RADIOACTIVE DECAY OF SOME NEUTRO IRRADIATED ISOTOPES

THESIS

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بسم الله الرحمن الرحيم

CONTENTS

SUMMARY

The decay of ^{160}Tb has been thoroughly investigated. Although the results of this studies have led to a fairly well-stablished decay scheme, several discrepances still exist. The 2^+ and 4^+ members of the ground state rotational band as well as the 2^+ and 3^+ members of the gamma-vibration band with k = 2 are unanbiguously assigned. However there is no clear understanding of the nature of the observed negative parity states. Up till now, it has never been attempted to measure angular correlation of a cascade which involves the 1386.44 kev level which has a doubted spin 3^-.

The present work was undertaken to resolve at least some of the remaining uncertainties in the level scheme of ^{160}Dy.

The decay scheme of ^{160}Tb has been studied by measuring the energy and relative intensity of each of the various gamma and beta transitions from the concerned radioactive isotope. ^{160}Tb sample has been irradiated in the A.R.E. reactor. The other isotopes applied for the instrumental calibration have been supplied from National Center for Radiation Research and Technology.

The measurements have been carried out using a H.P.Ge spectrometer and H.P.Ge-NaI(Tl) coincidence spectrometer coupled to an ORTE type 4096 channels pulse-height analyzer. The trapezoid method has been applied for the determination of the various gamma transition with a high prescision. Gamma-gamma coincidence measurements, between the observed gamma transitions, have been made. From gamma-gamma directional angular correlation measurements, it has been possible to estimate the spins and parities of some levels as well as the mixing ratios of their gamma transitions. Appropriate decay schemes have been constructed and discussed according to nuclear models. The results accomplished in this thesis can be summarized as follows :

1- Forty gamma transitions have been observed in the beta decay of ^{160}Tb to ^{160}Dy having energies in the range from

86.788 to 1312.142 kev. Five of these transitions are found to be new and have energies 97.640, 110.130, 121.713, 189.718 and 202.778 kev.

2- The level scheme of ^{160}Dy has been constructed and found to be composed of thirteen previously established levels.

3- To some up the result of our angular correlation measurements together with thos from conversion electron studies permit the assignment of 3^-, 2^-, 3^+, 4^+ and 2^+ spins for the excited levels at 1386.44, 1264.727, 1049.09, 283.323 and 86.788 kev. Also the multipolarities of the transitions 121.713 and 1102.617 kev were found as M1 + E2 and E1 + M2 respectively. Their mixing ratios were estimated and compared with the corresponding values derived from interval conversion studies.

4- On account of the calculated log ft values for B transitions feeding the levels of ^{160}Dy together with the corresponding relative intensities of the gamma-transitions, it was possible to suggest that the levels at 1285.58 has $J = 1^-$, the levels at 86.788 and 966.152 kev have $J = 2^+$, the levels at 1264.727 and 1358.648 kev have $J = 2^-$, the level at 1049.09 has $J = 3^+$, the levels at 1286.69, 1386.44 and 1398.93 kev have level at 3^-, the level at 283.823 kev has $J = 4^+$ and levels at 1155.67 and 1535.14 kev has $J = (4)^-$ and the level at 1288.8 kev has $J = 5^+$.

5- An explicit study of the rotation-vibration model which is later obtained by Faessler and Greiner(57)(1962), (1964), (1965), was under taken. The study includes the Hamiltonian of the vibration-rotational model and its solution. The ground state, beta vibrational and gamma vibrational bands were evaluated using this model for ^{160}Dy and compared with the experimental results. This study indicates that the rotational-vibration model can discribe the main physical features of the nuclear dynamics satisfactorily.

