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Role of Oxygen in the Quenching of Liquid Scintillators

H. H. Seliger, C. A. Ziegler, and I. Jaffe
National Bureau of Standards, Washington, D. C.

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The quenching effects of oxygen on the light outputs of several organic liquid scintillators have been compared under conditions of high-energy gamma irradiation and direct light excitation of the solute. The reduction by oxygen of the light output has been found to be primarily due to solute quenching. Results are obtained which support the collision-transfer mechanism proposed by Kallmann.

We have investigated the quenching effects of oxygen[1] in the liquid scintillators 2,5-diphenyloxazole/xylene and α-napthylphenyloxazole/xylene and have found evidence that the quenching of the light output is primarily a *solute* quenching effect. This is not in complete agreement with the work of other investigators.[2-4]

Oxygen-free solutions of 2,5-diphenyloxazole and α-napthylphenyloxazole, respectively, in xylene were prepared by vacuum distillation and flame sealed *in vacuo*, eliminating the uncertainties in gas removal inherent in the nitrogen and argon bubbling techniques. These solutions were then compared under light-excitation directly with solutions in which the dissolved oxygen content corresponded to equilibrium with dissolved air.

The solutions were irradiated with light in an arrangement shown in Fig. 1. The transmission spectra of the filter combinations used, shown in Fig. 2, were such that only the solute molecules could be excited and only the solute emission could be observed by the Dumont 6292 multiplier phototube used as the detector. The integrated current output from the phototube was taken to be a measure of the light output. The light incident on the solutions was confined to the spectral range 3500 A–4200 A. This is well above the absorption spectrum of xylene. In fact, only the long wavelength edge of the solute was excited. The light incident on the phototube was cut off below 4000 A by a filter to reduce stray scattering and reflection effects.

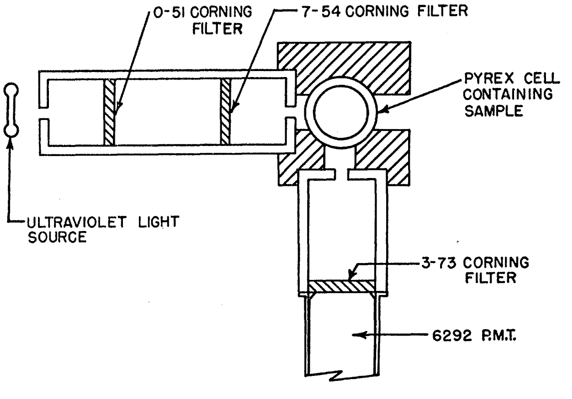

Fig. 1. Schematic drawing of light-excitation experiment.

Figure 3 shows the relative light output *versus* concentration curves for 2,5 diphenyloxazole in xylene solutions under irradiation by light 3500 A–4200 A. The solid curves are for air-saturated solutions at 28°C and the dashed curves are for air-free solutions. Oxygen is seen to produce an appreciable quenching effect under excitation conditions where only the *solute* can be excited. This was also confirmed for α-napthylphenyloxazole/xylene although the magnitude of the effect was different.

The concentrations at peak light output are roughly 20 times greater for the light excitation case than have been reported by Kallmann[2,3] for gamma-ray excitation (in which the solvent is mainly excited). As a check of the solutions, concentration curves for Ba^{137} gamma-ray excitation were obtained and are also shown in Fig. 3. The peak concentrations in this case agree with Kall-

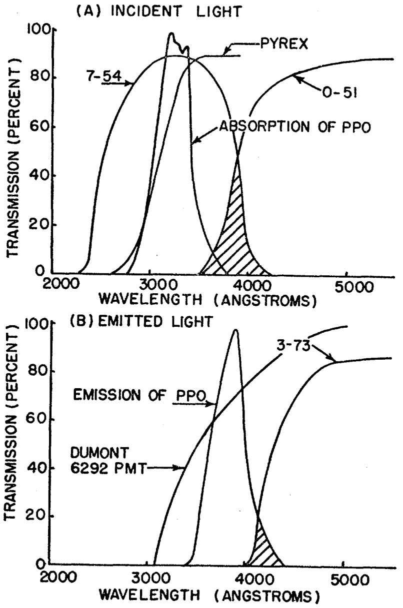

Fig. 2. Effective spectral ranges covered by the present experiments. (A) The shaded region shows the spectral range of the light exciting the solutions. (B) The shaded region shows the spectral range of the observed emission.

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[1] E. J. Bowen and A. Norton, Trans. Faraday Soc. **35**, 44 (1939).

[2] M. Furst and H. Kallmann, Phys. Rev. **97**, 583 (1955).

