Precision Electron-Gamma Spectroscopic Studies on some Odd Mass Deformed Nuclei

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The extraction of nuclear structure information from experimental observations using the rich variety of available experimental tools has been very successful especially in the last few years, resulting in the unraveling of new and interesting facets of nuclear structure. A large fraction of the success can be attributed to the nuclear structure studies centered on high spin states. The nonselective (n, γ) reactions that provide an apriori guarantee of disclosing all states in certain spins and excitation energy ranges along with many complementary selective processes and β-decay experiments have provided valuable information, especially on unstable nuclei. Much progress has also been made in understanding low spin states of nuclei through theoretical models based on varied assumptions. Yet a closer look at the information available even on the low-lying structure of many nuclei, especially those with odd mass, reveals several gaps or ambiguities. Resolving these issues is of importance for the undisputed acceptance of the current nuclear models, and that will lead to a deeper understanding of nuclear structure. The study of spins and parities of the nuclear excited states, and electromagnetic properties like reduced transition probabilities and mixing ratios, are fundamental and their correct predictions form the strongest validity test for any nuclear model. Spin and parity assignments of many well-established nuclear levels have been made in the past, in particular by application of the selection rules for β and γ transitions (log ft values) and γ and internal conversion data, by taking advantage of the electromagnetic response of nuclei. These nuclear e-γ spectroscopic studies reveal various important aspects of nuclear interactions and can clarify nuclear structure issues. The internal conversion phenomenon has been found to be extremely useful in the determination of the quantum mechanical properties of the different nuclear states, such as multipolarity, spin and parity. Internal conversion electron studies not only complement gamma data, but also provide additional information. While even-even spherical as well as deformed nuclei have been extensively investigated, and their structures relatively well understood, lesser work has been done on odd-mass spherical and deformed nuclei. Hence, electron and gamma spectroscopy of the odd mass nuclei followed by a systematic study of their level structures will help to work out the systematics and tendencies of their nuclear level spectra. As higher accuracy in determining the properties of the nuclear states like electromagnetic moments and transition rates, etc. is a pre-requisite to these studies, the use of high resolution HPGe detectors and magnetic spectrometers having high efficiencies for conversion electrons is a must. The Mini-Orange spectrometer with an arrangement of permanent magnets as a filter, in front of an Si(Li) detector is the preferred option, as it enhances the detector efficiency for conversion electrons and suppresses the influence of the gamma radiation and back scattered radiation.

With these considerations, the structure of the odd-mass deformed nuclei ^{153}Eu, ^{175}Lu, ^{177}Hf and ^{177}Lu were studied, following the radioactive decays of ^{153}Sm, ^{175}Yb, ^{177}Lu and ^{177m}Lu isotopes using electron-gamma spectroscopic techniques. A high purity germanium (HPGe) detector (GMX–10180-p, EG & G, ORTEC) of approximately 60cc volume with energy resolution of 1.8 keV at 1.33 MeV consisting of a preamplifier, a HV filter, detector bias supply and a spectroscopy amplifier was used as the gamma spectroscopy system. The system was optimized with respect to geometry and shielding for best performance and calibrated for efficiency. A Mini-Orange electron transporter having permanent magnet configurations, a LN_2 cooled Si(Li) detector, vacuum chamber and a high vacuum system was used as the electron spectroscopy system. This assembly called the

Mini-Orange Spectrometer was optimized in the control experiments. Both the systems were interfaced to a PC based 8K MCA supported by GammaVision® spectroscopy software for data acquisition as well as for analysis.

The aim of the present study on the odd-mass deformed nuclei ^{153}Eu, ^{175}Lu, ^{177}Hf and ^{177}Lu was to correlate the data on the levels of these nuclei as revealed through three essentially non-overlapping lines of investigations, namely the beta decay studies, (HI, xnγ) reaction studies and the particle transfer studies. The present experimental data were subjected to the 'bench mark' test of comparison with the most recent IAEA energy calibration standards. The excellent agreement with these standards provides the present work, a firm basis for the use of sum rules on the measured gamma energies to arrive at revised level schemes. The computer code GTOL that applies the Ritz combination principle, and the programs Logft and ENSDAT were utilized for this purpose.

In this work, the gamma energies, intensities and conversion electron intensities of all the transitions in ^{153}Eu, were determined with high precision. By a careful examination of weak gamma transitions and from the conversion electron data, controversial gamma transitions, unassigned multipolarities, unconfirmed energy levels and unassigned spins and parities were resolved. 57 interband and intraband gamma transitions connecting 19 energy levels were obtained and analyzed. A total of 38 conversion lines corresponding to 22 gamma transitions were observed, analyzed and the conversion coefficients (CCs) were determined by the Normalized Peak to Gamma (NPG) method with good precision. 22 of the CCs are being reported for the first time. By comparison of the present CCs with theoretical BRICCs, 22 gamma transitions were assigned multipolarities unambiguously, out of which 15 were assigned for the first time. Definite spin and parity assignments were also made for 4 levels for the first time.

In the study of ^{175}Lu, 13 γ transitions were observed and their energies and intensities were obtained with very high precision. 7 new γ transitions not given in Nuclear Data Sheets or previous beta decay studies were identified. A total of 23 CCs corresponding to 11 γ transitions were determined with highest precision to date. Of these, 14 are being reported for the first time. Multipolarities were assigned for 11 transitions and mixing ratios of M1+E2 admixtures were determined. Four new levels at 343.0, 353.3, 414.7 and 432.7 keV with spins and parities - $5/2^+$, $5/2^-$, $(9/2^-)$ and $7/2^+$ respectively, were identified, with evidence in the form of the populating and depopulating gammas and their conversion lines. for the first time in the decay of ^{175}Yb. A revised level scheme incorporating the additional information obtained in the present study that includes eight levels and 13 gamma transitions was constructed.

The high energy beta emitter, ^{177}Lu can serve as a useful tool for radio-therapeutic applications. Also, since the conversion spectrum of ^{177}Hf has well spaced, distinct and intense peaks it can also be used for the calibration of electron detectors in the low energy region. Energies and intensities of the gammas and conversion electrons emitted in the depopulation of excited levels in ^{177}Hf were precisely determined. Out of the total of 18 CCs 5 were reported for the first time. With a view to supplement the existing data on the level structures of ^{177}Hf, the beta decay of the 160.9d isomeric state in ^{177}Lu was also studied. Precise values were obtained for the energies and intensities of the 40 transitions of this decay. A total of 69 CCs, in the decay of ^{177m}Lu were determined for the first time. The energies, intensities and 23 CCs of 10 gammas in the isomeric transition decay branch of ^{177m}Lu were also determined. Mixing ratios of the M1+E2 transitions calculated from the present conversion coefficients were compared with theory.

References

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