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# Lifetime measurement of excited states in $^{121,123}$Te

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The levels up to 1.341 MeV in $^{121}$Te and up to 1.037 MeV in $^{123}$Te were excited via the $^{121,123}$Sb$(p,n,\gamma)$ reaction. For the first time, lifetimes of the energy levels at 758, 807, 811, 912, 944, 1149, and 1341 keV in $^{121}$Te and 784, 895, and 1037 keV in $^{123}$Te have been measured using the Doppler shift attenuation technique. For the 831 keV level in $^{121}$Te we have given a lower limit to the lifetime.

The excited states of the odd neutron nucleus $^{121,123}$Te, where the odd neutron occupies the $h_{11/2}$, $d_{3/2}$, and $s_{1/2}$ orbitals have not been studied in detail both theoretically and experimentally until now. The situation regarding the lifetimes of various levels is even worse. In $^{121,123}$Te, the lifetimes of only the first few low-lying states were known until now.[1,2] The present work, which is a part of the continuous program undertaken in this laboratory to measure the lifetimes of medium mass nuclei, was therefore undertaken to measure the lifetimes of the excited

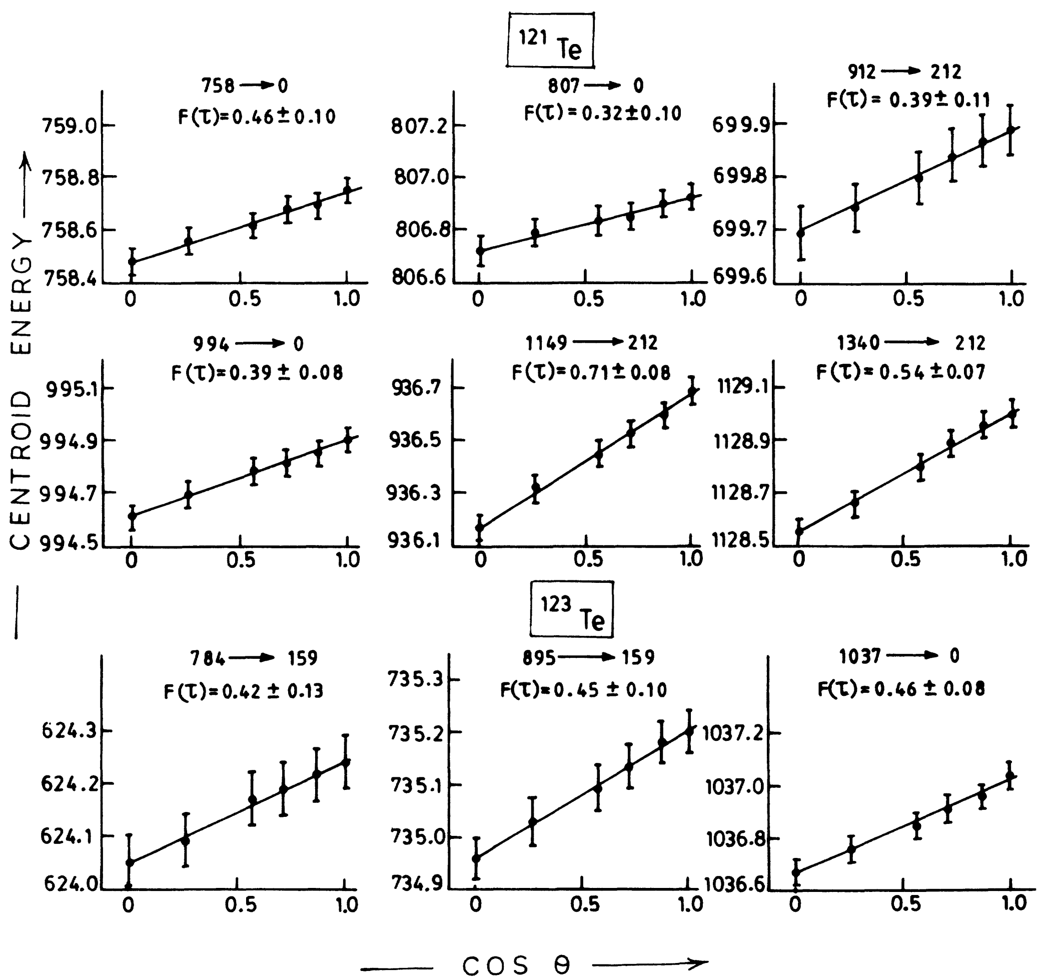


FIG. 1. Plots of $E_\theta$ vs $\cos\theta$ for several transitions in $^{121,123}$Te. The straight lines represent the least-squares fits to the experimental data.

