APPLICATION OF SOLID STATE DETECTORS IN STUDY OF NUCLEAR STRUCTURE

THESIS

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SUMMARY

The present work is concerned with the study of the decay scheme of ^{140}La , using solid state detectors. The high resolution GMX -Ge detector severes in studying the γ -radiations emitted from this decay. Ge-Ge coincidence circuit was applied in the coincidence spectra measurements.

The present work was undertaken to resolve some of the remaining uncertainties in the decay scheme of ^{140}La. The decay scheme of ^{140}La has been studied by measuring the energy and relative intensity of each transition.

It is worth noting that the energy and relative intensity of 36 γ -transitions have been observed in the β^- - decay of ^{140}La to ^{140}Ce having energies in the range from 26 to 3319 Kev. The γ -lines 936.7 , 1087.9 , 1303.5 , 1404.2 , 1415.3 and 2533.4 Kev. were confirmed. While other ones at 798.3, 902.0, 907,1521.8 and 2494 Kev. were not observed . The two γ -lines at 1924 and 2082 Kev. which were a source of large descripances in the privous studies are confirmed in the present work to be sum peaks.

Special care was paid in identifying the weak γ-transitions 936.7 , 1087.9 , 1415 .3 and 2533.4 Kev. The coincidence measurements were essential in the present study to insure the debated transitions.

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From the present results as well as from previous ones, a tentative level scheme of ^{140}Ce nucleus as populated from the decay of ^{140}La is given .

An explicit theoretical study was taken into consideration based mainly on the shell model calculations, using modified surface delta interaction (MSDI) system. From this view, the ^{140}Ce nucleus was represented by configurations in which 56 protons and the magic neutron number 82 to form a system of closed core ($^{138}_{56}Ba_{82}$) with two free protons occupying the next 3-orbits $1g_{7/2}$, $2d_{3/2}$ and 3 $S_{1/2}$. A comparison was made between theoretical and experimental calculations. Also the present calculations are in good agreement with the very recent publication (ref. 29) (1985) , in which they considered the 8-protons configuration .

INTRODUCTION

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Spherical nuclei are those which have closed shells for both protons and neutrons. Only five stable nuclei have this property namely ${}^{4}_{2}H_{2}$, ${}^{16}_{8}O_{8}$, ${}^{40}_{20}Ca_{20}$, ${}^{48}_{20}Ca_{28}$ and ${}^{208}_{82}Pb_{126}$. These nuclei are characterized by their high stability in nature as well as vanishing quadrupole character. The spherical shell model perfectely describes the energy levles of those nuclei as well as their characteristics.

When one or few nucleons are added to or taken out one of the closed shells while the other remains unchanged the spherical shell model is no longer valid. The single particle model plays important role in this case. The low lying energy states may be approximately described in terms of the motion of the added particles. There exists , however a weak coupling between this nucleonic motion and the oscillation of the closed shell core. This implies a significant enhancement of the electric multipole transitions between the low lying levels. Many experiments have been performed and have elucidated the level structure and the single particle motion of these nuclei.

${}^{140}Ce$ is one of the family of semimagic nuclei. Its own interest lies in that it has closed neutron shell (82) , and eight protons outside the closed $1g_{9/2}$ orbit. These excess proton cannot be all housed in the next $1g_{7/2}$ orbit because of the marked similarity observed between odd neighbours isotones ${}^{139}La$ and ${}^{141}Pr$. So these 8-protons are considered to move in the orbitals outside the $1g_{9/2}$ closed shell, the solution of these proton configurations could get the level structure of ^{140}Ce .

Many authers have considered this problem by different approaches. There exists many differences in the level sequences and the problem is not yet solved.

As a matter of fact the exact calculations need accurate experimental results. The previous of experimental investigations have successed in constructing a reasonable level scheme. Although there still exists major discrepancies between these studies not only in the γ- transitions and their branching ratios, but also in the doubtful of the presence of some excited states.

It is the aim of this work to study the nuclear structure of ^{140}Ce experimentally and theoretically. We make use of the recent development of the solid state Ge- detector to provide more precise measurements. In addition a finly adjusted Ge-Ge coincidence circuit is applied in the present study.

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CHAPTER I

NUCLEAR PROPERTIES

1.1. Nuclear Models :

1.1.1. : The Nuclear Shell Model:

In the early stage of its development, one of the main objectives of the shell model was to reproduce the so-called magic numbers. As more refinements were introduced , it was found that this model was capable of explaining not only the magic numbers but also many other nuclear properties such as spin and magntic moment.

In this model it is assumed that the nucleons in the nucleus move independently in a mean potential. Because of the short range nature of nuclear forces, the potential well must have sharp boundaries whose nature is governed by the boundaries of the nuclear matter distribution in the nucleus . Two potential wells were considered, namely the infinite square well and the harmonic oscillator well.

However, neither the pure square well nor the pure harmonic oscillator well is suitable as a realistic shell model potential. A realistic potential should in fact reproduce the experimental observed magic numbers 2, 8 , 20, 28, 50, 82 and 126.

