Employing Fast Neutrons to Study the Structures of Stable Xenon Nuclei

E.E. Peters[1], B.P. Crider[2], T.J. Ross[2], A. Chakraborty[2], A. Kumar[2], M.T. McEllistrem[2],
F.M. Prados-Estévez[2] and S.W. Yates[1,2]
[1]*Department of Chemistry, University of Kentucky, Lexington, KY 40506-0055, USA*
[2]*Department of Physics & Astronomy, University of Kentucky, Lexington, KY 40506, USA*

Inelastic neutron scattering with accelerator-produced neutrons offers many advantages for studying the structure of stable and very long-lived nuclei. With monoenergetic neutrons, nuclear levels can be examined near the threshold for their excitation without the attendant complications of feeding from higher-lying states. Although the recoil velocities of the excited nuclei are small, the Doppler-shift attenuation method (DSAM) has been developed to measure nuclear level lifetimes [1,2]. Using these experimental techniques, we have been able to study the structure of a large number of nuclei and to identify collective structural features, such as multiphonon excitations of the quadrupole, octupole, and heterogeneous types, and mixed-symmetry excitations. Recently, our attention has turned to providing structural information relevant to neutrinoless double-beta decay and the searches for this rare lepton-number-violating nuclear process.

The stable isotopes of xenon span a region which exhibits a remarkably smooth evolution in quadrupole collectivity; thus these nuclei may provide insight into the nature of this transition. Highly enriched (>99.9%) ^{130}Xe, ^{132}Xe, ^{134}Xe, and ^{136}Xe gases were converted to solid xenon difluorides and were used as scattering samples for inelastic neutron scattering measurements at the University of Kentucky Accelerator Laboratory. Lifetimes of levels up to 3.5 MeV in excitation energy in each isotope were determined using the Doppler-shift attenuation method. Gamma rays corresponding to new transitions and levels have been observed and reduced transition probabilities have been determined. This new information will be examined in an effort to elucidate the structures of these transitional nuclei.

The structures of ^{134}Xe and ^{136}Xe are also of relevance for neutrinoless double-beta decay experiments, specifically those searching for the decay of ^{136}Xe to ^{136}Ba. For example, the detector constructed by the EXO collaboration utilizes liquid xenon as the source and detector and is enriched to 80% in ^{136}Xe, while the remaining 20% is ^{134}Xe [3]. As neutrons may be produced by either incident muons or natural radionuclides present in the surroundings, excited states of either isotope may be populated by inelastic neutron scattering. Therefore, gamma rays emitted upon de-excitation with energies near the neutrinoless double-beta decay end-point energy, 2458.7 keV, may complicate the observation of this rare decay. In addition to the previously known 2414-keV gamma ray in ^{136}Xe, new gamma rays corresponding to transitions in ^{134}Xe have been observed in this energy region, within the resolution of the EXO detector. Gamma-ray production cross sections have been measured between 2.5 and 4.5 MeV.

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[1] T. Belgya, G. Molnár and S.W. Yates, *Nucl. Phys.* **A607**, 43 (1996).
[2] E.E. Peters, A. Chakraborty, B.P. Crider, B.H. Davis, M.K. Gnanamani, M.T. McEllistrem, F.M. Prados-Estévez, J.R. Vanhoy and S.W. Yates, *Phys. Rev. C* **88**, 024317 (2013).
[3] M. Auger *et al.*, *Phys. Rev. Lett.* **109**, 032505 (2012).