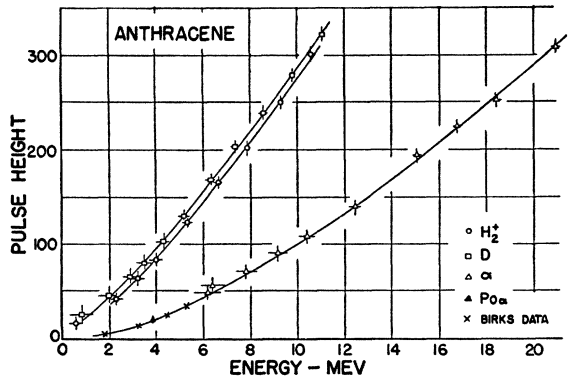

FIG. 1. Response of anthracene to molecular hydrogen ions, deuterons, and alpha-particles. Note that the molecular hydrogen ions are detected as two protons entering the crystal simultaneously.

amplified by a Los Alamos model 100 linear pulse amplifier and analyzed with a twelve-channel pulse amplitude analyzer. Essentially gaussian distributions were obtained with full widths at half-maxima of six to eight percent for the higher energy particles. The determination of the maximum energy of the incident particles accurate to one percent was obtained by measurement of the ranges in air.

The variation of the peak pulse height with energy for the different particles and crystals used is shown in Figs. 1 to 3. The vertical lines indicate estimates of the errors in the pulse heights. As the energy of the particles is reduced by the introduction of absorbers, the initial one percent uncertainty in the maximum energy produces progressively larger uncertainties in the calculated energies of the lower energy particles. The horizontal lines attached to the points show the total variation in energy at a given energy corresponding to a variation of one percent in the initial energy. These are not to be interpreted as errors in the determination of the energies, but rather as the amount by which the entire curve would be translated in energy for a one percent change in the initial energy.

The figures show a distinct difference in the behavior of the organic crystals and sodium iodide. The organic crystals have a nonlinear response of pulse height to energy in the entire region investigated. In sodium iodide protons and deuterons give linear response, while alpha-particles show a nonlinear relation over a low energy region with a linear response above an energy of about 10 Mev. This nonlinear response of the sodium iodide is certainly not due to deterioration of the crystal surface as has been proved by experiments with crystals freshly cleaved in a vacuum.

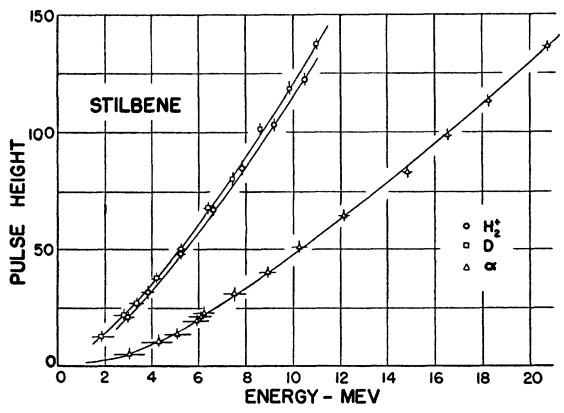

FIG. 2. Response of stilbene to molecular hydrogen ions, deuterons, and alpha-particles. The arbitrary pulse-height scale is the same as in Fig. 1.

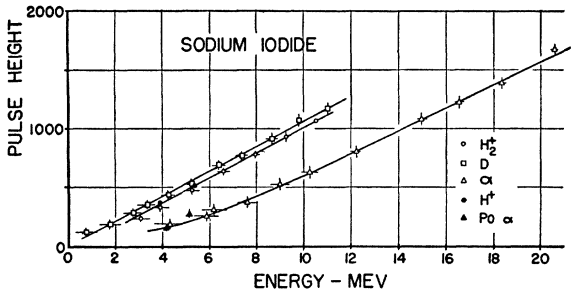

FIG. 3. Response of thallium activated sodium iodide to molecular hydrogen ions, deuterons, and alpha-particles. The arbitrary pulse-height scale is the same as in Figs. 1 and 2.

