DECAY TIME OF THE LUMINESCENCE OF A ZINC SULPHIDE NEUTRON DETECTOR FOR NEUTRON AND γ-RAY EXCITATION*

By G. M. Bailey† and J. R. Prescott‡

In experiments being conducted in this laboratory on $(d,n\gamma)$ reactions using fast coincidence techniques, an attempt was made to use phosphors containing zinc sulphide as the neutron detector.

When it was found that this type of detector did not produce the discrimination expected between neutrons and γ-rays, its response to both types of radiation was investigated in detail.

Experimental Technique

The neutron detector consisted of ZnS(Ag)§ moulded in a Lucite cylinder 1 in. in diameter by ¾ in. thick (Hornyak 1952), mounted directly on the face of a photomultiplier tube. Dumont 6292 and R.C.A. 6342 tubes were used, the first chosen for its low noise level, the second for its faster response.

A direct decay measurement for γ-excitation using a small photomultiplier collector time constant was not possible owing to the small pulse size obtained and the presence of a large background due to the long-term phosphorescence of the phosphor. Instead, the decay time was determined from a measure of the integrated pulse rise time.

The collector current pulses from individual scintillations were integrated by a long time constant ~ 10 μsec, and fed from a cathode follower into two cascaded wide band amplifiers (total rise time $3\cdot 6$ mμsec), and finally into the vertical amplifier of a Tektronix 545 oscilloscope (rise time 12 mμsec). Pulse rise times were determined photographically from a short time exposure spectrum. The oscilloscope sweep was later calibrated using a 10 Mc/s oscillator.

The form of the output pulse appearing across the load R, for an exponentially decaying scintillator having a time constant T, when $RC \gg T$, is

$$V_0(t) = (i_0 T/C)[1 - \exp(-t/T)], \quad \ldots \ldots \ldots \ldots (1)$$

C being the stray capacitance of the collector circuit to ground. The rise time (10–90 per cent.) of such a pulse is $2\cdot 2T$. Allowance must be made for the

apparatus rise time T_a, and, if T_m is the measured rise time, it can be assumed that

$$T_m^2 = T_a^2 + K^2 T^2, \ldots\ldots\ldots\ldots\ldots \quad (2)$$

K being a constant approximately equal to the theoretical value $2 \cdot 2$. If relation (2) is valid, a plot of $\log (T_m^2 - T_a^2)$ against $\log T^2$ for different exponentially decaying scintillators should be a straight line of slope 1, and intercept $\log K^2$ on the $\log (T_m^2 - T_a^2)$ axis.

The validity of this expression was tested by measuring the rise times of several organic scintillators which have known decay constants. The results are shown plotted in Figure 1; the points lie closely on a straight line of slope 1 as predicted. The value of K is found to be $2 \cdot 1$.
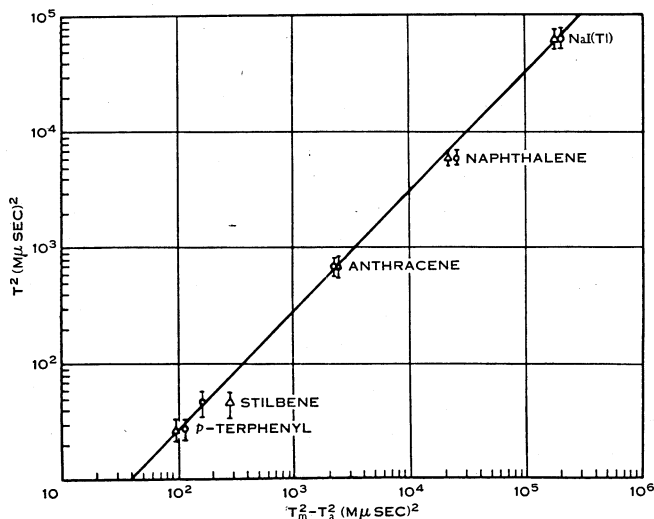

Fig. 1.—Square of scintillator decay time plotted as a function of square of effective rise time, for a number of scintillators under γ-ray excitation. $\triangle$ Dumont 6292 ; $\bigcirc$ R.C.A. 6342.

