Measurement of Response Functions for NE213 in 6.4 ≤ E_n ≤ 34 MeV

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Fast neutron response functions of NE213 liquid scintillation counters have been obtained by irradiating monochromatic neutrons in an energy range from 4.4 to 34.0 MeV. The NE213 liquid scintillator has been widely used for the fast neutron detection because of its good detection-efficiency and conspicuous performance responsible for a pulse shape analysis (PSA) to eliminate γ-ray events. From the light output distribution for neutron events in a liquid scintillation counter, we can estimate the detection efficiency for the purposes of time-of-flight (TOF) experiments, and we can deduce a response matrix for unfolding. Thus, the pulse height response functions for various neutron energies have been studied by many authors.¹⁻³) It is well known that a response function is affected by the size and form of the counter in which liquid scintillator is encapsulated. The present subjects are to investigate the fast neutron response functions and to compare these results among the NE213 counters having various sizes and forms by using higher energy monochromatic neutrons. Response functions for seven types of the neutron counters, i.e., 2"×1", 2"×2", 2"×4", 5"×2", 5"×3", 50cm×10cm×5cm and 50cm×10cm×7.5cm, were measured to investigate the contribution from effects of quantum escape, multiple scattering and light attenuation etc., and to determine the detection efficiency with respect to a bias-setting in the neutron energy.

Monochromatic neutrons were obtained from the ⁷Li(p,n)⁷Be reaction; neutrons leading to the ground state in ⁷Be were selected by means of the TOF technique. The incident proton-beams were provided by the AVF cyclotron at Cyclotron and Radioisotope Center, Tohoku University.⁴) In order to carry out accurate measurements, the time-of-flight facilities⁵) was employed in the present measurement. Figure 1 demonstrates a TOF spectrum of neutrons from the ⁶Li(p,n)⁶Be and ⁷Li(p,n)⁷Be reactions taken with the 5"×2" detector, and figure 2 shows the pulse height distribution gated by the proton and alpha events (upper part) in the pulse shape spectrum and gated by the alpha events only (lower part). An arrow in fig. 2 means the light out put from 34-MeV neutron. Together with pulse height distribution at different neutron energies as shown in fig. 3, we can get a relationship between the neutron energy and the light out put for E_n ≥ 4.0 MeV. Meanwhile, the light out put of γ-rays from ⁵⁶Co, ⁶⁰Co and ⁸⁸Y were translated to those of neutrons by following Verbinski et al.²) for the region E_n ≤ 8 MeV. Thus, we obtain a calibration curve which connects the light output and neutron
energy and used in a bias-setting.

Figure 4 presents detection efficiencies as functions of the neutron energy for bias-settings of 1.0 and 4.0 MeV in the electron energy. Solid lines in the figure mean Monte-Carlo predictions by the code 05S. 9) It should be noticed that the Monte-Carlo calculation underestimates the efficiency for higher energy neutrons, and this tendency is more apparent with the lower bias-setting. Discrepancy between the experimental results and predictions may be interpreted by the contributions from the reactions of $^{12}\text{C}(n,n')3\alpha$, $^{12}\text{C}(n,\alpha)^9\text{Be}$ and $^{12}\text{C}(n,p)^{12}\text{B}$ etc. for which the cross sections for the higher energy neutron are not correctly taken into accounts in the code 05S. As demonstrated in fig. 2, an alpha event from these reactions plays a significant role for higher energy neutrons and appears in lower light output region.

Figure 5 shows a pulse height distribution in the $2''\times1''$ detector for 35-MeV neutron. Solid and dashed lines in the figure mean the Monte-Carlo comparison with and without the effect of quantum escape, respectively. The experimental distribution is well reproduced by the Monte-Carlo prediction.

References

5) Orihara H. and Murakami T., to be published in Nucl. Instr. and Meth.
6) Textor R. E. and Verbinski V. V., ORNL-4160 (1968).
Fig. 1. Time-of-flight spectrum for the reactions $^6$Li(p,n)$^6$Be and $^7$Li(p,n)$^7$Be for $E_p = 24.5$ MeV at $\theta_{\text{Lab}} = 12^\circ$. Time per channel is 0.8 nsec, and the flight path is 24.6 m.

Fig. 2. Pulse height distribution of 34.0 MeV neutrons from the $^7$Li(p,n)$^7$Be (g.s) reaction. See text for the meaning of (a) and (b).

Fig. 3. Neutron detection efficiencies of $5''\times2''$ NE213 counter as functions of the neutron energy. Open and closed circles represent the experimental results with the bias-settings of 1.0 and 4.0 MeV, respectively. Solid lines are the Monte-Carlo predictions.
Fig. 4. Three dimensional display of neutron response functions with respect to the different energies of monochromatic neutrons. The pulse height is written in the $^{60}$Co light-unit.

Fig. 5. Pulse height distribution of 34.0-MeV neutrons and comparison with the Monte-Carlo predictions.