 

states of $^{121,123}$Te. Also, because of the nonselective nature of the $(p,n\gamma)$ reaction, if the incident proton carries enough angular momentum, essentially all the low-lying states will be populated, irrespective of their structure. Further the $Q$ values of the $(p,n\gamma)$ reaction for $^{121,123}$Sb are relatively low, $-1.780$ and $-0.839$ MeV, respectively. The target spin being $\frac{5}{2}$ and $\frac{7}{2}$, respectively, it is possible to populate states with $J=\frac{11}{2}$ and energy below 2 MeV strongly enough to be observed in a HPGe detector.

The excited states of $^{121,123}$Te were observed following the reaction of $^{121,123}$Sb$(p,n\gamma)$; $^{121,123}$Te using 4.0 MeV protons from the Chandigarh Cyclotron. The target employed was a self-supporting pellet of spectroscopically pure natural Sb, which was thick enough to stop incident protons. The target was mounted on a Carbon target holder and was placed in a thin walled chamber having tantalum as an inner lining. The $\gamma$ rays were detected in a 59 cm$^3$ HPGe detector having a 1.9 keV energy resolution at the 1.33 MeV $^{60}$Co line. Single $\gamma$-ray spectra were recorded at 90°, 75°, 55°, 45°, 30°, and 0°, with respect to

TABLE I. Excitation energy of the levels, attenuation factors, and lifetimes for transitions deexciting the levels of $^{121,123}$Te. The errors in experimental $F(\tau)$ are due to the uncertainty in the location of the peak.

| $E_{level}$ (keV) | $E_\gamma$ (keV) | Experimental $F(\tau)$ | Lifetime $\tau$ (fs) |
|---|---|---|---|
| | $^{121}$Te | | |
| 758.4(1) | 758.4(1) | 0.46(10) | $62^{+33}_{-17}$ |
| 806.7(1) | 806.7(1) | 0.32(10) | $110^{+70}_{-35}$ |
| 810.6(1) | 594.0(2) | 0.24(10) | $160^{+140}_{-55}$ |
| 830.5(1) | 387.4(1) | $\leq 0.21$ | $\geq 200$ |
| 911.8(1) | 699.7(1) | 0.39(11) | $85^{+45}_{-30}$ |
| 994.4(1) | 994.4(1) | 0.39(8) | $85^{+32}_{-25}$ |
| 1149.1(1) | 936.8(1) | 0.71(8) | $23^{+11}_{-9}$ |
| 1340.8(1) | 1128.8(1) | 0.54(7) | $46^{+14}_{-10}$ |
| | $^{123}$Te | | |
| 783.6(1) | 624.5(1) | 0.42(13) | $75^{+47}_{-30}$ |
| 894.7(1) | 735.7(1) | 0.45(10) | $65^{+35}_{-20}$ |
| 1036.6(1) | 1036.6(2) | 0.46(8) | $62^{+23}_{-17}$ |

