	124
Arabic Summary	

* * * * *

ABSTRACT

The level scheme of ^{153}Eu was investigated by observing the gamma-rays following the β^- - decay of the 47 h. ^{153}Sm using a high purity Ge (HPGe) detector and a Ge (Li)- Na I (Tl) fast-slow coincidence spectrometer. The energies and relative intensities of about fifty six gamma-ray transitions were determined. Five of them at energies of 124.91, 431.65, 443.24, 487.75 and 623.73 keV were observed and confirmed for the first time in the present singles and/or gamma-gamma coincidence measurements. These new transitions could be fitted into a proposed level scheme of ^{153}Eu . The β^- - decay branching ratios as well as the $\log (ft)$ values were obtained.

The level scheme of ^{153}Eu was also investigated via the angular correlation of gamma-rays using a high purity Ge (HPGe) and a Na I (Tl) detector for the first time. The angular correlation of the 510.36 - 89.37, 531.43 - 103.52, 533.17 - 103.52 and 616.28 - 103.52 keV gamma-ray cascades were measured. The spin and parity of the 719.15 keV level has been established as $\frac{1}{2}^+$. The spin and parity assignments to the 634.75 ($\frac{1}{2}^+$) and 636.61 ($3/2^-$) keV levels have also been confirmed. In addition, the multipolarity and E2/M1 mixing ratios for a number of transitions in ^{153}Eu have been established as follows:-

$$\delta(510.36) = -0.365 \pm 0.130 \quad , \quad \delta(531.43) = 0.37 \pm 0.095 \\ \quad \quad \quad - 0.120 \quad \quad \quad - 0.085$$

$$\delta(533.17) = 0.135 \pm 0.09 \quad \text{and} \quad \delta(616.28) = 0.315 \pm 0.120 - 0.130.$$

The level scheme of ^{103}Rh was investigated by observing the gamma-rays following the β^- - decay of the 39.4 day ^{103}Ru using the above mentioned spectrometers. Four new transitions at energies 45.25, 69.71, 256.72 and 311.71 keV were observed and confirmed in the present singles and/or gamma-gamma coincidence measurements. These new transitions were fitted into a proposed level scheme of ^{103}Rh . The β^- - decay branching ratios as well as the log ft values were obtained. Gamma-gamma angular correlation measurements were also performed using the HPGe-NaI (Tl) fast coincidence spectrometer. Correlations were deduced for the 513.99 - 53.3 and 556.66 - 53.3 cascades.

The spin and parity assignments of the 607.21 keV level has been established as $7/2^-$. The 649.74 keV level was confirmed to have a spin and parity $7/2^+$. In addition, the multipole mixing ratios for the 513.99 and 556.66 keV gamma-ray transitions are found to be $E1 + 9.83\% M2$ and $M1 + 11.43\% E2$, respectively.

Introduction:-

The solid state radiation detectors have achieved increasing emphasis due to their excellent energy resolution.

Many modifications have been made on the fabrication of semi-conductor detectors and its crystal shapes and sizes. Devices of sufficiently large volumes have been constructed to be used in gamma-ray spectrometers with reasonable intrinsic efficiency and with much more better resolution than that of Na I scintillation spectrometers.

The high resolution of these detectors made it possible to study the details of direct gamma-ray spectra. Although the main features of the low lying states of the ^{153}Eu and ^{103}Rh nuclei may be regarded as well established yet it is clear that several discrepancies exist concerning the presence of some energy levels and γ transitions, also the inconsistency concerning the multipolarity of some transitions, spins and parities of nuclear states led to the present investigation.

In the present investigation the gamma-ray energies and relative intensities in the decay of ^{153}Sm to ^{153}Eu and ^{103}Ru to ^{103}Rh was accomplished using Ge (Li), planer pure Ge and a coaxial pure Ge in singles gamma-ray spectrometers. Besides the different cascade relations were

confirmed and studied through γ - γ coincidence experiments using a Na I (Tl) Ge (Li) fast-slow coincidence spectrometer.

Angular correlation measurements have been performed using a coaxial HPGe- Na I (Tl) fast-fast coincidence spectrometer to determine the nuclear spin values of some energy levels in ^{153}Eu and ^{103}Rh and to obtain the mixing ratios and multipolarities of some γ -transitions in these two nuclei.

The thesis contains four chapters:-

The first Chapter includes a general review on the Nuclear disintegration studies of γ -ray transitions, γ - γ coincidence studies and γ - γ angular correlation analysis.

The different instrumental techniques and steps of measurements used in the present investigation are discussed in the second chapter.

In the third chapter the level scheme of ^{153}Eu was investigated by observing the gamma-rays following the β^- - decay of the 47 h ^{153}Sm . The energies and relative intensities of about fifty six gamma-ray transitions were determined. Five of them at energies of 124.91, 431.65, 443.24, 487.75

and 623.73 keV were observed and confirmed for the first time in the present singles and/or gamma-gamma coincidence measurements. The β^- -decay branching ratios as well as the $\log (ft)$ values were obtained.

The level scheme of ^{153}Eu was also investigated via the angular correlation of gamma-rays using a high purity Ge (HPGe) Na I (Tl) spectrometer for the first time. The angular correlation of the 510.36 - 89.37, 531.43 - 103.52, 533.17 - 103.52 and 616.28 - 103.52 keV gamma-ray cascades were measured. The spin and parity of the 719.15 keV level has been established as $\frac{1}{2}^+$. The spin and parity assignments to the 634.75 ($\frac{1}{2}^+$) and 636.61 ($3/2^+$) keV levels have also been confirmed. In addition, the multipolarity and E2/M1 mixing ratios for a number of transitions in ^{153}Eu have been established as follows:-

$$\delta(510.36) = -0.365 \pm 0.130, \quad \delta(531.43) = 0.37 \pm 0.095 \\ - 0.120 \quad \quad \quad - 0.085.$$

$$\delta(533.17) = 0.135 \pm 0.09, \quad \delta(616.28) = 0.315 \pm 0.120 \\ - 0.130$$

In Chapter four the level scheme of ^{103}Rh was investigated by observing the gamma-rays following the β^- -decay of the 39.4 day ^{103}Ru .

Four new transitions at energies 45.25, 69.71, 256.72 and 311.71 keV were observed and

confirmed in the present singles and/or gamma-gamma coincidence measurements. The β^- -decay branching ratios as well as the log ft values were obtained.

Gamma-gamma angular correlation measurements were also performed on this nucleus. Correlations were deduced for the 513.99 - 53.3 and 556.66 - 53.3 cascades. The spin and parity assignments of the 607.21 keV level has been established as $7/2^-$. The 649.74 keV level was confirmed to have a spin and parity $7/2^+$. In addition, the multipole mixing ratios for the 513.99 and 556.66 keV gamma-ray transitions are found to be $E1 + 9.83\% M2$ and $M1 + 11.43\% E2$, respectively.

CHAPTER I

NUCLEAR DISINTEGRATION STUDIES OF GAMMA-RAY TRANSITIONS