A detailed analysis shows the nonlinearity to be dependent on the ionization density produced by the incident particle. For high specific energy losses, as for example for alpha-particles below 9 Mev, the specific fluorescence (the number of light quanta emitted per centimeter of air equivalent) attains a constant value and is then independent of the specific energy loss.[5]

While this letter was being written, the work of Frey, *et al.*,[6] was reported, which agrees with the results described here.

The authors wish to thank A. L. Atkins, R. O. Kerman, and W. E. Kreger, who determined the cyclotron beam energy.

A more detailed analysis of the data presented here will be published later.

* Assisted by the joint program of the ONR and AEC.
† Now at North American Aviation, Inc.
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The Fluorescence Efficiencies of Some Crystals for Electrons and Heavy Particles*

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THE investigation described in the preceding paper was extended to a study of the fluorescence of anthracene, stilbene, and thallium activated sodium iodide crystals with incident monoenergetic electrons. This extension was particularly directed toward an investigation of the fluorescence efficiency of crystals to electrons as compared to heavy particles with the same specific energy loss. For this reason, electrons with energies of 500 to 5000 ev were used. A pulsed monoenergetic electron beam was provided by a specially constructed cathode-ray gun for examination of this region. The electron beam was focused on the crystal which was mounted on the end of a charge collector. This collector was connected to a vibrating reed electrometer.[1]

The electron beam was pulsed at a rate of ten thousand per second with pulse durations of 0.5 and 2.0 microseconds. Identical results were obtained with both types of pulses, indicating that no long-lived fluorescence of appreciable intensity could have been present. The maximum electron beam current was less than 5×10^{-13} ampere, so that no more than 300 electrons were incident on the crystal during any single pulse. Since the electron beam was defocused over an area of 4 mm² on the crystal, the mechanism for producing fluorescence was the same as for single electrons. The secondary emission coefficients of the crystals used are greater than one for the electron energies investigated, so that no sig-

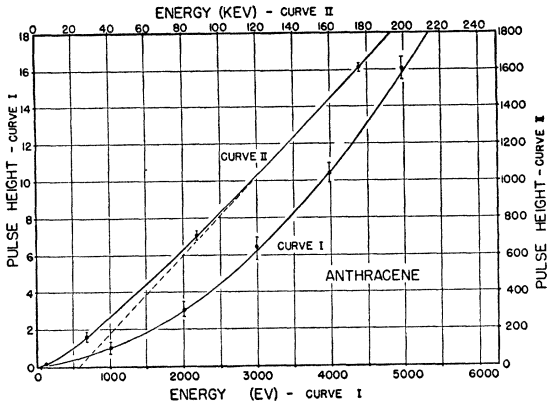

FIG. 1. Response of anthracene to electrons.

nificant charge collection should occur on these insulating crystals. The number of elastically scattered electrons which do not contribute to the pulse height was less than ten percent. The measured pulses were normalized using the conversion electrons of a Cs^{137} source which could be located with the same geometry as the electron beam.

Amplified pulses from the RCA 5819 photomultiplier tube were photographed on a Tektronix high speed oscilloscope. To extend the data of these low energy electrons, internal conversion electrons with energies from 27 kev to 624 kev were obtained from radioactive sources of Te^{127}, Nb^{91}, Hg^{203}, In^{114}, and Cs^{137}. The pulses from these electrons were analyzed with a twelve-channel pulse amplitude analyzer.

The pulse height *vs* energy curves are given in Figs. 1 and 2. The linear portions of the curves for anthracene and stilbene extrapolate to an intercept of about 22 kev on the energy axis, this agreeing with Hopkins' investigation of anthracene.[2] Sodium iodide shows a linear response throughout the energy region from 1000 ev to 624 kev, in agreement with the Stanford group,[3] while below 1000 ev there are indications of a small deviation from linearity.

The response of the anthracene crystal, whose behavior is probably typical of the organic crystals, to different ionizing radiation has been compared in Fig. 3 by considering the variation of the specific fluorescence dL/dx (expressed in arbitrary units per cm air equivalent) with the specific energy loss.

