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Observation of the room-temperature ^{125}Te Mössbauer effect in Mg_3TeO_6: Linewidth, recoil-free fraction, and isomer shift

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Fifty-eight-day $^{125}Te^m$ in a Mg_3TeO_6 host provides an easily produced, rugged, high recoil-free fraction and narrow-emission-linewidth source for ^{125}Te Mössbauer spectroscopy. The high f factor of this source opens the possibility of precision T-dependent Mössbauer-spectroscopy measurements in Te-bearing compounds with the source kept at room temperature. Using such a source at 300 K, we have measured the T dependence of the f factor for both Mg_3TeO_6 and cubic ZnTe absorbers and find Debye temperatures Θ_D of 390(2) K and 188(2) K, respectively. At 300 K, the f factor of Mg_3TeO_6 (0.46) is found to be an order of magnitude larger than in cubic ZnTe (0.040) thus making feasible room-temperature observation of the Mössbauer effect with the oxide source. Both emission and absorption linewidths of the oxide matrix have been examined and display a 14(3)% line broadening over the natural width (Γ_n), a result that is thought to be intrinsic to the oxide host. The isomer shift of Te metal (78 K) and cubic ZnTe (78 K) relative to Mg_3TeO_6 at 300 K is $+1.86(9)$ and $+1.21(3)$ mm/s, respectively. Mg_3TeO_6 is easily prepared in a pure form and yields reproducible crystal structure and Mössbauer-effect parameters. Mg_3TeO_6 provides a suitable standard matrix for ^{125}Te isomer shift and f-factor measurements.

I. INTRODUCTION

^{125}Te Mössbauer spectroscopy offers the prospect of chemically probing a wide variety of chalcogen-based organic[1] and inorganic[2,3] materials. In our laboratory, chalcogen-based semiconducting crystals and glasses have received particular interest over the years.[2,3] Unfortunately, to date these measurements have had to be performed at 78 K or lower, largely because the source matrices used such as ^{125}Sb in Cu,[4] or $^{125}Te^m$ in GeTe (Ref. 3) or ZnTe, possess low Debye-temperatures ($\Theta_D \lesssim 200$ K). Interest in Mg_3TeO_6 was recently stimulated by Pasternak, Van der Heyden, and Langouche[5] who reported observing a room-temperature ^{129}I Mössbauer effect with the 27.8-keV γ ray using sources of $^{129}Te^m$ in Mg_3TeO_6. The Debye temperature of this matrix can be established directly in ^{125}Te Mössbauer absorption spectroscopy. To evaluate this matrix for ^{125}Te spectroscopy, we have now measured the f factor and linewidth of Mg_3TeO_6 in the present work. Our results reveal Mg_3TeO_6 to possess a rather high Debye temperature, $\Theta_D = 390(2)$ K, yielding an f factor of 0.46 at room temperature. Our results on the $Mg_3{}^{125}Te^mO_6$ source reveal the emission linewidth to be broadened by 14(3)% over the natural width (Γ_n), a broadening which is thought to be intrinsic to the oxide matrix. In spite of this minor limitation, the high f factor of such sources at room temperature opens for the first time the possibility of precision T-dependent ^{125}Te Mössbauer spectroscopy measurements in a wide variety of Te salts.

II. PROCEDURE, SAMPLE PREPARATION, AND X-RAY CHARACTERIZATION

Mg_3TeO_6 samples were prepared by two methods, one wet chemical and the other dry chemical. Enriched ^{124}Te in its elemental form was oxidized in NH_4OH by 30% H_2O_2 followed by precipitation with magnesium nitrate. The precipitate was heated to 750 °C causing loss of volatile products and leaving Mg_3TeO_6 crystals. This chemical method has been shown[6] by Koudelka and Boolchand to provide rather high yield (> 90%) even when working with mg batches of the starting enriched ^{124}Te. The dry chemical route consisted of homogeneously mixing powders of TeO_2 and MgO in the molar ratio of 1:3 and forming pellets. The pellets were sintered at 900 °C for 12 h in air. The resulting samples were finely ground, mixed, pelletized, and sintered once again to promote homogeneity. Samples prepared by the wet and dry chemical route were both subjected to x-ray diffraction (XRD) using a Siemens diffractometer. Both samples yielded quite similar results as illustrated in Fig. 1. The XRD peaks are easily indexed on the hexagonal structure of Mg_3TeO_6 reported by Newham, Dorrian, and Meagher.[7] The lattice parameter of our sintered sample ($a = 8.59$ Å, $c = 10.33$ Å) and chemically prepared sample ($a = 8.60$ Å, $c = 10.34$ Å) are in good agreement with the published report of Newham, Dorrian, and Meagher[7] ($a = 8.58$ Å, $c = 10.30$ Å) who prepared their sample by sintering.

