interchanged in the magnetic field to cancel any difference. The accurately known ratio[5] of free electron to proton magnetic moments is used to express the ratio of g_J to the free-electron value, g_e. All the results appear in Table I. The errors represent 95% confidence limits. A more detailed report is being prepared.

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Paramagnetic Resonance Spectrum of Curium*

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We have observed the paramagnetic resonance spectrum of curium in anhydrous lanthanum trichloride at three-cm wavelength and room temperature. Seven lines can clearly be distinguished confirming the assignment of seven $5f$ electrons[1] and a ground state of $^8S_{7/2}$ analogous to the spectrum of gadolinium $[(4f)^7]$. The spectrum can be described by the following Hamiltonian:

$$\mathcal{H}=\beta\mathbf{H}\cdot g\cdot\mathbf{S}+B_2^0P_2^0+B_4^0P_4^0+B_6^0P_6^0+B_6^6P_6^6,$$

where P_m^n are operators and are given by Elliott and Stevens.[2] Following Bleaney *et al.*,[3] one defines for convenience

$$b_2^0=3B_2^0,\quad b_4^0=60B_4^0,\quad b_6^0=1260B_6^0,\quad b_6^6=1260B_6^6.$$

From the measured absorption lines when H is perpendicular to the c axis, we find that at room temperature

$$g=1.991_4\pm0.000_8,\quad b_2^0=8.2\pm0.2\text{ gauss},$$
$$b_4^0=2.2\pm0.2\text{ gauss},\quad (b_6^6-5b_6^0)\geqslant 3.7\pm0.5\text{ gauss},$$

which can be compared with Jeffries' recent values[4] of $g\cong2.00$, $b_2^0=11$ gauss at 77°K. The analogous spectra of Gd^{+3} in $LaCl_3$ determined by Hutchison *et al.*[5] gave the following parameters:

$$g=1.991\pm0.001,\quad b_2^0=9.1\pm0.1\text{ gauss},$$
$$b_4^0=1.81\pm0.04\text{ gauss},\quad b_6^0=0.69\pm0.15\text{ gauss}.$$

The small differences in the values of b_2^0 and b_4^0 are sufficient to give the appearance of different spectra for the two ions.

$LaCl_3$ single crystals were prepared by the method outlined by Anderson and Hutchison[6] in narrow quartz tubes. The curium was carefully purified so as to be free from any other rare earth elements. The best spectrum was obtained with a single crystal containing 20 μg of Cm^{244} at a dilution of about one part in 2000. The radiation damage caused by the intense α radiation caused all transitions except for the $\frac{1}{2}\rightarrow-\frac{1}{2}$ transition to disappear within 24 hours. Some lines caused by radiation damage were detected, but were of small intensity compared with the 7 fine structure lines. The crystal fluoresces very strongly with a light blue color. We have also observed the spectrum of Cm in a magnesium bismuth nitrate single crystal.[7] Seven lines were observed in a crystal containing about 15 μg of Cm. Larger amounts of Cm caused so much radiation damage so as to obscure the spectrum of Cm. Three intense lines caused by radiation damage stood out in particular. They fall at $g=2.003$ and with an average separation of 62 gauss with H parallel to the c axis. The three lines are characteristic of a hyperfine structure of N^{14}, the only isotope with nuclear spin 1 in this crystal. The radiation damage spectrum was not investigated in detail but there seem to be more than one nitrogen ion per unit cell.

In addition we have incorporated Cm into ThO_2 and $CaCl_2$. Many lines were observed, presumably caused by radiation damage. Similar lines were observed when these compounds were exposed to a cobalt source. We have also attempted, so far unsuccessfully, to find a hyperfine structure due to the nuclear moment of the odd isotope Cm^{245}. Work along this direction is being continued.

* Based on work performed under the auspices of the U. S. Atomic Energy Commission.

