

Evidence of M1 and E2 Strength in the Giant Resonance Region of Ce

R. PITTHAN and TH. WALCHER

Institut für Technische Kernphysik
der Technischen Hochschule Darmstadt, Germany (BRD)

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Inelastic electron scattering from Ce (50 and 65 MeV, 93°, 129° and 165°) had shown evidence for an M1 and an E2 resonance at 8.7 and 12.0 MeV, respectively. These assignments have been confirmed by DWBA calculations. Reduced transition probabilities are derived for the resonances mentioned, and for the giant E1 resonance.

In an earlier paper¹ we reported on the excitation of three resonances in the giant resonance region of Ce, Pr and La by inelastic electron scattering. To check the tentative multipole assignment given in that paper and to determine reduced matrix elements we have further analysed the spectra of Ce. The spectra were fitted² by Breit-Wigner shape curves for the resonances and by the radiative tail³ of the elastic peak calculated in Born approximation plus a polynomial in the energy of the final electron for the background. The best fit yielded resonances at 8.7, 12.0 and 15.1 MeV which correspond to the ones reported in Ref. 1, and one at 10 MeV, which was much weaker. To fix the background the total width of the resonance at 15.1 MeV, which is the well known giant E1 resonance, was taken as 4.35 MeV from (γ , abs.)-measurements⁴. The parameters varied were the total widths of the resonances at 8.7 and 12.0 MeV, the excitation energies, strengths, and the coefficients of the background polynomial. From the areas of the best fit curves of the resonances and the area of the elastic peak the ratio of the inelastic and elastic cross sections was obtained. The elastic scattering cross section was computed with a phase shift code⁵ using a Fermi type charge distribution with $c = 5.78$ fm and $t = 2.31$ fm⁶.

The cross section of the resonance at 15.1 MeV was compared with DWBA calculations using the hydrodynamical model⁷. A reduced transition probability of 40 ± 8 fm² was obtained from the 93° data; this agrees well with 40 fm² deduced from the (γ , abs.) measurements⁴. However, the measured cross sections are larger than those calculated with 40 fm² at backward angles indicating a transverse contribution which cannot be explained by the transition current in the hydrodynamical model. An electric spin flip contribution as it is known for the giant dipole resonance of light nuclei^{8,9} could be the reason.

The figure shows the measured ratio of the inelastic cross section of the 12.0 MeV resonance to the Mott cross section together with the corresponding DWBA curves for an E2 and an E3 transition. The DWBA curves were again calculated using the hydrodynamical model⁷. The figure shows that E2 is clearly favored. A comparison with calculated angular distributions (not shown) excludes the multipolarities $\lambda = 1$ and $\lambda \geq 4$ in accordance with the qualitative arguments given in Reference 1. An E0 assignment cannot be ruled

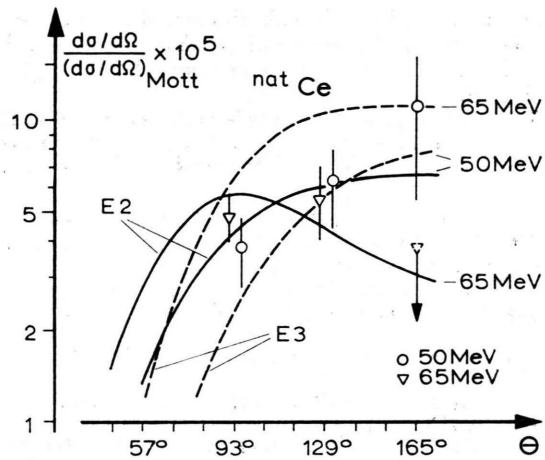


Fig. 1. The ratio of the inelastic cross section of the resonance at 12.0 MeV to the Mott cross section is plotted for primary energies of 50 and 65 MeV as a function of scattering angle. The curves show the result of DWBA calculations assuming an E2 assignment with $B(E2, 0) = 2.5 \times 10^3$ fm⁴ (solid lines) and an E3 assignment with $B(E3, 0) = 4.3 \times 10^5$ fm⁶ (dashed lines). Measured points for 93° and 129° are not drawn exactly at these angles in order to show the error bars more clearly.

ed out from the measurements, but seems to be unlikely since the corresponding strength would have to be explained by a collective breathing mode whose excitation energy is expected to be higher due to the low nuclear compressibility¹⁰. The results including the total width are given in the Table 1. The 12.0 MeV resonance can be identified with the isoscalar E2 resonance predicted by BOHR and MOTTELSON¹¹ at 11.2 MeV. The B -value exhausts 70% of their sum rule. A weak resonance barely observed at 24 MeV might be the corresponding isovector resonance in this model.

The cross section of the resonance at 8.7 MeV exhibits the transverse angular dependence of a magnetic transition. We tried to analyse the data with two models. The code of TUAN et al.¹², which uses a transition current contribution only, cannot reproduce the angular dependence for any spin assignment. The code of DRECHSEL¹³ using a pure spin flip model gives roughly the correct dependence assuming an M1 transition, although the agreement is still not satisfactory. The B -value given in the Table 1 was calculated using model "E" of this code. However, other spin flip models of this code reproduce the angular distribution

Table 1. The results for the three resonances. See text for model dependence of the reduced transition probabilities. The single particle units WU are defined as in Ref. 14 and Γ_t for the E1 resonance was taken from Reference 4.

