HALF-LIFE MEASUREMENTS OF EXCITED STATES IN $^{132}$Te, $^{134}$Xe

O.J. Roberts$^a$, A.M. Bruce$^a$, F. Browne$^a$, N. Mărginean$^b$
T. Alexander$^c$, T. Alharbi$^{c,h}$, D. Bucurescu$^b$, D. Deleanu$^b$
D. Delion$^b$, D. Filipescu$^b$, L. Fraile$^e$, I. Gheorghe$^b$, D. Ghiţă$^b$
T. Glodariu$^b$, D. Ivanova$^d$, S. Kisyov$^d$, R. Mărginean$^b$
P.J.R. Mason$^c$, C. Mihaï$^b$, K. Mulholland$^f$, A. Negret$^b$
C. Nîţă$^b$, B. Olaizola$^e$, S. Pascu$^b$, P-A. Söderström$^g$
P.H. Regan$^c$, T. Sava$^b$, L. Stroe$^b$, S. Toma$^b$, C. Townsley$^c$

$^a$University of Brighton, Brighton BN2 4GJ, UK
$^b$National Institute of Physics and Nuclear Engineering, Bucharest, Romania
$^c$University of Surrey, Guildford GU2 7XH, UK
$^d$University of Sofia, Sofia, Bulgaria
$^e$Universidad Complutense de Madrid, Madrid, Spain
$^f$University of the West of Scotland, Paisley PA1 2BE, UK
$^g$RIKEN Nishina Center for Accelerator-based Science, Wako, Saitma, Japan
$^h$Dept. of Physics, Almajmaah University, P.O. Box 66, 11952, Saudi Arabia

(Received December 10, 2012)

The $^7$Li+$^{130}$Te reaction was used to populate excited states in $^{132}$Te and $^{134}$Xe. The experiment at the Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest, Romania, used an array of high-purity germanium (HPGe) and cerium-doped lanthanum bromide (LaBr$_3$(Ce)) detectors to measure sub-nanosecond half-lives using fast-timing techniques. The half-lives of the yrast 4$^+$ and 6$^+$ levels were measured in the $N = 80$ nuclei $^{132}$Te and $^{134}$Xe, respectively. An upper limit of $T_{1/2} \leq 40$ ps was assigned to the 4$^+$ level in $^{132}$Te and $T_{1/2} = 1075(155)$ ps was assigned to the 6$^+$ level in $^{134}$Xe. The systematics of the $B(E2)$ strengths around the $N = 82$ shell closure are discussed.

DOI:10.5506/APhysPolB.44.403
PACS numbers: 21.10.Re, 21.10.Tg, 23.20.Lv, 27.60.+j

* Presented at the Zakopane Conference on Nuclear Physics “Extremes of the Nuclear Landscape”, Zakopane, Poland, August 27–September 2, 2012.
1. Introduction

The nuclei near the doubly-magic closed shell nucleus $^{132}$Sn are of particular interest due to the interplay of single particle and collective degrees of freedom. The energy level systematics of the low-spin states in the $N = 80$ nuclei exhibit an increase as the $Z = 50$ shell closure is approached and all have a long-lived $I^\pi = 10^+$ isomer based on the $(\nu h_{11/2})^{-2}$ configuration. Prior to this work, the only Te isotopes in which the half-life of the $4^+$ state had been measured were $^{126}$Te (2.8(1) ps [1]) and $^{134}$Te (1.4(1) ns [2, 3]). Therefore, $^{132}$Te has been measured to complete our understanding of the systematics in this region. Similarly, the half-life of the $6^+$ level in $^{134}$Xe was also studied in order to understand the trend in the $B(E2; 6^+ \rightarrow 4^+)$ systematics across the $N = 80$ isotones.

2. Experimental set-up

A 31.5 MeV $^7$Li beam delivered by the 9 MV Tandem van der Graaff accelerator at NIPNE, Bucharest impinged on a 1 mg/cm$^2$ $^{130}$Te target, which was backed with 20 mg/cm$^2$ of $^{208}$Pb. The energy of the beam (which had an intensity of $\sim 3$ pA), was chosen to be close to the Coulomb barrier ($\sim 27$ MeV) in order to suppress fusion–evaporation reaction channels. Excited levels were populated in $^{132}$Te via the $^{130}$Te($^7$Li,$\alpha p$) incomplete-fusion transfer reaction, and in $^{134}$Xe via the $^{130}$Te($^7$Li,$p2n$) reaction. The $\gamma$ rays from the de-exciting states were detected by 8 HPGe and 11 LaBr$_3$(Ce) detectors focused on the target position. Gates on transitions feeding and de-exciting the states of interest in the HPGe detectors, were used to produce an $E_\gamma$–$E_\gamma$–$\Delta t$ cube. This was symmetrised so that the two $\gamma$-ray energies detected in the LaBr$_3$(Ce) detectors; $E_{\gamma_1}$ and $E_{\gamma_2}$, increment the ($E_{\gamma_1}$, $E_{\gamma_2}$) and ($E_{\gamma_2}$, $E_{\gamma_1}$) elements and the time difference between the peaks in the forward and backward time spectra is $2\tau$ [4].

