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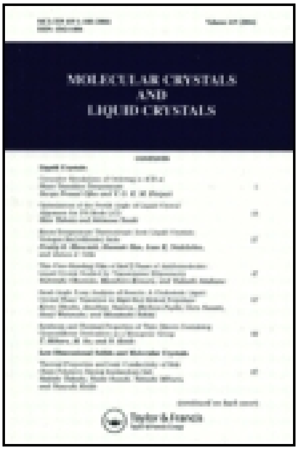

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E. A. Yates [a] , D. G. Crandall [a] & J. Kirkbride [a]
[a] EG&G, Inc., Santa Barbara Division, Santa Barbara, California
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Quenching Measurements on Organic Scintillators†

E. A. YATES, D. G. CRANDALL, and J. KIRKBRIDE

EG&G, Inc., Santa Barbara Division Santa Barbara, California

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Abstract—The time distribution of the light output of several liquid scintillators has been measured. Attempts were made to shorten the time distributions of the scintillations by the addition to the liquids of dissolved oxygen and various organic chemicals. Bromobenzene and oxygen were found to be the most effective in quenching the tail of the scintillation and shortening the decay time.

1. Introduction

The objective of this continuing study is to develop faster liquid organic scintillators having shorter decay times and a minimum of long-tail light output. In the experimental method being used, the time distribution of the decay of the scintillation light emission was measured in the nanosecond range. The fluor decay equipment for these measurements has been developed at EG&G, Inc., Santa Barbara Division, over the past three years.[1]

It has long been known that oxygen dissolved in organic fluors reduces both the light output and the decay time. Oxygen, therefore, was chosen as the first quencher to be examined. Several other quenchers were selected from a series examined by Hayes.[2] The base liquids employed in the work to date were NE 211, Ne 213, NE 226, trimethylbenzene, and toluene. The NE series of liquids was manufactured by Nuclear Enterprises, Ltd.

2. Oxygen Quenching

The liquid scintillators were contained in glass cylinders, measuring 1- by 1-inch with a side-filling stem. Pure oxygen was gently bubbled through the liquids at atmospheric pressure by means of a narrow teflon

† Supported by the U.S. Atomic Energy Commission through the Lawrence Radiation Laboratory, Livermore, California.

tube. Usually it took about 10 minutes, as judged by pulse height, to saturate the scintillator solution.

In the current program, the first liquid selected for study was NE 226 because this liquid should have a minimum of chemical interaction with dissolved oxygen. Figure 1 shows the effect on NE 226 (C_6F_6 base) of bubbling first with N_2, then with O_2, and then with N_2 again. It is seen that after the second N_2 bubbling, the scintillator was restored to the condition it had after the first N_2 bubbling. Decay measurements were made on the sample at times indicated in Fig. 1, and the results of these measurements are shown in Fig. 2. It is noted that O_2 quenching considerably reduces the ratio of tail-to-peak responses.

Similar experiments were performed on NE 211, NE 213, toluene with 3 grams of PPO per liter, and trimethylbenzene with 2 grams of p-terphenyl per liter. In all cases, the quenching results closely followed those obtained on NE 226, Fig. 1 and 2.

Several oxygen-bubbled samples were sealed off, immediately measured, and then remeasured after several weeks. In most cases, the effects of oxygen quenching had partially disappeared. Figure 3 shows the effects on NE 213.