Neutron activation of the wet chemically prepared Mg_3TeO_6 sample was performed at the University of Missouri Research reactor. A 20-mg quantity of $Mg_3{}^{124}TeO_6$ was activated for a 2-week period at 3×10^{14} neutron flux to produce a 6.5-mCi quantity of 58 days $^{125}Te^m$ by (n,γ) reaction on ^{124}Te. The activated sample was heated at 600 °C for 12 h to thermally anneal radiation damage, prior to evaluation in the ^{125}Te Mössbauer-effect experiments. Neutron irradiation of Mg_3TeO_6 produces no undesirable radioactive species due to the presence of Mg or O in the target. In the pulse height spectrum of the source taken with a Xe-filled proportional counter (shown in Fig. 2), we can clearly discern the Te K_α (27.5 keV) and K_β (31.0 keV) x rays and the Mössbauer γ ray at 35.5 keV. The prominent peak at 6 keV is the escape peak of the 35.5-keV γ ray.

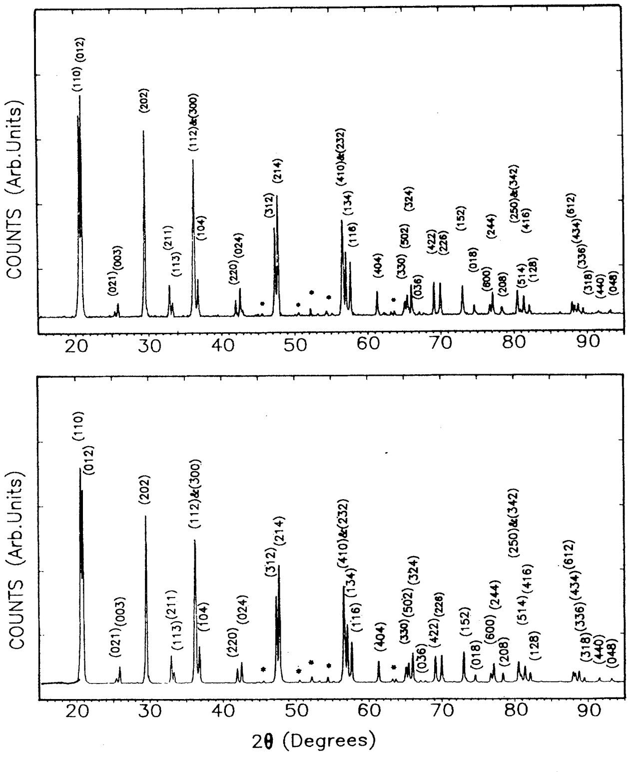

FIG. 1. X-ray-diffraction scans of wet (top) and dry (bottom) chemically processed Mg_3TeO_6 samples taken with a Siemens Diffractometer using Cu K_α radiation. The peak identification is taken from Ref. 7. The peaks with asterisks are thought to result from impurities.

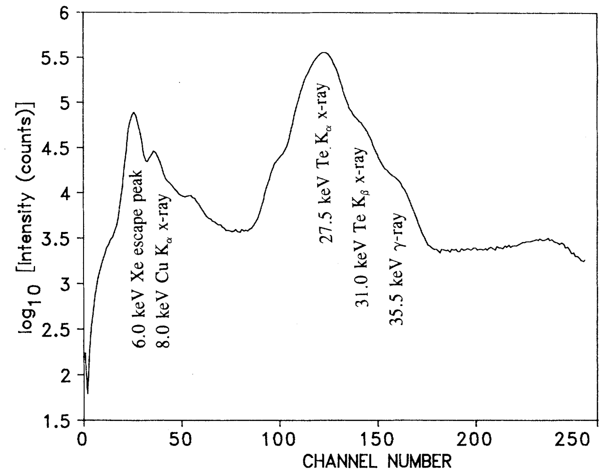

FIG. 2. Pulse height spectrum of the $Mg_3{}^{125}Te^mO_6$ source taken with a Xe-filled proportional counter.

