

Analysis of High Energy X-Ray Spectra

G. C. BALDWIN AND G. S. KLAIBER
 Research Laboratory, General Electric Company,
 Schenectady, New York
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AN impediment to studies of nuclear phenomena induced by high energy quanta is the fact that artificial sources necessarily give continuous spectra of quanta. Since one must know the x-ray spectrum before one can calculate accurate cross sections from excitation curves,¹ experimental determination of the spectrum is essential to quantitative use of betatrons and synchrotrons. To obtain this, one must employ a process whose cross section as a function of quantum energy is known. The most satisfactory process available is pair production. Several methods for analyzing high energy x-ray spectra have been considered in which the total energies of a large number of positron-electron pairs generated in a suitable target by the x-ray beam are measured, and the resulting number-*vs.*-energy distribution divided by the theoretical total cross section for pair formation. This involves either laborious analysis of thousands of cloud-chamber photographs or elaborate coincidence methods which are difficult when dealing with pulsed radiation with the distribution in time typical of betatron radiation.

This note is to point out that x-ray spectra can be determined without observing both members of each pair. Although the energy of one member of a pair does not determine the energy of the quantum which produced that particular pair, it is possible to calculate statistically the energy distribution of quanta which will produce an observed distribution of positrons. With the need for coincidence or cloud-chamber technique eliminated, more convenient methods can be employed.

The differential cross section for pair production is ordinarily expressed in the form $\psi(u, W)du$ where $u = U/W$, W being the quantum energy and U being the total energy of the positron.² The distribution in u for any given W is roughly independent of u . If one considers the production of positrons with fixed values of U , for example of 20 Mev and of 25 Mev, respectively, it is found that the values of u corresponding to these two positron energies become more and more nearly equal as W increases, hence for W well above the thresholds the respective values of $\psi(u, W)du$ tend toward equality. This is seen more readily by transforming the differential cross section into the form $\psi'(W, U)dW$, when it is found that the curves characterized by different values of the parameter U rise rapidly at first from their respective thresholds, then merge into a slowly varying envelope which is nearly independent of U . The total number of positrons of a given energy U produced by a spectrum whose distribution function is $n(W, E)$, E being the maximum energy, is

$$\pi(U, E) = \int_0^\infty n(W, E)\psi'(W, U)dW.$$

The excess of the number of 20-Mev over 25-Mev positrons, for example, will be almost exactly proportional to the number of quanta lying between about 21 and 26 Mev, because of the peculiar behavior of $\psi'(W, U)$.

If, therefore, one measures the number-energy distribution of positrons, $\pi(U, E)$, produced by x-rays of maximum energy E in a thin target of low atomic number, one can calculate the x-ray spectrum by first differentiating $\pi(U, E)$ with respect to U and then dividing by the envelope of the $\psi'(W, U)$ curves. Having an approximate spectrum (probably correct to within 10 percent except at the high energy tip) one should be able by further analysis to obtain a more accurate spectrum. Calculations to test this point are now being carried out by Drs. R. H. Vought and Leo Seren of this Laboratory, to whom we are grateful for discussions of this method.

We intend to carry out the indicated experiment first in an exploratory way with a cloud chamber and later by an integral method, registering the magnetically analyzed positrons either in a photographic emulsion or by means of counters.

¹ G. C. Baldwin and G. S. Klaiber, *Phys. Rev.* **71**, 3 (1947).
² Bruno Rossi and Kenneth Greisen, *Rev. Mod. Phys.* **13**, 258-261 (1941); H. Bethe and W. Heitler, *Proc. Roy. Soc.* **146**, 83 (1934).

Absorption of Methyl Alcohol and Methylamine for 1.25-Cm Waves

W. D. HERSHBERGER
 RCA Laboratories, Princeton, New Jersey
 AND
 JOHN TURKEVICH
 Frick Chemical Laboratory, Princeton, New Jersey
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FIVE sharp lines in the microwave absorption spectrum of methyl alcohol have been observed and the frequencies in megacycles are given quite accurately by the formula:

$$\nu = \nu_0 + 20m^2,$$

where m is integral and takes on all values from 0 to 4, while ν_0 is 24,930 Mc.

Ten lines in the spectrum of methylamine have been found. Six of these fit the curve

$$\nu = \nu_0 - 32m - 50m^2,$$

but the four remaining lines appear to belong to some other sequence. ν_0 is 25,436 Mc and only the lines for m from 2 to 7 have been observed owing to the limits of operation of the klystron used.

Molecules of this type have been treated as slightly asymmetrical tops with free internal rotation by Nielsen¹ with energy levels given by $F(J, K, K_1, K_2) = BJ(J+1) - K^2B + A_1K_1^2 + A_2K_2^2$ where $K = K_1 + K_2$.

The transition $\Delta J = \pm 1$ gives us frequencies twice as high as those observed; the transition $K=0 \leftrightarrow K=1$ with all other quantum numbers unchanged gives us approximately the observed frequency. For this transition, K , K_1 , and K_2 could not be co-linear.

The rotational constant B of CH_3F lies in the same range as that of the two other molecules named but no absorption lines for this material have been found. The above hypothesis has the advantage of simplicity over one involving the tunnel effect as in ammonia or one involving hindered rotation about a C-N or C-O bond.

¹ H. H. Nielsen, *Phys. Rev.* **40**, 445 (1932).