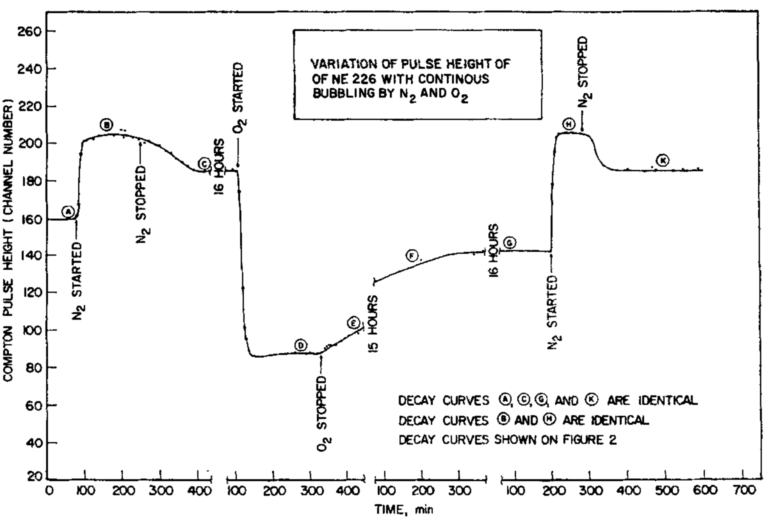

Figure 1. Variation of pulse height of NE 226 with continuous bubbling by N_2 and O_2.

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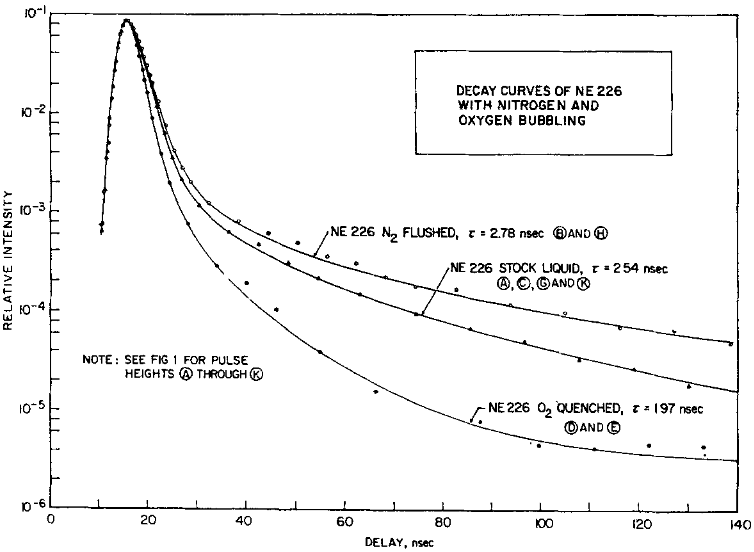

Figure 2. Decay curves of NE 226 with nitrogen and oxygen bubbling.

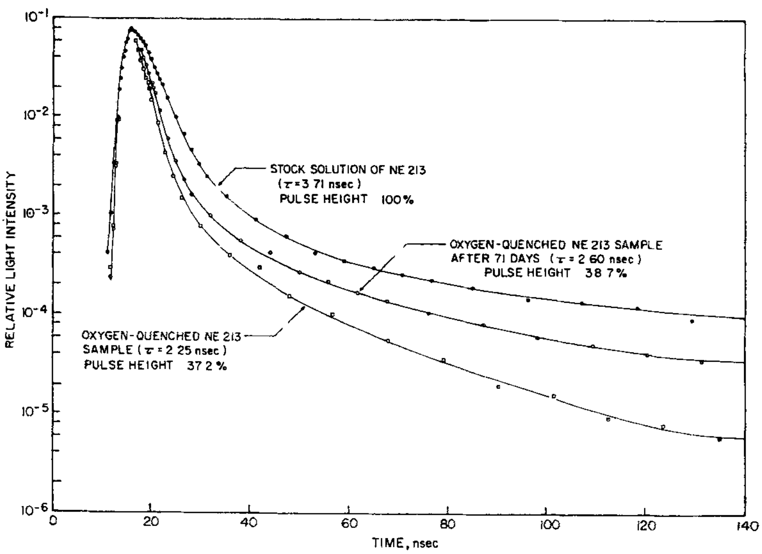

Figure 3. Effects of oxygen quenching on NE 213.

3. Solvent Quenching

Hayes[2] showed that acetophenone and bromobenzene were exceptionally strong quenchers of the light output of liquid organic scintillators. The way that these quenchers affected the time distribution of the light emission, however, was not known.