In choosing the value of the decay constants for the various scintillators it was realized that the physical dimensions could be of importance (Birks and Little 1953). This factor largely determines the variance of values quoted in the literature. A large variance was evident in the case of naphthalene and anthracene and so these were measured using the technique of Bittman, Furst, and Kallmann (1952). In the other cases the mean of values quoted by Liebson, Bishop, and Elliot (1950), Lundby (1950), Bittman, Furst, and Kallmann (1952), and Swank and Buck (1955) was used.

Decay of ZnS(Ag)+Lucite for γ-Ray Excitation

Measurements of pulses from the detector when excited by γ-rays from ^{60}Co indicated a fast decay. The resulting decay constants for the two tubes used, taken from the calibration line, were Dumont 6292 : $8 \cdot 4 \pm 2 \cdot 3$ mμsec,

R.C.A. 6342 : $8 \cdot 5 \pm 2 \cdot 7$ mμsec, giving a mean of $8 \cdot 5 \pm 2 \cdot 5$ mμsec. The accuracy of the measurements of rise times was limited by the fluctuating nature of the pulses, due partly to the long-term phosphorescence of the ZnS(Ag) and partly to the superimposed photomultiplier noise ; this latter effect being more noticeable with the 6342 tube.

Decay of the Scintillator for 2·6 MeV Neutrons

Using neutrons produced by the ^{2}H(^{2}H,n)^{3}He reaction from the University of Melbourne 750 keV electrostatic generator and the technique described above, it was found that the pulse rise time from the zinc sulphide was very much slower than that observed for γ-rays. On account of the relatively slow decay, a direct measurement of the decay form was possible.

The decay appeared complex, but from a number of photographs of the decay it was found to be satisfactorily represented by a combination of two exponential decay regions, together with a very much longer decaying tail of a few microseconds. No initial fast decay component was observed, and the results gave decay constants : $0 \cdot 13 \pm 0 \cdot 02$, $0 \cdot 34 \pm 0 \cdot 04$ μsec for 2·6 MeV neutrons.

On closer analysis a hyperbolic decay for the light intensity of the form

$$I(t) = I_0/(1+kt)^\beta \quad \dots\dots\dots\dots\dots\dots \textbf{(3)}$$

could be fitted to the results for the first microsecond over which it was estimated 75 per cent. of the total light intensity was emitted. The exponent β was found to be closely one.

Conclusions

The decay time of a ZnS(Ag)+Lucite neutron detector has been reported to have a principal decay constant of 40 mμsec for fast neutrons, whilst ZnS(Ag) in powder form has this same decay time for γ- and α-particle excitation (Koontz 1953 ; Koontz, Keepin, and Ashley 1955).

The results obtained for neutron excitation, whilst being in disagreement with Koontz, agree with the decay form observed by several investigators for α-particle excitation of ZnS(Ag) (Bittman, Furst, and Kallmann 1952 ; Hornyak 1952 ; Emmerich 1954 ; Smidt 1955). This is to be expected since the detection process takes place mainly from (n,p) scattering in the Lucite, and the ^{32}S(n,p)^{32}P reaction in the phosphor.

The rapid decay for γ-bombardment has been noted by Emmerich (1954), and points to the absence of the slow recombination process between diffusing positive holes and electrons which takes place when the phosphor is excited by highly ionizing particles (Smidt 1955).

References

BIRKS, J. B., and LITTLE, W. A. (1953).—*Proc. Phys. Soc. Lond.* A **66** : 921.

BITTMAN, L., FURST, M., and KALLMANN, H. (1952).—*Phys. Rev.* **87** : 83.

EMMERICH, W. S. (1954).—*Rev. Sci. Instrum.* **25** : 69.

HORNYAK, W. F. (1952).—*Rev. Sci. Instrum.* **23** : 264.

KOONTZ, P. G. (1953).—A.E.C.U. Rep. 2913.

KOONTZ, P. G., KEEPIN, G. R., and ASHLEY, J. E. (1955).—*Rev. Sci. Instrum.* **26** : 352.

LIEBSON, S. H., BISHOP, M. E., and ELLIOT, J. O. (1950).—*Phys. Rev.* **80** : 907.

LUNDBY, A. (1950).—*Phys. Rev.* **80** : 477.

SMIDT, V. D. (1955).—*Ann. Phys., Lpz.* **15** : 325.

SWANK, R., and BUCK, W. (1955).—*Rev. Sci. Instrum.* **26** : 15.