Linewidths of the 46.5- and 99.1-keV Levels of W^{183}

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Using Re^{183} sources in cubic matrices of tungsten metal and tantalum metal, lower limits to the half-lives of the $\frac{3}{2}^-$ 46.5-keV and $\frac{5}{2}^-$ 99.1-keV levels of W^{183} are found to be 188 ± 4 psec and 975 ± 40 psec, respectively.

INTRODUCTION

Several investigators[1-4] have observed the Mössbauer effect of the 46.5-keV ($\frac{3}{2}\overset{M1}{\rightarrow}\frac{1}{2}$) and the 99.1-keV ($\frac{5}{2}\overset{E2}{\rightarrow}\frac{1}{2}$) γ rays of W^{183}, using reactor-produced sources of Ta^{183} in a tantalum metal host. Utilizing tungsten metal foil absorbers, Agresti, Kankeleit, and Persson[2] observed a single emission line from these sources, and obtained, from the observed linewidths, lower limits to the half-lives of the two states. Recently Mekshes and Hershkowitz[4] have observed the Mössbauer effect of the 46.5-keV transition following Coulomb excitation on a tungsten metal target. The Mössbauer linewidths observed in Coulomb-excitation experiments are somewhat broader than those obtained in experiments with radioactive sources, and the results are summarized in Table I. In this paper we report on Mössbauer-effect experiments using sources of Re^{183} in cubic hosts of tantalum metal and tungsten metal.

EXPERIMENTAL METHODS

The Mössbauer-effect studies were carried out with both the source and the absorber at the liquid-helium temperature, in a conventional transmission geometry utilizing a cryostat described earlier.[5] Sources were produced by proton bombardment of tungsten metal foils to produce Re^{183} by (p, xn) reactions and by α-particle bombardment of tantalum metal foils to produce Re^{183} by $_{73}Ta^{181}(\alpha, 2n)$. In either case the metal foils were chemically etched to remove oxidized surface layers before they were annealed for 2 days at 800°C *in vacuo*. Such a heat treatment was conducive to the narrowing of the width of the Mössbauer line.

The constant-acceleration Mössbauer drive was calibrated with the magnetic hyperfine spectrum of Fe^{57} in Fe metal at 23°C. This was done using a source of Co^{57} in Cu and an enriched foil of metallic Fe^{57} as an absorber. From the magnetic hyperfine spectrum the nonlinearity of the drive was found to be less than $\frac{1}{2}\%$ for the velocity range used for the 99.1-keV γ-ray resonance. Calibration of the drive at the high-velocity ranges was performed with an α-hematite absorber following a standard extrapolation procedure. The 99.1-keV γ ray was detected by a 1.2-cm^3 Ge(Li) detector possessing a 6-keV resolution at 100 keV. The 46.5-keV γ ray was detected by a high-resolution 0.6-cm^3 Ge(Li) detector having a 350-eV resolution at 50 keV. The absorbers used in each experiment were foils of natural tungsten metal. The results are shown in Figs. 1 and 2. The data were fitted by the method of least squares to a single Lorentzian line shape to extract the full width at half maximum (FWHM), and corrections[6] were made for the finite absorber thickness. Recently Raj and Puri[7] calculated the recoilless fraction for the 46.5-keV transition in W^{183} and the 100.1-keV transition in W^{182} in a body-centered cubic tungsten metal lattice. These calculations were based on the phonon spectrum of the tungsten metal lattice obtained from neutron diffraction results. Following their calculations, we have assumed the recoilless fraction for the 46.5- and the 99.1-keV transitions in tungsten metal at 4.2°K to be 0.726 and 0.20, respectively. For the 46.5-keV transition, we take the value of the maximum resonant cross section[8] to be $\sigma_0 = 2.265 \times 10^{-19}$ cm^2 assuming the internal-conversion coefficient $\alpha_T = 9.0$, and for the 99.1-keV transition, we take the value[8] of $\sigma_0 = 7.899 \times 10^{-20}$ cm^2 assuming $\alpha_T = 4.3$ and a branching fraction of 48.6%. We estimate the effective absorber thickness T of the tungsten foil absorbers used in our experiments to be 0.726 for the 99.1-keV transition and 3.6 for the 46.5-keV transition.

