cannot be obtained from this experiment. We hope, however, to carry out experiments on the polarization of γ-rays emitted from polarized (as opposed to aligned) nuclei, which, among other things, should give the sign of the magnetic moment.

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Comparison of Total Photoneutron Yield from 160- and 320-Mev Bremsstrahlung

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THAT an appreciable fraction of the photoneutrons produced by a high energy (320-Mev) bremsstrahlung might be the result of quanta of energy greater than 150 Mev was pointed out by Eyges[1] on analysis of high energy[2,3] and lower energy[4] absolute photoneutron production cross sections and of transition curves.[2,5,6] Eyges proposes that the nuclear absorption cross section for photons has a resonance maximum in the region of 15 to 20 Mev, then falls almost to zero and rises once again somewhere above 100 Mev. The results of the present experiment bear out the essential validity of this theory.

In this experiment, the total photoneutron yield measurements previously reported[2] for the 320-Mev bremsstrahlung from the Berkeley synchrotron were repeated at 160 Mev maximum energy for nine elements. Full energy (320-Mev) measurements were also made on these nine elements at the same time as a check. The experimental arrangement used was very similar to that previously described.[2] Neutrons were counted at 90° to the beam direction with a boron trifluoride proportional counter in a "long counter" geometry of paraffin. The pulses from the counter were clipped to 0.5-microseconds pulse length.

The ionization chamber beam monitor was calibrated at both energies for equivalent numbers of low energy quanta by two methods. The first was the induced 10-minute half-life β^+ activity in copper foils because of the $Cu^{63}(\gamma, n)Cu^{62}$ reaction as used by Sagane.[7] The second was the photodisintegration of deuterium as determined by direct neutron counting from water and heavy water targets. Both of these reactions are presumably sensitive only to quanta below 50 Mev. The deuterium yield was 6.5 percent higher from 160-Mev bremsstrahlung than the copper yield for equal copper and deuterium yields at 320 Mev. The average of the deuterium and copper results was used.

Table I gives the ratios of total photoneutron yields for equivalent $Cu^{63}(\gamma, n)$ and $D(\gamma, n)$ reaction yields (i.e., for the same number of quanta below 30 Mev) from 320-Mev bremsstrahlung and 160-Mev bremsstrahlung. The probable counting errors of these ratios are less than 3 percent in every case except carbon (error 4 percent). The relative yields at 320 Mev checked within statistics the previously reported values.[2] Although the beam-pulse length at half-energy was only 20 microseconds, no neutron pile-up occurred in the counter because of the long average diffusion time (about 200 microseconds) of neutrons in the paraffin of the "long counter." Neutron pile-up and counts resulting from scattered gamma-rays or electrons were checked for, both by increasing the counter voltage by 100 volts and by reducing the beam intensity by a factor of four. In both cases the counts per unit beam were the same within statistics, indicating negligible contribution from either effect.

TABLE I. Ratios of total photoneutron yields.

Element	Be	C	Al	Fe	Cu	Mo	Ta	W	Pb
Yield at 320 Mev / Yield at 160 Mev	1.21	1.18	1.48	1.23	1.28	1.30	1.28	1.33	1.30

If the calibration methods described can be assumed to normalize the beam to equal numbers of quanta between 0 and 30 Mev for full and half energy beams, the shapes of the bremsstrahlung spectra at these energies indicate that only quanta of greater than 140 Mev energy could account for the 30 percent increase in yield actually observed.

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Effect of Intrinsic Moment of Electron on Spectroscopic Isotope Shift*

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IT is pointed out below that the intrinsic moment of the electron[1-3] has a non-negligible effect on the spectroscopic isotope shift. In a central electric field, according to the third paper listed in reference 1 the first order effect of the magnetic moment μ_e on the energy of an s electron is

$$\langle H'''\rangle = -\langle \mu_e \rho_2 (\mathcal{E}\boldsymbol{\sigma})\rangle = 2\mu_e \int_0^\infty fg\mathcal{E}_r r^2 dr, \quad (1)$$

where $\mathcal{E}$ is the electric field, $\mathcal{E}_r$ its radial component, ρ_2, $\boldsymbol{\sigma}$ the usual Dirac matrices and f, g are the radial functions defined in reference 1; r is the distance from the center of the nucleus. Calculations were made for a model in which the charge Ze is distributed with density proportional to r^{n-2} in $r<a$. The change in the electrostatic potential energy caused by the finiteness of the nucleus is referred to as δV, changes in $\langle \delta V\rangle$, $\langle H'''\rangle$ caused by change $\delta' a$ for fixed n by $\delta'\langle \delta V\rangle$, $\delta'\langle H'''\rangle$, respectively. The ratio to the volume effect[4] is

$$\mathfrak{R} = \delta'\langle H'''\rangle/\delta'\langle \delta V\rangle = -\gamma(2\rho+1)(2\rho+n+1)(e^2/mc^2)/[4\pi a(2\rho+n)], \quad (2)$$

where

$$\gamma = Z\alpha, \quad \rho = (1-\gamma^2)^{\frac{1}{2}}, \quad (3)$$

and α is the fine structure constant. In Eq. (2) the electronic wave function is approximated by the first nonvanishing power of r in f and g for a Coulomb field and[3] $\mu_e \cong -(\alpha/2\pi)(e\hbar/2mc)$. For Pb^{208}, with $a = 0.5A^{\frac{1}{3}}10^{-13}$ cm,

$$\mathfrak{R} = -0.050. \quad (4)$$

The interaction of Eq. (1) is related to that invoked by Foldy[5] for the electron-neutron force.[6] It may be noted that in the non-relativistic approximation,

$$H''' \cong -(\hbar\mu_e/2mc)\,\mathrm{div}\,\mathcal{E}, \quad (5)$$

and for this, values about 10 times those of Eq. (4) result if one calculates with relativistic wave functions. The parameter $2\mu_e/(ea) = -e^2/(2\pi amc^2) \cong -1/20$. The ratio $f/g \cong -\gamma/2$ is ~ -0.3 for

Pb^{208}. The latter factor is nearly compensated by the fact that for V a change in a produces appreciable potential changes only well inside the nucleus, while $\mathcal{E}_r r^2$ is largest at the nuclear surface where fg is largest.

