parallelism of the planes of polarization requires the latter situation. If the bending of the lines of force in a vibration is to be less than 0.2 radians, then it follows from Alfvén's formulas[9] that the connection between the magnetic field and the maximum transverse velocity of the material, v_t, is

$$B > 5v_t(4\pi\rho)^{\frac{1}{2}} \text{ gauss}, \tag{1}$$

where ρ is the density of the interstellar medium. Now v_t is $2^{\frac{1}{2}}$ times the root mean square transverse velocity and is 2 times the root mean square component along the line of sight, which may be taken to be $7\frac{1}{2}$ km/sec on the basis of Adams' measurements[10] of the velocities of discrete clouds of atoms producing the multiple interstellar absorption lines. Thus, take as typical $v_t = 1.5\times 10^6$ cm/sec and $\rho \geqslant 10^{-23}$ g/cm^3 for the clouds of matter producing the lines and those producing the polarization. Then Eq. (1) gives $B \geqslant 10^{-4}$ gauss. Some additional support for such a large value of the magnetic field is given by the fact that in order to explain the observed interstellar polarization Spitzer and Tukey require slightly stronger fields in their detailed theory, while Davis and Greenstein require a field whose minimum value is nearly this large.

The existence of fields of this strength and their dominance over the motion of the interstellar matter indicates that the concept of isotropic turbulence may not apply to the interstellar gas.[8] The various theories of the origin of cosmic rays may also require modification if such field strengths are established.

Many interesting and most helpful discussions with Professor J. L. Greenstein are gratefully acknowledged.

[1] W. A. Hiltner, Science 109, 165 (1949).
[2] J. S. Hall, Science 109, 166 (1949).
[3] J. S. Hall and A. H. Mikesell, Pub. U. S. Naval Obs. 17, Part 1 (1950), see Figs. 4 to 7.
[4] L. Spitzer and J. W. Tukey, Science 109, 461 (1949); Astrophys. J., to be published.
[5] L. Davis and J. L. Greenstein, Phys. Rev. 75, 1605 (1949).
[6] H. Alfvén, *Cosmical Electrodynamics* (Oxford University Press, 1950).
[7] E. Fermi, Phys. Rev. 75, 1169 (1949).
[8] A. Schlüter and L. Biermann, Z. Naturforsch. 5a, 237 (1950).
[9] Reference 6, p. 80.
[10] W. S. Adams, Astrophys. J. 97, 105 (1943).

Scintillation Pulse Sizes of Solid Noncrystalline-Type Phosphors

M. G. Schorr and E. C. Farmer
Physics and Electronics Section, Tracerlab, Inc., Boston, Massachusetts
January 2, 1951

SINCE the initial report[1] on the solid noncrystalline-type phosphor, a more careful investigation of the relative pulse sizes from these scintillation materials under different types of radiation has been made. The solid phosphors are prepared by method (2) as given in reference 1. For some applications where large light pulses are not required, the plastic phosphor offers several advantages.

Measurements have been made using a Jordan-Bell type amplifier with a 0.2-μsec rise time. Data were taken utilizing three different photo-multiplier tubes: RCA 5819, 1P21, and 1P28 at fixed tube voltages and at room temperature. All samples studied were 5 mm thick. Integral bias curves were obtained and then analyzed to give average pulse sizes. Here the average pulse height results are proportional to the area under the integral bias curves divided by the extrapolated counting rates. Table I summarizes some representative values obtained in this fashion using several of each of the different type photo-tubes and different samples of plastic phosphor. The stilbene used in the experiments was purified and grown in our laboratories. Also included are values for a typical liquid phosphor. The results of other authors are included for comparison.

Although Kallmann's value represents integrated output current, it is included here because it should also be proportional to average pulse size. Of particular interest from the table is the relative improvement of the plastic phosphor on using the ultraviolet sensitive photo-multiplier tubes. A rough analysis of these

TABLE I. Ratios of pulse heights of several phosphors.

Tube type	Stilbene/1 percent terphenyl in plastic β's and γ's	Stilbene/1 percent terphenyl in plastic Po-α's	Anthracene/1 percent terphenyl in xylol β's and γ's	Anthracene/stilbene β's and γ's
RCA 5819	6.0	3.5	7.3	1.8
Harrison[a]			2.9	
Hofstadter[b]				1.67
RCA 1P21	3.5		2.5	1.3
Harrison[a]			2.0	
Montgomery[c]			3.3[e]	
RCA 1P28	3.4		2.3	1.2
Harrison[a]			1.5	
Kallmann[d]			2.2	

[a] See reference 2.
[b] R. Hofstadter, Nucleonics, p. 69 (May, 1950).
[c] C. G. Montgomery and D. D. Montgomery, Phys. Rev. 80, 757 (1950).
[d] H. Kallmann and M. Furst, Phys. Rev. 79, 857 (1950).
[e] This value for both cosmic particles and gamma-rays.

data based on the average spectral responses of the three different type photo-multiplier tubes yields an emission maximum of about 3700A for the plastic phosphor, which is in good agreement with the emission spectra of terphenyl liquids as reported by Harrison.[2] However, work is in progress to obtain more accurate emission data. Further, it is estimated that for the light geometry employed that each Sr-90 beta-particle results in the emission of about 6 photo-electrons at the photo-cathode of the RCA 5819 tube as compared with 63 for anthracene. One could expect to improve these figures by a factor of two with better optical coupling. Also, our investigations indicate that the pulse size increases with increase in degree of polymerization.

