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HYPERFINE INTERACTION OF ^{181}Ta IN NICKEL[†]

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Nuclear gamma resonance spectroscopy was used to study the hyperfine interaction of ^{181}Ta impurities in nickel at room temperature and above the Curie point. Both the hyperfine field for ^{181}Ta in nickel at room temperature and the isomer shift relative to Ta metal have been derived.

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The 6.2 keV gamma resonance of ^{181}Ta has recently been used successfully for studying electric quadrupole hyperfine interactions [1] and isomer shifts [2]. Up to now, however, the magnetic splitting of the 6.2 keV gamma rays has only been observed in externally applied magnetic fields [3]. The present paper reports on the first application of this gamma resonance to the study of magnetic hyperfine interactions by measuring the magnetic splitting of the 6.2 keV gamma rays of ^{181}Ta impurities in nickel metal at room temperature.

Using a single-line Ta metal absorber (4 mg/cm^2 thick) and a ^{181}W(Ni) source, Mössbauer spectra were measured with the source heated above the Curie point of nickel, and at room temperature. The source was prepared by diffusing the ^{181}W activity for a period of 20 hours at 10^{-8} Torr and a temperature of

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1350°C into a single-crystal disc of nickel metal, cut perpendicular to the [111]-direction. For the room temperature measurement, the sinusoidally moved source was magnetized in longitudinal direction by an external polarizing field of 1.7 kOe produced by a small permanent magnet. The stray field at the absorber, which was kept at room-temperature for both measurements, was negligible small (< 1 Oe).

The results of the measurements are presented in fig. 1. With the source heated above the Curie point, a single-line spectrum is observed (fig. 1a), while at room temperature the emission line is widely split by magnetic hyperfine interaction (fig. 1b). In longitudinal direction, the total spectrum resulting from the 9/2 → 7/2 E1 transition, would consist of 16 components with $\Delta m = \pm 1$. Due to the small size of the resonance effect in the split spectrum, however, the velocity range had to be chosen so small that only the three outermost absorption lines were observed.

The results of the least-squares fit analysis of both spectra are given in table 1. A dispersion modified Lorentzian line with fixed amplitude of the dispersion term (with $2\xi = -0.30$) [3] was fitted to spectrum (a). The split spectrum was analyzed with a superposition of dispersion modified Lorentzians using $g(7/2)\cdot\mu_N\cdot H_{eff}$ as the only parameter to determine the line positions. To this end, the g-factor ratio $g(9/2)/g(7/2) = 1.78\pm0.02$ [3] and the isomer shift at room temperature, IS = -39.8±0.2 mm/s, were kept constant during the fit. The latter value was linearly extrapolated from a measurement of the temperature dependence of the isomer shift for ^{181}Ta(Ni) in the temperature range from 412°C to 730°C [4].

The measured isomer shift for ^{181}Ta(Ni) is the largest one observed up to now for ^{181}Ta impurities in metallic lattices [2], and it fits well into the

systematics found for isomer shifts of impurities of ^{181}Ta, ^{57}Fe, ^{99}Ru, ^{197}Au, and ^{193}Ir in transition metal hosts [5,6]. From the size of the magnetic splitting in the groundstate, given in table 1, and taking into account the external polarizing field, a value of H = (-)89.6±1 kOe can be derived for the induced hyperfine field at room temperature. Previously a value of H = -98±2 kOe has been measured by spin-echo NMR at 4.2 K [7]. We may therefore derive for the reduced hyperfine field at room temperature a value of H(298)/H(4.2) = 0.91±0.02, which is in good agreement with the results of a recent TDPAC study of the temperature dependence of H for $^{181}Ta(\underline{Ni})$ [8].

The experimental linewidth of the magnetically split spectrum is by a factor of 6 larger than the one found for the single line spectrum. Accordingly, the total summed effect observed in the split spectrum is reduced with approximately the same ratio. An inhomogeneous distribution of hyperfine fields, caused for example by non-zero and varying impurity concentrations, could be the main reason for this appreciable line broadening in the ferromagnetic case, especially since a strong dependence of the hyperfine field on the impurity concentration is expected for the nickel host [9]. The use of sources produced by ion implantation technique could solve this problem. Then, the high resolving power inherent in this gamma resonance would provide unique opportunities for studying the temperature dependence of the hyperfine field in the immediate neighbourhood of the Curie point with supreme resolution.

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Table 1. Summary of experimental results.

