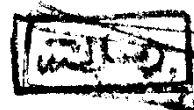


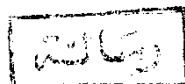
NUCLEAR STRUCTURE STUDY OF
A RADIOACTIVE ISOTOPE

BY

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ABSTRACT

The gamma ray transitions from the states populated in ^{133}Cs due to the electron capture decay of ^{133}Ba were investigated using HPGe detector with crystal diameter 44.8 mm and crystal length 41.8 mm. Coincidence studies were undertaken with HPGe, NaI(Tl) detectors employing slow-fast coincidence circuit.

Internal conversion coefficients were determined making use of Si(Li) detector and its arrangements.

The energies and intensities of measured gamma rays were evaluated. The multipolarity of some gamma lines were fixed. The level scheme of ^{133}Cs was constructed, log ft values, spins and parities were deduced. Theoretical transition multipolarities were calculated and compared with experimental results.

GENERAL INTRODUCTION

In low energy physics, there are many ways one can study the structure of the nucleus. But, by far, gamma-ray spectroscopy offers the most comprehensive means of investigating the decay scheme of the nucleus.

The development of the Ge(Li) (Lithium-drifted Germanium) and HPGe (Hyper pure Germanium) detectors with an energy resolution, which is vastly superior to that of the high efficiency NaI(Tl) gamma ray detector, allows the possibility of detection of many close lying energy levels and weak intensity gamma transitions. Also the development of Si(Li) detector, which is easy to use than than magnetic lens spectrometer beside its excellent response, wide range of measurements and good resolution, enables one to estimate the transition multipolarities, which are required in evaluating the spins and parities of the investigated energy states.

This improvement in gamma ray spectroscopy has resulted in the need to develop the supporting electronics both for energy and coincidence measurements.

In the present work a single gamma ray spectrometer consisting of a HPGe detector, a preamplifier, a research

amplifier and multichannel analyzer, was used for energy and intensity of gamma ray transitions determinations, beside a Si(Li) detector was also used for determination of conversion electrons energy and intensity. A gamma-gamma coincidence spectrometer consisting of a high resolving power HPGe detector and Na(Tl) crystal was used for studying gamma cascade, enables us in level structure proposal.

The choice of long lived 10.74 year ^{133}Ba isotope for investigation in the present study was due to some discrepancies with regard to multipolarities assignment reported in previous data concerning the 160.6 KeV and 302.8 KeV gamma transitions. Accordingly the aim of the present work is not only to reveal such discrepancies, but also to re-assignment of gamma transition multipolarities as well as spin-parity assignment of the 160.6 KeV level.

CHAPTER I

THEORETICAL PRINCIPLES

THEORETICAL PRINCIPLES

1.1- Introduction :

From early measurements on Coulomb scattering⁽¹⁾, it knows that the atomic nucleus is a small massive central particle (radius $\ll 10^{-11}$ cm) which possesses virtually the whole mass of the atom, and carries a positive charge equal to the atomic number of the atom. The nucleus is build up of protons and neutrons; the former supply the positive charge, whilst both contribute to the mass. From general quantum-mechanical considerations such a confined system will possess energy levels characterized by quantum numbers.

The atomic nucleus has certain time-independent properties⁽²⁾ such as mass, size, charge and intrinsic angular momentum, and certain time-dependent properties such as radioactive decay and artificial transmutations.

Nuclei, like atoms, can be found in excite states of definite energies. Transitions between such excite states take place by the emission of electromagnetic radiations (gamma rays) completely analogous to atomic spectral lines. The main difference is that, whereas the separation of the atomic states is of several electron-volts, the separation

between nuclear states are about several Kiloelectron-volts.

In all cases the total number of nucleons must be conserved. A particular nucleus (in its ground state) must be described in terms of several quantum numbers "angular momentum" (spin), parity and isotopic spin. This is the minimum number of quantum numbers required to describe the nuclear states. Such study of nuclear energy states is called "nuclear spectroscopy".

In the absence of an exact theory, a number of nuclear models have developed. These utilize different sets of simplifying assumptions. Each model is capable of explaining only a portion of experimental data about nuclei. It is known that in the ground state and in the lowest excited states of a nucleus, the nucleons have a very small interaction, then the "independent-particle models" take place. We shall discuss the shell model as an example from the broad group of independent-particle model.

1.2- Shell Model :

It is expected that the concepts and ideas - that effected in description, and determination of the electronic structure of the atom - should be carried over into nuclear physics. One of these ideas is that of the "shell structure" or "level structure" with certain closed shells because of the stability for a given number of particles.