Since one possible application of the plastic phosphor would lie in the use of very large samples, the light pulses from a long rod (3 cm diam$\times$20 cm) has been studied under irradiation from a beta-source. Preliminary results give total light transmitted through 20 cm of material about $\frac{1}{4}$ that of the light generated near the photo-tube end of the rod with a corresponding loss in counting efficiency.

Information on both the "long rod" experiments and studies on the effect of polymerization will be reported at a later date.

[1] M. G. Schorr and F. L. Torney, Phys. Rev. 80, 474 (1950).
[2] F. G. Harrison and G. T. Reynolds, Phys. Rev. 79, 732 (1950).

Gamma-Ray Spectrum of K^{40}†

Myron L. Good
Department of Physics, Duke University, Durham, North Carolina
December 4, 1950

THE gamma-ray spectrum of K^{40} has been measured using a scintillation spectrometer. The crystal was a one-inch cube of NaI-Tl mounted as shown in Fig. 1. A modified Jordan and Bell pulse amplifier and an electronic differential pulse height discriminator were employed. Amplifier gain and discriminator window width were monitored by a pulse generator, the pulse

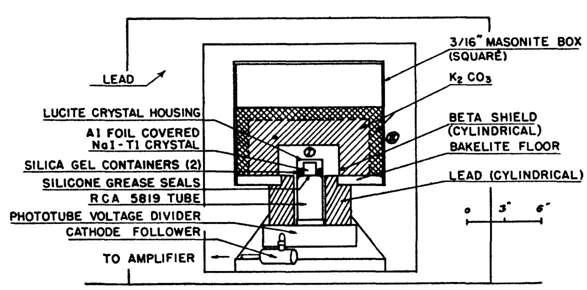

FIG. 1. Arrangement of crystal, sources, and photo-tube. In this experiment the entire cross-hatched region was filled with K_2CO_3.

voltage measurement being made by a standard cell potentiometer which also served to monitor the photo-tube supply voltage.

The source of K^{40} was 25 lb of normal potassium carbonate in a box surrounding the crystal housing (Fig. 1). The beta-shield was 1.5-mm brass in this experiment. For comparison spectra, Co^{60} and Zn^{65} were used. They were placed at position *I* (Fig. 1) to minimize scattering effects.

Photo-tube gain was monitored during the data run by means of a standard source of gamma-radiation placed at position *II*. Gain shifts of one or two percent were encountered and corrected.

The differential pulse height distributions of Zn^{65}, Co^{60}, and K^{40} were recorded, corrections being made for amplifier linearity and window width variations. The K^{40} background was subtracted from the comparison spectra. For the K^{40} itself, background was negligible. The data (Fig. 2) show photo-electron lines well resolved from the Compton distributions. The annihilation quanta of the ($\approx$3 percent abundant) positrons[1] of Zn^{65} yield a prominent photo-electron line (P_2). The Compton edge is lost in the counts arising from backscattered radiation. The photo-electron line

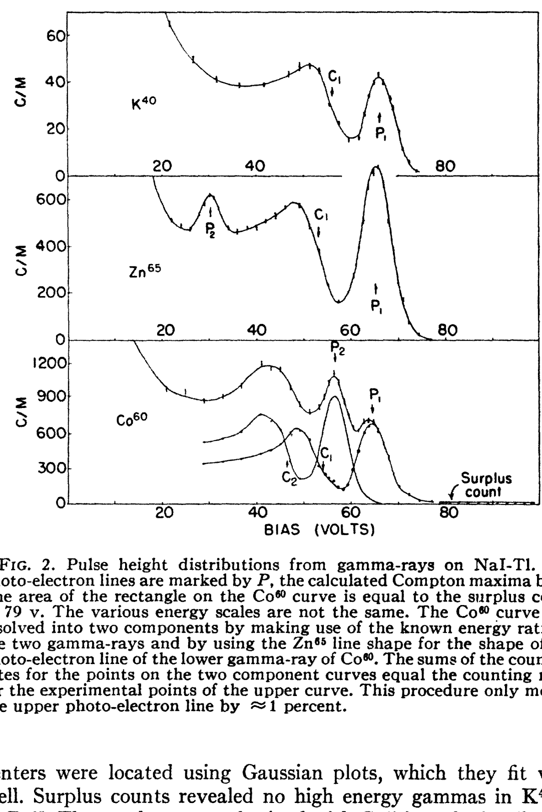

FIG. 2. Pulse height distributions from gamma-rays on NaI-Tl. The photo-electron lines are marked by *P*, the calculated Compton maxima by *C*. The area of the rectangle on the Co^{60} curve is equal to the surplus count at 79 v. The various energy scales are not the same. The Co^{60} curve was resolved into two components by making use of the known energy ratio of the two gamma-rays and by using the Zn^{65} line shape for the shape of the photo-electron line of the lower gamma-ray of Co^{60}. The sums of the counting rates for the points on the two component curves equal the counting rates for the experimental points of the upper curve. This procedure only moved the upper photo-electron line by $\approx$1 percent.