E_x/MeV	λ_π	$B(X\lambda, 0)/\text{fm}^{2\lambda}$	Γ_γ/eV	Γ_γ/WU	Γ_t/MeV
8.7 ± 0.3	1^+	0.4 ± 0.2	0.9×10^2	6 ± 3	2.2 ± 0.4
12.0 ± 0.2	2^+	$(2.5 \pm 0.8) \times 10^3$	1.0×10^2	12 ± 4	2.8 ± 0.3
15.1 ± 0.2	1^-	40 ± 8	5.0×10^4	8.0 ± 1.6	(4.35)



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nearly as well although with different B -values. A model dependence of a factor of two has therefore to be considered in addition to the experimental error given in the Table 1.

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The Mössbauer Effect of the 60.0 keV Transition in ^{155}Gd and the 54.5 keV Transition in ^{157}Gd

J. GÖRING and R. HERBIG

Institut für Technische Kernphysik
Technische Hochschule Darmstadt

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Using the Mössbauer technique the lifetimes of the 60.0 keV level in ^{155}Gd and the 54.5 keV level in ^{157}Gd have been measured.

^{155}Gd and ^{157}Gd are strongly deformed nuclei with a similar structure differing in only two neutrons. Therefore a comparison is very interesting. While on ^{155}Gd many experiments have been done¹, only a few papers on ^{157}Gd have been published²⁻⁴. Here we give our first results of lifetime measurements of the first excited rotational states in these nuclei.

Whereas Mössbauer measurements have been performed in ^{157}Gd using the 64.0 keV transition^{3,4}, the ME of the first excited state has been observed for the first time. This was only possible by using a γ -detector with a high energy resolution.

The ^{157}Gd activity ($T_{1/2}=15$ h) was produced at the Darmstadt Electron Linear Accelerator by means of the reaction $^{158}\text{Gd}(\gamma, p)^{157}\text{Eu}$. The ^{157}Eu was separated and imbedded in a Gd_2O_3 matrix. For the absorber we used enriched $^{157}\text{Gd}_2\text{O}_3$ (69.6%). The thickness was 47 mg $^{157}\text{Gd}/\text{cm}^2$.

The temperature of source and absorber was 4.2 °K. Using a Ge(Li)-detector with an energy resolution of better than 1.7 keV any background of the 64.0 keV

transition and the X-rays could be avoided. The experimental details have been described elsewhere⁴.

The observed spectrum is shown in Figure 1. As known from other measurements⁴ the hyperfine interaction is very small in comparison with the linewidth. Therefore a single Lorentzian was fitted to the data. The experimental linewidth was found to be

$$\Gamma(54.5) = (73.5 \pm 1.5) \text{ mm/sec.}$$

For the correction of the line broadening due to the absorber thickness we used the theoretical conversion coefficients of HAGER and SELTZER⁵ and the mixing ratio $\delta(E2/M1)$ from the Tables of LEDERER et al.⁶. The interpolated value turned out to be $\alpha_{th}(54.5) = 12.60$. With a Debye temperature of $\Theta = 220$ °K⁷ and an assumed error of 10% we got the Debye-Waller factor $f(54.5) = 0.43 \pm 0.03$. Therewith the linewidth was corrected⁸ by the factor 1.91, and the lifetime $\tau(54.5) = (187 \pm 12) \text{ psec}$ * was found. As a test for this correction we estimated the maximum absorption (center of the resonance) as $(33.5 \pm 2.3)\%$, which is in very good agreement with the experimental value of $(32 \pm 4)\%$.

The lifetime of the 60.0 keV level in ^{155}Gd has been estimated from Coulomb excitation data⁹ to be $\tau(60.0) = 140 \text{ psec}$, while KRUSCHE et al.¹⁰ reported $(350 \pm 90) \text{ psec}$. From a Mössbauer experiment¹¹ a larger value of $(2.7 \pm 0.7) \text{ nsec}$ was obtained. Because of this discrepancy the lifetime was re-measured and analysed in the way described before.

The ^{155}Eu activity produced by means of the reaction $^{154}\text{Sm}(n, \gamma)^{155}\text{Sm}(\beta^-)^{155}\text{Eu}$ ($T_{1/2} = 1.7 \text{ y}$) was separated and imbedded in a CeO_2 matrix. 13 mg $^{155}\text{Gd}/\text{cm}^2$ of enriched $^{155}\text{Gd}_2\text{O}_3$ (94.4%) were used as an absorber. The experimental linewidth was found to be

$$\Gamma(60.0) = (36.2 \pm 4.6) \text{ mm/sec.}$$

Reprint requests to the present address: J. G., Faculty of Science, Osaka University, Toyonaka, Osaka, 560 Japan.

* The error includes also an assumed error for α_{th} of 10%.