may significantly contribute to its localization.

Further analysis of the shape and intensity of the scattering lines and of their temperature dependence must await a more sophisticated model. At the present time the 185-cm^{-1} scattering is not understood.

We have also observed an absorption band in the infrared for $E \parallel c$ at 167 cm^{-1}, similar to the α_{zx} Raman scattering peak. Such absorption must arise from odd-parity modes such as the p and f modes mentioned above. In fact, the Green's function calculations[10] predict that these modes lie very close to the d modes. Details of this work will be published in a future communication.

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REORIENTATION MEASUREMENT IN Mg^{24}

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The reorientation effect in Coulomb excitation with S^{32} ions was used to deduce the static quadrupole moment of the first excited $J^\pi = 2^+$ state in Mg^{24}. The value obtained in this experiment is $Q_{2^+} = -0.26 \pm 0.08$ b.

In the last few years the reorientation effect in Coulomb excitation was successfully used[1] to determine the quadrupole moments of excited states in the mass region $A > 100$. This Letter describes a measurement of the static quadrupole moment of the first excited $J^\pi = 2^+$ state in Mg^{24}. In this case, the influence of the static quadrupole moment of the 2^+ state on the multiple Coulomb excitation is expected to be large. Assuming an intrinsic quadrupole moment $Q_0 \sim 0.8$ b for Mg^{24} and using S^{32} ions, the reorientation effect amounts to a 25% change in the excitation cross section for backward angles. The change due to the population of the 2^+ state through other low-lying excited states in Mg^{24} is smaller than 1%. The estimated correction due to transitions via the giant dipole resonance states[1] is also less than 1%. Therefore, reorientation measurements in light nuclei should provide reliable values of the static quadrupole moment of the first excited state.

In the present experiment, sulfur beams of 42, 48, and 55.6 MeV produced by the High Voltage Engineering Corporation Model MP tandem Van de Graaff accelerator of the Max-Planck-Institut was used to bombard Mg^{24} self-supporting targets of 76, 150, 310, and 550 $\mu g/cm^2$ thickness. At the bombarding energies chosen, the elastic scattering cross section was measured in this laboratory and does not show any deviation from the Rutherford cross section. The gamma rays following the Coulomb excitation have been detected by a 22-cm^3 large Ge counter positioned 6 cm from target at 0° with respect to the beam. Because the Mg nuclei were recoiling into vacuum, the 1.37-MeV gamma line of the decay of the first excited 2^+ state is Doppler shifted and broadened by as much as 100 keV depending on the recoiling angle. In this way the Doppler shift determines the scattering angle of the sulfur. For an isotropic gamma-ray distribution, the observed line shape would depend on the differential cross section for all scattering angles. In this case, however, the angular distribution is not isotropic and the line shape depends on the differential cross section weighted by the particle-gamma correlation function. The influence of reorientation effect on the line shape is expected to be large at high Doppler shifts corresponding to large scattering angles.

The gamma spectrum from a 150-$\mu g/cm^2$ target using a sulfur beam of 48 MeV is shown in Fig. 1(a). The counter had a resolution of 3.5 keV for the photopeak of Co^{60}, and between the photopeak and Compton edge there was a continuum of about 1% of the photopeak intensity. The contributions of this continuum and the background are indicated in Fig. 1(a) by solid lines. After the background subtraction, the experimental data were fitted [Fig. 1(b)] by the theoretical line shape,

$$\frac{d\sigma}{dE_\gamma} = \frac{d}{dE_\gamma}\int d\Omega_\gamma d\Omega_p \frac{dw}{d\Omega_\gamma}(\theta_p, \theta_\gamma, \varphi_\gamma)\frac{d\sigma_{\rm Ruth}}{d\Omega_p}(\theta_p), \quad (1)$$

varying only two parameters, namely the static quadrupole moment Q_{2^+} and the normalization factor. In expression (1), $dw(\theta_p, \theta_\gamma, \varphi_\gamma)/d\Omega_\gamma$ is the angular distribution of the gamma ray for a certain scattering angle, which was obtained from Winther and de Boer's computer program.[2] The integration in (1) also extends over the finite solid angle of the gamma-ray counter; the kinematical transformations include terms up to $(v/c)^2$ where v is the velocity of the recoiling Mg^{24}.

