Journal of the Korean Nuclear Society
Volume 11, Number 2, June, 1979

《**Original**》

Comparison of Light Output from NE213 for Electrons and Protons

Hyun Kook Shin and Byung Joon Koh, Ph.D.

Reactor Control Lab, KAERI

(Received May 28, 1979)

Abstract

The light output of the NE213 liquid scintillator to electrons and protons was measured by coincidence spectrometer which employs the time of flight technique. The proton energies (3.2Mev, 4Mev, 5Mev, 6Mev) represent the kinetic energies of recoil protons from elastic scattering of a polyenergetic neutron source Am-Be (about 2-9 Mev) at angle of 45° and 60°. The response of the NE213 liquid scintillator to protons was varied nonolinearly as the energy increased, while the response to electrons was varied linearly. The light intensity produced by electrons was relatively larger than that of protons in the rate of about three times when the same energy was introduced. The results of the light output to protons were similar to those of Batchelor et al.

요 약

Time of flight Technique를 사용한 coincidence spectrometer에 의해 액체 형광물질(liquid scintillator) NE213의 전자와 양자에 대한 빛 방출량을 측정하였다. 이 실험에서 양자에너지 (3.2Mev, 4Mev, 5Mev, 6Mev)는 2Mev에서 9Mev에 이르는 여러 에너지 분포를 갖고 있는 Am-Be 중성자원을 사용하여 중성자 탄성산란의 각도(45° and 60°)와 측정기간의 거리를 조절하므로서 얻었다.

NE213액체발광물질의 빛 방출량은 전자 에너지에 대해 선형적인 응답을 보였으며 양자에 대한 응답은 에너지 증가에 따라 비선형적이었다. 빛의 세기도 전자에 의한 응답이 양자에 의한 것보다 약 세배 가량 컸다. 본 실험결과는 Batchelor et al 이 발표한 실험결과와 거의 비슷했다.

1. Introduction

Organic scintillators are widely used for detecting nuclear radiations. Information about the response of organic scintillators to different radiations is of practical importance because of the technological applications which have evolved. Furthermore, response data must be available in order to make progress towards understanding the basic light producing mechanism.

The relative response of the organic scintillator NE213 to electrons and protons has been measured by several authors[1,2,3,5] and getting some results which are not quite

comparable with each other. Such discrepancies be understood[1] if the response of a scintillator to radiations somehow depends on geometrical factors(including volume and light reflection effects), as well as on the purity of the sample and on the electronics of the associated circuitry.

The response of these organic materials is usually critically dependent upon the specific ionization of the detected particles. Some of these scintillators respond to an ionizing particle by emitting a light pulse which is sum of a short (a few ns) and a long (several μs)[8] decay time component.

If particles of heavior or slower than fast electrons, which produce a high ionization, are used for excitation, the scintillation efficiency is reduced. Due to this effect, the scintillation response to electrons, protons are different. The specific energy loss dE/dx and ionization density vary markedly with particle energy E, except for fast electrons and other particles with relative velocities. Therefore, the light output generally varies nonlinearly with E and depends on the nature of the ionizing particle.

Birks[8] has proposed a formula to describe this behavior.

$$dL/dx = S(dE/dx)\{1+KB(dE/dx)\}^{-1} \quad (1)$$

Where

dL/dx = flourescence light energy emitted per path length.

dE/dx = Specific energy loss for the charge particle(a function of particle type and energy)

S = Scintillation efficiency

K = Relative quenching probability

B = Constant related to quenching effect

Equation (1) can be rewritten in the form:

$$dL/dE = S[1+KB(dE/dx)]^{-1} \quad (2)$$

Where dL is the quantity of fluorescence light generated when a charged particle with energy E loses a quantity of energy dE through ionization along a path increment dx within the scintillator.

For electrons with energies $\geq$125KeV, the specific energy loss would be nearly zero and equation (3) reduces to a linear expre ssion of:

$$L(E) = SE + L_0 \quad (3)$$

The theory, thus, predicts that light output for fast electrons varies linearly with energy.

2. Experimental Details

In the present experiment an indirect method was employed for measuring the response of a scintillator to charged particles. The indirect method uses two scintillation counters. This spectrometer requires an incident neutron to be scattered elastically from a hydrogen nuclius in the first detector. The scattered neutron must then travel over a known flight path and interact in the second detector.

The time-of-flight of the scattered neutron is measured by the time interval between the scintillator pulses in the first and second detectors. Kinematically, the kinetic energy of the incident neutron is specified in terms of the scattering angle, the flight path, and flight times of the scattered neutron.

