The Nuclear Moments of the 67.4 keV Level in ^{61}Ni

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The hyperfine structure of ^{61}Ni in $NiCr_2O_4$ has been measured with the Mössbauer technique. The magnetic dipole moment and the electric quadrupole moment of the 67.4 keV level in ^{61}Ni have been determined as

$$\mu = (+0.479 \pm 0.006)\ \mu_N \quad \text{and} \quad Q = (-0.20 \pm 0.03)\ b\,.$$

This paper presents a contribution to the Mössbauer studies in Ni-compounds performed in this laboratory [1, 2]. The compound $NiCr_2O_4$ * is of particular use for a more precise determination of the nuclear moments of the 67.4 keV level in ^{61}Ni. The magnetic hyperfine field at 4.2 °K at the Ni site is known [3] to be about 450 kOe, the largest one in a Ni system observed sofar. Furthermore the rather large electric field gradient allows a more precise determination of the quadrupole moment. The magnetic field and the field gradient are of particular interest in solid state physics.

The $NiCr_2O_4$ is a normal spinel with a tetragonal distortion below about 310 °K. The tetrahedron around the Ni is elongated parallel to the c axis. The Curie temperature is about 65 °K [4].

The single line source of ^{61}Co in $Ni_{0.85}Cr_{0.15}$ was produced at the Darmstadt Electron Linear Accelerator by means of the reaction $^{62}Ni(\gamma,p)^{61}Co$. The experimental details have been described by ERICH [1]. The thickness of the absorber was 1566 mg/cm².

The Mössbauer spectrum at 4.2 °K (Fig. 1) shows a large magnetic splitting with a small contribution of an electric quadrupole interaction. The solid line gives the result of a least-squares fit procedure.

The shape of the spectrum is very sensitive to the ratios of the magnetic dipole and electric quadrupole moments of the excited state and the ground state of the nucleus. We found $g(67.4)/g(0) = -0.384 \pm 0.005$ and $Q(67.4)/Q(0) = -1.18 \pm 0.17$.

The magnetic splitting of the ground state was determined as $g(0)\ \mu_N H_{hf} = (3.10 \pm 0.02)$ mm/sec. Using the well known magnetic moment of the ground state [5] $\mu(0)/\mu_N = -0.74868 \pm 0.00004$ we got for the magnetic hyperfine field $|H_{hf}| = (442 \pm 3)$ kOe and for the magnetic moment of the excited state $\mu(67.4)/\mu_N = +0.479 \pm 0.006$. Assuming an axial symmetric electric field gradient with an angle Θ with respect to the direction of the magnetic field the value

$$e\,Q(0)\,V_{zz}(3\cos^2\Theta - 1)/8 = (-0.13 \pm 0.01)\ \text{mm/sec}$$

is derived.

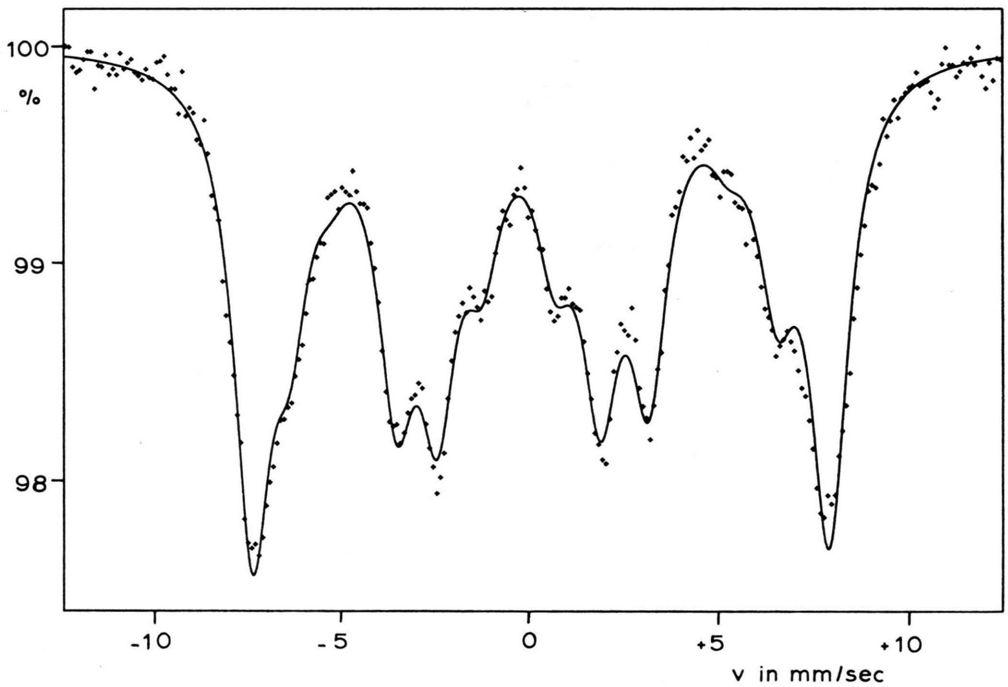

Fig. 1. Mössbauer spectrum of the 67.4 keV transition in ^{61}Ni at 4.2 °K. Source: ^{61}Co in $Ni_{0.85}Cr_{0.15}$. Absorber: $NiCr_2O_4$.