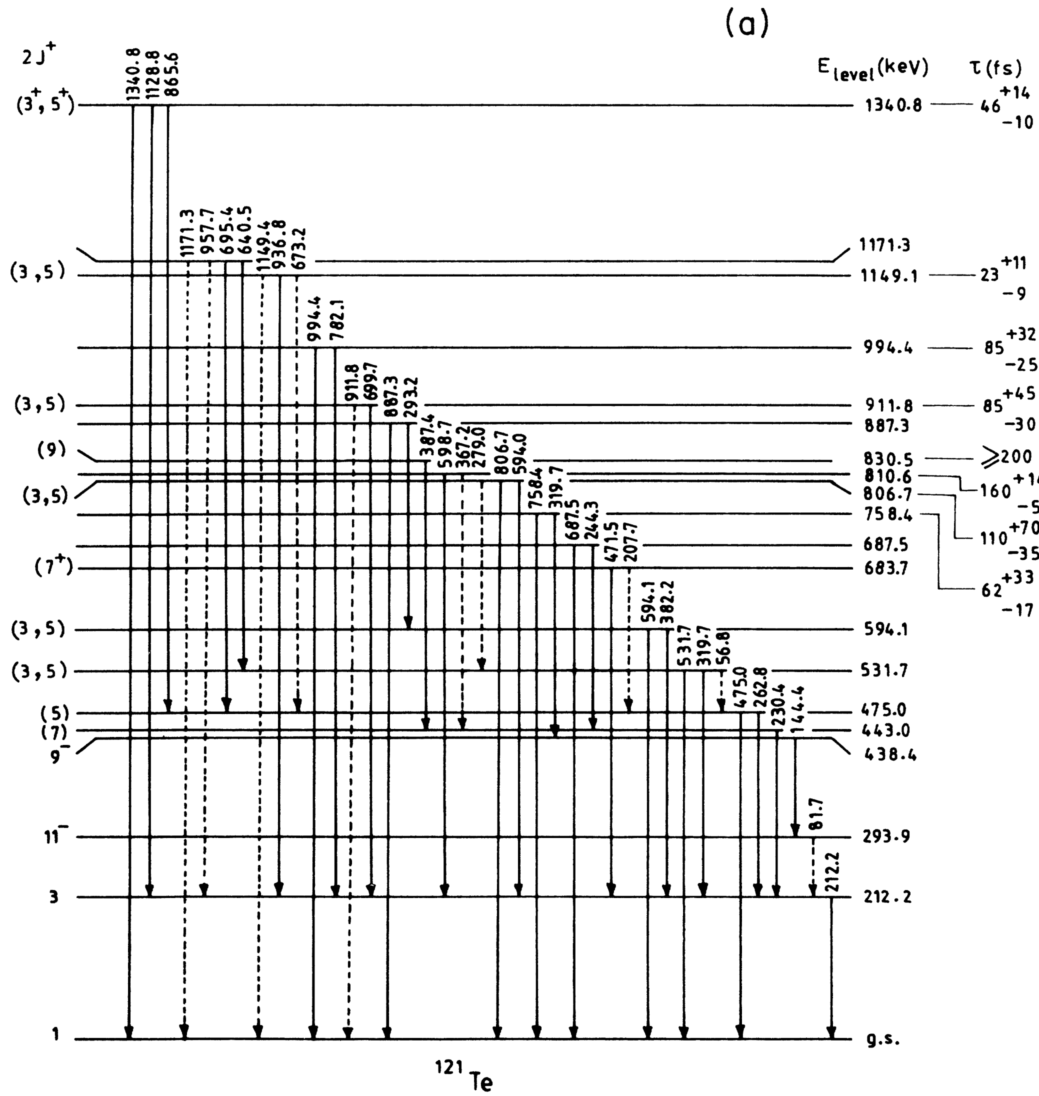


FIG. 2. (a) Partial decay scheme of $^{121}$Te. (b) Partial decay scheme of $^{123}$Te.