Both the heavy particles and electrons seem to give a region of linear response (the specific fluorescence increasing linearly with energy) but starting at quite different values of dE/dx. At some larger dE/dx, the response becomes nonlinear for both types of particles, and at even larger values of dE/dx the specific

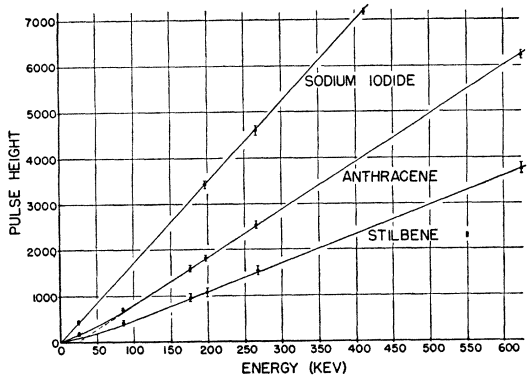

FIG. 2. Response of anthracene, stilbene, and sodium iodide to electrons.

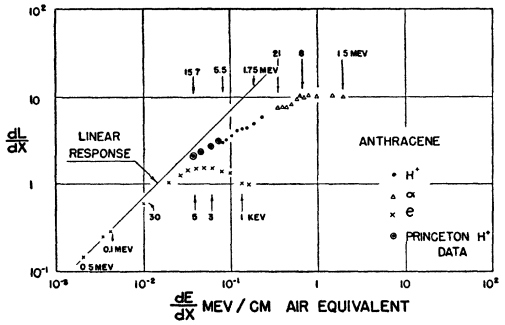

FIG. 3. Dependence of the fluorescence efficiency upon the specific energy loss for heavy particles and electrons in anthracene.

fluorescence saturates. The data for electrons of less than 1000 ev indicate a decrease in dL/dx, but these effects might be due to surface influences of the crystal since the range of a 1000-ev electron in anthracene is only 2.5×10^{-6} cm. However, we do not believe that the different results for the electrons and heavy particles could be due to surface effects, since x-rays of 27 kev which produce electrons inside the crystal gave agreement with the above results.

The valuable assistance of Mr. Chester Lob and the use of the facilities of the Tube Laboratory of the Electrical Engineering Department are deeply appreciated. A complete account of this work will appear at a later date.

* Assisted by the joint program of the ONR and AEC.
† Now at North American Aviation, Inc.
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Coherent Neutron Scattering Cross Section of V^{51}*

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ALTHOUGH the total thermal neutron scattering cross section for vanadium is 5.0 barns, comparable to other nuclei, the coherent part, σ_{coh}, is an order of magnitude less than any other nucleus studied. Shull and Wollan[1] give $\sigma_{coh}<0.1$ barn, since it was too low to be measured by diffraction methods. As V is monoisotopic (spin 7/2), this almost complete incoherence can be accounted for by assuming the two spin scattering amplitudes ($J=3$, $J=4$) times their weight factors ($\frac{7}{16}$, $\frac{9}{16}$) to be equal in magnitude and opposite in sign. Hamermesh and Muehlhause[2] have computed $\sigma_{coh}=0.03b$ (negative phase) using data on the 2700-ev scattering resonance.[3]

The coherent cross section has been determined by the total reflection of a thermal neutron beam from a mirror surface of vanadium. Using a technique previously described by one of us[4] σ_{coh} was compared to σ_{coh} of N_2 ($=9.1$ barns)[1] by observing the decrease in reflectivity as the pressure of nitrogen gas surrounding the mirror was increased until its index of refraction equaled the index of refraction of vanadium, giving no reflection. The difference from unity, δ, of the index of refraction of solids is given by

$$\delta=n\sigma_{coh}{}^{\frac{1}{2}}\lambda^2/4\pi^{\frac{1}{2}},$$

where n=number of nuclei/cc. This formula has been verified for gases.[5]

Figure 1 shows the reflection from a 1-min wide beam, incident at ~2.5 min on a 2.5-in. diameter mirror at different gas pressures. In Fig. 2 is shown the reflected intensity of the entire beam,