The configuration of the detector and neutron source are shown in fig. 1. The primary detector consisted of a NE213 (2" diameter x 2" long) liquid scintillator coupled to the cathode of Mullard 56 AVP photomultiplier. For the secondary detector arrangement, a large size (12" diameter x 2" long) NE213 liquid scintillator coupled by a plastic light pipe to Mullard xP1040 photomulti-

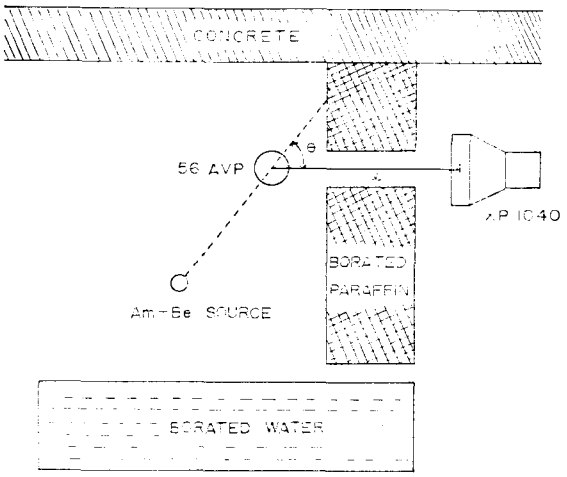

Fig. 1. Schematic diagram of scattering arrangement used in the present study.

plier was used to increase the detecting efficiency

A polyenergetic neutron beam from an Am-Be Source (about 2-9 Mev) was used to bombard the primary detector. The secondary detector was shielded from the direct neutron beam by borated paraffin in order to reduce random coincidences.

The pulse height spectrum of recoil protons in the primary detector were measured by placing the Am-Be Source at a different angle to the primary detector, and selecting a narrow time interval in the time-of-flight spectrum of the scattered Am-Be neutrons.

Neutron time-of-flight spectra were measured using a time to amplitude convertor whenever the scattering angle and detector distance were changed. Typical time-of-flight spectra of the scattered Am-Be neutrons is shown in Fig. 2. gamma ray spectra from sodium-22, and cesium-137, were measured by the primary detector to get the compton spectra. These compton spectra serve as calibration points for determining the light output of the recoil protons relative to electrons. The compton edge,

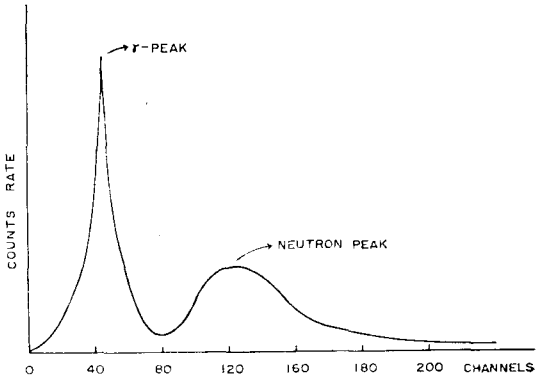

Fig. 2. Typical time of flight spectra of the neutrons.

which intensity is to correspond to the maximum compton electron energy produced by the associated gamma ray.

A detailed block diagram of the electronics apparatus is shown in Fig. 3. The high voltage power supplies to primary and secondary photomultiplier were fixed at 1600 volts and 2300 volts respectively. The pulse-

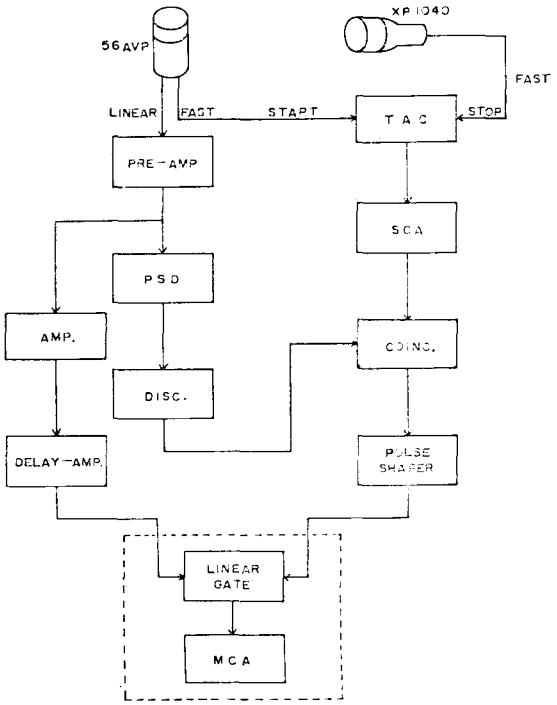

Fig. 3. Block diagram of the complete electronic Circuitry.

height signals from the linear output of the primary photomultiplier were amplified by a preamplifier and passed to a linear amplifier. The pulse amplitudes were equivalent to the time integral of the scintillation light pulses. The output of the linear amplifier was then fed into a delay amplifier. This was necessary to have a time delay introduced in the time to amplitude converter and the single channel analyser. Then, the delayed linear signal was sent to the linear gate in the multichannel analyser.