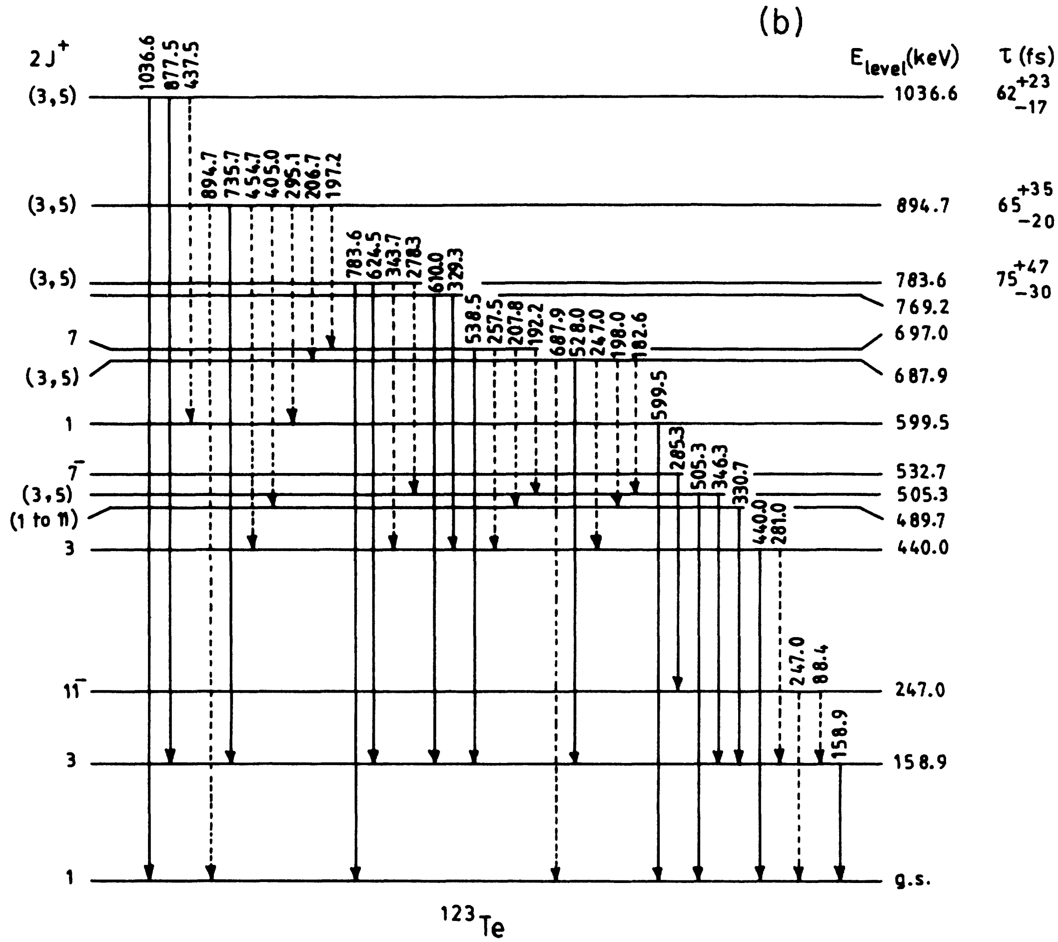


FIG. 2. (*Continued*).

the incident beam direction. Further details of the experimental arrangement and method of analysis are given elsewhere.[3]

The experimental values of the attenuation factor $F(\tau)$ for different $\gamma$ rays were calculated from the slope of straight lines, which were least-squares fits to the experimental data, using the relation

$$E_\theta = E_{90}[1+\beta(0)F(\tau)\cos\theta] ,$$

where $E_\theta$ is the energy of the $\gamma$ ray at an angle $\theta$ from the beam direction and $\beta(0)$ is the velocity of the recoiling nucleus in the forward direction. Because the beam energy were close to threshold for most of the levels, the $(p,n)$ reaction is predominantly a compound-nucleus one, therefore with a thick target, this would lead to a symmetric neutron angular distribution of about 90° in the center of mass (c.m.) system, resulting in an average neutron velocity in the beam direction of zero. It is therefore safe to assume that the mean forward recoil velocity of the $^{121,123}$Te nuclei is just the c.m. velocity.

Theoretically, the quantity $F(\tau)$, which is a function of mean nuclear lifetime, was calculated for $^{121,123}$Te recoiling in natural Sb using the stopping power theory of Lindhard *et al.*,[4] taking into account the Blaugrund approximation[5] for the effect of nuclear scattering. In these calculations, the target thickness was explicitly taken care of by dividing the target into ten layers. The effect of cascade feeding was considered by the method of Hoffman *et al.*[6] The plots of $E_\theta$ vs $\cos\theta$ and their best fits for some of the $\gamma$ rays in $^{121,123}$Te are shown in Fig. 1.

The excitation energy and lifetime of the levels are summarized in Table I. The errors in the lifetime correspond to the errors in the experimental values of $F(\tau)$. However, an additional error of up to 20% may be attributed to the results, due to the uncertainty in the nuclear stopping power, which predominates at the low recoil velocity ($\beta \approx 0.1\%$) of $^{121,123}$Te nuclei for incident protons of 4 MeV. The partial decay scheme from the levels investigated in this work is shown in Figs. 2(a) and (b) for $^{121,123}$Te. Transitions shown as dashed lines are having interference from other competing reactions. $J^\pi$ values are taken from the literature.[1,2]

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