The Mössbauer spectrometer consisted of an electromechanical drive (K4 motor) from Austin Science Associates. The data were recorded in a 286 personal-computer-based multichannel analyzer using the PCA-2 card from the Nucleus, Inc. The 35.5-keV γ rays from the $Mg_3{}^{125}Te^mO_6$ source were detected using the escape peak (6 keV) in a Xe-gas-filled proportional counter (Fig. 2). With our setup, we could retrieve, analyze, and plot a spectrum in the background mode while accumulating a spectrum in the foreground.

Two types of Mössbauer-effect experiments were undertaken. Observed line-widths of the $Mg_3{}^{125}Te^mO_6$ source were systematically studied with cubic ZnTe absorbers of varying thickness, with both the source and absorber cooled to 78 K in an exchange-gas liquid-helium Dewar. The observed line shapes were least-squares fit to a Lorentzian profile to extract the centroid, full width at half maximum (Γ_{obs}), and the integrated intensity. These measurements permitted us to obtain the emission linewidth (Γ_s) of the source. A parallel set of linewidth measurements of the source were performed using the chemically prepared Mg_3TeO_6 material as an absorber, to establish the absorber thickness dependence of Γ_{obs}. These measurements permitted us to obtain the absorption linewidth (Γ_a) in the Mg_3TeO_6 absorber.

The second type of Mössbauer-effect experiment included measurements of the integrated intensity (area) under the resonance using the $Mg_3{}^{125}Te^mO_6$ source at 300 K, and an absorber (either of cubic ZnTe or of Mg_3TeO_6) cooled to a temperature T in the range $12 < T < 300$ K. We used a He closed-cycle cryostat, Displex model CS202 from APD, Inc. with the DMX-20 shroud to vary the temperature of the absorber. We have developed a special mounting arrangement to completely decouple vibrations of the expander from the absorber. In our system, the vibration decoupling was checked by measuring the linewidth of the inner two lines of α-Fe. No line broadening was observed upon switching on the expander. A Lakeshore Cryotronics model DRC 80C temperature controller with Si-diode thermometers were used to measure and control the temperature of the absorber to ±1 °C in the $12 < T < 300$ K range. The T dependence of the integrated area $A(T)$ in these experiments is directly proportional to the f factor $f(T)$ of the absorber since the temperature of the source is kept fixed. The observed $f(T)$ variation was fit to a Debye model to extract an effective Debye temperature (Θ_D). For this purpose, we used a nonlinear least-squares-fitting routine to analyze measured $f(T)$ results to obtain Θ_D. Results of both types of Mössbauer-effect measurements, i.e., those performed at 78 K and those at variable temperatures, are correlated and, as we will show, uniquely permit a reliable evaluation of the Mg_3TeO_6 matrix for ^{125}Te Mössbauer-spectroscopy work.

III. MÖSSBAUER-SPECTROSCOPY RESULTS

Figure 3 illustrates spectra of several Te-based compounds taken with the $Mg_3{}^{125}Te^{m}O_6$ source at 300 K. The temperature of the absorber is indicated in each case. As can be seen from Fig. 3, the room-temperature Mössbauer effect of the 35.5-keV γ ray is rather easily observed using the source with a thin (28 mg/cm^2 of natural Te) Mg_3TeO_6 absorber.

Figure 4 summarizes the observed linewidths as a function of absorber thickness for both cubic ZnTe and Mg_3TeO_6. The cubic ZnTe absorbers used presently were the same ones used by Oberschmidt and Boolchand[8] several years ago to demonstrate that ^{125}Sb sources in the Cu matrix yield the natural width for the 35.5-keV γ ray. The natural linewidth of the 35.5-keV γ resonance Γ_n equals $h/\bar{\tau} = 2.6$ mm/s based on $\bar{\tau} = 2.13$ ns for the 35.5-keV level.[9] The minimum observable linewidth in a Mössbauer experiment equals $2\Gamma_n = 5.2$ mm/s. From the observed linear variation of Γ_{obs}, we have obtained the extrapolated linewidth for zero absorber thickness, which represents the sum of the emission and absorption linewidths, i.e., $\Gamma_s + \Gamma_a$. For cubic ZnTe absorbers, since $\Gamma_a = \Gamma_n$, as demonstrated in Ref. 8, the extrapolated width of 5.66(8) mm/s, greater than $2\Gamma_n$, implies that the $Mg_3{}^{125}Te^{m}O_6$ source does not yield the natural width. From this result, we deduce the source linewidth $\Gamma_s = 3.06(8)$ mm/s, and it is greater than the natural width $\Gamma_n = 2.6$ mm/s by 18(4)%. Results obtained with Mg_3TeO_6 absorbers of varying thickness yield an extrapolated linewidth of 5.94(8) mm/s from which we deduce an absorption linewidth $\Gamma_a = 2.88(8)$ mm/s, which is 11(3)% greater than Γ_n. Thus, both the source and absorber matrix of Mg_3TeO_6 give about a 14(3)% line broadening over Γ_n. This clearly indicates that the small broadening is largely intrinsic to the oxide matrix, a point we shall return to later. These linewidth results are summarized in Table I.

