Acetone-based liquid scintillator loaded with lithium-6(^{6}Li)

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Introduction

Motivation

- Purpose of this research is to make LS(liquid scintillator) more economically from a material and synthesizing point of view.
- Water is a good candidate for these and even safety issue.
- But fluor cannot be solubilized in water without surfactant.

What is LS?

LS is a type of chemical compound used in particle physics. It commonly used in experiments involving neutrino detection. When a loading particle interacts with neutrino, it produces flashes of light signal called scintillations. And these can be detected by photomultiplier tubes so we can measure the intensity and timing of these scintillation and determine various properties of the particles.

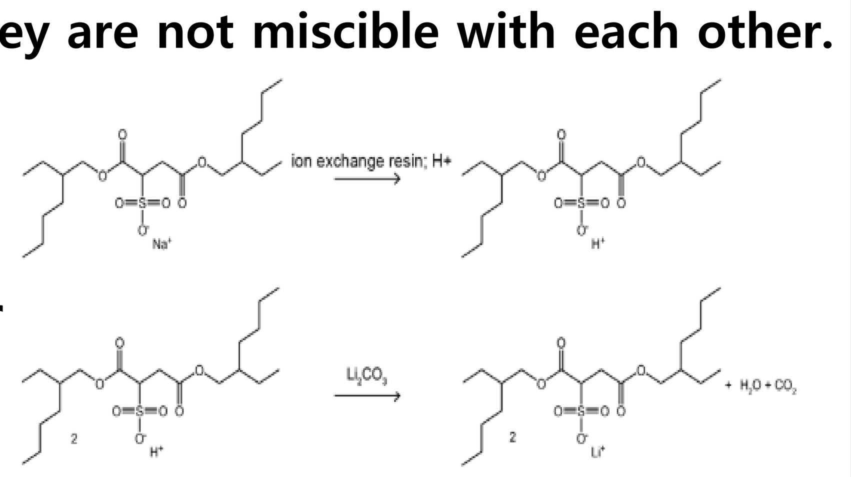
Key point

- Make fluor soluble in water loaded with ^{6}Li
- No use of any surfactants
- Need to dissolve fluor, second wavelength shifter, and to load ^{6}Li
- Long term stability over several years
- High light yield to detect neutron hit in a small cell

Development of AbLS

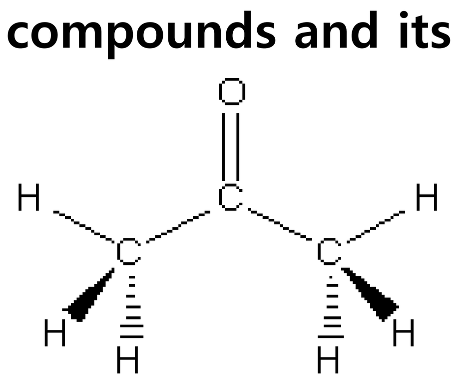
To synthesize LS with water, the first step is to mix water with its base solvent. However, the base solvents of LS are typically apolar and often organic. As water is polar and inorganic, they are not miscible with each other.

- Loading ^{6}Li w/ and w/o surfactant
- Nonionic surfactant
  - Ethoxlated nonylphenol
  - Polyoxyethylen(10)Nonylephenyl Ether
- Method
  - mix LS + lithium aqueous solution
  - mix LS + surfactant + Lithium ion compound

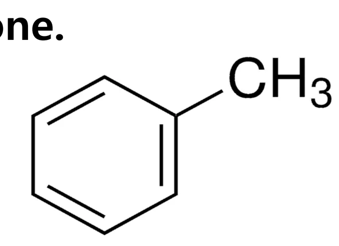


Scheme 1. Synthesis of LiDOSS.

The matter is to identify a solvent that can dissolve fluorescent compounds and secondary wavelength shifters while remaining soluble in water. Acetone is identified as a suitable option due to its strong solvency for organic compounds and its ability to dissolve in water without requiring surfactants.



Acetone's unique property as a solvent for both organic and inorganic substances led to its consideration as a suitable solvent. Many fluorescent compounds and secondary wavelength shifters are organic and apolar, so they can solve in acetone.



Toluene, a common solvent in traditional LS, has a benzene ring and is luminescent, while acetone lacks luminescent properties.

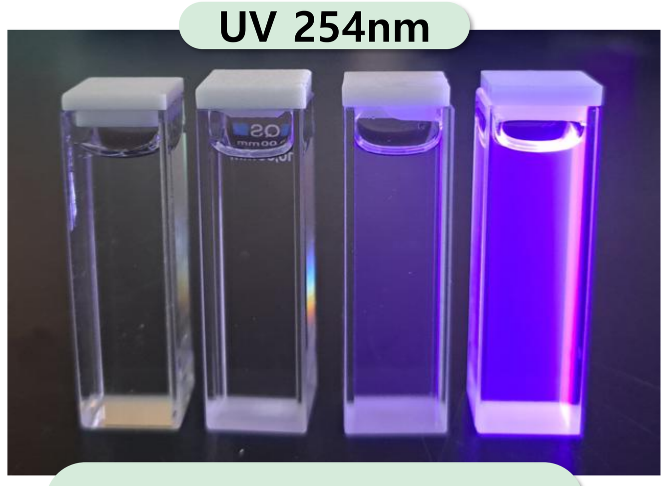
Toluene
Absorption: 260–270nm
Emission: 285–290 nm (weak)

Fluorescent compound
Absorption: Ultraviolet 200-400nm (primarily 250–300nm)
Emission: 350–370 nm

⇒ The necessary luminescence can be effectively achieved by fluorescent compound alone.