centers were located using Gaussian plots, which they fit very well. Surplus counts revealed no high energy gammas in K^{40} or in Zn^{65}. The surplus count obtained with Co^{60} is undoubtedly due to coincident counting of the two cascade gammas. Using the Co^{60} upper gamma-ray as standard[2] at 1.332±0.001 Mev, the energies determined from these curves are:

K^{40}: 1.459±0.007 Mev

Zn^{65}: 1.127±0.009 Mev (accepted value[3] 1.118 Mev).

This work was performed independently and confirms the results of the nearly identical experiment of Bell.[4] Bell obtained 1.462±0.01 Mev for the K^{40} gamma-ray energy.

The measured energy of the annihilation quantum line (0.520 Mev) is a little larger than the accepted value (0.511 Mev), probably because of the shape of the large background on which the line stands. This is analogous to the effect reported by Bell[5] in which m_0c^2, as determined by subtracting pair-peak from photo-peak energies, is consistently too low.

The error given for K^{40} is smaller than that for Zn^{65} because in the case of K^{40}, the comparisons to the standard source were made without turning the tube off, and hence are more consistent. About two-thirds of the errors arise from tube gain shifts.

The author wishes to express his indebtedness to Drs. Walter M. Nielsen and Henry W. Newson for their cooperation in this work.

† This work was supported in part by joint contract with ONR and AEC.
1 W. M. Good and W. C. Peacock, Phys. Rev. **69**, 680 (1946).
2 Lind, Brown, and DuMond, Phys. Rev. **76**, 591A, 1838 (1949).
3 Jensen, Laslett, and Pratt, Phys. Rev. **76**, 430L (1949).
4 Bell and Cassidy, Phys. Rev. **79**, 173L (1950).
5 Bell, Science **112**, 7 (1950).

The Fast Neutron Disintegration of C^{12} and B^{10}

J. L. PERKIN
Wheatstone Physics Laboratory, King's College, London, England
January 8, 1951

BORON-LOADED nuclear research emulsions were exposed to neutrons with energies extending up to 24 Mev. The neutrons were produced from a lithium target bombarded by 7-Mev deuterons from the Cavendish Laboratory cyclotron.

Calculations similar to those described by Green and Gibson[1] were carried out to identify the 700 disintegration stars observed in the emulsion with the following results: (a) 485 stars caused by the $C^{12}(n, n)3\alpha$ reaction, (b) 100 stars caused by the $B^{10}(n, H^3)2\alpha$ reaction, (c) 35 stars which could have been caused by either reaction, (d) 80 stars which did not satisfy either of the calculations.

The disintegration of the compound nuclei C^{13} and B^{11} formed in these reactions may proceed through a number of possible intermediate stages. If the experimental values for the energies of the emitted particles are used, the excited states of the nuclei involved in these various possible modes of disintegration can be calculated for each star. Comparison of the results with the values of the excited states found in previous experiments[2] shows that most, if not all, of the disintegrations proceeded via an intermediate stage involving the Be^8 nucleus.

A histogram of the values of the excited states of Be^8 for the $B^{10}(n, H^3)2\alpha$ reaction is shown in Fig. 1(a). Although statistically weak, the histogram does indicate levels at points previously reported.

The results for the reaction $C^{12}(n, n)3\alpha$ are complicated by the fact that the identities of the two α-particles associated with the disintegration of the intermediate nucleus Be^8 are not known. If all possible values for the energy of the excited state of Be^8 are plotted (i.e., three per star), the significant values appear as peaks on a continuous background at points known from other

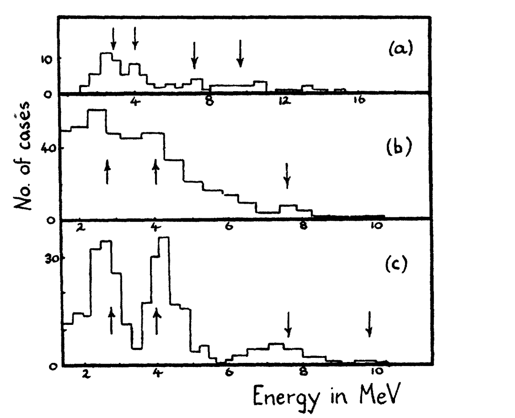

FIG. 1. Excited states of the intermediate nucleus Be^8: (a) from the reaction $B^{10}(n, H^3)2\alpha$, (b) from the reaction $C^{12}(n, n)3\alpha$ (all possible values), (c) from the reaction $C^{12}(n, n)3\alpha$ (unique values). The arrows refer to the values of the excited states previously known.