To obtain the line shape, another integration has to be carried out taking into account the energy loss of the incoming and outgoing particles in the target. The energy loss of S^{32} and the recoiling Mg^{24} in the 48-MeV measurement gives rise to an energy spread of the Doppler-shifted gamma ray of $\lesssim 2.5$ keV. In order to check this procedure, targets of various thicknesses between 76 and 550 $\mu g/cm^2$ were used in the measurements with 55.6-MeV S^{32} and gave consistent

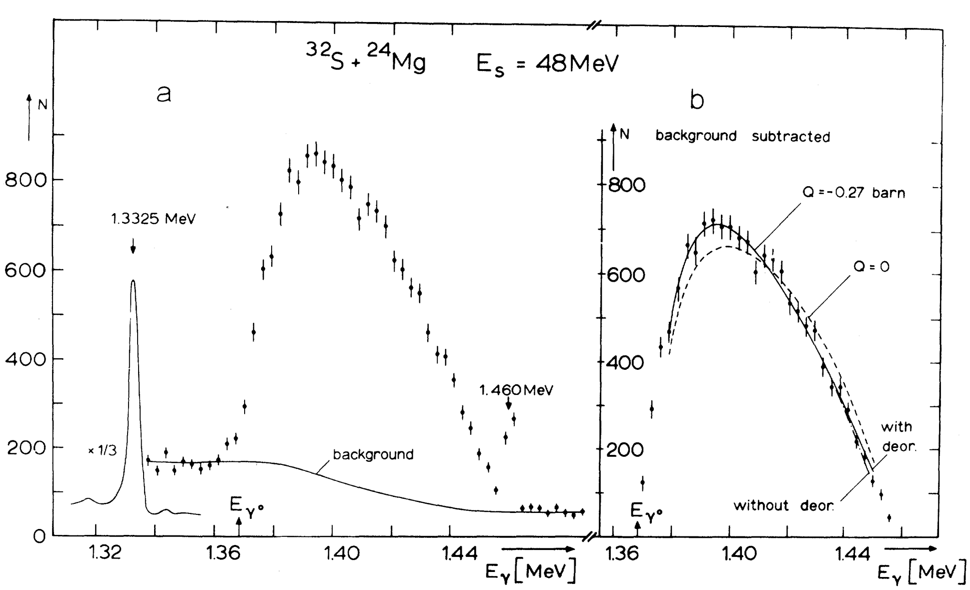

Fig. 1. (a) The 1.37-MeV gamma line in Mg^{24} observed at 0° with a Ge counter. The sharp line refers to a ^{60}Co source. (b) Comparison of the theoretical line shapes for $Q_{2^+} = -0.26$ and 0 b with the experimental data.

Table I. The results of the analysis are shown for various bombarding energies E_{lab} of S^{32}. The static quadrupole moment Q_{2^+} and the χ^2, normalized by its expectation value $E(\chi^2)$, are given with and without correction for deorientation.

	Corrected for deorientation		Not corrected for deorientation	
E_{lab} (MeV)	Q_{2^+} (b)	$\chi^2/E(\chi^2)$	Q_{2^+} (b)	$\chi^2/E(\chi^2)$
42.0	0.26	1.47	0.22	1.31
48.0	0.27	0.77	0.23	0.64
55.6	0.27	1.18	0.24	1.45
55.6	0.24	0.57	0.21	0.65

results.

In the present stage of the experiment, the essential uncertainties come from the attenuation of the angular correlation. The recoiling nuclei are decaying almost entirely in vacuum and the atoms are highly ionized. The magnetic hyperfine splitting due to the unpaired electrons can cause a deorientation of the nuclear alignment. Only the influence of the charge state 11+ was considered because other charge states give negligible effects. The important quantity in the deorientation process is $\omega\tau$, which is the average precession angle of the nuclear spin. The Larmor frequency ω was calculated assuming that only a 1s electron contributes to the magnetic field. For $\tau = 1.6$ psec and for a gyromagnetic factor of 0.5, $\omega\tau = 4$.

In the model of static magnetic perturbation the attenuation factors[3] of the Legendre polynomials P_2 and P_4 are

$$G_2 = 1 - \frac{6}{25}\frac{(\omega\tau)^2}{1+(\omega\tau)^2}p(v)$$

and

$$G_4 = 1 - \frac{4}{5}\frac{(\omega\tau)^2}{1+(\omega\tau)^2}p(v), \qquad (2)$$

respectively. In this expression, $p(v)$ is the probability for the charge state 11+ to occur at the recoiling velocity v.

An observable change of the line shape caused by deorientation is expected in the region where the Doppler shift is larger than 75% of the full Doppler shift. This is for two reasons:

(a) The P_4 term is important for backward scattered S^{32} whereas for medium scattering angles the P_2 term over-weighs the P_4 term. From (2) it follows that G_4 attenuates the gamma angular distribution much stronger than G_2.

(b) For the 48-MeV measurement the probability $p(v)$ is 0.25 at the maximum velocity and drops down to 0.06 for a velocity corresponding to 50% of the full Doppler shift.[4]

The average over all measurements of the quadrupole moment in the first excited state of Mg^{24} gives $Q_{2^+} = -0.26 \pm 0.08$ b. To get the order of magnitude of the possible systematic error due to the deorientation the data have also been analyzed without taking these effects into account. The two evaluations are compared in Table I. The differences are less than 15%.

According to the rotational model one may deduce the quadrupole moment of the first excited state from the transition probability. The value obtained in this way[5] $Q_{rot} = -0.21 \pm 0.01$ b is consistant with the present result.

Using the technique described in this paper, measurements of the quadrupole moments of first excited states in Ne^{22} and Si^{28} are under way.

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