LIFETIME DETERMINATION OF EXCITED STATES IN ^{106}Cd*

S.F. Ashley[a], A. Linnemann[b], J. Jolie[b], P.H. Regan[a]
K. Andgren[a,c], A. Dewald[b], E.A. McCutchan[d], B. Melon[b]
O. Möller[b], N.V. Zamfir[d,e], L. Amon[d,f], N. Boelaert[b,g]
R.B. Cakirli[d,f], R.F. Casten[d], R.M. Clark[h], C. Fransen[b]
W. Gelletly[a], G. Gürdal[d,i], M. Heidemann[b], K.L. Keyes[j]
M.N-. Erduran[f], D.A. Meyer[d], A. Papenberg[j], C. Plettner[d]
G. Rainovski[k], R.V. Ribas[l], N.J. Thomas[a,c], J. Vinson[d]
D.D. Warner[m], V. Werner[d], E. Williams[d], K.O. Zell[b]

[a]Department of Physics, University of Surrey, Guildford GU2 7XH, UK
[b]Institut für Kernphysik der Universität zu Köln, 50937 Köln, Germany
[c]Department of Physics, Royal Institute of Technology, Stockholm, Sweden
[d]WNSL, Yale University, New Haven, CT 06520, USA
[e]Institutul Naţional de Fizică şi Inginerie Nucleară, Bucureşti, Romania
[f]Department of Physics, Istanbul University, Istanbul, Turkey
[g]Universiteit Gent, Vakgroep Subatomaire en Stralingsfysica, Gent, Belgium
[h]Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA
[i]Clark University, Worcester, MA 01610-1477, USA
[j]Institute of Physical Research, University of Paisley, Paisley PA1 2BE, UK
[k]Department of Physics and Astronomy, SUNY, Stony Brook, NY 11794, USA
[l]Instituto de Física, Universidade de São Paulo, C.P. 05315-970, Brazil
[m]CCLRC, Daresbury Laboratory, Daresbury, Warrington WA4 4AD, UK

(Received November 11, 2006)

Two separate experiments using the Differential Decay Curve Method have been performed to extract mean lifetimes of excited states in ^{106}Cd. The medium-spin states of interest were populated by the ^{98}Mo(^{12}C, 4n) ^{106}Cd reaction performed at the Wright Nuclear Structure Lab., Yale University. From this experiment, two isomeric state mean lifetimes have been deduced. The low-lying states were populated by the ^{96}Mo(^{13}C, 3n)^{106}Cd reaction performed at the Institut für Kernphysik, Universität zu Köln. The mean lifetime of the $I^{\pi} = 2_1^+$ state was deduced, tentatively, as 16.4(9) ps. This value differs from the previously accepted literature value from Coulomb excitation of 10.43(9) ps.

PACS numbers: 21.10.Tg, 23.20.Lv, 25.70.Gh, 27.60.+j

* Presented at the Zakopane Conference on Nuclear Physics, September 4–10, 2006, Zakopane, Poland.

1. Introduction

In terms of low-lying excitations, the cadmium nuclei are considered some of the best examples of quasi-vibrational nuclei (see reference [1] and references therein). However, from the systematics of the $B(\mathrm{E2})$ values of the $I^\pi = 2^+_1 \rightarrow 0^+_1$ and $I^\pi = 4^+_1 \rightarrow 2^+_1$ transitions in $^{104-110}$Cd [2], the $B(\mathrm{E2})$ values in ^{106}Cd appear to be larger than the systematic trend of the light cadmium isotopes, whose $B(\mathrm{E2})$ values decrease, approaching ^{102}Cd [3]. Within the medium-spin regime, it is evident that there are collective structures with occupation of at least one $\nu h_{11/2}$ orbital [4].

This paper summarises two experiments using the Recoil Distance Method (RDM) and Differential Decay Curve Method to determine $B(\mathrm{E2})$ values for various transitions in ^{106}Cd.

2. Experimental details

2.1. DDCM experiment of the medium-spin states in ^{106}Cd

For population and analysis of the medium-spin states in ^{106}Cd, an experiment was performed at the Wright Nuclear Structure Laboratory, using the New Yale Plunger Device [5] and SPEEDY γ-ray array [6] consisting of seven HPGe clover detectors, four at 41.5° and three at 138.5°, with both angles relative to the beam axis. The ^{98}Mo(^{12}C, 4n)^{106}Cd reaction channel was utilised, with $E(^{12}\mathrm{C})_{\mathrm{LAB}} = 60$ MeV. Further details of the experiment can be found in [7].