The closed nuclear shells ideas are worked out in mathematical detail by Mayer (1948)⁽³⁾, Mayer (1950)⁽⁴⁾ and Mayer and Jensen (1955)⁽⁵⁾. These ideas can be summarized as; the stable nuclei associate a certain numbers of nucleons 2, 8, 20, 28, 50, 82 and 126 like that of the atomic numbers of the inert gases (which have complete outer shells). This means that the nucleons inside the nucleus are grouped in shells and that numbers - which named "magic numbers" - correspond to complete shells. Since, these magic numbers are labeled to both "proton" numbers and "neutron" numbers, this suggests that there are separate shell structures for protons and neutrons. Quantum mechanical calculations have used to determine the order in which these shells are filled with nucleons making use of the idea of strong coupling between the orbital angular momentum of a nucleon and its spin angular momentum.

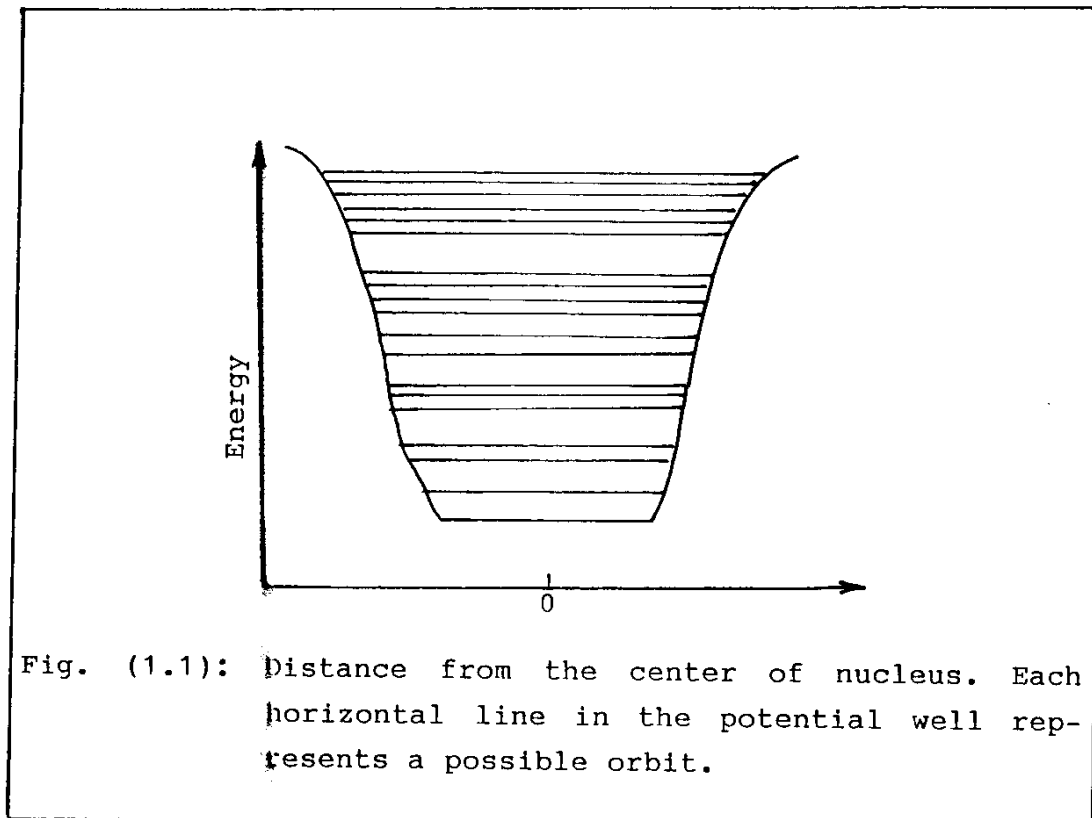


Fig. (1.1): Distance from the center of nucleus. Each horizontal line in the potential well represents a possible orbit.

To simplify such computations, Mayer⁽³⁾ assumed that each nucleon in a nucleus is acted on by an average force of the forces exerted by all the other nucleons. They assumed also that each nucleon moves along its own orbit, independent of the others. Each nucleon in its orbit has a fixed amount of energy, so that it occupied a definite energy levels. The relationship between a nucleon's energy level, its distance from the centre of the nucleus, and the average nuclear force in the nucleus is shown in fig. (1.1) by means of a potential energy diagram which takes the form of a "well" with rounded edges.

Since, neutron and proton has the spin of the electron ($\frac{1}{2} \hbar$), then Pauli-Exclusion principle must be applied; which states that "no two identical particles can be in the same quantum state which is specified by its total angular momentum and by its parity".