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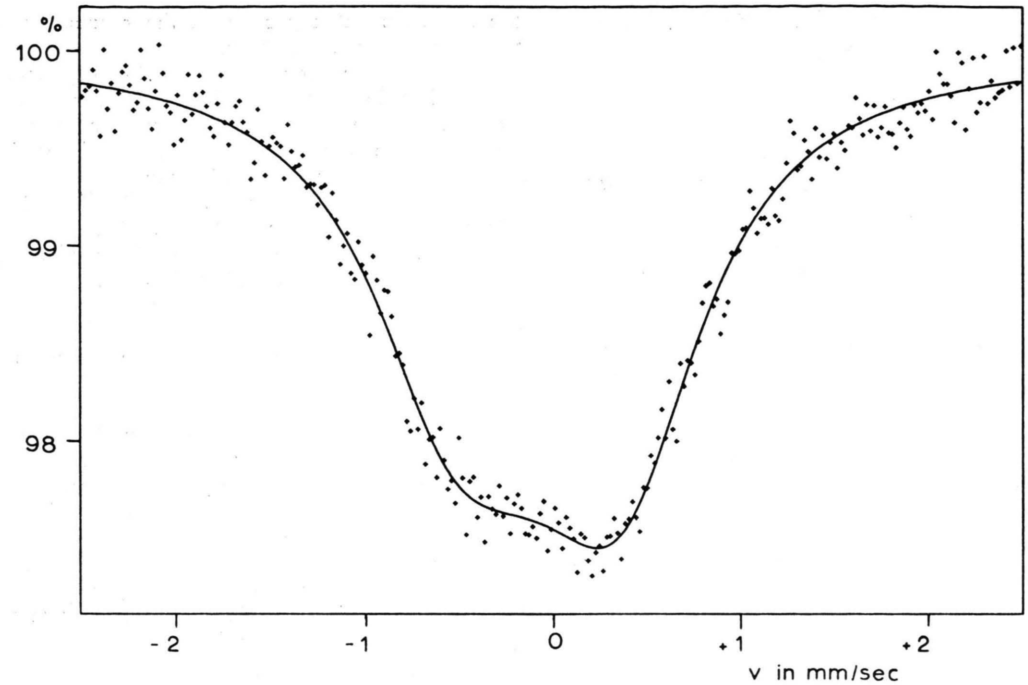

Fig. 2. Mössbauer spectrum of the 67.4 keV transition in ^{61}Ni at 77 °K. Source: ^{61}Co in $Ni_{0.85}Cr_{0.15}$. Absorber: $NiCr_2O_4$.

At 77 °K a rather large pure electric quadrupole interaction has been observed (Fig. 2). From this we obtained the ratio $Q(67.4)/Q(0) = -1.26 \pm 0.20$ and $e\,Q(0)\,V_{zz}/4 = (+0.23 \pm 0.02)$ mm/sec. Using the known moment of the ground state [6]

$$Q(0) = (+0.162 \pm 0.015)\ b$$

the value of $V_{zz} = (+1.28 \pm 0.22) \times 10^{18}$ V/cm^2 can be deduced.

Taking the average of both measurements we found the ratio $Q(67.4)/Q(0) = -1.21 \pm 0.13$, which leads to $Q(67.4) = (-0.20 \pm 0.03)\ b$.

The value of the magnetic moment $\mu(67.4)$ is in excellent agreement with those reported by ERICH [1] and LOVE et al. [7]. Previously an attempt was made to evaluate the quadrupole moment of the excited state by measuring the hyperfine structure of some Ni boracites [8], and a value of $Q(67.4) = (-0.40 \pm 0.24)\ b$ had been found. The estimated value $Q(67.4) = (+0.05 \pm 0.15)\ b$ reported in a recent paper of LOVE et al. [7] is not in agreement with our result.

The calculated magnetic moments [9, 10] are in fairly good agreement with the experimental values. Too small quadrupole moments have been obtained for the ground state [10, 11], whereas no value for the excited state have been calculated. These experimental nuclear parameters should be support a better understanding of the low-lying states of ^{61}Ni [9–12]. Furthermore good values of the ratios of the moments are of particular interest for the analysis of the usually unresolved Mössbauer spectra of ^{61}Ni in solid state physics.

The source of the large magnetic hyperfine field at 4.2 °K is not known yet, but should be explained probably in terms of the incompletely quenched orbital momentum caused by the Jahn-Teller distortion [13]. Also the rather large electric field gradient should be due to this effect. Therefore it should be axial symmetric and parallel to the c axis.

For the Curie temperature LOTGERING [14] reported a value of (80 ± 10) °K, while PRINCE [4] found about 65 °K. The measurement with liquid nitrogen shows that the Curie temperature is below 77 °K.

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