The fast pulses from the primary photomultiplier were fed to the TAC(time to amplitude convertor) as a start signal. In the same manner, the large size secondary photomultiplier sent fast pulses to the TAC as a stop input. Then, the TAC produced an output signal which contained particle flight time information between primary and secondary detectors. The output, then, passed to a timing SCA which selected the predetermined flight time within its window.

The PSD (pulse shape discrimination) unit was used for eleminating gamma-ray back ground from true events.

The SCA output pulses and PSD discriminator output pulses are both sent to the coincidence circuit. The output pulse from the coincidence circuit went to a pulse shaper which made these pulses into 4 volts high x 6 us long rectangular pulses to trigger a gate circuit in the Laben compact analyser.

The time resolution of this system was measured using gamma-rays. The annihilation radiation of sodium-22 was used for this measurement. Fig. 4 shows total coincidence rate versus delay time. Its full width half maximam was 4ns. These time resolution were good enough to distinguish between neutron events and gamma events on

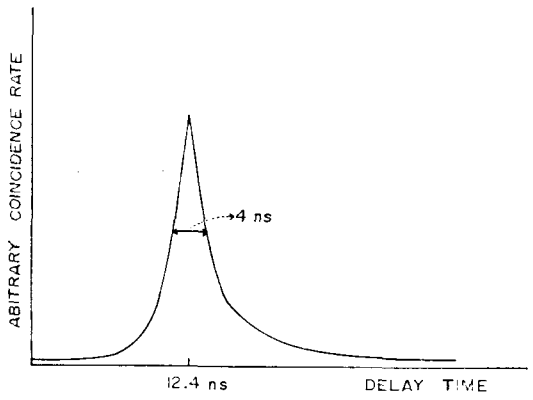

Fig. 4. Flight time spectrum by annihilation reaction of Sodium-22.

the basis of flight times.

The gamma peak was used for the TAC calibration using known standard cables, lengths with delays of 13ns, 20ns and 23ns, TAC calibration curve is shown in Fig. 5.

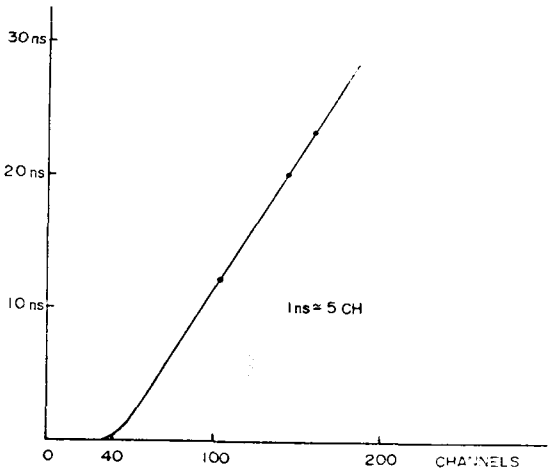

Fig. 5. Time to Amplitude convertor calibration line with known standard cables.

3. Analysis

A typical proton recoil spectra are shown in Fig.6. It was obtained from a 45° scattering (Lab. angle) and the selected neutrons flight time was about 18ns. The distance between the two detectors was 45cm. The-