A single nucleon has orbital angular momentum " ℓ " due to its motion in its own orbit and also spin angular momentum " s ". We can use the spectroscopic notation (used for describing the atomic structure) to know the nuclear structure and the positions of nucleus. Thus the values of the orbital angular momenta " ℓ " can be associated also with symbols as follow :

ℓ value :-	0	1	2	3	4	5	6	
notation :-	s	p	d	f	g	h	i	

Each level actually consists of $(2\ell+1)$ substates each with a different angular wave function^(6,7). Due to the two different possible orientations of the nuclear spin, a level can accommodate $2(2\ell+1)$ protons. In addition, it can accommodate $2(2\ell+1)$ neutrons, since the two particles are different and do not therefore exclude each other.

But we must take in account that the angular momentum of the "nucleus" is the summation of the total angular momentum " j " of individual nucleons. This kind of coupling

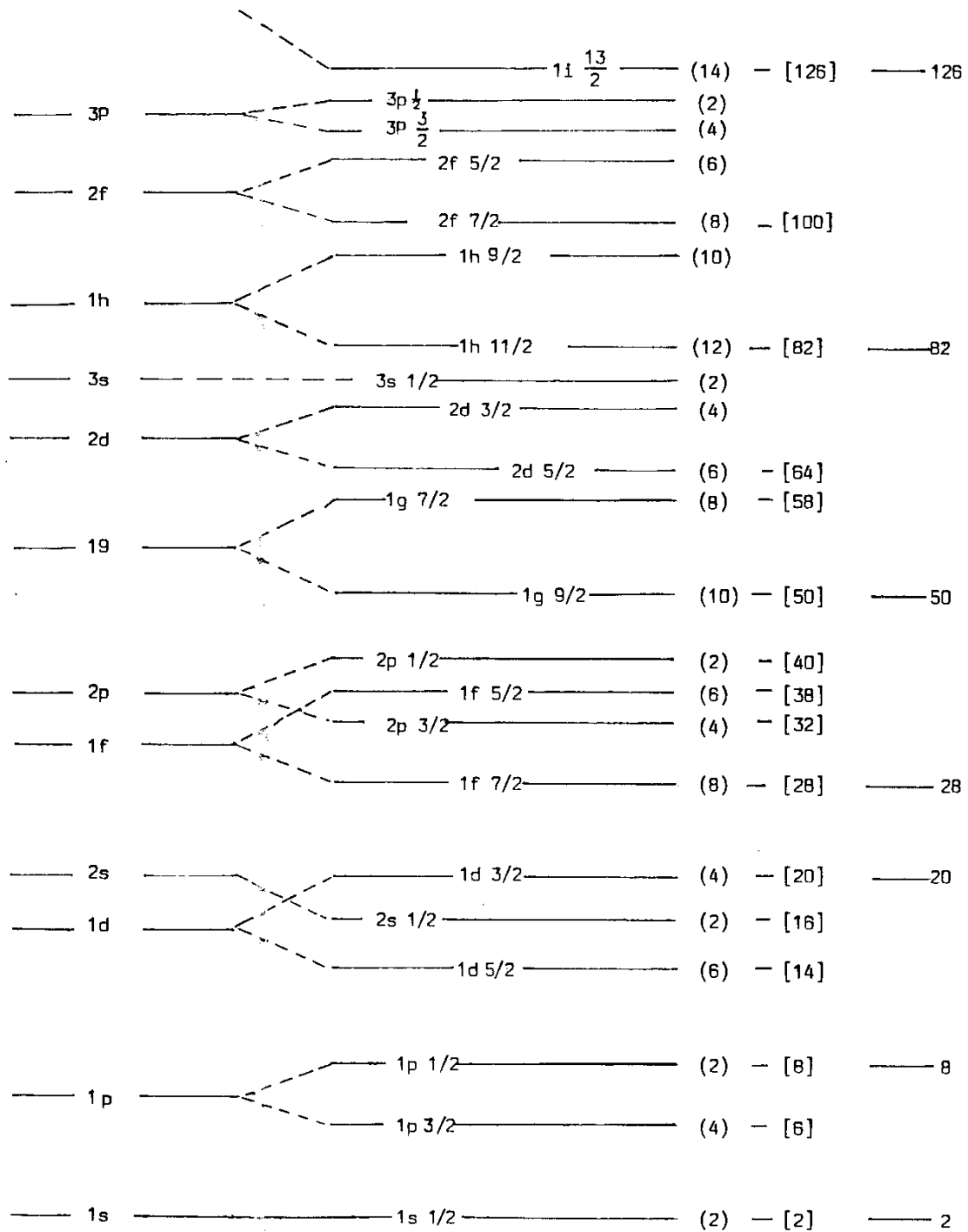


Fig. (1.2): Schematic representation of level sequence showing the level splitting due to spin-orbit interaction.