Results of Mössbauer-effect measurements performed with the $Mg_3{}^{125}Te^{m}O_6$ source held at room temperature and a Mg_3TeO_6 absorber mounted in a He closed-cycle cryostat appear in Fig. 5. In this set of experiments, as we alluded earlier, changes in the integrated area $A(T)$ under the γ resonance profile directly reflect the T dependence of the f factor $f(T)$ of the thin Mg_3TeO_6 absorber, since the source temperature and the geometry of the set-

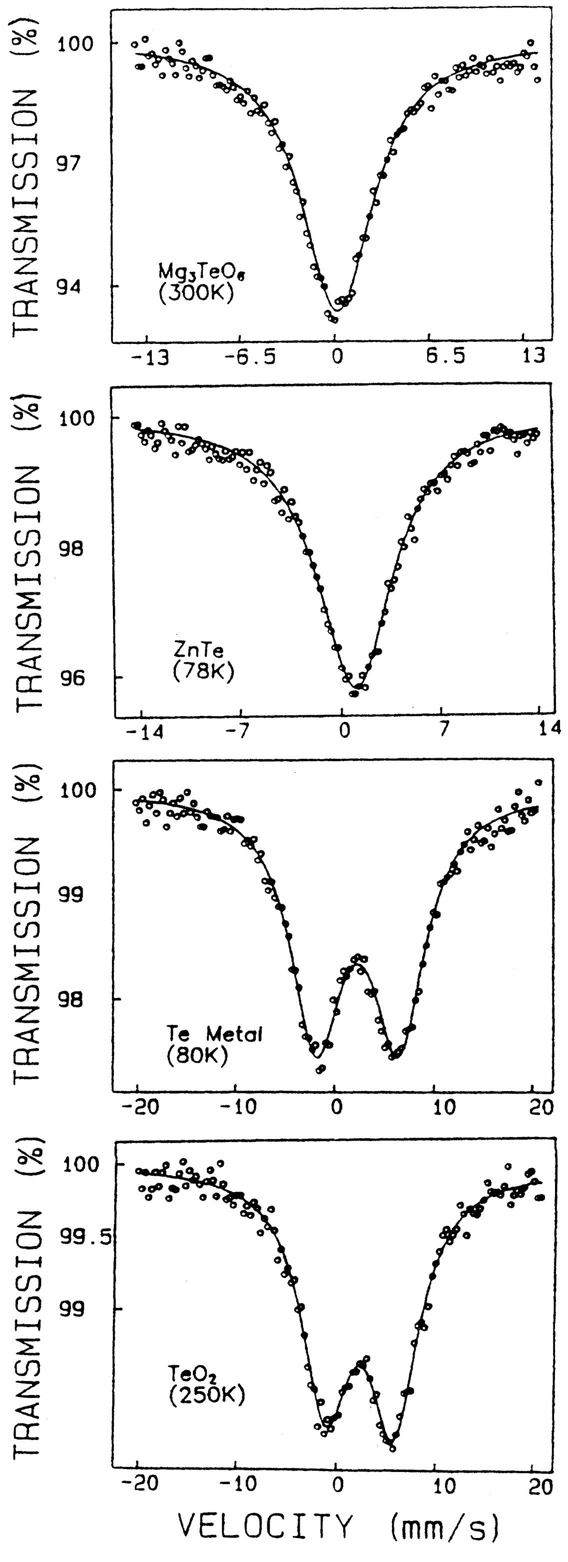

FIG. 3. Mössbauer spectra of Te-based compounds at indicated temperatures taken with a $Mg_3{}^{125}Te^{m}O_6$ source at 300 K. The absorbers made out of natural Te had thicknesses of Mg_3TeO_6, 1.75 mg/cm^2 ^{125}Te; ZnTe, 2 mg/cm^2 ^{125}Te; Te metal, 3 mg/cm^2 ^{125}Te; and TeO_2, 3 mg/cm^2 ^{125}Te.

