The Absorption of 17-Mev Gamma-Rays in Lead and Aluminum[*]

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A GAMMA-RAY spectrometer has been constructed and used to measure the energy distribution and absorption of gamma-rays which are emitted in the $Li^7(p, \gamma)Be^8$ reaction. The method utilizes the measurement of the momentum of the electrons emitted in pair production. The schematic arrangement is shown in Fig. 1.

A thin lead radiator is placed in a homogeneous magnetic field with the surface of the radiator parallel to the direction of the field. Gamma-rays striking the radiator normal to its surface produce positron and electron pairs which are deflected in opposite directions by the magnetic field to follow circular paths. Two counters, c_1 and c_2, are placed in the plane of the radiator with a separation distance $2r$. Coincidences between the counters are recorded. Except for a very low background of accidental coincidences, coincidences will be recorded only when the electron and positron of a pair have momenta such that the sum of their radii of curvature is equal to r.

It is readily seen that in the case in which both the electron and positron are emitted with an energy greater than 2 Mev, the sum of their momenta, and hence the sum of their radii of curvature, is nearly proportional to the energy of the incident gamma-ray. If the radii are calculated exactly for the case of a 17-Mev gamma-ray, one finds that the sum of the radii of curvature of the two particles varies only 3 percent over all possible distributions of energy between the two. If the energies of the electrons are restricted to be greater than 0.5 Mev, then the variation in the sum is one percent. Under the latter condition it is seen that for a given value of field strength and counter separation the spectrometer is sensitive to gamma-rays in a very narrow energy band.

While the above discussion is based on the assumption that the electrons are emitted in a direction perpendicular to the surface of the radiator, it is readily seen that the normal spread in the angle of emission does not seriously decrease the obtainable resolution. Since the average spread in angle of emission is of the order of m_0c^2/E, for E equal to 17 Mev the average angle is only 1/34 radian. Another factor contributing to the spread in angle of emission is the scattering of electrons in the radiator. This is dependent on the radiator thickness. A factor which minimizes the effect is that the spectrometer utilizes 180-degree focusing.

The experimental arrangement which was used is described below. A magnetic field of about 5000 gausses was supplied by a magnet having a pole face of 32-cm diameter and air gap 2.5 cm high. The lead radiator was 0.20 g/cm^2 thick with an area of 2 cm×15 cm. It was placed near a diameter of the magnet. The counters were symmetrically located at either end of the radiator, with a separation between centers of 24.6 cm. The counter diameters were 1.8 cm. The cyclotron target from which the gamma-rays originated was at a distance of 50 cm from the radiator. The incident gamma-ray beam was collimated in the vertical direction to have a spread of 1 cm. The counters were shielded from the direct beam by several centimeters of lead.

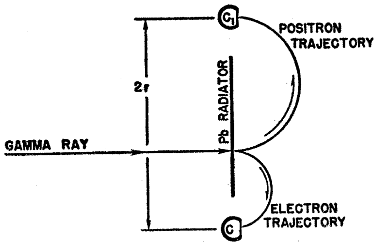

FIG. 1. Schematic diagram of geometrical arrangement. Magnetic field is perpendicular to the paper.

TABLE I.

Absorber	Thickness	Absorption coefficient Theoretical	Absorption coefficient Observed	Standard statistical error
Lead	21.8 g/cm^2	0.066 cm^2/g	0.062 cm^2/g	0.003 cm^2/g
Lead	11.4	0.066	0.067	0.004
Aluminum	20.6	0.022	0.024	0.003

A distribution curve was obtained which gives the relative intensity of pairs observed as a function of Hr for the magnetic field. A third Geiger counter was used to monitor the primary beam intensity. The results of these measurements are given in Fig. 2. It is seen that there is a strong maximum indicated at about 17.5 Mev. The tail on the low energy side may indicate the presence of some further line structure, as has been suggested by previous investigators.[1] However, this tail may be due to the lack of resolution, electron scattering in the foil, or scattering of gamma-rays in the collimator.

The absorption coefficients of the gamma-rays in lead and aluminum were determined by measuring the transmission of absorbers when the spectrometer was adjusted for an Hr corresponding to the maximum of the distribution curve. It is believed that in this manner one measures the absorption coefficient without the confusing effects of degraded radiation. The results are given in Table I. The values predicted by the theory are also given.

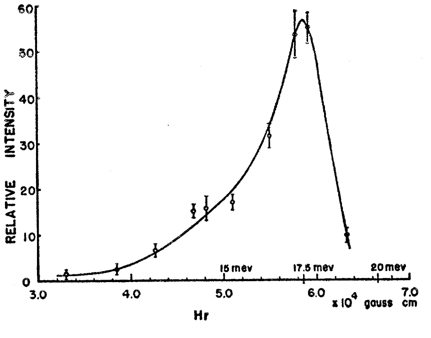

FIG. 2. Relative intensity of observed pair coincidences as a function of Hr. Ordinate scale is arbitrary. Standard statistical errors are indicated.

