Observation of Natural Linewidth for the 35.5-keV γ Resonance in Te^{125}

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Linewidth measurements of Cu: Sb^{125} sources as a function of cubic ZnTe absorber thickness are performed at 4.2 and 78 °K. The data show that $\Gamma_{source} = 5.20 \pm 0.08$ mm/sec and that the Debye temperature Θ_D of cubic ZnTe is (175 ± 9) °K. Sizable line broadening is observed in commercially obtained polycrystalline ZnTe. This is attributed to the presence of hexagonal ZnTe in such samples. The quadrupole splitting in Te metal at 78 °K is measured to be 7.30 ± 0.08 mm/sec.

I. INTRODUCTION

In a recent publication[1] it was shown that Cu: Sb^{125} sources exhibit a narrow and reproducible linewidth for the 35.5-keV γ resonance in Te^{125}. In this paper we report on linewidths measured as a function of cubic ZnTe absorber thickness. The principal results from the present investigations are (a) Cu: Sb^{125} sources exhibit an emission linewidth of 5.20 ± 0.08 mm/sec, which agrees well with the minimum observable linewidth of $2\Gamma_n$, (b) the Debye temperature Θ_D of cubic ZnTe is (175 ± 9)°K, and (c) commercially obtained samples of polycrystalline ZnTe contain appreciable fractions of the hexagonal phase that show Mössbauer line broadening in these samples.

These results have the following significance: 60-day Cu: I^{125} and 58-day $ZnTe^{125m}$, the single-line sources hitherto used in Te^{125} Mössbauer spectroscopy exhibit broad linewidths.[1-3] Cu: Sb^{125} sources on the other hand, on account of their narrow linewidth and a long parent life of 2.7 yr, offer a promise of precision Te^{125} γ-resonance studies in future. The Te^{125} resonance has a broad natural linewidth $2\Gamma_n$; and invariably the presence of hyperfine interactions leads to partially resolved spectra. A meaningful analysis of such spectra to yield reliable hyperfine splittings generally can be possible only after due considerations to linewidths.[4] A spectrum of Te metal [Fig. 1(c)] taken with this new source gave, for the quadrupole components, the narrowest observed linewidths so far reported (Table I). The quadrupole splitting (QS) in Te metal[5] at 78 °K is measured to be 7.30 ± 0.08 mm/sec.

II. EXPERIMENTAL

The ZnTe absorber material for the present work was obtained from the following suppliers. Sample *A* consisted of cubic single-crystal chips from Gould Industries, Cleveland, Ohio; sample *B* consisted of 99.999%-pure polycrystalline ZnTe bought from Research Inorganic Chemical Corp, Sun Valley, Calif.; and sample *C* consisted of enriched $ZnTe^{125}$ absorber, hot pressed in a Lucite matrix and was made available by New England Nuclear, Boston, Mass. The crystal chips were powdered to a grain size of 125 mesh. To achieve uniformity in absorber thickness, the powdered ZnTe was mixed with Coffeemate before encapsulating in an Al holder. The sources were prepared by diffusing carrier-free Sb^{125} in high-purity Cu foils and details of the preparation appear in Ref. 1. The constant-acceleration drive was calibrated using a Cu: Co^{57} source and Fe^{57} metal and details of the experimental arrangement appear elsewhere.[2]

III. RESULTS AND CONCLUSIONS

Figure 1 shows typical Te^{125} velocity spectra obtained in the present work. Narrowest linewidths were observed using ZnTe absorbers from sample *A*. These experiments were performed at 78 and 4.2 °K using the same absorbers. In these measurements the source and absorber were maintained at the same temperature. A summary of the linewidth data as a function of absorber thickness

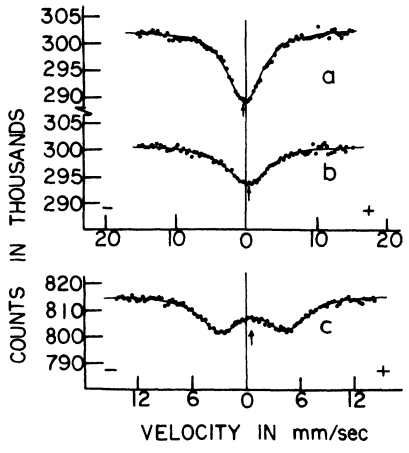

FIG. 1. Velocity spectra of (a) ZnTe sample *A*, (b) ZnTe sample *B*, and (c) Te metal absorbers taken with Cu: Sb^{125} source, with both source and absorber at 78 °K. See Table I for other details.

TABLE I. Analysis of experimental data shown in Fig. 1.

Absorber	Thickness (mg/cm^2 Te^{125})	$\Gamma_{observed}$ (mm/sec)	Isomer shift (mm/sec)	Quadrupole splitting (mm/sec)
ZnTe sample *A*	3	5.95 ± 0.15	−0.24 ± 0.07	•••
ZnTe sample *B*	3	7.30 ± 0.30	+0.12 ± 0.08	a
Te metal[b]	4	5.42 ± 0.16	+0.72 ± 0.09	7.30 ± 0.08

[a]See text.

[b]99.9999%-pure polycrystalline Te metal from Spex Industries, Metuchen, N. J. The source and absorber were maintained at 78 °K for these experiments.

appears in Fig. 2. The data were fit to a straight line and gave the following results:

4.2 °K, $\Gamma_{source} = 5.30 \pm 0.05$ mm/sec ,

$f_{ZnTe} = 0.57 \pm 0.01$;

78 °K, $\Gamma_{source} = 5.10 \pm 0.08$ mm/sec ,

$f_{ZnTe} = 0.32 \pm 0.02$.

