Magnetic moment of the first excited state of ^{121}Sb and the hyperfine field in Pd_2MnSb

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The Mössbauer effect of ^{121}Sb in Pd_2MnSb is used to derive a more accurate value for the magnetic moment of the first excited state (37.15 keV): $\mu_e = (2.518 \pm 0.007)\mu_N$. The hyperfine field is found to be 651 ± 5 kOe at 80 K and 706 ± 5 kOe at 18 K.

[RADIOACTIVITY $^{121}Sn^m$ in $BaSnO_3$; measured Mössbauer effect in ^{121}Sb level, $E = 37.15$ keV in Pd_2 MnSb; deduced hyperfine field, ^{121}Sb level deduced μ.]

Two previous determinations of the magnetic moment of the first excited state (37.15 keV) in ^{121}Sb show a slight inconsistency. The first value, $\mu_e = (2.51 \pm 0.03)\mu_N$, was derived[1,2] from the Mössbauer spectrum of ^{121}Sb in MnSb. For this determination, the values for the internal field and for the small quadrupole interaction in MnSb were taken from a nuclear magnetic resonance experiment. Later, however, a smaller value, $\mu_e = (2.45 \pm 0.02)\mu_N$, was derived from the Mössbauer spectrum of ^{121}Sb in NiMnSb,[3] and this value has generally been used since.[4]

The hyperfine field at ^{121}Sb in Pd_2MnSb, which was recently determined to be $|H| = 579 \pm 5$ kOe at 100 K,[5] is roughly twice as large as the field available in both previous measurements, and thus it offers an excellent opportunity to obtain a more accurate value for this moment. In this paper we describe this measurement. We also extend the measurement of the hyperfine field to lower temperatures and determine the sign of this field.

The sample of Pd_2MnSb was prepared from 99.9% pure Pd and Mn and 99.999% pure Sb by induction melting in argon atmosphere. The sample was then powdered, sealed in quartz under vacuum, annealed for 48 hours at 1070 K, and slowly cooled. X-ray spectra showed that the sample was single phase. Mössbauer spectra were recorded using a $^{121}Sn^m$ in $BaSnO_3$ source and a 20 mg/cm^2 Pd_2MnSb absorber. Figure 1 shows spectra at 80 and 18 K. The spectra were fitted using a sum of Lorentzian curves. The absorber in this experiment was chosen to have an effective thickness $t \leq 1$, in which case an analysis appropriate to a thin absorber can be used.[6] The validity of this approximation[7] is also supported by the fact that we obtained the same magnetic moment ratio from spectra taken at three different temperatures, i.e., at three different absorber thicknesses. From the analysis a line width of 3.4 ± 0.2 mm/sec was obtained and a magnetic moment ratio of $\mu_e / \mu_g = 0.7486 \pm 0.0020$. Using the known[8] ground state magnetic moment, $\mu_g = (3.3635 \pm 0.0003)\mu_N$, we derive $\mu_e = (2.518 \pm 0.007)\mu_N$ for the excited state magnetic moment. This confirms the first measurement[2] of this moment, but is in disagreement with the more recent determination.[3]

This value of the moment was then used to derive hyperfine fields of $H = 651 \pm 5$ kOe at 80 K