The stock scintillator employed in the present experiments was the same as the one used by Hayes; namely, toluene with 3 grams of PPO per liter. The stock liquid was brought to laboratory equilibrium by bubbling it with air, and the decay time and pulse height were then measured. After acetophenone and oxygen had been added separately and in combination, these measurements were repeated, with the results shown in Figure 4. Because acetophenone primarily affected the fast decay in the first decade and oxygen strongly affected the tail, this combination of quenchers permitted the overall decay curve to be varied in detail.

This experiment was repeated with acetophenone concentrations of 0.0, 0.02, 0.04, 0.06, 0.08, and 0.10 per cent by volume. Also, for a separate measurement, oxygen was bubbled into each solution. It was found

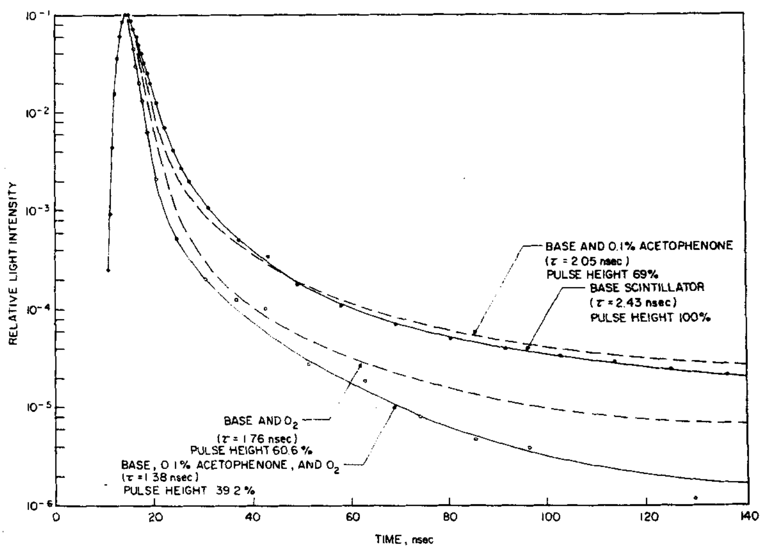

Figure 4. Quenching with acetophenone and oxygen.

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that the pulse-height, decay-time, and tail amplitudes all varied in a linear fashion with acetophenone concentration.

Table 1 presents the results of a series of measurements made with other quenching liquids. Pulse heights were reduced in all cases; decay times and tail-to-peak ratios, however, increased in some cases but not others. The data in Table 1 clearly show that oxygen is the best quencher of tail emission and that piperidine is the best reducer of decay time. The prompt decay constant in Table 1 is extracted from the 70- to 7-per cent light intensity section of the decay curve.

TABLE 1 Effects of Various Quenching Agents on Toluene Scintillators

Quencher	Quencher Concentration (per cent by volume)	Relative Pulse Height	Prompt Decay Constant (nsec)	Peak-to-Tail Ratio (at 100 nsec after peak)
None	0	100	2.43	4,700
Oxygen	Equilibrium†	61	1.76	11,700
Acetophenone	0.10	69	2.05	2,800
Bromobenzene	0.50	54	1.91	11,400
Cyclohexanone	5.0	28	3.40	1,430
Acetic Acid	10.0	49	2.24	4,800
Acetone	5.0	30	3.59	1,550
Piperidine	1.50	35	1.32	6,600
4-Picoline	2.50	25	1.89	3,580
Pyridine	1.50	28	2.08	3,200
Thiophene	15.0	45	2.39	3,200
Chlorobenzene	0.05	57	2.41	4,000
Bromocyclohexane	10.0	48	2.23	5,900

† 7.15×10^{-3} mole per liter (per Reference 3).

4. Conclusions

Oxygen, in its effects of reducing decay time and tail light output, is the most powerful single quencher examined. It was found, however, that sealed-off samples slowly lose the effect of dissolved oxygen over several months. Next to oxygen, bromobenzene is the best all-around quencher for reducing the scintillation tail. It also reduces the decay time. Acetophenone reduces the decay time but leaves the tail unchanged.

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