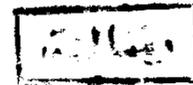


STUDY OF THE RADIOACTIVE DECAY  
OF SOME IRRADIATED ISOTOPES

Radioactive Decay of  
 $Cd^{117}$ ,  $Cd^{117m}$  and  $Pm^{144}$

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U.A.R.

~~43426~~

~~7920~~

by  
Mona Mohamed Abd Latif Mohsen  
B.Sc.

1967



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## SUMMARY

The decay scheme of cadmium 117, its isomer cadmium 117m and promethium 144 have been studied by measuring the energy and relative intensity of each of the various gamma and beta transitions from the concerned radioactive isotopes. The  $Cd^{116}$  samples have been irradiated in the U.A.R. reactor whereas the  $Pm^{144}$  isotope has been obtained by the irradiation of Ta, Er and Gd targets by 660-680 MeV protons in the synchro-cyclotron of the Joint Institute, Dubna. The various other isotopes applied for the instrumental calibration have been supplied from the U.A.R. Atomic Energy Establishment.

The measurements have been carried out using a scintillation coincidence spectrometer consisting of RIDL 200 channel pulse height analyser with a coincidence gate of resolving time  $2\tau = 2 \times 10^{-6}$  sec. and NaI(Tl) crystals after being calibrated for energy and intensity. A simplified technique has been adopted to estimate the backscattered radiation and so the gamma-ray energies in the low energy region have been accurately determined. The peeling-off method has been applied for the determination of the various gamma transitions with a high precision. Gamma-gamma coincidence measurements between these determined gamma transitions have been made. The resulting decay schemes have been also studied

review of the shell model and unified model in order to evaluate the possible spins and parities of the different levels.

The results accomplished in this thesis can be summarised as follows:

1. Eight transitions have been observed in the electron-capture decay of  $\text{Pm}^{144}$  to  $\text{Nd}^{144}$ . Beside the known transitions of energies 695, 610, 475 keV, five new transitions have been observed and found to have energies of 530, 300, 220, 130 and 80 keV with uncertainty within 10 keV.

2. The decay scheme of  $\text{Pm}^{144}$  as well as the level scheme of  $\text{Nd}^{144}$  have been constructed. In addition to the three well known states at 695, 1305 and 1780 keV, three new states have been established at 1910, 1445 and 1225 keV. Moreover another level of energy 2210 keV has been also proposed in the present decay scheme, in accordance with that previously observed in the beta decay of  $\text{Pr}^{144}$  to  $\text{Nd}^{144}$ .

3. The measured energies and relative intensities of the gamma transitions in  $\text{Nd}^{144}$  have been applied to estimate the possible electron capture transitions of the  $\text{Pm}^{144}$  parent nucleus. In addition to the well known 1195 and 290 keV electron capture transitions, it has been possible to predict

two other electron capture groups of energies 1055 and 590 keV and relative intensities 5.2% and 38.5% respectively and log ft values of 8 and 7.8 respectively.

4. There is an indication that the new established levels in  $\text{Nd}^{144}$ , at 1910 and 1445 keV have positive parity and probable spins of 4 and 2 respectively. These assignments have been made on account of the allowance of the corresponding gamma transitions as well as the log ft values of the appropriate electron capture transitions.

5. Twenty one transitions have been observed in the beta decay of  $\text{Cd}^{117}$  and  $\text{Cd}^{117m}$  to  $\text{In}^{117}$  extending from 2260 keV to 270 keV. Two of these transitions are new and found to have energies of 1650 and 480 keV.

6. The level scheme of  $\text{In}^{117}$  as well as the decay scheme of  $\text{Cd}^{117}$  and  $\text{Cd}^{117m}$  have been constructed. Such levels have been found to be in agreement with the previously reported ones and settle the discrepancies occurring in the data reported by previous authors.

7. The measured energies and relative intensities of the gamma transitions in  $\text{In}^{117}$  have been applied to estimate the possible beta transitions of the two isomeric states of the  $\text{Cd}^{117}$  parent nucleus. The 1640, 990, 700,

and 440 keV beta transition energies of  $\text{Cd}^{117\text{m}}$  with  $\log ft$  6, 5.8, 4.6, 4.4 and 4 respectively are in complete agreement with that previously reported. In addition to the well known 2250, 2160 and 670 keV beta transitions of  $\text{Cd}^{117}$ , with  $\log ft$  of values 7.2, 7.2 and 4.6 respectively, it has been possible to predict another beta group with energy 1120 keV and a  $\log ft$  value of 6.

8. On account of the  $\log ft$  of the appropriate beta transitions of  $\text{Cd}^{117\text{m}}$  and by taking into consideration the corresponding relative intensities of the gamma transitions, it can be concluded that the levels at 2260, 2100, 2000, 1710 and 1060 keV may have spins and parities of  $11/2^-$ ,  $11/2^-$ ,  $11/2^-$ ,  $11/2^-$  and  $7/2^+$  respectively.

9. There is an indication that the levels in  $\text{In}^{117}$ , resulting from the decay of  $\text{Cd}^{117}$ , at 1890, 1440, 400 and 310 may have spins and parities of  $(1/2^+$  or  $3/2^+)$ ,  $(1/2^-$  or  $3/2^-)$ ,  $5/2^-$  and  $1/2^-$  respectively. This is probable on account of the allowance of the corresponding relative intensities of the gamma transitions as well as the  $\log ft$  values of the appropriate beta transitions.