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Radiation Damage Experiments in III-V-Compounds*

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So far relatively few investigations on radiation damage have been published in which x-ray techniques were used to detect the effect of nuclear radiation on metals and semiconductors. It seemed of interest to see if x-rays could give information on the effect of radiation on the III-V-compounds. This group of compounds crystallizes in the zinc blende structure and

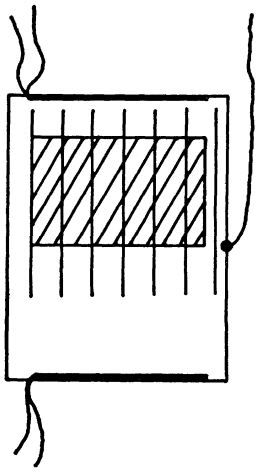

FIG. 1. Specimen with soldered leads for temperature and resistivity measurements. Shadowed part is irradiated. Vertical lines show locations where x-ray beam scanned the specimen.

shows very interesting electrical properties, which were originally studied by Welker and co-workers.[1]

In the present investigation two samples of GaSb and one of InSb were irradiated with approximately 2×10^{17} 12-Mev deuterons/cm^2 at the University of Illinois cyclotron. All the specimens were single crystals (approximately as thick as the range, i.e., about 17 mils) and oriented in such a way that the (100) planes were perpendicular to the deuteron beam. The specimens were glued to a piece of aluminum which was kept at liquid nitrogen temperature. The temperature of the specimens was measured at different locations with copper constantan couples, which were soldered to the specimens. An aluminum screen prevented the beam from hitting either the thermocouples or those parts of the specimens which were later used as a reference. During the irradiation the temperature observed was never higher than -130°C. The leads of the thermocouples were also used to measure the resistance of the specimens during irradiation. The lower part of the cryostat contained Mylar windows, which made it possible to observe the (200), (400), and (600) reflections from all specimens at liquid nitrogen temperature, the (400) reflection being a fundamental line and the other reflections being superlattice lines.

During irradiation the resistance of all three specimens increased sharply at the beginning and then slowly decreased with increasing integrated flux. After irradiation the cryostat was transferred to the x-ray equipment. A beam of monochromatic copper $K\alpha$ radiation was focused on the specimen by means of a curved rocksalt monochromator and the reflections were obtained on a photographic plate at a distance of 50 cm from the specimens. By taking the previously mentioned aluminum screen away it was possible to compare the irradiated part with the nonirradiated part of the same crystal. By moving the entire cryostat parallel to the (100) planes of the specimen, x-ray reflections from different locations of the same specimen could be obtained, as shown in Fig. 1. Three different effects were observed. They are given schematically in Fig. 2.

(a) The reflections remain sharp, but the intensity of the reflections from the irradiated part of the specimen was smaller than the intensity of the nonirradiated part.

(b) The lattice parameter of the irradiated part is of the order of a tenth of a percent larger than the parameter of the nonirradiated region.

(c) The lines are curved systematically toward the center of the irradiated region.

These three effects were observed in all reflections from all specimens, in the fundamental as well as in the superlattice lines. The effect varied, however, depending on the specimen, the thickness of the aluminum screen in front of the specimen, the reflection, etc.

These observations seem to suggest the following model. During irradiation, "spikes"[2] which have a configuration different from the matrix material are introduced in the specimen. Specifically we like to think that the material melts and then resolidifies in the structure of the liquid, which is different from the solid structure, as is the case with germanium. This metastable structure is preserved at these low temperatures. Because the specific density of this "liquid structure" is higher than that of the normal solid, the presence of these spike regions gives rise to tensions, which tend to curve the lattice planes and produce the curved reflections. The rigid frame of nonirradiated material around the damaged region prevents the relaxation of the lattice, resulting in an increase in lattice parameters. The x-rays scattered from the spikes no longer fulfill the Bragg condition; therefore the intensity of the reflections in the irradiated part is lower.

This model would also explain the decrease in resistance, because the conductivity of GaSb and InSb in the liquid state is higher than in the solid state. The sharp increase in the beginning of the run is probably due to semiconductor effects (traps are introduced). The relative intensities of the reflections from different specimens seem to suggest that the damage is not uniformly distributed throughout the range of the deuterons. This could indicate that electron-phonon interactions contribute to the damage. This nonuniform distribution of the damage makes it very

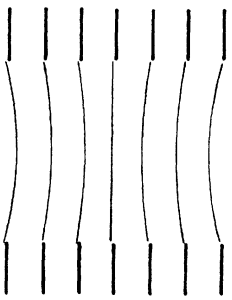

FIG. 2. Schematic reproduction of film after exposing specimen on the location shown in Fig. 1.

difficult to analyze the intensities in terms of order-disorder transformations. However, after comparing the intensities of fundamental and superlattice lines of different specimens one is led to the conclusion that the spikes might well be surrounded by disordered regions. The observations made during and after annealing of the specimens can also be understood on the basis of this model. The spikes with the quasi-liquid configuration transform to the normal solid configuration below room temperature. This can be deduced from the shape and the intensity of the x-ray lines.

