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APPLICATION NOTE

Energy Transfer in a Liquid Scintillator Investigated using Time-Resolved X-ray Excited Luminescence Spectroscopy

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Introduction

Liquid scintillator detectors are widely utilised in neutrino and astroparticle detection experiments. One liquid scintillator that is increasingly being used in large scale detection experiments is linear alkylbenzene (LAB). LAB is an attractive scintillator due to its low cost, high flash point and low toxicity, making it easier to handle than previously used toxic and flammable organic solvents. LAB is commonly used together with the fluo-22-diphenylacetic (PFO) which increases luminescence yield and shifts the luminescence to longer wavelengths. The LAB/PFO scintillator system is already used at the Daya-Bay¹ and RENCI² neutrino detection experiments and is the scintillator of choice for the upcoming JUNO³ and JUNO⁴ detectors.

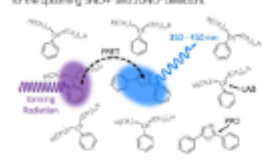


Figure 1 LAB/PFO Scintillator System

A schematic of the scintillation process in the LAB/PFO system is shown in Figure 1. Ionizing radiation, such as γ rays, travel through the LAB solvent and excite a molecule of LAB to a high energy state. The excess energy in the LAB is non-radiatively transferred (FRET) to a nearby PFO molecule promoting it to an excited state. Relative de-excitation of the PFO back to its ground state results in violet/blue luminescence which can be detected.

Since energy is transferred between the LAB and PFO via FRET, the luminescence behaviour will depend on the number of PFO molecules and their distance from excited LAB molecules. Higher concentrations of PFO decrease the average spacing between excited LAB and PFO molecules, increasing the luminescence yield and decreasing the average luminescence lifetime. Many detection experiments utilise pulse shape discrimination techniques, which analyse the luminescence decay profile after a scintillation event, to distinguish different radioactive particles.

Understanding the luminescence decay behaviour of the scintillator system is crucial for this type of analysis. In this application note, the effect of PFO concentration on the luminescence decay profile of the LAB/PFO system is investigated using time-resolved X-ray excited luminescence spectroscopy with an Edinburgh Instruments FL51000 Photoluminescence Spectrometer.

Materials and Methods

PFO (Sigma Aldrich) was dissolved in LAB (Cape Canada) at a series of concentrations between 1 g/L and 20 g/L and pipetted into quartz cuvettes. X-ray excited luminescence spectra and decay of the LAB/PFO solution were measured using an Edinburgh Instruments FL51000 Photoluminescence Spectrometer coupled to the XSI X-ray Sample Chamber (Figure 2).

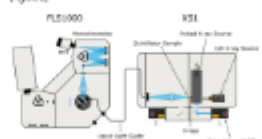


Figure 2 FL51000 X-ray excited luminescence spectroscopy setup

The XSI X-ray Sample Chamber is an X-ray shielded enclosure that can be equipped with multiple X-ray sources for the investigation of new scintillator materials. To acquire the X-ray excited luminescence spectra of LAB/PFO the XSI was equipped with a compact 60kV continuous wave X-ray source. For the luminescence decay measurements the LAB/PFO was excited by a 40 kV pulsed X-ray source which was optically pumped using an Edinburgh Instruments HR-400 pulsed diode laser. The X-ray excited luminescence from the scintillator is collected by a liquid light guide which delivers it to the FL51000 where it is wavelength selected and detected. The FL51000 was equipped with a PMT-900 detector that is sensitive from 200-650nm and time-correlated single-photon counting (TCSPC) electronics.

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X-ray Excited Luminescence Lifetime of Scintillators

Liquid scintillator detectors are widely utilised in neutrino and astroparticle detection experiments. One that is increasingly being used in large scale detection experiments is linear alkylbenzene (LAB). LAB is an attractive scintillator due to its low cost, high flash point, and low toxicity; making it easier to handle than previously used toxic and flammable organic solvents. In this Application Note, the spectral and time-resolved X-ray excited luminescence of a liquid scintillator is studied using a Photoluminescence Spectrometer and X-Ray sample chamber.

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