A new spectrometer is now under construction which is expected to yield improved resolution with much higher counting rates. It is hoped that the new apparatus will permit one to make measurements of absolute gamma-ray intensities in addition to measurements of the sort described here. Such absolute measurements will require determinations of the constants of the apparatus and the efficiency of the radiator for pair production.

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** Tekniska Hogskolan, Stockholm, Sweden.
[1] L. A. Delsasso, W. A. Fowler, and C. C. Lauritsen, Phys. Rev. **51**, 391 (1937).

Microwave Spectra and Zeeman Effect in a Resonant Cavity Absorption Cell*

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A MICROWAVE spectroscope has been constructed with a gas-filled resonant cavity instead of the wave guide currently used. The particular cavity tested here is of a type ordinarily used as an X-band wave meter. Such a large cavity gives a sufficiently high Q-value (i.e., long equivalent path length) and decreased effects of intensity saturation, when operated at K-band frequencies. When it is placed in an arrangement containing a Klystron source and a linear frequency sweep, there results an oscilloscopic display of a sharp cavity resonance curve. By tuning the cavity resonance to a spectral line at a sufficiently low pressure, a picture such as that shown in Fig. 1 is obtained.

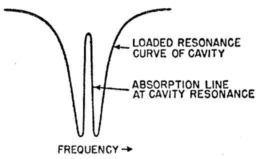

FIG. 1. Absorption line in cavity resonance.

The sensitivity of this method is enough to detect the nuclear hyperfine structure of ordinary ammonia lines of quantum numbers $JK=11$, 22, 33, 44, 55, 66, and 77.

In attempting to increase the sensitivity of the apparatus the author has tried the method originated by Dr. W. D. Hershberger,[1] in which the reflector grid of the Klystron tube is frequency modulated by a 100-kc source, in addition to the low frequency sweep, and the detected output is amplified by a narrow-band receiver at the modulating frequency or its second harmonic. The resulting sensitivity is increased to such an extent that even the nuclear hyperfine lines seem to be almost as strong as the main lines without modulation.[2] By this method we have also confirmed many of the weaker lines of SO_2 found by Professor E. B. Wilson's group (to be published).

With the aid of the frequency-modulation scheme, the Zeeman effect for microwave spectral lines has been observed with a cavity, specially constructed out of a nonmagnetic cylinder and magnetic end plates acting as pole pieces, by applying an axial magnetic field up to 3000 gausses. In agreement with the results of Coles and Good[3] each absorption line of ammonia is split into a doublet. In the case of a cavity, a doublet is observed for a mode which has the microwave electric field perpendicular to the external magnetic field (TE modes), and a triplet for a cavity mode which has components both perpendicular and parallel to the magnetic field (TM modes).

Still more interesting is the fact that all the nuclear hyperfine lines of ammonia have been split by the magnetic field into doublet or triplet components in essentially the same way as the main lines themselves. A typical spectral diagram for a TE mode is shown in Fig. 2.

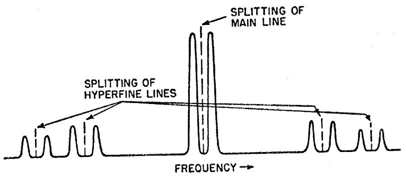

FIG. 2. Zeeman splitting of an NH_3 line and its hyperfine structure.

Measurements of the Zeeman separation as functions of the magnetic field strength and the quantum numbers of the spectral lines for ammonia and other gases are in progress.

My thanks are due Mr. S. P. Cooke and other members of the Microwave Group in this Laboratory for valuable discussions and technical help, and to Professor E. B. Wilson, Jr., for much advice.

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[1] Kindly communicated by Professor E. B. Wilson, Jr., from discussions at the Symposium on Molecular Structure and Microscopy, Ohio State University, Columbus, Ohio, June 9–14, 1947.
[2] Progress Report No. 4, for Contract N5ori-76, Cruft Laboratory, Harvard University, July 1, 1947.
[3] D. K. Coles and W. E. Good, Phys. Rev. **70**, 979 (1946).

The Neutron-Scattering Cross Section at the Cadmium Resonance

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THE existence of slow neutron-scattering resonances was shown experimentally in 1944 by A. Langsdorf.[1,2] They have since been studied with neutron-filter methods by Wollan *et al.*,[3] Dancoff and Lichtenberger,[4] and Fermi and Marshall.[5] Independently, Goldhaber *et al.*[6,7] found a strong scattering resonance in manganese.

The scattering cross section at the cadmium resonance has recently been measured using a beam of neutrons from a single crystal monochromator.[8] The energy spread of the neutrons was about one quarter of the width of the reso-