[3] H. Kallmann, U. S. Army Signal Corps Progress Report, February 1955 (unpublished).

[4] F. N. Hayes, Los Alamos Report LA-1837, October, 1954 (unpublished).

mann's data. In the gamma-ray measurements the pulse-height distribution and the discrimination level were such that the integral of the pulse-height distribution was an acceptable index of the relative light output, as verified by Liebson.[5] The filter arrangement of Fig. 1 was not used.

The relative increases in light output (at the various solute concentrations) due to oxygen removal are the same for light excitation as for gamma-ray excitation within the accuracy of the measurements. On the basis, we attribute the oxygen-quenching effect to occur in the *solute*.

The data of Fig. 3 permits us to infer something in addition concerning the mechanism of the solvent-to-solute energy transfer. If the energy transfer were by means of solvent photon emission and subsequent solute absorption as proposed by Birks,[6] the concentrations at peak light output should be the same, independent of the method of excitation. The widely different peak-concentrations observed tend to support the collision-transfer mechanism suggested by Kallmann. The evidence is not entirely conclusive, however, since the spectrum of the exciting light used in these experiments was not identical to the emission spectrum of xylene.

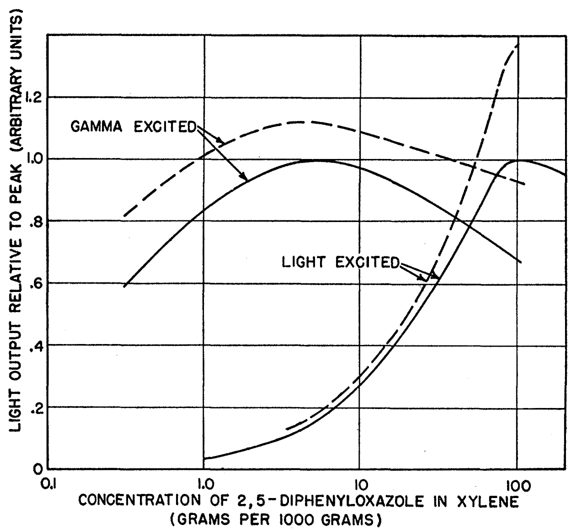

FIG. 3. Light output *versus* concentration curves for air-saturated and air-free 2,5 diphenyloxazole in xylene under gamma ray and under light-excitation. The solid lines are for air-saturated solutions and the dashed lines are for air-free solutions.

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[5] S. H. Liebson, Nucleonics **10**, 7, 41 (1952).

[6] J. B. Birks, *Scintillation Counters* (McGraw-Hill Book Company, Inc., New York, 1953).

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Evidence for the 258-kev Gamma Ray of Sn^{113}†

GERALD GARDNER AND JOHN I. HOPKINS
Vanderbilt University, Nashville, Tennessee

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Measurements have shown that there appears to be a 258-kev gamma ray of Sn^{113} and that its intensity relative to that of the 393-kev gamma ray is $12\%\pm2\%$. The half-life for each gamma ray was measured to be approximately 130 days.

EVIDENCE has been obtained by means of the NaI(Tl) scintillation spectrometer for the presence of a 258-kev gamma-ray transition in the decay of Sn^{113}. A 255-kev gamma ray, together with gamma rays of energies 400.9 kev and 393.3 kev has been reported as belonging to Sn^{113} by Cork *et al.*,[1] who proposed a decay scheme consisting of orbital electron capture followed by emission of all gamma rays in cascade. Thomas *et al.*[2] proposed a decay scheme consisting of electron capture followed by the emission of a single gamma ray of energy 390 kev, having failed to confirm the presence of any other gamma rays. The work of both Cork and Thomas was carried out with beta-ray spectrometers.

Recent work by Deschamps and Avignon[3] using a spectrometer of rather low resolving power failed to confirm the presence of any gamma ray except that of energy 393 kev.

Figure 1 is typical of the Sn^{113} spectra obtained. The theoretical Compton electron distribution should have electrons with a maximum energy of 238 kev. However, the finite resolution of the spectrometer results in a shift of the high-energy shoulder to an energy lower than 238 kev, to around 235 kev. The presence of a low-intensity peak at energy of 258 kev (Fig. 1) does not seem attributable to the Compton electron distribution.

In order to evaluate the intensity of this peak, a Compton electron distribution was subtracted from the

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† Supported by an Atomic Energy Commission Research Contract.

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[2] Thomas, Haynes, Broyles, and Thomas, Phys. Rev. **82**, 961 (1951).

[3] Y. Deschamps and P. Avignon, Compt. rend. **236**, 478 (1953).