Optimization of liquid organic scintillator composition for fast neutron spectrometry

Jaroslav Jánšký, Jiří Janda, Věra Mazáňková, František Čvachovec
1 University of Defence, Faculty of Military Technology, Department of Mathematics and Physics, Brno, Czech Republic
2 University of Defence, NBC Defence Institute, Výškov, Czech Republic
3 University of Defence, Faculty of Military Technology, Department of Mathematics and Physics, Brno, Czech Republic

Abstract

Liquid organic scintillators are important devices for measurements of neutron radiation. This work aims to develop and optimize the composition of liquid organic scintillators so it can be used for fast neutron spectrometry. As the neutron radiation is usually accompanied with γ-ray radiation, this work is focused on γ/ν discrimination. In our experiments, the 252Cf is used as a radiation source for a fixed field of γ rays and neutrons, and 137Cs is used as radiation sources for pure γ rays. The scintillators within 20 ml glass vials are placed above the photomultiplier (PMT) RCA 8575. The two parameter scintrometric system NGA-01 is used to analyze the energy and discrimination characteristics. It is shown first that from six preselected solvents, the DIPN and 1-Methylanthiphenyl are capable of good γ/ν discrimination in combination with luminophore PYR. In second stage the solvent is DIPN and the concentration of luminophores is varied. The concentration of luminophore PYR from 3 g/l to 9 g/l is shown to be best for γ/ν discrimination. The energy threshold for good γ/ν discrimination is 0.14 MeVee. Luminophore THIO (2,5-(5-tert-butyl-benzoxazol-2-yliophene) has best γ/ν discrimination at concentrations from 3.4 g/l to 5 g/l and the energy threshold is 0.20 MeVee. These scintillators at optimal concentrations have lower energy threshold for γ/ν discrimination than reference liquid scintillator Aquaphot AB. However the stilbene crystal scintillator is better than scintillators from this work.

Measurements

(a) Two-parameter histogram from the measurement of liquid scintillator with PYR (1 g/l) dissolved in DIPN, (b) zoomed two-parameter histogram of the energy channel of the liquid scintillator with PYR (1 g/l) with highlighted two energy channel intervals for channels 1 to 50 and channels 91 to 100, (c) number of pulses as the function of discrimination parameter for these two intervals.

Chemicals

Solvents:
- Di-iso-propylnaphthalene Mixed Isomers, CAS 38640-62-9, TCI Chemicals (labeled DIPN),
- 1-Methylanthiphenyl, CAS 90-12-0, TCI Chemicals,
- Diethylbenzene, CAS 25340-17-4, Sigma-Aldrich,
- Dodecylbenzene (hard type) (a mixture of branched-chain isomers) CAS 25265-78-5, TCI Chemicals,
- Propylbenzene, CAS 103-65-1, Sigma-Aldrich,
- 1-Phenylcyclohexane, CAS 2189-60-8, Sigma-Aldrich.

Luminophores:
- 2-(4-lFluorophenyl)-6-lFluorobenzoxazole, CAS 17064-47-0, Sigma-Aldrich (labeled XAZ),
- 2-(4-BiPhenylyl)-6-phenylbenzoxazole, CAS 17046-47-0, Sigma-Aldrich (labeled XAZ),
- 2,5-Bis(5-tert-butyl-benzoxazol-2-yliophene, CAS 7128-64-5, Sigma-Aldrich (labeled THIO),
- 1-Phenyl-3-(2,4,6-trimethyl-phenyl)-2-pyrazoline, CAS 60078-97-9, TCI Chemicals (labeled PYR).

Conclusions

It has been demonstrated that from six preselected solvents, only Di-iso-propylnaphthalene Mixed Isomers and 1-Methylanthiphenyl are capable of good γ/ν discrimination in combination with the PYR luminophore. Afterwards the influence of the concentration of luminophores on the γ/ν discrimination was studied. The concentration of the PYR luminophore from 3 g/l to 9 g/l is found to be the best for γ/ν discrimination. The energy threshold where Figure of Merit FOM=1.27 is determined to be 0.14 MeVee. The THIO luminophore has the best γ/ν discrimination at concentrations from 5 g/l to 9 g/l and the energy threshold where FOM=1.27 is observed to be 0.17 MeVee. The XAZ luminophore has the best γ/ν discrimination at concentrations ranging from 2.4 g/l to 3 g/l and the energy threshold where FOM=1.27 is 0.20 MeVee. However, the stilbene crystal scintillator is better than the scintillators based on this work.

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Properties of the solvents with the PYR, THIO and XAZ luminophores, and their variations with the concentration. (a) the energy thresholds where FOM=1.27 (PMT voltage adjusted), and (b) the energy channel of 137Cs Compton edge normalized to PMT voltage 1600 V.

Comparison with Stilbene