TABLE I. The half-life values of the 46.5- and the 99.1-keV states obtained from the Mössbauer and other experiments.

Energy	FWHM observed (mm/sec)	FWHM zero thickness (mm/sec)	Half-life $t_{1/2}$ (psec)	Reference
46.5 keV	(49.80 ± 1.6)	35.2 ± 1.2	174 ± 6	4 [a]
	...	32.0 ± 0.8	184 ± 5	2 [b]
		...	158 ± 3	3 [b]
	(46.5 ± 1.0)	31.2 ± 0.6	188 ± 4	Present work
99.1 keV	...	...	707 ± 35	9
	...	3.9 ± 0.4	720 ± 70	2 [b]
	...	3.57 ± 0.16	770 ± 40	10 [a]
	(3.1 ± 0.09)	2.82 ± 0.09	975 ± 40	Present work

[a] Coulomb excitation.

[b] Ta^{183} sources in Ta metal.

EXPERIMENTAL RESULTS

99.1 keV. The Mössbauer effect of the 99.1-keV γ ray was observed with a Re^{183} source in a tantalum metal matrix. With a natural tungsten foil absorber of 80-μ thickness, the observed spectrum was least-squares-fitted to a single Lorentzian line shape to yield a FWHM of 3.10 ± 0.09 mm/sec. After correcting for the thickness of the absorber, we found a FWHM of 2.82 ± 0.09 mm/sec. This linewidth corresponds to a half-life of

$$t_{1/2}(\tfrac{5}{2}^-) = 975 \pm 40 \text{ psec}.$$

46.5 keV. Re^{183} in a tungsten metal matrix was used as the radioactive source with a tungsten metal foil of 40-μ thickness as absorber to observe the Mössbauer effect with the 46.5-keV γ ray. The FWHM of the observed spectrum was found to be 46.5 ± 1.0 mm/sec. Corrected to zero absorber thickness, this reduces to 31.2 ± 0.6 mm/sec. The corresponding half-life of the $\frac{3}{2}^-$ level works out to be

$$t_{1/2}(\tfrac{3}{2}^-) = 188 \pm 4 \text{ psec}.$$

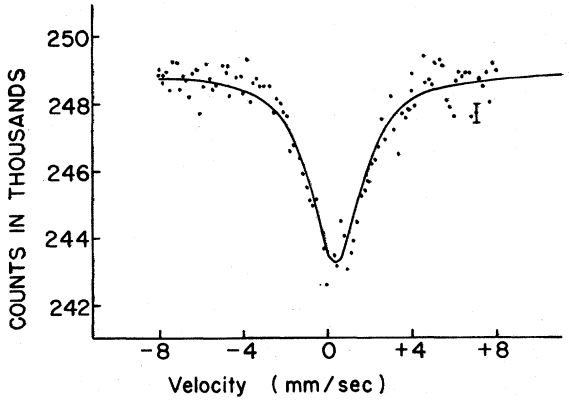

FIG. 1. Mössbauer spectrum of the 99.1-keV γ ray obtained with a source of Re^{183} in Ta metal and a W metal foil absorber of 80-μ thickness.

DISCUSSION

The present measurements lead to a new lower limit for the half-life of the $\frac{5}{2}^-$ level of W^{183}, 975 ± 40 psec. The error of 4% in the measured half-life derives mainly from the statistical error in the experimental data, which is almost an order of magnitude larger than the velocity resolution of the Mössbauer spectrometer.