INTRODUCTION

INTRODUCTION

Nuclear spectroscopy is concerned with the measurement of the properties of nuclear energy levels, among these properties being the energy of the levels, the angular momentum (or "spin") and parity various electric and magnetic moments and the various partil decay probabilities. Also the aim of nuclear spectroscopy is to determine the detailed properties, such as the type of nucleon coupling (LS or JJ). and even the discovery of new constants, such as the isotopic spin. One of the powerful techniques for such investigation is to measure the gamma-transitions in radioactive nuclei using recently developed semiconductor spectrometers. Semiconductor spectroscopy using lithium drift germanium crystals is now-adays the most widely used for its superior resolution and high ability to detect weak gamma intensities.

In the present investigation, a hyper pure germanium detector (H.P.Ge) was used for single spectra estimation and H.P.Ge-NaI(Tl) coincidence technique was used in coincidence measurement.

The H.P.Ge detector size is 40.9 mm diameter and 39.5 m.m length with total active volume of 4[illegible] cc. The window to detector distance is 5 m.m, coupled to pre-amplifier, an ORTEC model 450 linear amplifier and an ORTEC type 4096 channels pulse-height analyzer with the fast-slow coincidence sircuit. The complex gamma-ray spectrum has been analysed by using the trapezoid method leading to the gamma-ray energies and intensities. The time relation between these determinal gamma transitions, studied by gamma-gamma coincidence spectrometer, has been used.

The directional angular gamma-gamma correlation experiment has been used in determining the multipole orders of some gamma transitions and to assist in determining the spin of some levels in the decay scheme. The least fit has been used to evaluate the correlation coefficients from the experimental data.

A decay scheme can be constructed for some radioactive nuclei with the necessary parameters of the involved levels. This can be made by taking into account the results obtained from the single gamma-ray spectrum, gamma-gamma coincidence and directional gamma-gamma correlation measurements together with the relative intensities and end point energies of the beta transitions of the parent nucleus. Such spectroscopic data are of valve in demonstrating the validity of the shell and unified models.

In a shell model, a spherically [illegible] binding field representing the average effect of the [illegible] between

CHAPTER I

VARIETIES OF COLLECTIVE MOTION

CHAPTER 1

VARIETIES OF COLLECTIVE MOTION

Many features of nuclei indicate that nuclear motion does not consist only in simple single-particle excitations as might be suggested by the shell model. Instead there are several typical effects which imply a collective motion, that is a motion where many nucleons move coherently with well-defined phases. In order to understand this kind of coherent motion of nucleons let us start by giving illustrations of some typical examples. There are four important types of collective motion :

1). The surface vibrations of the nuclear shape are a motion of nucleons from one region of the nuclear sphere into another one. The arrows in Fig. 1-1(a) show this collective ordered motion. They are also indicated in Fig. 1-1(b) where the nuclear radius periodically oscillates about an equilibrium value R_o. In this case the density in the nuclear sphere also increases and decreases periodically (compression modes).

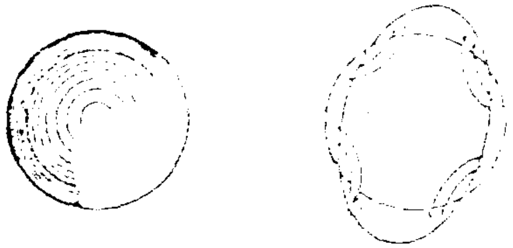

Fig. 1-1(a) Schematic figure of surface vibrations. The arrows indicate a possible flux (stream lines) of nucleons. The left-hand figure shows the spherical nucleus. The right-hand figure shows the distortion of the sphere.

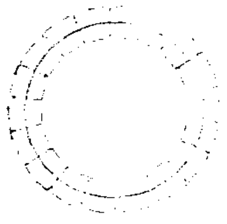

Fig. 1-1(b) Compression mode. In contrast to the motion shown in Fig. 1-1(a), the radial oscillations of the surface lead to density vibrations.