Experiments are in progress to verify and extend the present observations. The detailed results of this work will be published shortly.

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Ferrimagnetic Resonance in Yttrium Iron Garnet

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THE discovery of ferrimagnetism in yttrium iron and rare earth iron garnets was recently announced by Bertaut and Forrat.[1] It was discovered independently, though somewhat later, by Geller and Gilleo[2] of these Laboratories. The garnets constitute a whole new class of magnetic oxides of cubic symmetry which are structurally completely distinct from the now familiar ferrites. A study of ferrimagnetic resonance in one of these compounds has been made possible by Nielsen's[3] success in the growth of almost exactly stoichiometric single crystals of yttrium-iron garnet [$Y_3Fe_2(FeO_4)_3$]. The experimental specimens used were polished spheres of various sizes from 0.005 in. to 0.020 in. Some of these same spheres were used in the single-crystal structural analysis described in reference 2.

Two frequencies were used in these experiments, 9300 and 24 000 Mc/sec. Data were taken at various temperatures in the range from 2.85° to about 540°K. Transmission cavities were used in both cases. At the lower frequency, a rectangular cavity operating in the TE_{102} mode was used, while at 24 000 Mc/sec a cylindrical TE_{013} cavity was used. Temperatures different from that of the room were reached by using techniques in which the specimen and its mounting rod were cooled or heated rather than the entire cavity. In the spectrometer used in these experiments, a klystron was sawtooth-modulated so as to sweep across an entire mode. The transmission cavity containing the specimen sphere acted as a filter passing only radiation near its natural frequency. The relative power absorbed by the sample was obtained from the variation in the height of the cavity transmission characteristic with magnetic field. Semiautomatic data recording schemes were used at both frequencies.

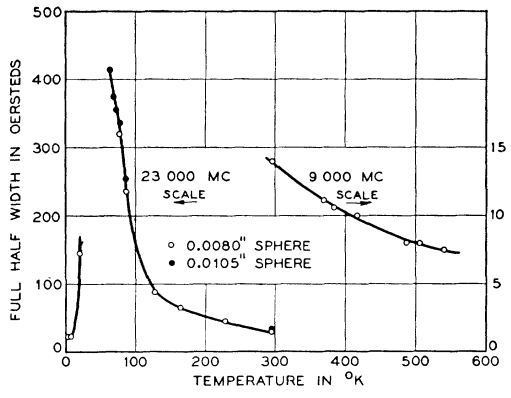

FIG. 1. Plot of line width with the steady field along [100] against absolute temperature. Note the scale change in the vertical coordinate near 300°K. Line width is defined as the field interval between points of $\frac{1}{2}(\mu'')_{max}$. The 295°K line widths of 13 oe at 9300 Mc/sec and 31 at 24 000 Mc/sec indicate a frequency dependence of line width.

Shape and width of the resonance lines.—At every temperature, it was found that the line width was a function of crystallographic direction. Figure 1 shows the line width data for the steady field parallel to [100].

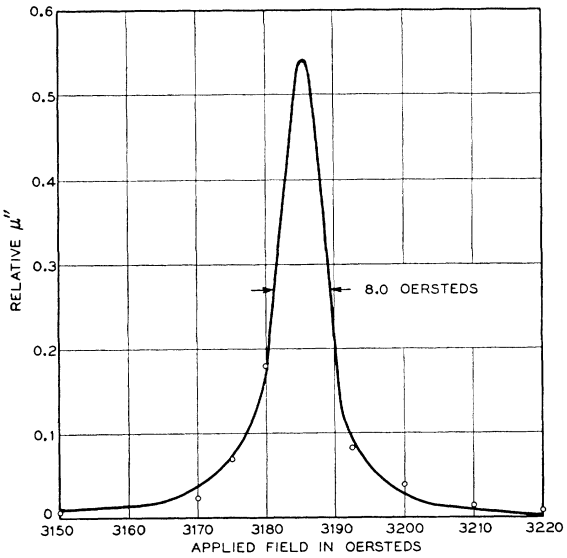

FIG. 2. Line shape taken at 540°K with the steady field along [100]. Curves for the other crystal directions are not shown since they so closely overlap. At this temperature the first-order anisotropy constant $K_1/M_s=2.27$ oersteds. The circled points are those of the Lorentzian curve $y=5.4\{1+[(x-3185.5)/4]^2\}^{-1}$.