## INTRODUCTION

Considerable information, about the energy levels and decay schemes of various radioactive nuclei can be obtained by studying their beta and gamma radiations. So by investigating the beta and gamma spectra, resulting from an excited nucleus after being bombarded with an energetic projectile, a decay scheme of that nucleus can be constructed and the properties of the involved nuclear levels can be determined. This experimental information is of value not only in describing nuclear structure but also in testing the validity of the nuclear models.

Various instruments have been used for studying gamma-ray energies and intensities as magnetic spectrometer, proportional counter spectrometer and scintillation spectrometer. Scintillation spectrometry, using thallium activated iodide crystals, is the most widely used and versatile technique for this study. It combines high efficiency, resulting from the high stopping power of the iodide crystal, with moderate resolution and has the advantages of compactness and relative simplicity. The present extensive use of the scintillation method is due partly to the application of the photoelectron multiplier to the detection

of the light plastic is due partly to the discovery of new scintillating materials or phosphors such as anthracene and the alkali halides.

In the present investigation a NaI(Tl) crystal of 2 inch height by 2 inch diameter coupled to (10-17) RCA photo-multiplier have been used with (34-20) RIDL 200-channel pulse height analyser with a coincidence gate of resolving time  $2\tau = 2 \times 10^{-6}$  sec. The complex gamma-ray spectrum has been analysed to its various components using the peeling-off method leading to the gamma-ray energies and intensities. The time relation between these determined gamma transitions have been studied by gamma-gamma coincidence measurements. In this study the energies in coincidence with a definite energy, selected by a differential discriminator, are fed and recorded through a linear gate on the 200 channel analyser.

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 and gamma-gamma coincidence measurements together with the relative intensities and end point energies of the beta transitions of the parent nucleus. Such spectroscopic data are of value in demonstrating the

validity of the shell model and unified model. So it was decided to investigate the single particle and vibrational levels as well as the gamma transitions from even-even and odd-even nuclei.

In the present investigation the  ${}_{60}\text{Nd}^{144}$  is taken as an example of deformed even-even nuclei. The vibrational levels of that nucleus have been studied by considering the electron capture decay of the parent nucleus  $\text{Pm}^{144}$ . This nucleus has been chosen because further studies have to be made in the low energy region of the gamma-ray spectrum. The lack of sufficient information concerning that part is due to the fact that, the analysis of the low energy transitions is difficult for they lie in the region of the backscattering spectrum resulting from the high energy gamma-rays. Moreover, some of the proposed energy levels in  $\text{Nd}^{144}$  have not been confirmed yet. Draper et al. (1960)<sup>(45)</sup> studied the level scheme of  $\text{Nd}^{144}$  by investigating a number of neutron capture gamma rays. In addition to the well known levels at 2181, 1783, 1313 and 696 keV he proposed two levels at 2373 and 1560 keV which need more confirmation. Eissa et al. (1966)<sup>(50)</sup> studied the decay scheme of  $\text{Pm}^{144}$  and reported two doubted levels at 2400 and 1530 keV whose presence need to be proved. The 2110 keV level with a  $3^+$  assignment proposed by the same

was used for the study of the radiation from the parent nucleus  $^{144}\text{Pr}$ . It is desirable to study thoroughly the decay scheme of  $^{144}\text{Pr}$  in order to construct a reliable level scheme of  $^{144}\text{Nd}$ .

In order to study single particle and collective states of odd-even nuclei the  $^{117}_{49}\text{In}$  has been investigated which results from the beta decay of the parent nucleus  $^{117}\text{Cd}$  and  $^{117m}\text{Cd}$ . The study of the decay scheme of this nucleus has been chosen since its known decay scheme still requires further investigation. Sharma et al. (1964)<sup>(61)</sup> reported 13 levels up to 2450 keV among which the levels at 1700 and 660 keV are probable. The problem has been reinvestigated by Arns et al. (1965)<sup>(63)</sup> who has been able to confirm some of the previous levels and failed to observe the levels at 2450, 1410 and 660 keV. In addition to that, he has been able to report a new level at 400 keV. He also performed directional correlation experiments from which the allowable spin assignments and types of radiation have been obtained for the levels and gamma rays involved. Huskova et al. (1965)<sup>(64)</sup> has investigated the decay scheme of  $^{117}\text{Cd}$  nucleus confirming some of the levels reported by the previous authors<sup>(61,63)</sup>. They failed to observe the levels at 2320, 2190, 1830, 1070, 360 and 590 keV reported by Sharma<sup>(61)</sup> and Arns<sup>(63)</sup>. He has also been unable to observe neither the 1410 and 660 keV

levels reported by Sharma nor the new level at 400 keV suggested by Arns. It is thus clear that there is a discrepancy between some of the levels mentioned by the above authors. It has been found reasonable to reinvestigate the decay scheme of  $\text{Cd}^{117}$  and  $\text{Cd}^{117\text{m}}$  in order to check previous results, concerning the energy levels and their spins and parities, which are essential to construct a more reliable decay scheme.