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Temperature Dependence of Pulse-Height Distribution in Liquid Scintillator

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Investigations at this laboratory of energy transfer in liquid scintillator were stimulated by these earlier reports and in course of a spectral study concerning the relative pulse-height distributions from the liquid scintillator, we found that the pulse-height distributions for ^{241}Am (alpha particles, 5.49 and 5.44 MeV), ^{131m}Xe (internal conversion electrons, 134 and 164keV), ^{14}C and ^{3}H in liquid scintillator increase markedly with decreasing temperature, and that the counting efficiency of the beta-emitters also increases with decreasing temperature, although that for alpha particles and internal conversion electrons remain unchanged.

First each sample was measured for 200 or 400 sec at 8.8°C, and then cooled and measured as described below.

Wrapped with polyethylene film, the sample vial was dipped into a mixture of salt and ice until the temperature of the sample solution reached −12°C, and then rapidly placed on the porours polystyrene plate which was attached on the top of the sample changer of the liquid scintillation system, and the spectrum was measured for 20 sec. During the period, the temperature of the sample solution went up to −11.2°C. The measurement of the sample was repeated 10 or 20 times at −12 to −11.2°C in the same manner as described above, and the spectrum was accumulated with a multichannel pulse-height analyzer. Therefore, the sum of the counting intervals at −12 to −11.2°C was 200 or 400 sec.

For lower temperature (approx. −67°C) a mixture of solid carbon dioxide and ethanol was used. The sample vial was dipped into the freezing mixture, and the sample solution was cooled to −67°C. The measurement for a period of 20 sec was repeated 10 or 20 times in a similar manner as above. The temperature of the sample solution during the measurement was −67 to −66.2°C.

The temperature of the photomultipliers of the liquid scintillation system was kept at 8.8°C all through the measurement.

The peak of ^{131m}Xe corresponds to 134 and 164 keV internal conversion electrons. Although the spectra were shifted from the initial pulse-height position, i. e., the ordinary temperature position, toward higher pulse-height, identical counting rates were obtained for both samples within the limits of the counting statics at three different temperatures

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because alpha particles and energetic internal conversion electrons are counted with almost 100% counting efficiency at ordinary temperature, and hence the pulse-height shifts observed do not cause an increase in counting rate.

The pulse-height distribution of ^{14}C and ^{3}H was also shifted to higher pulse-height with decreasing temperature. Consequently, even the very soft beta particles from ^{14}C and ^{3}H came to be counted so that the counting rates of these nuclides increased.

Energy migration from one solvent molecule to its adjacent neighbors may be described by the mechanism proposed by Voltz and co-workers involving Coulombic and electron exchange interactions. Changed particles can excite molecules to a particular higher energy level as well as to the well-known molecular states of energy by means of optical collisions, the cross sections of which are approximately proportional to the aquare of the dipole moment of the induced molecular electronic transitions. However, in view of the results obtained in our investigation, especially at low temperature, the increase in pulse-height may be well described by the Birks-Conte model which postulates the migration of excitation energy by means of the successive formation and dissociation of excimers. That is, it would seem quite reasonable to suppose that at low temperatures the formation of solvent excimers would be promoted and that the increase in energy transfer between solvent molecules, in light output of the liquid scintillator occurs, because the condition of excimer formation is the parallel orientation of two adjacent molecules.