2.2. Lifetime determination of isomeric states in ^{106}Cd

The deduction of the $I^\pi = 9^-$ and 8^- isomeric state lifetimes was performed using the 330μm and 2008μm target-stopper distances from the Yale experiment. The lifetime of the $I^\pi = 9^-$ state at $E_x = 3678$ keV in ^{106}Cd was deduced by gating on the shifted component of the 646 keV, $I^\pi = 11^- \rightarrow 9^-$ transition and projecting, fitting, deconvoluting and normalising the stopped and shifted components of the 269 keV, $I^\pi = 9^- \rightarrow 7^-$ transition, as detailed in [8]. The deduced mean lifetime, τ, of the $I^\pi = 9^-$ state at $E_x = 3678$ keV is 0.89(20) ns.

A similar procedure was performed for the mean lifetime of the $I^\pi = 8^-$ state at $E_x = 3507$ keV in ^{106}Cd by gating on the shifted component of the 598 keV, $I^\pi = 10^- \rightarrow 8^-$ transition and projecting, fitting, deconvoluting and normalising the stopped and shifted peaks of the 188 keV, $I^\pi = 8^- \rightarrow 6^-$ transition. The deduced mean lifetime of the $I^\pi = 8^-$ state at $E_x = 3507$ keV is 1.7(5) ns.

2.3. DDCM experiment of the low-spin states in ^{106}Cd

A second experiment was performed at the Institut für Kernphysik, Universität zu Köln, which utilised the Köln plunger and the ^{96}Mo(^{13}C, 3n) ^{106}Cd reaction at $E(^{13}\mathrm{C})_{\mathrm{LAB}} = 43$ MeV. In this experiment, twenty distances were measured, eight of which (6 μm, 8 μm, 13 μm, 16 μm, 18 μm, 21 μm, 25 μm and 37 μm) are used in the preliminary analysis presented here. The reaction γ rays were detected using seven individual segments of one germanium cluster detector (one segment was at an angle of 0° and the other six segments were at an angle of 34.5° relative to the beam axis) and five additional single crystal germanium detectors, each at an angle of 141.5° relative to the beam axis.

For both experiments, prompt coincidences were sorted into angle-dependent γ–γ matrices and were analysed with the TV matrix viewer [9]. The lifetimes were deduced by using the Differential Decay Curve Method (DDCM) [10].

2.4. Preliminary analysis of the $I^\pi = 2_1^+$ state lifetime

From the Köln experiment, three separate 1 keV wide energy coincidence gates were placed on the backward shifted component of the 861 keV, $I^\pi = 4_1^+ \rightarrow 2_1^+$ transition. Projecting, fitting, deconvoluting and normalising the stopped and backward shifted components of the 633 keV, $I^\pi = 2_1^+ \rightarrow 0_1^+$