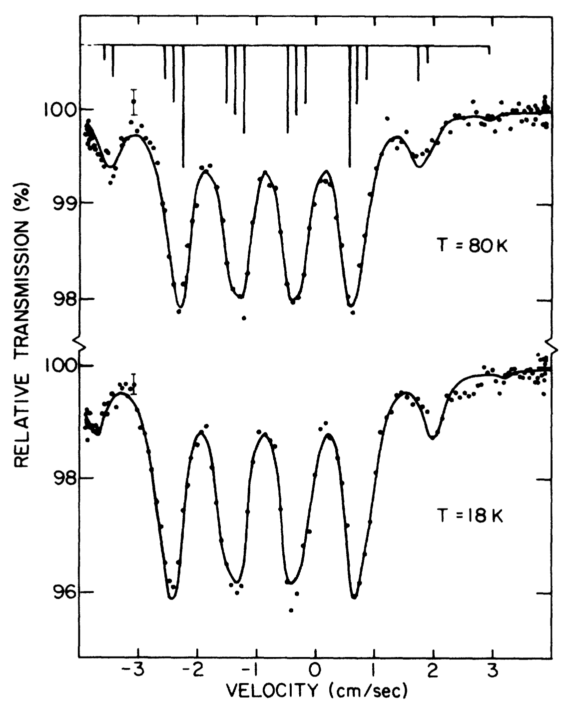

FIG. 1. Mössbauer spectra of ^{121}Sb in Pd_2MnSb at 80 and 18 K. The source was $^{121}Sn^m$ in $BaSnO_3$ at the same temperatures.

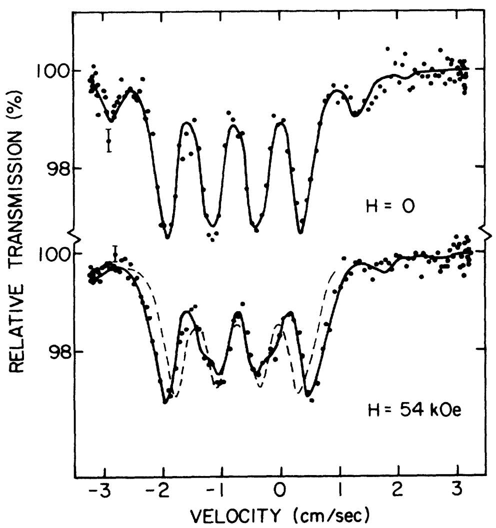

FIG. 2. Mössbauer spectra of ^{121}Sb in Pd_2MnSb without external field and with a 54 kOe longitudinal magnetic field applied to the absorber and a 50 kOe field at the source. The solid line is the best fit for a positive hyperfine field, while the dashed line shows the calculated spectrum for a negative field.

and $H = 706 \pm 5$ kOe at 18 K. The positive sign was obtained separately by applying to the absorber an external longitudinal magnetic field of 54 kOe from a superconducting magnet, as in our earlier measurement on Te.[9] The source was located at a point where the magnetic field was slightly smaller (50 kOe) and the γ radiation was detected along the magnetic field direction. Figure 2 shows spectra obtained with and without the external field. The solid and dashed curves show the calculated spectra for a positive and a negative field, respectively. Because of the polarizations of the individual transitions in the source and absorber, the resulting spectral shapes are quite different depending upon the sign of the field in the absorber. This is typical for a split-source-split-absorber combination in this experimental arrangement, as pointed out earlier.[9] The difference is especially obvious for the two central lines, which tend to become very asymmetric for a positive hyperfine field.

The apparent discrepancy between the hyperfine fields derived from our experiment and the earlier determination[5] at 100 K is resolved by the following considerations: (a) Use of the correct ratio of moments, as derived in this experiment, results in approximately a 5% increase in the field; and (b) as can be seen from the magnetization curve of Pd_2MnSb,[10] a temperature decrease from 100 to 80 K increases the magnetization by a few percent. Thus, there is no substantial disagreement between the measurements.

The measured positive sign and magnitudes of the fields for Sb and Te can be compared with the calculated curve given in Ref. 9, which is based on the theory of Jena and Geldart[11] who use a scaling factor normalized to Cu_2MnSn. The agreement is excellent if a somewhat larger scaling factor is used for the Pd_2MnSb host. It would be worthwhile to measure also the hyperfine fields at I and Xe impurities in Pd_2MnSb to determine whether these continue to follow the prediction and decrease in going from I to Xe. This behavior, if confirmed, would be quite different from that observed[12] for hyperfine fields at these impurities in Fe metal, where a maximum is reached at Xe.

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