The present measurement of the half-life of the $\frac{5}{2}^-$ level of W^{183} may be compared with the previous two Mössbauer measurements, first by Agresti, Kankeleit, and Persson, employing reactor-produced sources of Ta^{183}, and second by Hardy *et al.*[9] using Coulomb excitation on tungsten metal. In both these earlier measurements, radiation damage of the source lattice could have been partly responsible for the broader emission line

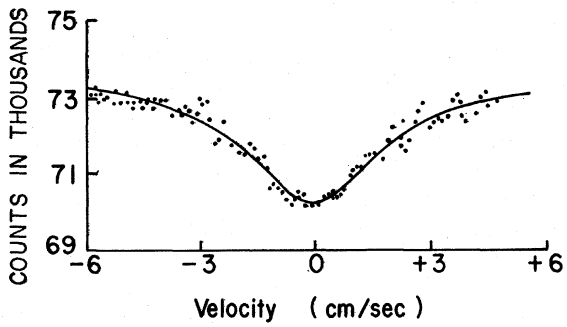

FIG. 2. Mössbauer spectrum of the 46.5-keV γ ray obtained with a source of Re^{183} in W metal and a W metal foil absorber of 40-μ thickness.

observed for the 99.1-keV γ resonance, which resulted in a lower half-life measurement for the $\frac{5}{2}^-$ level. The Mössbauer linewidths observed by Agresti, Kankeleit, and Persson for Ta^{182} sources in Ta metal exhibited source broadening. It is therefore expected that their measurement with Ta^{183} sources in the same tantalum metal host as Ta^{182} sources would also exhibit broader emission linewidths for the 46.5- and 99.1-keV γ resonances. It is gratifying that the linewidths observed by us utilizing annealed sources of Re^{183} in cubic tantalum metal have yielded a narrower linewidth for the 99.1-keV γ resonance.

Recently we performed Mössbauer experiments with reactor-produced Ta^{182} sources in tantalum metal with a view to investigating the radiation damage caused by thermal-neutron capture in tantalum metal. Our observations of the 100.1-keV γ resonance in W^{182} have revealed a 15% reduction in the source linewidth on suitably annealing the tantalum foil. This would suggest that by carefully annealing the cyclotron-produced sources of Re^{183} in tantalum metal we repaired the structural damage to the tantalum lattice incurred during the α-particle bombardment.

In Coulomb-excitation experiments one would expect structural damage to be caused in the target by the incident projectile locally striking and dissipating energy. In these experiments, it may be mentioned that an additional factor causing line broadening of the nuclear γ resonance arises owing to self-absorption in the source itself. This is one of the disadvantages built in the technique itself. It is therefore not surprising that the present measurements lead to a 20% narrower emission linewidth of the 99.1-keV γ resonance than the linewidth reported by Hardy *et al.*

Finally our half-life measurement of the $\frac{5}{2}^-$ level of W^{183} disagrees with the measurements of Ashery quoted by Gilad *et al.*[10] (Table I). It is difficult to make a meaningful comparison of these observations in view of the fact that details of the latter measurement are not available in Ref. 10.

Our measurement of the half-life of the 46.5-keV level of W^{183} agrees well with the one measured by Agresti, Kankeleit, and Persson and overlaps within the quoted experimental errors the measurements of Mekshes and Hershkowitz (Table I). In the present measurement of the half-life of the 46.5-keV level, the source used was Re^{183} in a tungsten metal lattice. Although the source was annealed, it should be mentioned that we would expect broadening of the emission linewidth on account of self-absorption in the source. Broadening of the Mössbauer line on account of self-absorption may be particularly pronounced for the present experimental conditions in view of the fact that the recoilless fraction of the 46.5-keV γ ray for tungsten metal host at the temperature of liquid helium is estimated to be 72.6%. It is therefore not surprising that although the present measurement of the half-life of the 46.5-keV state agrees well with the one of Ref. 2, there is a sizable difference in the measurements of the half-life of the 99.1-keV state. We are in the process of repeating the half-life measurement of the 46.5-keV state using a Re^{183} source in tantalum metal to avoid Mössbauer line broadening on account of self-absorption in the source.

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