$\gamma$-rays. Calculations now under way confirm this expectation. Owing to the higher efficiency of counters for electrons than $\gamma$-rays, such correlations may be easier to observe experimentally.

* This work was carried out while one of us (G.G.) held a fellowship from the Radio Receptor Company, Inc., of New York.

[1] D. R. Hamilton, Phys. Rev. **58**, 122 (1940).

[2] R. Beringer, Phys. Rev. **63**, 23, (1943); Y. Watase, Proc. Phys. Math. Soc. Japan **23**, 618 (1941); S. Kikuchi, Y. Watase, and J. Itoh. Zeits. f. Physik **119**, 185 (1942).

[3] E. U. Condon and G. H. Shortley, *Theory of Atomic Spectra* (The Cambridge University Press, New York, 1935).

[4] W. Heitler, Proc. Camb. Phil. Soc. **32**, 112 (1936).

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## Effect of Absorption on Decay of Infra-Red Sensitive Phosphors*

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THERE have been different opinions expressed regarding the order of the process involved in the decay of infra-red sensitive phosphors.[1] Urbach and Ward presented some evidence from excitation and exhaustion curves that the process was of the second order for alkaline earth sulfides and selenides. Fonda reported that there was evidence that the decay of the natural phosphorescence of ZnS was according to a second-order process while the decay of the phosphorescence due to infra-red stimulation was according to a first-order process.

By taking into account the absorption of the incident infra-red and the emitted visible light, we have derived an equation for the decay curve under infra-red stimulation. The derivation is based on a second-order process and is similar to one made by de Groot[2] for the decay of the luminescence of ZnS. The usual expression for a second-order process is $B=B_0(1+\alpha t)^{-2}$ where $B$ is the brightness, $B_0$ is the initial brightness, and $\alpha$, in our case, is proportional to the infra-red intensity, the infra-red absorption coefficient, and the quantum efficiency. Because of absorption, $\alpha$ has a different value at different depths in the phosphor and the simple equation above should be replaced by

$$B(t)=B_0\int_0^\infty \frac{\exp\left[-(\mu_1+\mu_2)x\right]}{(1+\alpha t\exp\left[-\mu_1 x\right])^2}dx, \tag{1}$$

where $\mu_1$ and $\mu_2$ are the absorption coefficients for infra-red and visible light. By a simple change of variable, Eq. (1) becomes

$$B(t)=B_0\frac{P+1}{(\alpha t)^{P+1}}\int_0^{\alpha t}\frac{y^P}{(1+y)^2}dy, \tag{2}$$

where $p=\mu_2/\mu_1$.

It is easily shown that the slope of a logarithmic plot of the decay curve at large values of the time is $-(p+1)$ if $p\leqslant 1$. This explains the failure of our decay curves to give the value of $-2$ for this slope as required by the simple theory.

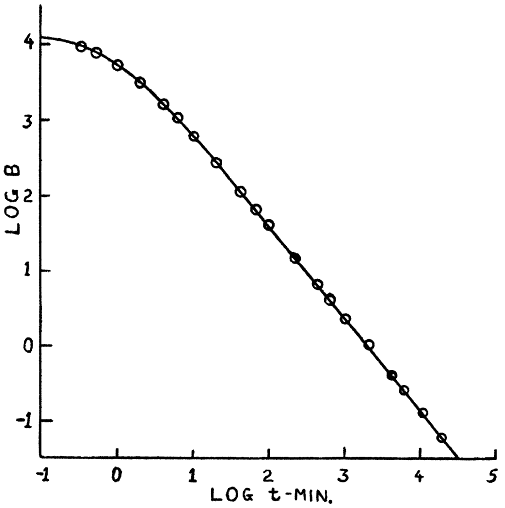

FIG. 1. Decay in brightness of strontium selenide-samarium-europium phosphor under infra-red stimulation.

Figure 1 shows the decay in brightness of a strontium selenide-samarium-europium phosphor under infra-red stimulation. The curve is calculated from Eq. (2) with $B_0=13{,}800$, $\alpha=1.30$, and $p=0.25$ for which Eq. (2) becomes

$$B=13{,}800\frac{1.25}{(1.3t)^{1.25}}\left[\frac{1}{4\sqrt{2}}\ln\frac{(1.3t)^{\frac{1}{2}}+\sqrt{2}(1.3t)^{\frac{1}{4}}+1}{(1.3t)^{\frac{1}{2}}-\sqrt{2}(1.3t)^{\frac{1}{4}}+1}\right.$$
$$\left.+\frac{1}{2\sqrt{2}}\tan^{-1}\frac{\sqrt{2}(1.3t)^{\frac{1}{4}}}{1-(1.3t)^{\frac{1}{2}}}-\frac{(1.3t)^{\frac{1}{4}}}{(1+1.3t)}\right].$$

No precise measurements of the absorption coefficients have been made, so it is not possible for us to check the value of 0.25 obtained here for $p$. The excellent agreement with the experimental data leads us to believe that the form of the equation is essentially correct.

The details of the calculation will be submitted for publication in the very near future.

* The work described in this letter was carried out under Contracts OEMsr 982 and NObs 28370 between the Polytechnic Institute of Brooklyn and the Office of Scientific Research and Development, and the Bureau of Ships, respectively.

[1] See the reports of Urbach, Ward, Fonda, *et al.*, Report of the March, 1946 meeting of the Optical Society of America at Cleveland, Ohio.

[2] W. de Groot, Physica **7**, 432 (1940).

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## The Origin of the Synchrotron

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April 18, 1946

A RECENT letter by Veksler[1] has made me aware of the fact that the failure to refer to his previously published work in my letter on the synchrotron[2] may have created an unfortunate impression. The reason for this failure is simply that I was entirely ignorant of his work until it was pointed out to me near the end of October, after my letter had appeared.

This seems to be another case of the independent occurrence of an idea in several parts of the world, when the time is ripe for the idea. The present great interest in very high energy particles furnished the need for new methods of acceleration, and the principle of phase stability applied to cyclotron-like devices is a promising solution. Since my first thoughts on the subject occurred near the beginning of July, 1945, it is clear that Veksler's discovery of the principle was earlier.

[1] V. Veksler, Phys. Rev. **69**, 244 (1946).

[2] E. M. McMillan, Phys. Rev. **68**, 143 (1945).