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THE QUADRUPOLE INTERACTION IN ZINC METAL

W. Potzel, A. Forster and G. M. Kalvius

Physik Department, Technische Universität München, D-8046 Garching, Germany

Résumé. — Des spectres Mössbauer du zinc métal ont été obtenus avec la transition 1/2-5/2 (93 keV) de 67Zn. On trouve que le gradient de champ électrique est de symétrie axiale avec une valeur de eq = +(3.02 ± 0.05) \times 10^{17} \text{ V/cm}^2.

Abstract. — Mössbauer experiments have been performed with the 93.3 keV 1/2-5/2 transition in 67Zn metal. The electric field gradient was found to be axially symmetric with a value of eq = +(3.02 ± 0.05) \times 10^{17} \text{ V/cm}^2.

The 93.3 keV resonance in 67Zn possesses an extreme sensitivity for the measurement of hyperfine interactions. The nuclear Zeeman splitting can be observed in magnetic fields of -100 Oe/1. The center shifts of the resonance patterns of various zinc chalcogenides /2,3/ which all contain the zinc atom in the +2 oxidation state are very large compared to the line width. The quadrupole interaction of the spin 5/2 groundstate of 67Zn (the excited state has I = 3/2 and thus shows no quadrupole splitting) has been thoroughly studied in ZnO /4/. Only incomplete data were available for zinc metal /5/. In this note we report on measurements to determine the electric field gradient in zinc metal.

For a source we used 67Ga in Cu. The 67Ga (T1/2 = 78h.) activity was obtained in situ by irradiation of a copper foil with 35 MeV α-particles. The foils were not annealed after irradiation. A single resonance line is emitted.

The absorber consisted of Zn metal powder, enriched to 89.7% in 67Zn, which was annealed at 650 K in argon atmosphere for 12 h. and thereafter slowly (30 K/h.) cooled to room temperature. The absorber thickness was 1.4g 67Zn/cm^2.

To generate Doppler velocities in the range from ~1μm/s to a few 100μm/s a piezoelectric quartz spectrometer /6/ was used, which produced a sinusoidal motion with a frequency of ~500 Hertz. Data were collected in a modified time mode with a PDP8 computer via a fast interface /7,8/, especially designed for high channel advance rates. The γ-rays were detected by a NaI-scintillation counter of 2mm thickness. The spectrometer was calibrated using the known /4/ quadrupole splitting in ZnO.

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**Figure 1** displays a Mössbauer absorption spectrum scanned to a maximum velocity of ±65μm/s. The computer fit gives the following results (only the statistical errors are given):
- center shift S = (15.1 ± 0.2)μm/s
- quadrupole interaction e²qQ = +(165 ± 3)kHz = (12.4 ± 0.2) MHz
- average full width at half maximum W = (2.3 ± 0.2)μm/s
- average absorption area A = (7.6 ± 0.9)\times 10^{-6} W.

Fig. 1 : Mössbauer spectrum at 4.2 K of a 67GaCu source and a polycrystalline 67Zn metal absorber.

Within the accuracy of our experiment the separation between the three resonance lines is 2:1, indicating that the asymmetry parameter η = 0. Using the known /9/ quadrupole moment of Q67(5/2) = 0.17b we find for the electric field gradient in Zn metal, eq = +(3.02 ± 0.05) \times 10^{17} \text{ V/cm}^2. This value is in fair agreement with a recent theoretical calculation /10/, which gave eq = +(4.5 ± 0.60) \times 10^{17} \text{ V/cm}^2.

Using the results of previous /11, 12/ measurements of quadrupole interactions by perturbed angular correlations and nuclear orientation one may derive the following quadrupole moments :
- for the spin-9/2 state in 67Zn : Q67(9/2) = +(0.68 ± 0.03)b
for the spin-9/2 state in $^{69}$Zn : $Q^6(9/2) = -(0.38 \pm 0.05)b$

Thermodynamic and inelastic neutron scattering data give evidence for a strong anisotropy of the mean square displacement $\langle x^2 \rangle$ of the Zn atoms in hexagonal metal. This should lead to differences in the intensities of the hyperfine lines due to the Goldanskii-Karyagin effect. Although the data of figure 1 give some indication of such a behaviour a definite conclusion cannot be drawn within the present limits of error.

We have performed additional experiments using a $^{67}$GaCu source and an enriched $^{67}$ZnO absorber. The transmission spectrum shows a threeline pattern due to the quadrupole interaction in ZnO. Using the known Debye-temperature for ZnO ($\Theta_D = 309$ K) we deduce an effective Debye-temperature for zinc metal of $\Theta_D \approx 240$ K. This value is considerably lower than the results derived from both, calorimetric ($\Theta_D = 322$ K) and elastic data ($\Theta_D = 328$ K). This discrepancy could be due to lattice defects in our absorber of Zn metal powder. Zn atoms on (or close to) strongly distorted lattice sites will most likely produce a much larger and smeared out quadrupole pattern, which either escapes detection within the velocity range of the present experiment or just contributes to the background intensity. For $^{67}$ZnCu we find an effective recoilfree fraction of $0.15$, which corresponds to a lower limit for the Debye-temperature of $\Theta_D \geq 260$ K. This again is a much lower value than the Debye-temperature of the pure copper matrix ($\Theta_D = 343$ K).

References