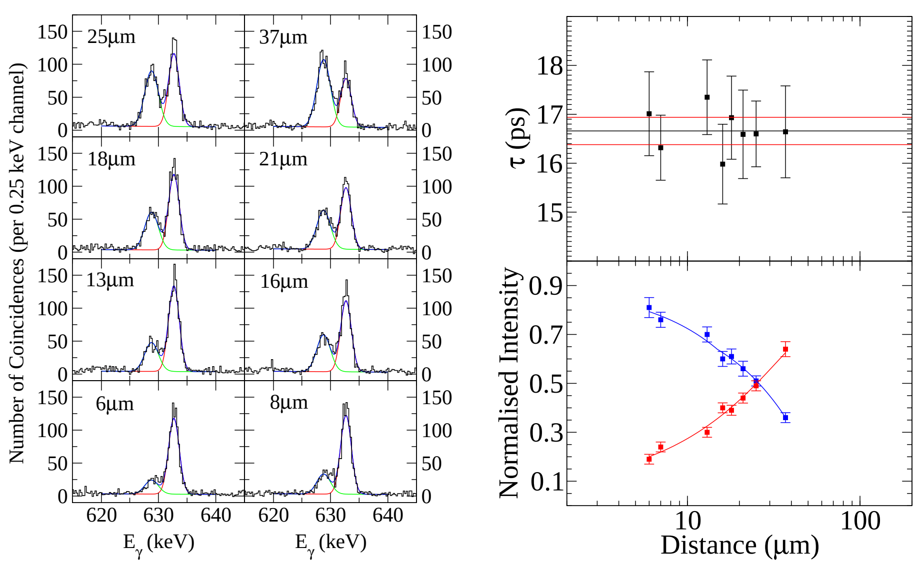

Fig. 1. Left: Projection and deconvolution of the stopped and backward-shifted components of the 633 keV, $I^\pi = 2_1^+ \rightarrow 0_1^+$ transition in ^{106}Cd. The gate was set on the backward-shifted component of the 861 keV $I^\pi = 4_1^+ \rightarrow 2_1^+$ transition for a series of distances between 6μm and 37μm. Right bottom: Normalised intensities of the stopped (decreasing as a function of distance) and shifted (increasing as a function of distance) components of the 633 keV $I^\pi = 2_1^+ \rightarrow 0_1^+$ transition. Right top: Corresponding mean lifetimes at each individual distance measured. The weighted mean lifetime of this particular gate for the $I^\pi = 2_1^+$ state at $E_\mathrm{x} = 633$ keV is 16.7(16) ps.

transition yields mean lifetimes of 15.5(14) ps, 16.7(16) ps (see Fig. 1) and 17.4(19) ps. The weighted mean of these values yielded a mean lifetime of the $I^\pi = 2_1^+$ state of 16.4(9) ps.

3. Discussion and conclusion

For the isomeric states, the $I^\pi = 9^-$ and $I^\pi = 8^-$ mean lifetimes of 0.89(20) ns and 1.7(5) ns compare well to the previously reported values of 1.0(+2,-4) ns and 1.7(6) ns deduced by the "centroid shift method" [11]. For the $I^\pi = 2_1^+$ state, the mean lifetime of 16.4(9) ps, presented here, differs from the literature value of 10.43(9) ps deduced from Coulomb excitation [2].

S.F.A. would like to acknowledge financial support from EPSRC DTG studentship. Work supported in part by the US DOE under grant nos DE-FG02-91ER-40609 and DE-FG02-88ER-40417. P.H.R. would like to acknowledge financial support from EPSRC and the Yale University Flint and Science Development Funds. J.J. and A.L. would like to acknowledge financial support from the Deutsche Forschungsgemeinschaft.

REFERENCES

[1] S.W. Yates, *J. Phys.* **G31**, S1393 (2005).

[2] ^{104}Cd: G.A. Müller *et al., Phys. Rev.* **C64**, 014305 (2001);
^{106}Cd: M. T. Esat *et al., Nucl. Phys.* **A274**, 237 (1976);
^{108}Cd: I. Thorslund *et al., Nucl. Phys.* **A564**, 285 (1993);
^{110}Cd: S. Harissopulos *et al., Nucl. Phys.* **A683**, 157 (2001).

[3] N. Boelaert, Masters Thesis, Universiteit Gent, Belgium, 2006.

[4] ^{106}Cd: P.H. Regan, *et al., Nucl. Phys.* **A586**, 351 (1995);
^{108}Cd: M. Piiparinen, *et al., Nucl. Phys.* **A565**, 671 (1993);
^{110}Cd: S. Juutinen *et al., Z. Phys.* **A336**, 475 (1990);
S. Juutinen, *et al., Nucl. Phys.* **A573**, 306 (1994).

[5] R. Krücken, *J. Res. Natl. Stand. Technol.* **105**, 53 (2000).

[6] C.W. Beausang *et al., Nucl. Instrum. Methods* **A452**, 431 (2000).

[7] K. Andgren, *et al., J. Phys. G* **31**, S1563 (2005).

[8] S.F. Ashley, Ph.D. Thesis, University of Surrey, UK, to be submitted.

[9] J. Theuerkauf, TV, unpublished, `http://www.ikp.uni-koeln.de/~fitz`

[10] A. Dewald *et al., Z. Phys.* **A364**, 163 (1989); G. Böhm, *et al., Nucl. Instrum. Methods* **A329**, 248 (1993).

[11] W. Andrejtscheff *et al., Nucl. Phys.* **A437**, 167 (1985).