The modification necessary to make the theory fit the observed magic numbers was introduced by Mayer[1,2] and Haxel et al.,[3] independently. They pointed out the single-particle levels may be split considerably by spin-orbit interactions. In particular, if the interaction is of the type which couples the spin and orbital angular momenta parallel to each other, every

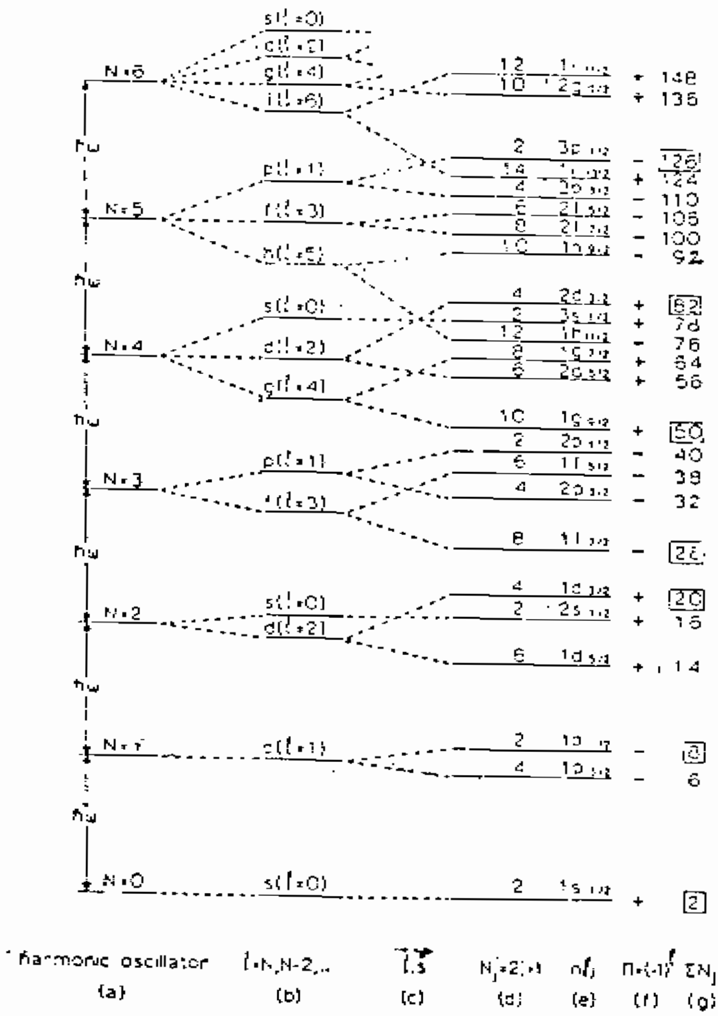

Fig. (1-1) Schematic representation of level sequance showing the level splitting due to spin- orbit interaction.

level, except the S levels , splits into two substates with total angular momentum, fig.(1-1)

$$J = \ell + \frac{1}{2} \quad \text{and} \quad J = \ell - \frac{1}{2}$$

Where J, is the total angular momentum quantum number for a single nucleon. The energy difference between those two substates is proportional to $2\ell + 1$, which means that the splitting increases with ℓ .

The scope of the model based on the spin-orbit level scheme is greatly increased by supplementary coupling rules [2] .

The following simple coupling rules for the ground state have been abstracted from the experimental data , they are also generally in agreement with calculations performed on the basis of conventional nuclear forces and trial wave functions.

i. Even-Even Nuclei :

These nuclei have zero ground state total angular momentum and even parity.

ii. Even-Odd or Odd-Even Nuclei :

The ground state properties are determined by those of odd nucleon.

iii. Odd-Odd Nuclei :

All nuclei of odd number of both neutrons and protons except ^{2}H , ^{6}Li , ^{10}B and ^{14}N are unstable. The ground state spin is determined in this case applying Nordheim's rules [4,5] . Accordingly it has been able to formulate two empirical coupling rules. Two rules for the ground state are present :

a. Strong rule :

In this case, if for one of the two odd nucleons spin and orbital angular momentum are parallel and antiparallel for the other or vice-versa.

i.e. $J_n = L_n + \frac{1}{2}$, $J_p = L_p - \frac{1}{2}$

for the opposite

$$J_n = L_n - \frac{1}{2} , \quad J_p = L_p + \frac{1}{2}$$

The total ground state spin is the lowest possible one of the vector sum :

$$J = \left| J_n - J_p \right|$$

b. Weak rule :

In this case if the odd proton and neutron are in states, where the intrinsic spin ½ and the orbital angular momentum "L" are parallel or antiparallel for both particles :

$$J_n = L_n + \frac{1}{2} , \quad J_p = L_p + \frac{1}{2}$$

or antiparallel for both

$$J_n = L_n - \frac{1}{2} , \quad J_p = L_p - \frac{1}{2}$$

Then the total angular momentum of the ground level will be

$$J = J_n + J_p .$$