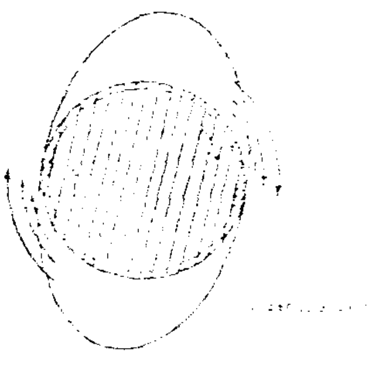

Fig. 1-2. Schematic figure of the rotation of a deformed nucleus. The tidal wave is moving around the nuclear core. The latter may also rotate but with a smaller angular velocity. This can be achieved through the existence of a superfluid layer between.

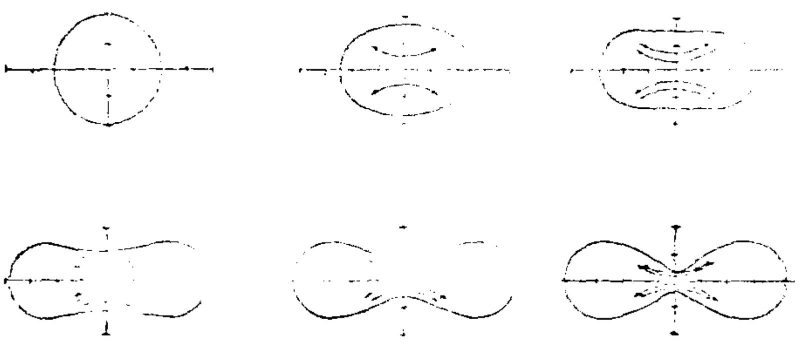

Fig. 1-3. Schematic figure of nuclear fission. The various possible stages of the separation of the nucleus into two pieces are indicated.

2). The rotations of deformed nuclei are another example of coherent, in-phase motion of nuclear matter (see Fig. 1-2). A sort of a tidal wave of nucleons moves around a nuclear core.

3). The process of nuclear fission is immediately understood from Fig. 1-3 as a collective motion of the nucleons. The nucleons move apart from each other in order to separate into two pieces. The various stages of this process from one sphere to two spherical nuclei are indicated in the figure. The arrows represent the flow of nuclear matter.

The three processes discussed so far take place more or less in the surface region of the nucleus. Even in the case of rotations the interior spherical core (the shadowed area in Fig. 1-2) may be viewed as being mainly at rest dur[illegible] rotations, and only the bumps of nuclear matter outside the core may be considered to move. This is because the potential field of the core will not change during the rotation and therefore the nucleons of the core do not experience any resistance or contribute to the energy of the motion, in contrast to the situation for the tidal wave.

4). A collective behavior involving the nuclear interior is established in the photonuclear giant resonance motion where the electric field E of the photon [illegible] on protons only and, because the center of mass has to be at rest, the neutrons have to move in an opposite direction to that of the

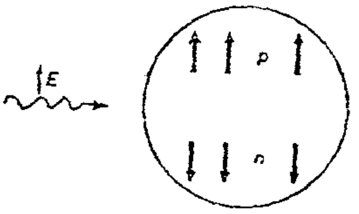

Fig. 1-4. Schematic figure of giant dipole motion in nuclei. The electric field of the -ray, E, pushes the protons upwards. The neutrons then move downwards in order to keep the center of mass fixed.

protons. The nuclear surface is fixed during this process while protons and neutrons move coherently but in opposite directions (Fig. 1-4).

These examples may suffice to give an impression of the various types of collective behavior in nuclei. Of course, if a certain set of experimental data can be explained on the basis of a collective theory constructed from physical pictures such as those given above, this already provides a confirmation of the collective nature of the observed excitations. However there are some general effects typical of collective spectra which enable us to see very quickly the degree of the collective nature of the excitations in question. In fact, a nucleus never has only collective levels (modes) or only single-particle levels (modes) but always both. One will see later on that pure collective and pure single-particle modes are an idealization, In reality both types of motion are mixed and therefore it may sometimes be very