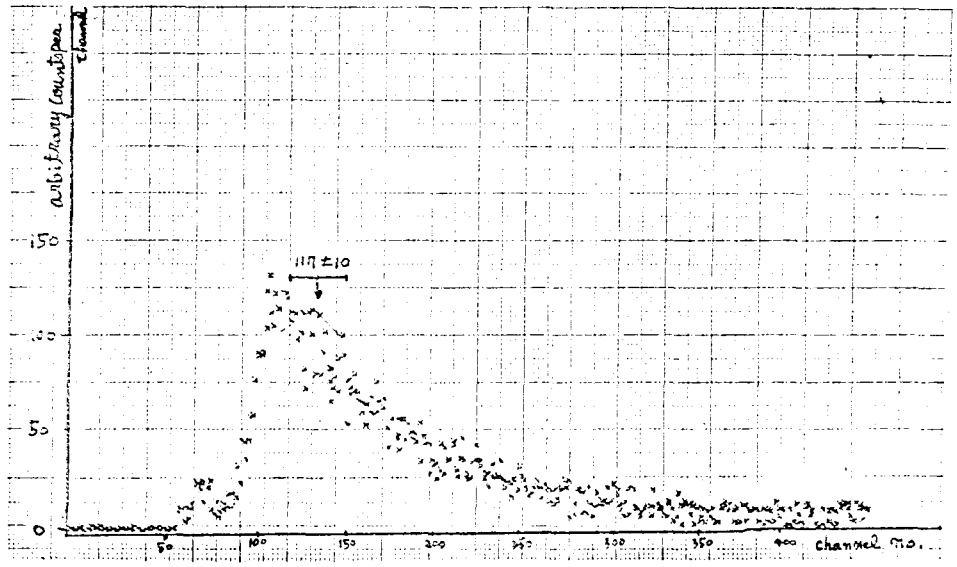

Fig. 6. Typical recoil proton spectrum with 45° scattering angle, 18ns flight time: proton energy 3.2 Mev.

refore, the expected recoil proton energy was about 3.2 Mev. The obtained proton recoil spectra shows a lot of high background. Thus, it was difficult to analyse because the recoil peaks were broad and smeared by high background.

Chagnon[7] had already noticed that this spectrometer suffers from the background common to all coincidence systems which is caused by accidental coincidences.

In this experiments, the random coincidence background was measured as shown in fig. 7, using an interval of about 10ns, scattering angle of 45°, in which the delay is too long for gamma radiation and too short for neutrons.

This background distribution is similar to those of chagnon et al's. However, the recoil proton peaks, compared with those of chagnon et al, is very small. It is considered

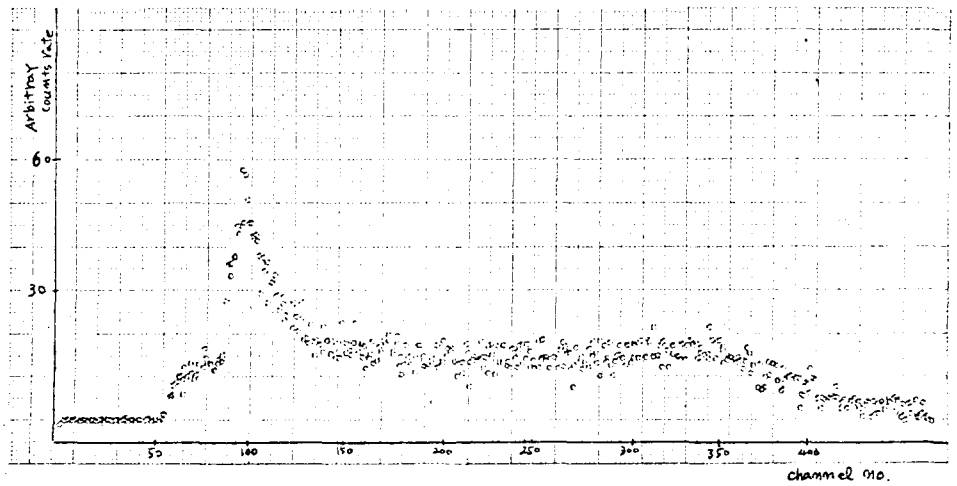

Fig. 7. Random Coincidence Spectrum with 45° scattering angle and 10ns flight time.

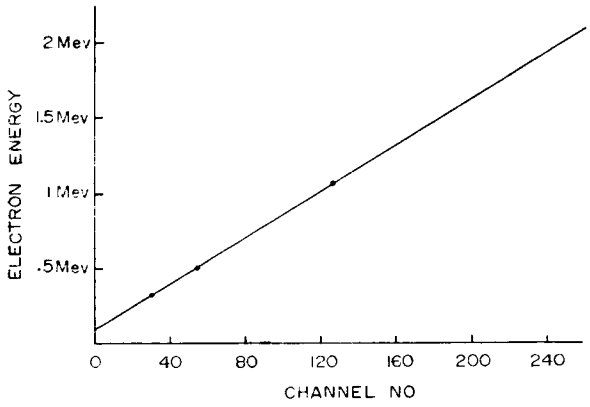

Fig. 8. Electron calibration line using Na-22, Cesium-137.

that the relatively weak neutron source was used in the experiment instead of a strong monoenergetic neutron source. Thus, in analysing the data, the background distribution was considered.