	T (°C)	W/2 (mm/s)	IS (mm/s)	$g(7/2)\mu_N H_{eff}$ (mm/s)	total effect (%)
single-line	412(5)	0.20(1)	-36.96(5)	---	1.6(3)
magn. split	25(1)	1.2(3)	---	8.93(5)	0.25(5)

Figure Caption

Fig. 1. Absorption spectra obtained with a Ta metal absorber at room temperature and a $^{181}W(\underline{Ni})$ source at 412°C (a) and at 25°C (b), respectively. On top of fig. 1b the individual transitions are assigned to the observed hyperfine components.

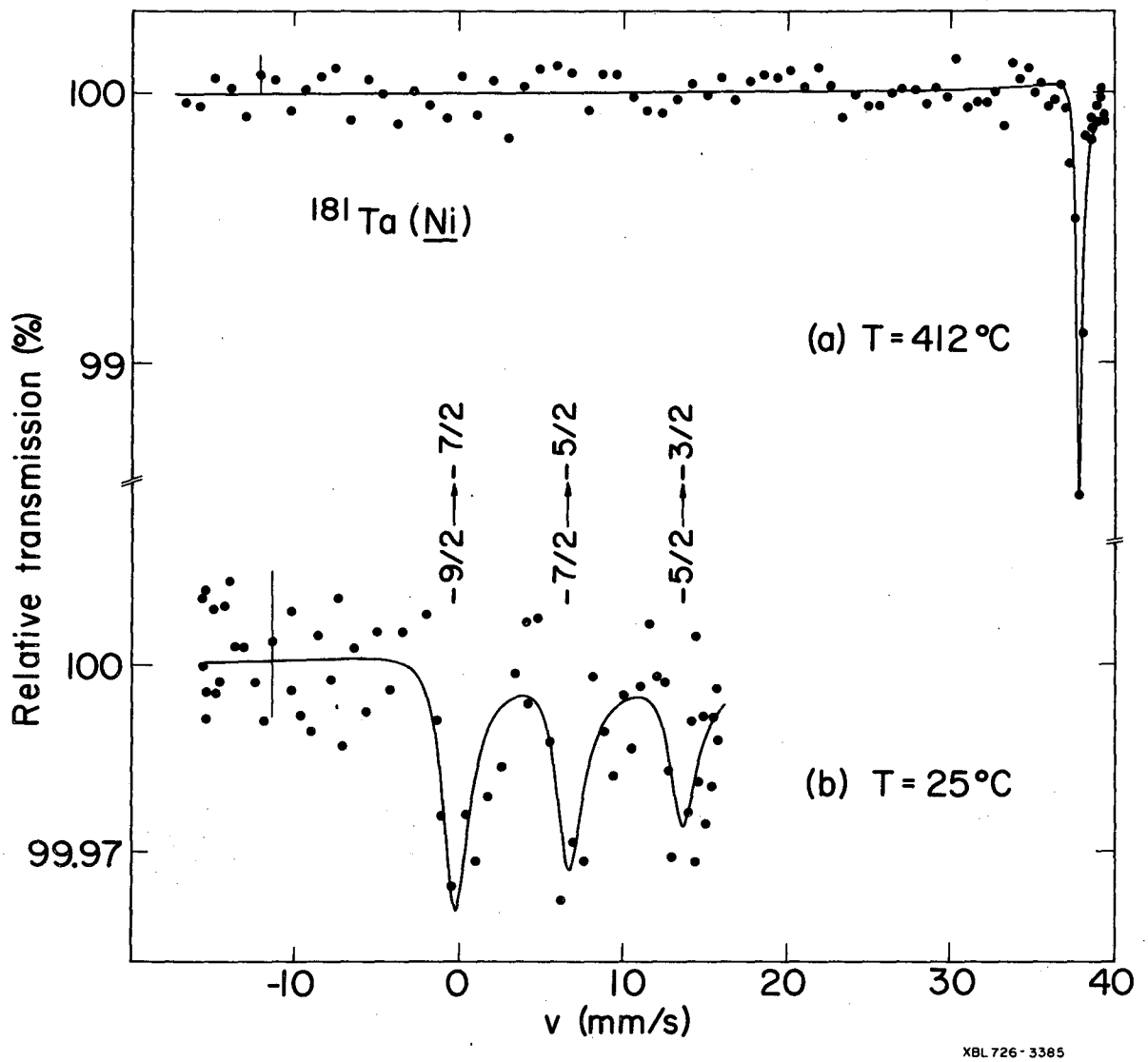
100
99
100
99.97
Relative transmission (%)
^{181}Ta (Ni)
(a) T = 412 °C
(b) T = 25 °C
-9/2 → 7/2
-7/2 → 5/2
-5/2 → 3/2
-10
0
10
20
30
40
v (mm/s)
XBL 726-3385

Fig. 1

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