3. Results

3.1. Half-life of the $4^+$ level in $^{132}$Te

Excited states up to the $I^\pi = 8^+$ state in $^{132}$Te were populated, and are shown in Fig. 1. The other two low-lying isomeric states at 2723 ($I^\pi = 10^+$) and 1925 keV ($I^\pi = 7^-$), were not populated. The $2^+ \rightarrow 0^+$ (974 keV) transition was used as a gate in the HPGe detectors and gates were applied on the $5^- \rightarrow 4^+$ (383 keV) and $4^+ \rightarrow 2^+$ (697 keV) transitions in the LaBr$_3$(Ce) detectors, to produce the time spectrum in Fig. 1. The 383 keV transition was used as it was more clearly detected than the highly converted [5], yrast 103 keV transition from the $6^+$ isomer. Due to the low statistics in the resulting time spectrum, an upper limit of $T_{1/2} \leq 40$ ps could only be assigned.
Half-life Measurements of Excited States in $^{132}$Te, $^{134}$Xe

Fig. 1. Left: A partial level scheme for $^{132}$Te up to $I^\pi = 8^+$. Right: The forward and backward time spectra for the 383 and 697 keV transitions which show a Gaussian distribution, indicating $T_{1/2} \leq 40$ ps for the $4^+$ level in $^{132}$Te.

The results from this study were interpreted using shell model calculations, which used a $^{132}$Sn core and a ($\pi g_{7/2})^2$ and ($\nu h_{11/2})^{-2}$ configuration in the model space. Theoretical and experimental $B(E2)$ values are shown in Fig. 2 for some of the even-$A$ Te isotopes. For the $4^+$ level in $^{132}$Te, these calculations estimate a $B(E2; 4^+ \rightarrow 2^+)$ of 8.16 W.u., which would infer a $T_{1/2}$ of $\sim 10$ ps. This is in agreement with the measured value of $T_{1/2} \leq 40$ ps.

Fig. 2. Left: A comparison of the experimental and theoretical $B(E2)$ values from the $2^+_1$, $4^+_1$, and $6^+_1$ yrast states in some of the even–even $Z = 52$ (Te) isotopes. Right: $B(E2; 6^+ \rightarrow 4^+)$ systematics across the $N = 80$ isotones, including the value for the $6^+$ in $^{134}$Xe measured in this study. The $B(E2; 6^+ \rightarrow 4^+)$ value in $^{138}$Ce was taken from recent work by Alharbi et al. [6].

3.2. Half-life of the $6^+$ level in $^{134}$Xe

Excited levels up to the tentatively assigned $8^+$ were populated in $^{134}$Xe as shown in Fig. 3. Gates were made on the $4^+ \rightarrow 2^+$ and $2^+ \rightarrow 0^+$
transitions (884 and 847 keV, respectively) in the HPGe, and on the $8^+ \rightarrow 6^+$ (861 keV) and $6^+ \rightarrow 4^+$ (405 keV) transitions in the LaBr$_3$(Ce) detectors. The relative times between these transitions were then projected to give the time spectrum in Fig. 3. Despite the low statistics due to the weak reaction channel, a half-life of 1075(155) ps was obtained by fitting a slope to the exponential tail of the distribution as shown in Fig. 3. This corresponds to a $B(E2; 6^+ \rightarrow 4^+)$ of $1.2 \pm 0.2$ W.u., in good agreement with the downward trend of the $B(E2; 6^+ \rightarrow 4^+)$ systematics across the $N = 80$ isotones as shown in Fig. 2.

![Fig. 3. Left: A partial level scheme for $^{134}$Xe. Right: The forward time spectrum of the $6^+$ in $^{134}$Xe, showing the fit to the exponential tail. It was created using the 861 and 405 keV transitions in the LaBr$_3$(Ce) detectors.](image)

4. Summary and conclusion

A combination of LaBr$_3$(Ce) and HPGe detectors was used to measure the half-life of the $4^+$ level in $^{132}$Te ($T_{1/2} \leq 40$ ps) and the $6^+$ level in $^{134}$Xe ($T_{1/2} = 1075(155)$ ps). The latter value corresponds to a value of $1.2 \pm 0.2$ W.u. for the $B(E2; 6^+ \rightarrow 4^+)$, which is in good agreement with the trend of these systematics across the $N = 80$ isotonic region.

REFERENCES