The light output of electrons in organic scintillators is known to be a linear function of energy for electrons above approximately

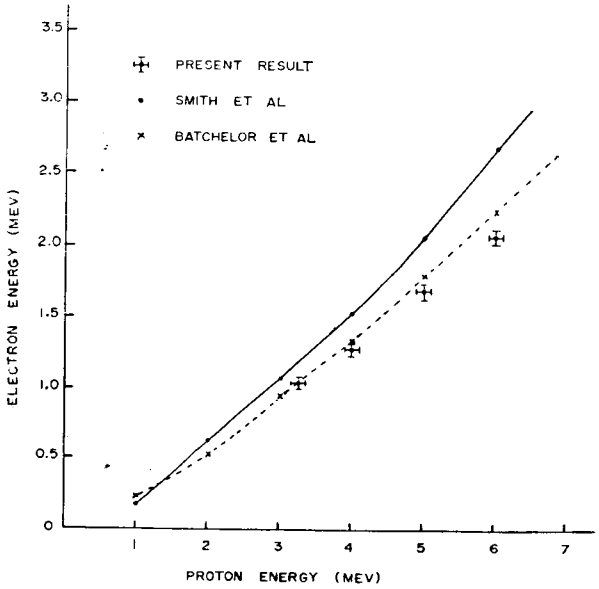

Fig. 9. Relative response to electrons and protons of NE213 liquid scintillator. Solid and dashed curvces are the previous results of Smith et al and Batchelor et al respectively.

100Kev. The Laben compact Analyser was calibrated in units of equivalent electron energies of the Compton edge. Fig. 8 shows the calibration curve of sodium-22 and cesium 137.

The measured proton recoil energies (3.2 Mev, 4 Mev, 5 Mev, 6Mev) with equivalent electron energies are listed in table 1. The uncertainties in recoil proton energies were due to selection of the neutron flight time interval and scattering angle. The response of the NE213 and the relative response of different authors results are plotted in Fig.-9.

Table 1. The Response of NE 213 Liquid Scintillator to Protons and Electrons

Proton Energy (Mev)	Equivalent Electron Energy (Mev)	Corresponding Channel Number
3.2±0.2	1.0±0.08	117±10
4.0±0.2	1.3±0.12	153±15
5.0±0.2	1.7±0.12	200±15
6.0±0.2	2.0±0.12	253±15

4. Conclusion

The response of the NE213 liquid scintillator was measured by a coincidence spectrometer, using an Am-Be neutron and gamma-ray source.

The response of the light output from NE 213 to protons and electrons was found to be different, and the light output produced by proton was relatively smaller than that of electrons in the rate of about one third when the same energy was used. The light output responses of the NE213 liquid scintillator to recoil protons were nonlinear as the energy is increased.

In comparison with previous results, the present results are found to be more similar to those of Batchelor et al than the work of

Smith et al as shown in Fig. 9.

It is considered that the little discrepancy between the present work and Batchelor et al's work could be caused by the volume of liquid scintillator. Present work employed a 2″ diameter×2″ long cylindrical shape liquid scintillator, while Batchelor et al used a 2″ diameter×$2\frac{1}{2}$″ long cylindrical shape liquid scintillator.

References

1) A. BERTIN & A. VITALE & PLACCI Nuclear Instr. and Meth. 91 (1971) 649-652.
2) R.L. CRAUN & D.L. SMITH Nucl. Instr. and Meth. 80 (1970) 239-244.
3) D.L. SMITH, R.G. POLK & T.C. MILLER Nucl. Instr. and Meth. 64 (1968) 157-166.
4) R. MADEY & F.M. WATERMAN Nucl. Instr. and Meth. 104 (1972) 253-256.
5) R. BATCHELOR, W.B. GLLBOY, J.B. PARKER & J.H. TOWLE Nucl. Instr. and Meth. 13 (1961) 70-82.
6) P.R. CHAGNON, G.E. OWEN & L. MADANSKY Rev. Sci. Instr., Vol. 24 No.8 (1953) 656-660.
7) P.R. CHAGNON, G.E. OWEN & L. MADANSKY Rev. Sci. Instr., Vol. 26 No. 12 (1955) 1165-1170.
8) J.B. BIRKS The Theory and practice of Scintillation Counting (Macmilan, New York, 1964).
9) MARION & FOWLER Fast Neutron Physics, Part 1.
10) The Radiochemical Centre 1977/78 Catalogue Amersham England.