STUDY OF THE ENERGY LEVELS OF SOME RADIOACTIVE ISOTOPES

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S U M M A R Y

The Beta-decay of 18.6 h ^{159}Gd analysis is so important because of its location in the region of deformed nuclei. The previously studies have led to a fairly well established decay scheme, several descripancies still exist concerning the presence of some gamma lines beside the ambiguous J assignment of the 854 Kev level.

The present work was under taken to resolve some of the remaining uncertainties in the decay scheme of ^{159}Gd. The decay scheme of ^{159}Gd has been studied by measuring the energy and relative intensity of each of the various γ- and β-transitions from the concerned radioactive isotope.

The measurements had been carried out using GMX-Ge spectrometer and H.P.G-(GMX-Ge) coincidence spectrometer coupled to a Nourland type 4096 channels puls-hight analyzer. Trapisoidal method has been applied for the determination of various γ -transitions with a high precision. γ - γ coincidence measurements between the observed γ -transitions have been made.

Appropriate decay scheme have been confirmed and discussed according to the nuclear models. The results accomplished in this thesis can be summarized as :

1- 18 γ -transitions have been observed in the β-decay of ^{159}Gd to ^{159}Tb having energies in the range from 57 to 854 Kev.

In the present work the 334 Kev γ-transition observed previously was not confirmed.

2- The level scheme of ^{159}Tb has been confirmed and found to be composed of 9 previously established levels.

3- On account of the calculated log ft-values of ^{159}Tb together with the corresponding relative intensities of the γ-transitions, it was possible to suggest that the level at 854 Kev has $J^{\pi} = ½^{-}$ and the levels at 674, 348 and 57 Kev have $J^{\pi} = 5/2^{+}$, 617 and the ground state have $J^{\pi} = 3/2^{+}$, the level at 580 Kev has $J^{\pi} = ½^{+}$, the level at 363 Kev has $J^{\pi} = 5/2^{-}$ and the level at 37 Kev has $J^{\pi} = 7/2^{+}$.

4- The magnetic moment of the ground state band was calculated and is found to be 1.56 (9).

5- An explicite study of the spectra of odd-A nucleus was undertaken based mainly on the deformed shell model calculations.

The study includes different interpretations to the model, taking also into account the possible existance of B- and γ -vibrations.

A comparison was made between theoretical and experimental results.

INTRODUCTION

INTRODUCTION

Nuclear spectroscopy helps in identifying of some nuclear characteristics such as energy and momentum, the former locates the state and the latter describes it. This is a very useful tool to verify the validity of nuclear models.

As far the accuracy in measurements are more reliable and acceptable to be compared with the theoretical calculations.

The latter developments in detecting techniques as well as in nuclear electronics make it plausible to gain new results about the depated points arise in the nuclear studies.

The ^{159}Tb nucleus is one of those nuclei which are under discussion because of the ambiguities arise between different authors.

This nucleus is considered to be an ideal case to be compared with the rotational band model. This fact necessitates very accurate experimental informations.

The present work deals with the carefull study of the level scheme of ^{159}Tb as obtained from the decay of ^{159}Gd nucleus. The application of the very high resolution GMX-Ge detector and very low time resolution in the Ge-Ge fast-slow coincidence circuit make it possible to get powerful and precise experimental data to be copared with the theoretical interpretations based mainly in the deformed shell model calculations.

CHAPTER I

NUCLEAR MODELS AND TRANSITION PROBABILITIES

I.1- Introduction :

Data on the excited levels of odd nuclei are accumulating rapidly. Particularly in the region of the deformed nuclei, the nuclei posses a very complicated set of levels. This information can be used to suggest models of the nucleus in order to understand the nature of atomic nucleus and to explain different properties of the nuclei. Each model serves to correlate a portion of the experimental knowledge about nuclei, usually within a more or less narrow range of phenomena, but fails when applied to data outside the range.

