CONVERSION ELECTRON SPECTROSCOPY OF HEAVY NUCLEI*

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A description is given of the novel electron spectrometer SACRED, which uses a multi-element Si array to detect cascades of conversion electrons. Its application to the study of "shears" bands in ^{199}Pb and highly deformed structures in ^{222}Th is also described.

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1. Introduction

The existence of a second minimum in the nuclear potential energy surface with a 2:1 axis ratio has been experimentally well documented for nuclei with Z = 92–97 and N = 141–151 (*e.g.* [1]). In these nuclei the second minimum arises because the liquid drop contribution to the total nuclear potential is weakened by the presence of a large Coulomb component and is easily modulated by the strong shell effects arising at these nucleon numbers. In this case the superdeformed state which lies lowest in energy (typically 2–3 MeV above the ground state) has no collective angular momentum and is isomeric. This is in contrast to the behaviour of the observed SD bands in nuclei with Z $\approx$ 66, N $\approx$ 86 (*e.g.* [2]) and $Z \approx 80$, $N \approx 112$ [3] where centrifugal effects play a dominant role, and the highly deformed structure is not observed at low spin. This has implications for

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quantitative measurements of absolute spin, band-head properties and studies of the decay-out mechanism which are all difficult to realize when the second minimum lies at high (> 5 MeV) excitation energy, as in the case of mass 150 and 190 nuclei, or if the population cross-sections are very low ($< 10\mu$b) as in the case of the fission isomers.

Recently, calculations have been performed using the shell correction approach [4] which predict that the SD minima in Th isotopes with $A > 220$ lie lower than 4 MeV at spin zero. As it is known that these isotopes can be populated using (heavy ion, xn) reactions with reasonable cross-sections (> 10 mb) it might be expected that the yield of the population of the second minimum should be one or two orders of magnitude greater than for the fission isomers. If this were the case then the identification of the SD states could be achieved by observing the decay sequence within the second minimum using conventional coincidence techniques. This is essential as it is expected that the branch to fission would be rather weak which precludes the use of fission tagging techniques such as those used to observe transitions in ^{240}Pu [5]. An experimental difficulty lies in the fact that transitions in the second minimum in this mass region from states with $I < 14\hbar$ will be heavily converted, so that γ-ray arrays cannot be employed. This paper describes a novel spectrometer which is capable of detecting multiple conversion electrons emitted simultaneously and its application to the study of low energy transitions in heavy nuclei.

2. SACRED, Silicon Array for ConveRsion Electron Detection

The key component of the spectrometer is a silicon PIN diode array, manufactured by Hamamatsu Photonics, which is a single crystal 25×25 mm square, electrically divided into 25 (5×5 mm) elements with individual readouts. This detector array is placed 0.555 m from the target on the axis (90° to the beam direction) of a superconducting solenoid magnet (see Fig. 1).

The magnetic field profile is such that electrons emitted from the target with energy in the region of interest (50–200 keV) have a high probability of hitting all elements of the detector. In the experiments described here, the value of the component of field along the magnet axis was 0.52 T at the target, reaching a maximum value of 0.60 T at 0.29 m from the target, and 0.045 T at the detector. This had the effect of reducing the average angle (to the solenoid axis) from 27° for 100 keV electrons emitted from the target to 8° when incident onto the detector, thus reducing the background from scattering and re-detection. The efficiency for detection of 100 keV electrons with this field configuration is about 10 %.

Initial source measurements with SACRED were carried out at the University of Liverpool before the spectrometer was moved to the University

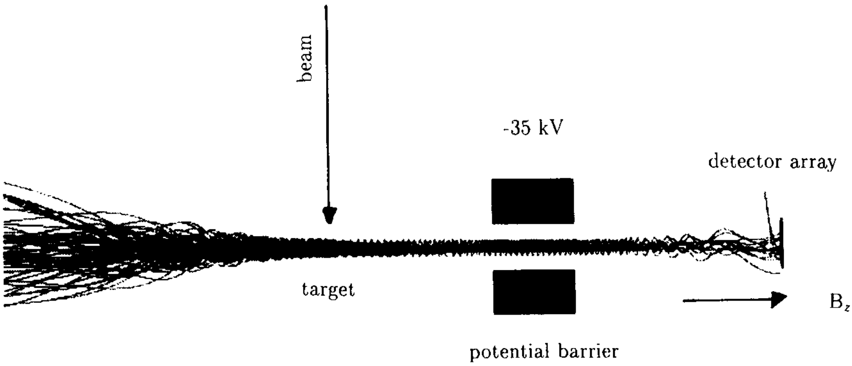

Fig. 1. Scheme of SACRED, showing several electron trajectories.

of Jyväskylä, where in-beam tests and measurements were carried out. Essential to the successful measurement of prompt electrons emitted directly from the target was the development of an electrostatic barrier which repels low energy δ-electrons originating from collisions of the beam and target atoms. This barrier consists of a cylindrically shaped electrode placed approximately half way between the target and the detector (each at ground potential). For oxygen beams incident on heavy targets it was found that a voltage of -35 kV on the barrier was sufficient to reduce the counting rate arising from δ electrons to an acceptable level. In the measurements described here the outputs from the elements were paired (except for the central element) so that 13 channels were separately amplified and digitized.