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Ferromagnetic Resonance in Single Crystals of Cobalt-Zinc Ferrite

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WE succeeded in growing single crystals of Co-Zn ferrite, and its ferromagnetic resonance was observed at 9310 Mc from room temperature to the Curie temperature.

Single crystals of the ferrite were prepared as follows: 6.7 g Fe_2O_3, 1.9 g CoO, 1.4 g ZnO, and 12 g borax were mixed, kept at 1320°C for 3 hours in a platinum crucible, cooled at a rate of 1°C/min until 1150°C, and then the current was turned off.

A crystal used in the present experiment was a beautiful octahedral crystal, about 1 mm^3 in volume. The Curie point of this crystal was observed from the resonance experiments at *ca* 340°C. Moreover, from Guillaud's Curie temperature data[1] for various compositions of Co-Zn ferrites, our crystal seems to have the composition $Co_{0.7}Zn_{0.3}Fe_2O_4$.

A crystal was cut at the (100) plane into two pyramid-type specimens, and one of them was mounted at the bottom of the resonant cavity so as to make the (100) plane consistent with the direction of both the rf magnetic field and the dc magnetic field.

The experimental procedure and method were given in previous papers.[2,3]

Resonance fields and line half-widths from room temperature to *ca* 300°C were observed, and the results of measurements made with the [110] and [100] directions respectively parallel to the dc static field are shown in Fig. 1.

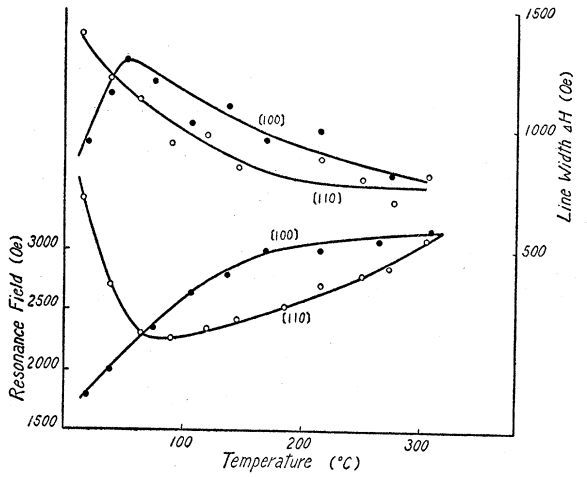

FIG. 1. Variation of the resonance field and the line half-width with temperature for the [110] and [100] directions in a single crystal of $Co_{0.7}Zn_{0.3}Fe_2O_4$.

The curves of resonance field *vs* temperature for these two directions cross at *ca* 70°C, and the line width for the [100] direction has a maximum value near this temperature.

Sintered polycrystalline specimens of the same composition were used to determine the demagnetizing factor N and magnetic saturation values M_s of the single crystal. Namely, resonance experiments were performed from room temperature to the Curie point for various specimens (a sphere 2 mm in diameter; a disk 0.25 mm in thickness and 3.12 mm in diameter; and a pyramid form whose base was 1 mm along the edges).

A second peak at lower magnetic field was always observed in the case of the experiment with polycrystalline specimens from *ca* 70°C to 100°C, as we had previously reported in the experiment with Mn-Zn single crystals,[4] and this "double peak" seems to have also an intimate relation with the phenomena in which the anisotropy energy K_1 changes its sign.

The demagnetizing factor N and the saturation magnetization M_s at each temperature were calculated from the resonance fields of polycrystalline specimens, and substituting these values in Kittel's resonance formula,[5] K_1 and g of the single crystal were determined for each temperature as shown in Table I in the fourth

TABLE I. Crystalline anisotropy energy K_1 and g-factors, as functions of temperature.

Temp. °C	g_p	M_s gauss	$K_1 \times 10^5$ ergs/cm³	g
20	2.07	516	2.36	1.91*
40	2.10	450	1.34	1.92*
60	2.11	381	0.16	1.96*
80	2.12	338	−0.21	2.06
120	2.15	269	−0.41	2.12
160	2.16	203	−0.34	2.12
200	2.17	134	−0.21	2.17
240	2.18	61	−0.07	2.16
280	2.19	8	−0.01	2.15

and the last column, respectively. The g-factors of the single crystal near room temperature could not be determined with sufficient accuracy because of a considerable increase in the value of K/M_s and NM_s in Kittel's formula, so these values are marked with asterisks.

In Table I g-factors obtained from the experiment with a spherical polycrystalline specimen, whose diameter is 2 mm, are also included in the second column, g_p. The values of g and g_p at high temperatures coincide satisfactorily with one another within the limits of error.

Experiments at a wavelength of 1.2 cm are being planned.

Details of the present experiment will be published in Science Reports of the Research Institute of Tohoku University.

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Low Energy γ-Transitions in Some Rare Earth Isotopes*

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SEVERAL of the rare earths, when activated by neutron capture, decay by β-emission followed by an internally converted γ-transition of about 100 kev energy. In most cases, these energies have been well determined previously.[1] In order to obtain relative intensities of conversion lines and assign transition