The shell model shows that it is a reasonable good approximation for the majority of nuclei, except for certain mass number regions where both the neutron and proton numbers lies in the middle between closed shells. This model can at best explain the properties of ground and low excited states. It will certainly breakdown for highly excited nuclei, where pauli's exclusion principle no longer puts sharp restrictions on the individual particle motions and where the coupling between them makes features of collective motion predominant.

The collective model was suggested by A. Bohr and B. Mottelson[1], and it is successful in explaining certain excited levels of nuclei in terms of the collective rotation or oscillation of nuclei.

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Flowers (1952)[5] and Pryce (1954)[6]. At these magic numbers their occurs something analogous to the closure of the shells in the electronic structure of the noble-gas atoms. The nuclear shell model was suggested by Haxel et.al., (1949)[3] and Mayer (1950)[7] primarily as a self-consistent explanation of the magic numbers. It was also presented independently by Feenberg and Hammack (1949)[8] and Nordheim (1949)[9].

The starting point of all shell models is the solution of the schrodinger equation for a particle moving in a spherically symmetrical central field of force, i.e. in a field of force in which the potential energy V of the particle with respect to the respect to the centre is a function V(r) of it's radial distance r only. The radial shape of the nuclear field is now well known from the scattering experiments, Hofstadter (1956)[10] and Yuan and Wu (1961)[11], but the form of V(r) is not suitable for simple solution of the schrodenger equation.

Since, however, the shell model is not only primarily concerned with the total binding energies but also with the levels corresponding to the states of motion of nucleons, it is sufficient to consider only simple forms of potential function such as :

a) The square well potential.

b) The harmonic oscillator potential well.

c) The spin orbit coupling.

In harmonic oscillator potential the sequence of single particle levels consists of equally spaced bands of highly degenerate levels in ℓ, the orbital angular momentum. There would be closed shells at 2, 8, 40, 70, 112 and 168 nucleons, these are not the nuclear magic numbers. The ℓ-degeneracy is removed in the square-well potential. The occupation numbers $2(2\ell + 1)$ predict shell closures at total particle numbers 2, 8, 18, 20, 34, 40, 68, ... which again is not the series of nuclear magic numbers. Several attempts have been made to modify the potential, to yield the observed magic numbers.

The most successful is the proposed by Mayer (1949)[2] and by Haxel et.al., in (1949)[3], according to which a non-central component should be included in the force acting on a nucleon in a nucleus.

If this noncentral force is an interaction depending on the relative orientation of the orbital angular momentum and the spin momentum of the nucleon, then a different periodicity can easily arise. It is assumed in this model that the spin-orbit force separates the motion of a nucleon with orbital momentum ℓ into sub-states with total angular momentum quantum number $j = \ell \pm \frac{1}{2}$ and that the level with higher spin is the more stable. In this model the shell closures occur at particle numbers 2, 8, 20, 50, 82 and 126 exactly as required by experiments.