TABLE I. ^{125}Te linewidth results deduced from Fig. 4. Γ_s and Γ_a represent the source and absorber linewidths.

Absorber	T (K)	Γ^a_{obs} (mm/s)	Γ_s (mm/s)	Γ_a (mm/s)
ZnTe[b]	78	5.66(8)	3.06(8)	2.60(8)
Mg_3TeO_6	78	5.94(8)	3.06(8)	2.88(8)

[a] Extrapolated width measured using the $Mg_3{}^{125}Te^mO_6$ source at 78 K.

[b] In Ref. 8 these absorbers were shown to yield $\Gamma_a = \Gamma_n = 2.60$ mm/s.

up is kept fixed. We have least-squares fitted the observed $f(T)$ dependence, to extract the Debye temperature of the Mg_3TeO_6 absorber and obtain a value of $\Theta_D = 390(2)$ K.

We cooled a cubic ZnTe absorber in a He closed-cycle cryostat and systematically recorded spectra using the $Mg_3{}^{125}Te^mO_6$ source at 300 K. In relation to Mg_3TeO_6, the $f(T)$ variation in cubic ZnTe displays a sharper T dependence, and this is indicative of a lower Θ_D in the II-VI semiconductor. A least-squares fit of the observed variation yields $\Theta_D = 188(2)$ K for cubic ZnTe, which compares favorably with the x-ray Debye temperature of 180(6) K due to Blattner, Walford, and Baldwin.[10]

IV. DISCUSSION

A. Debye temperature of Mg_3TeO_6

The Mg_3TeO_6 Debye temperature $\Theta_D = 390(2)$ K deduced from the present ^{125}Te absorption Mössbauer spectroscopy is significantly higher than $\Theta_D = 320$ K deduced by Pasternak, Van der Heyden, and Langouche[5] from $^{129}Te^m$ labeled Mg_3TeO_6 sources in ^{129}I emission Mössbauer spectroscopy. In the latter, one actually measures the local vibrational density of states at an ^{129}I impurity formed in the β decay of a $^{129}Te^m$ parent in the Mg_3TeO_6 matrix. Since chemical bond rearrangement in solids generally proceed on a time scale (10^{-10}–10^{-12} s) much faster than the mean life (21.6 ns) of the 27.8-keV state, the difference in Θ_D's between the ^{129}I and the ^{125}Te measurements are rather curious. We recognize that the chemical bonding of I daughter in the [IO_6] unit probably displays a slightly reduced ionicity in relation to Te in the parent [TeO_6] unit. This is suggested by the Pauling electronegativities of Te, I, and O of 2.1, 2.5, and 3.5, respectively. However, such a small change in ionicity alone is not likely to be the principal reason for the striking change in Θ_D. Furthermore, the ionic radii of