For these calculations, α_T the internal-conversion coefficient of the 35.5-keV transition was taken to be 13.5.[6] The Γ_{source} values are in good agreement with $2\Gamma_n = \hbar/\tau = 5.20 \pm 0.04$ mm/sec based on the electronically measured half-life of 1.475 ± 0.010 nsec[7] for the 3/2$^+$ state.

On a Debye model, the measured f values of cubic ZnTe translate to a mean Θ_D of (175 ± 9)°K. Recently, Blattner *et al.*[8] have measured an x-ray Debye temperature Θ_M of (180 ± 6)°K for cubic ZnTe. The values of Θ_D and Θ_M are in good agreement with each other but both these results are at variance with the value of 100 °K, the Debye temperature of ZnTe source in an I^{127} Mössbauer experiment.[9]

Sizable line broadening was observed in polycrystalline ZnTe samples *B* and *C*. For example, for an absorber thickness of 3 mg/cm^2 of Te^{125}, the linewidths for samples *B* and *C* were found about 20% broader than those for sample *A* (Figs. 1 and 2). X-ray diffraction patterns of sample *B* in contrast to those of sample *A* showed additional peaks that can be identified with the hexagonal phase of ZnTe. Spinalescu-Carnaru[10] has shown that ZnTe films exist both in cubic (zinc-blende) and hexagonal (wurzite) phases and further that nucleation of a given phase depends sensitively on the local stoichiometry at the time of crystallization. The line broadening observed in samples *B* and *C* may thus be attributed to the existence of an unresolved QS in hexagonal ZnTe present in these samples. From the x-ray data it is difficult at this moment to reliably estimate the fraction of hexagonal phase present in these samples and thus deduce uniquely the QS in this noncubic phase. We have noted that the color of the cubic sample *A* is dull orange in contrast to a brown color of the noncubic samples. Attempts to achieve a purely cubic phase in the polycrystalline ZnTe samples by heating in vacuum above 500 °C (above this temperature the hexagonal phase is reported[10] to be unstable) and quenching in air were partially successful. A reduction in linewidth accompanied by a change in color was observed in the quenched polycrystalline samples.

IV. CONCLUDING REMARKS

The narrower emission linewidths for Cu: Sb^{125} sources in contrast to those of Cu: I^{125} and $ZnTe^{125m}$ sources deserves a few comments. Sb is known to dissolve[11] in Cu although the same cannot be said of I in Cu. It is very likely that on electroplating I^{125} on Cu, a technique used to prepare Cu: I^{125} sources, one forms CuI. This compound is known to exist both in a cubic and noncubic phase.[12] Te, the daughter formed as a consequence of electron capture of CuI^{125}, most likely sits in a noncubic environment. In this context it is relevant to point

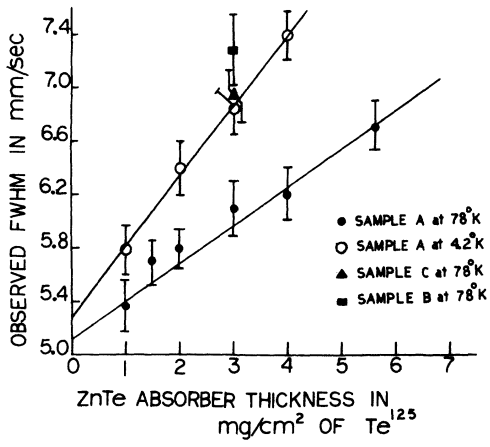

FIG. 2. Summary of observed linewidths plot as a function of ZnTe absorber thickness. For sample *A*, data taken at 4.2 and 78 °K were fit to a straight line. Samples *B* and *C*, each 3 mg/cm^2 thick, gave 20% broader linewidths than that obtained with sample *A*. These measurements were performed using Cu: Sb^{125} source and in all measurements, the source and absorber were maintained at the same temperature.

out that both cuprous and cupric telluride exhibit quadrupole broadening[13] at Te^{125}. For $ZnTe^{125m}$ sources, on the other hand, failure to achieve natural linewidths in the absence of resonant self-absorption in the source matrix, is due to the difficulty of achieving a purely cubic phase in polycrystalline samples of ZnTe. These considerations on line broadening are also relevant to Mössbauer spectroscopies of $I^{127,129}$ where matrices of ZnTe and Cu have been used to achieve single-line sources or absorbers or both.

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[1]P. Boolchand, J. Nucl. Inst. and Methods (to be published).
[2]P. Boolchand, B. L. Robinson, and S. Jha, Phys. Rev. B 2, 3463 (1970).
[3]M. Pasternak and A. L. Spikervet, Phys. Rev. **181**, 574 (1969).
[4]E. Gerdau, W. Rath, and H. Winkler, Z. Phys. 257, 29 (1972).
[5]C. E. Violet and R. Booth, Phys. Rev. **144**, 225 (1966).
[6]R. S. Narsisi, thesis (Harvard University, 1959) (unpublished).
[7]C. Hohenemser and R. Rosner, Nucl. Phys. A. **109**, 364 (1968).
[8]R. J. Blattner, L. K. Walford, and T. O. Baldwin, J. Appl. Phys. **43**, 935 (1973).
[9]G. J. Perlow and M. R. Perlow, J. Chem. Phys. **45**, 2193 (1966).
[10]I. Spinulescu-Carnaru, Phys. Status Solidi **18**, 769 (1966).
[11]M. Hansen, *Constitution of Binary Alloys* (McGraw-Hill, New York, 1958), p. 1177.
[12]A. Taylor and B. J. Kagle, *Crystallographic Data on Metal and Alloy Structures* (Dover, New York, 1963), p. 80.
[13]P. Boolchand and S. Jha (unpublished results).