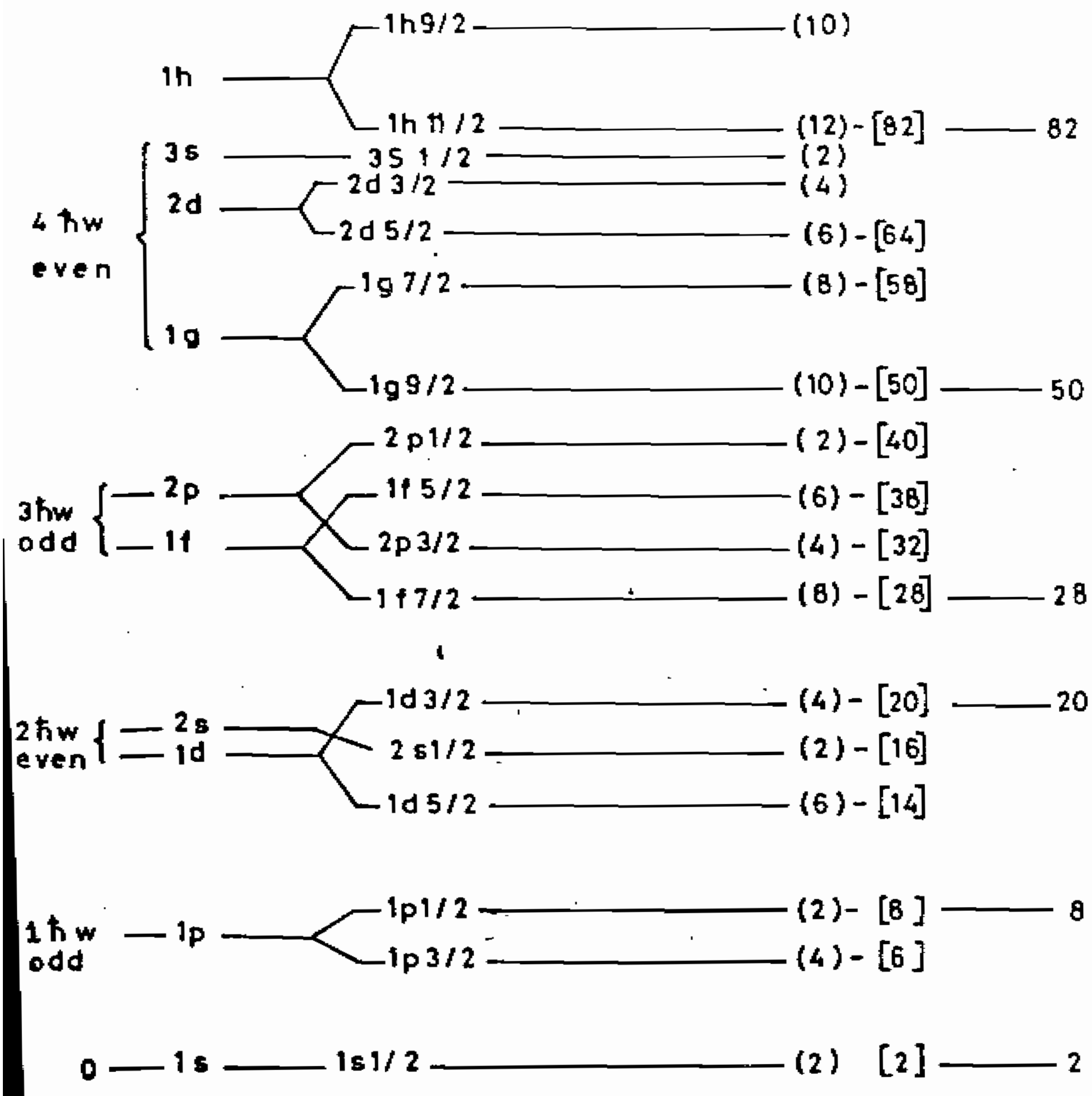
The energy splitting depends on the oscillator number n. Emperical data show that the splitting increases with increasing n and with increasing nuclear radius, i.e. whenever an angular momentum appears for the first time in the level scheme, the splitting of this level into $j = \ell \pm ½$ will be particularly large. Since the energy of a level depends strongly on the alignment of spin and orbit, the j-value of a level, together with its n-and ℓ -values, must be specified, the number of protons or neutrons filling a level with spin J will be equal to 2J+1. The level sequence proposed by Mayer (1955)[12] is shown in Fig. (1) which indicates the level splitting brought about by spin-orbit interaction.

The resulting angular momentum value $J = \ell \pm ½$ is written at the level. Round brackets give the degeneracy of the level 2J + 1. Square brackets give the total occupation numbers.

Nuclear ground state :

The shell model makes unique predictions about the properties of those nucleonic configurations in which either one proton or one neutron is present outside, otherwise closed neutron and proton shells, or in which just one nucleon is missing from a closed shells configuration. In these cases angular momentum, parity, are that of the missing nucleon.

For all such nuclei the shell model predications are in agreement with the experimental findings. The same holds



Figure(1):Schematic representation of level sequence showing the level splitting due to spin-orbit interaction.