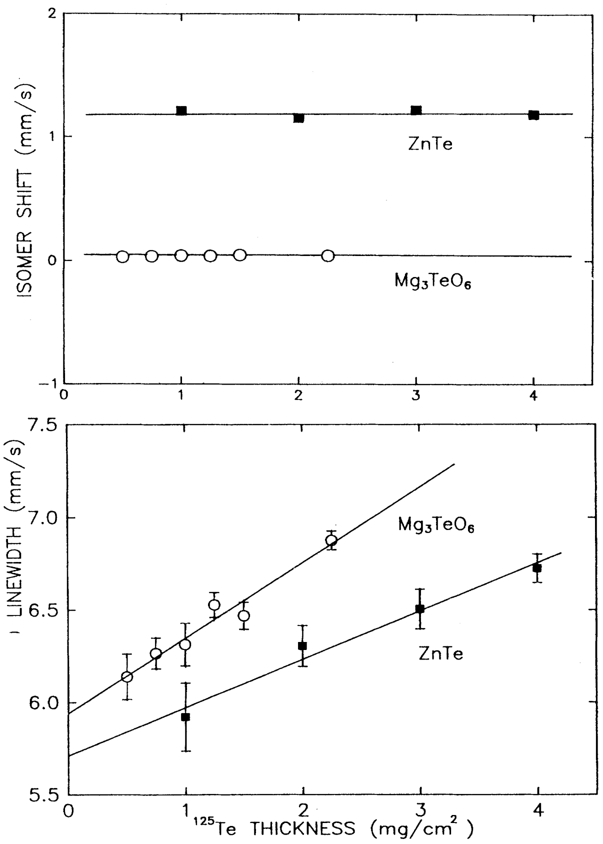

FIG. 4. (Top) Isomer shift (δ) and (bottom) observed linewidths (Γ_{obs}) results on cubic ZnTe and Mg_3TeO_6 absorbers. For these measurements both the $Mg_3{}^{125}Te^mO_6$ source and absorbers were at 78 K.

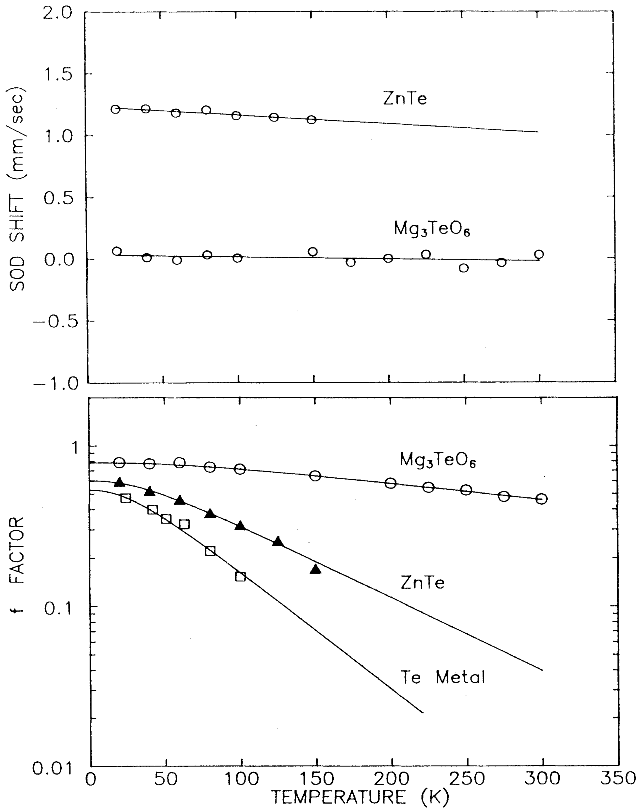

FIG. 5. T dependence of (top) isomer shift (δ) and (bottom) recoil-free fraction (f) of Mg_3TeO_6, cubic ZnTe, and Te-metal absorbers. The $f(T)$ dependence has been least-squares fit (smooth line) yielding Debye temperatures Θ_D of 390(2) K, 188(2) K, and 148(2) K, respectively, for Mg_3TeO_6, ZnTe, and Te metal.

I^{7+} (53 pm) and Te^{6+} (56 pm) are also nearly the same so that one would be hard pressed invoking a rattling of the I^{7+} daughter in the TeO_6 cage.

It is possible that the local vibrational density of states probed in the source experiments are intrinsically different from those in the absorber experiment. Here we must recognize that we are comparing the local vibrational density of states in Mg_3TeO_6 probed by a quiescent ^{125}Te atom (in the absorber experiment) to those probed by an ^{129}I atom formed from nuclear transmutation of $^{129}Te^m$ parent atom (in the source experiment). In the latter, conceivably, the vibrational temperature of the ^{129}I probe can be higher than its equilibrium value largely because of precursor events (related to the isomeric transition $^{129}Te^m \rightarrow {}^{129}Te$, and β decay $^{129}Te \rightarrow {}^{129}I$). Normally such precursor events in metals relax on a timescale of picoseconds and for this reason such states are not observed in Mössbauer spectroscopy. In insulators, on the other hand, the relaxation may be significantly slowed down because of a reduced conduction electron charge density, and the ^{129}I daughter may not completely attain its quiescent equilibrium vibrational state even in 20 ns before the 27.8-keV Mössbauer γ-ray transition occurs. We believe such a nuclear aftereffect is probably responsible for the reduced effective Debye temperature observed by Pasternak, Van der Heyden, and Langouche.[5] If indeed this is the case, it is likely that a measurement of the Te Debye temperature in a $Mg_3{}^{125}Te^mO_6$ source, would yield a Θ_D less than 390 K, the value that we have measured in a Mg_3TeO_6 absorber. This we are currently examining.