3. In-beam measurements

The two reactions were investigated: ^{186}W(^{18}O$,5n$)^{199}Pb and ^{208}Pb(^{18}O,4n)^{222}Th, both at bombarding energies of 95 MeV. The first reaction provides a reasonable yield of conversion electrons from the strongly converted M1 transitions which de-excite the "shears" bands in ^{199}Pb [6]. Figure 2a shows the conversion electron spectrum taken in coincidence with several of the strongest transitions in the A11/ABC11 band [6] in ^{199}Pb. Coincidence transitions in this band are clearly identified. The second reaction proceeds as a small (5%) fraction of the total nuclear reaction cross section, the rest being fission. Figure 2b shows the conversion electron spectrum in coincidence with 182_L ($2^+ \to 0^+$) transition in the ground state band in ^{222}Th. The yrast sequence in ^{222}Th consists mostly of weakly converting $E1$ transitions [7], so that the average electron multiplicity is rather low. There was also a significant number of triple electron coincidences. An investigation of these revealed tentative evidence for several coincident transitions with rotational-like energies, apparently in coincidence with both the

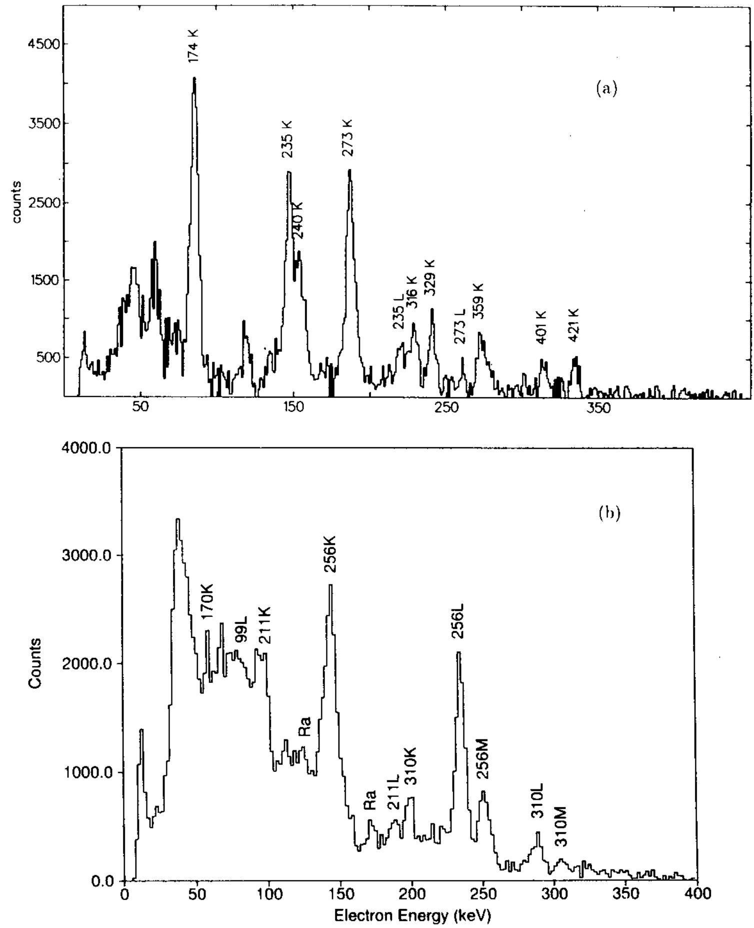

Fig. 2. Electron spectrum in coincidence with (a) transitions in the A11/ABC11 band in ^{199}Pb [6] and (b) the 182_L transition in ^{222}Th [7].

lowest $2^+ \rightarrow 0^+$ and $4^+ \rightarrow 2^+$ transitions in ^{222}Th. This band would be populated with about 1% of the intensity of the yrast band. Further investigations are in progress to determine the multipolarity of the transitions and whether these are candidates for transitions within the SD second minimum in ^{222}Th.

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