The unusually high Θ_D of Mg_3TeO_6 makes this matrix most attractive for ^{125}Te Mössbauer spectroscopy. $^{125}Te^m$ labeled Mg_3TeO_6 sources yield a high enough recoil-free fraction at room temperature (Fig. 3) that these sources can be used routinely at 300 K to record spectra of Te-bearing compounds at lower temperatures. With $Mg_3{}^{125}Te^mO_6$ sources, ^{125}Te Mössbauer-effect methodology can be practiced like ^{57}Fe and ^{119}Sn methodology, where measurements with the source at 300 K are routine. Experimentally, one cannot overemphasize the ease of performing T-dependent Mössbauer experiments with the source at room temperature. For, in such a case, only absorber cooling is required and a substantial range of temperature variation can be probed.

B. Linewidth in Mg_3TeO_6

The present ^{125}Te results clearly demonstrate that the Mg_3TeO_6 host does not display the natural width either in the source or in the absorber. Furthermore, both the emission linewidth of the $Mg_3{}^{125}Te^mO_6$ source and absorption linewidth in Mg_3TeO_6 reveal about a 14(3)% broadening over the natural width (Γ_n). This implies that the source linewidth taken with a cubic absorber would result in half of that broadening, i.e., 7(2)% over the minimum observable width of $2\Gamma_n$. This may be compared to the result of Pasternak, Van der Heyden, and Largouche,[5] who found their $Mg_3{}^{129}Te^mO_6$ sources to yield a 19% broadening over the minimum observable width ($2\Gamma_n$). In their experiment Pasternak used a Cu ^{129}I absorber to measure the source linewidth and corrected for the finite thickness of the absorber. Clearly in both the ^{125}Te and ^{129}I Mössbauer experiments some line broadening in the Mg_3TeO_6 host is observed.

The origin of this line broadening, we believe, is intrinsic to the structure of Mg_3TeO_6. The crystal structure of Mg_3TeO_6 provides for two inequivalent $[TeO_6]^{6-}$ units in the crystallographic unit cell, with one of these octahedra characterized by a Te-O bond length of 1.66 Å while the other octahedra characterized by a longer Te-O bond length of 1.84 Å. These crystal structure results suggest that the electric field gradient at the two octahedrally coordinated Te^{6+} species probably vanishes, but their isomer shifts may be intrinsically different because of differences in the Te^{6+}-O charge-transfer effects. The small line broadening in Mg_3TeO_6 could result from the chemical inequivalence of these two sites producing slightly different isomer shifts. Thus, the emission and absorption line shape in the Mg_3TeO_6 matrix is best deconvoluted in terms of two singlets with slightly different centroids. From the observed broadening, we can place an upper limit to the difference in isomer shift of the two Te^{6+} species in Mg_3TeO_6 of 0.15 mm/s. The larger broadening in the ^{129}I emission experiment[5] could then be understood in terms of the larger (factor of 4) nuclear moment[11] $\Delta\langle r^2\rangle$ for the 27.8-keV transition in relation to that of the 35.5-keV transition in ^{125}Te.

C. ^{125}Te isomer shift and recoil-free fraction in Mg_3TeO_6

During the course of this work, we have measured the T dependence of the isomer shift of Mg_3TeO_6 and of cubic ZnTe in the range $12 < T < 300$ K. The results appear in Fig. 4. Because of the high Θ_D, in Mg_3TeO_6, the second-order Doppler shift between 300 and 78 K is rather small 0.01(2) mm/s. With this calibration, it will be possible to quote isomer shifts of Te compounds relative to Mg_3TeO_6 at 300 K even when measured at lower temperatures. The Mg_3TeO_6 isomer shift for both the dry and wet chemically prepared samples are identical, and this shift is characteristic of a Te^{6+} species.

The principal drawback of the use of ZnTe as a standard for ^{125}Te isomer shifts or f factors is that polycrystalline samples can exist in both the cubic and hexagonal forms yielding different chemical shifts and linewidths.[8] Polycrystalline samples bought off the shelf are usually neither cubic nor hexagonal but a mixture of the two phases. This may be the reason for the slight difference in isomer shifts (Table II) given here to those reported by Sakai and Maeda,[12] who used ZnTe as a reference. The Cu ^{125}I source used by Sakai and Maeda in their work[12] yields a smaller f factor than the source used presently, as can be seen by their need to record spectra with the source and absorber cooled to 16 K. In the present work the isomer shifts in Table II are quoted relative to Mg_3TeO_6 at 300 K, and the shift of ZnTe pertains to the cubic ZnTe single-crystal chip.[8]

The use of the Mg_3TeO_6 host as a standard for the ^{125}Te isomer shift and f-factor measurements has several appealing features. First, the high Θ_D permits easy observation of the Mössbauer effect at room temperature. For example, a significant (6%) absorption signal is ob-

TABLE II. ^{125}Te Mössbauer-effect parameters deduced from the spectra of Fig. 3, δ-isomer shift, Δ-quadrupole splitting, Γ_{obs}-observed linewidth. The thickness of the absorbers appear in the Fig. 3 caption.

Absorber	T (K)	δ^a (mm/s)	Δ (mm/s)	Γ_{obs} (mm/s)
Mg_3TeO_6	300	0	0	6.33(13)
	78	0.01(2)	0	6.75(12)
ZnTe	78	+1.21(3)	0	6.43(13)
Te metal	78	+1.86(9)	7.83(9)	6.17(21)
	24	+1.87(6)	7.77(6)	6.09(14)
α-TeO_2	250	+2.02(7)	6.81(7)	5.86(15)
	78	+2.03(5)	6.99(5)	6.40(11)
	24	+2.07(4)	7.05(4)	6.44(10)

[a] Relative to Mg_3TeO_6 at 300 K.

served using a thin Mg_3TeO_6 absorber (28 mg/cm^2 of natural Te). There is no explicit need to use enriched ^{125}Te absorbers for this purpose. Second, the resonance line shape yields a narrow linewidth with a shift that is the smallest of any Te compound largely because in Te^{6+}, formally, the absence of 5s electrons leads to a reduced contact charge density on the nucleus. Thus, all ^{125}Te isomer shifts will be positive relative to Mg_3TeO_6. This situation is reminiscent of ^{119}Sn spectroscopy, where the perovskite $BaSnO_3$ is used as a standard. The perovskite also possesses a high Θ_D and displays the smallest shift because formally, Sn^{4+} lacks 5s charge density, and this reduces the contact charge density at ^{119}Sn. Thirdly, Mg_3TeO_6 can be prepared in a pure form rather easily either by a dry or wet chemical method and yields an isomer shift that is rather reproducible. Finally the measurement of the T dependence of the f factor in Mg_3TeO_6 (see Fig. 5 and Table III) now permits a measurement of the f factor of any Te compound at any temperature by a direct comparison of the integrated areas. For this purpose one merely needs to record the integrated area under the resonance of a Te absorber of interest and compare it to that of a Mg_3TeO_6 absorber of known thickness, run at the same temperature.

V. CONCLUSIONS

^{125}Te Mössbauer-spectroscopy experiments reveal Mg_3TeO_6 to possess high $\Theta_D = 390(2)$ K, yielding a room-temperature recoil-free fraction of 0.46(1). Mg_3TeO_6 displays a narrow absorption and emission profile, possessing a linewidth which is only 14(3)% broader than the natural width $\Gamma_n = 2.6$ mm/s. Fifty-eight-day $Mg^{125}Te^{m}O_6$ sources can be easily prepared by neutron irradiation of ^{124}Te enriched Mg_3TeO_6 samples with no interfering radioactivity produced by Mg and O. Such sources can be used repeatedly with no detrimental effect due to neutron irradiation provided the source matrix is suitably annealed. Such sources display high f factor and narrow linewidths and open the possibility of precision T-dependent measurements in Te-bearing compounds with the source kept at room temperature.

TABLE III. T-dependence of the recoil-free fraction $f(T)$ of the Mg_3TeO_6 absorber for the 35.5-keV γ ray based on $\Theta_D = 390$ K (see Fig. 4).

T (K)	f (T)
0	0.785
20	0.782
40	0.772
60	0.756
80	0.736
100	0.711
120	0.686
140	0.659
160	0.632
180	0.605
200	0.578
220	0.553
240	0.528
260	0.504
280	0.481
300	0.459

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