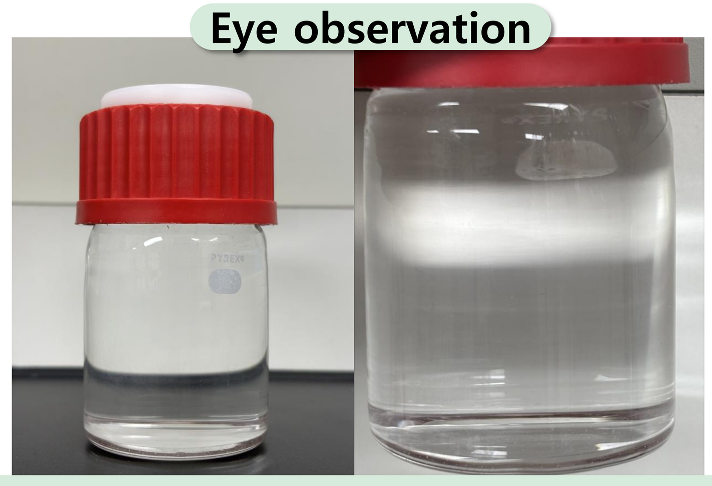
- Observations of AbLS sample

UV 254nm



Water, Acetone, AbLS, GdLS

Eye observation

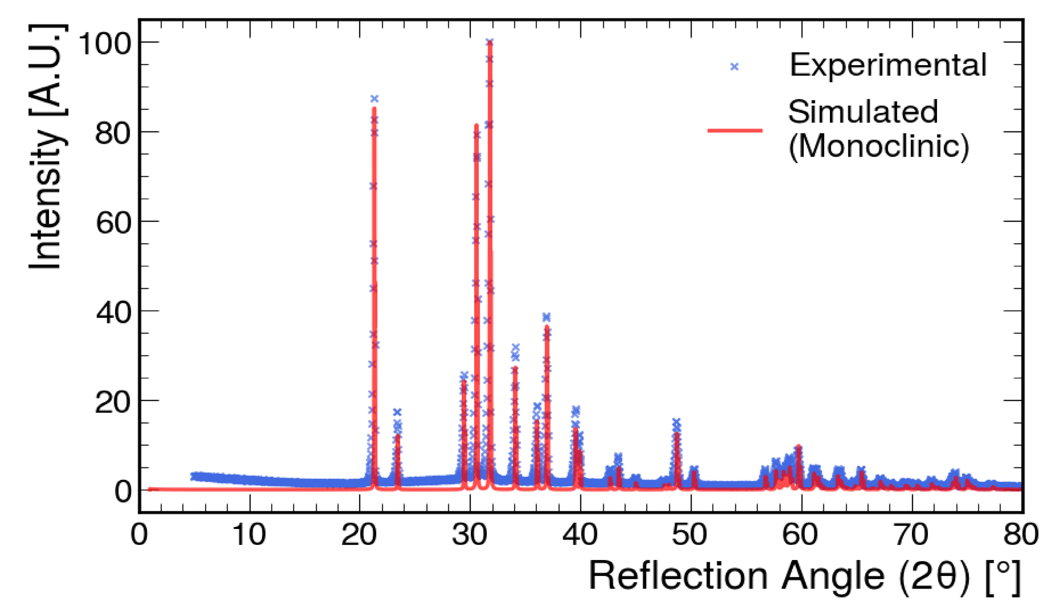


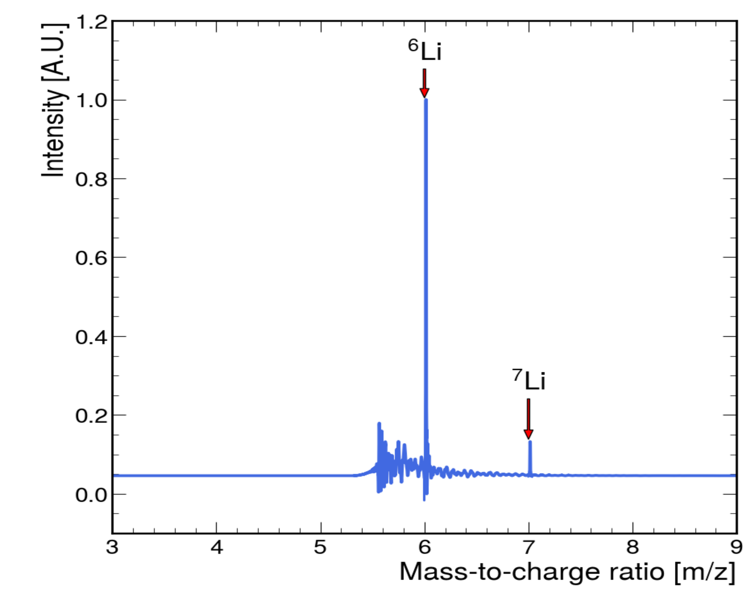
Liquid scintillator sample loading 6-Lithium(0.1%)

After numerous trials and errors, the optimal ratio of water and acetone for the desired mixture was determined thus enabling the synthesis of LS with water as a component.

Performance Test

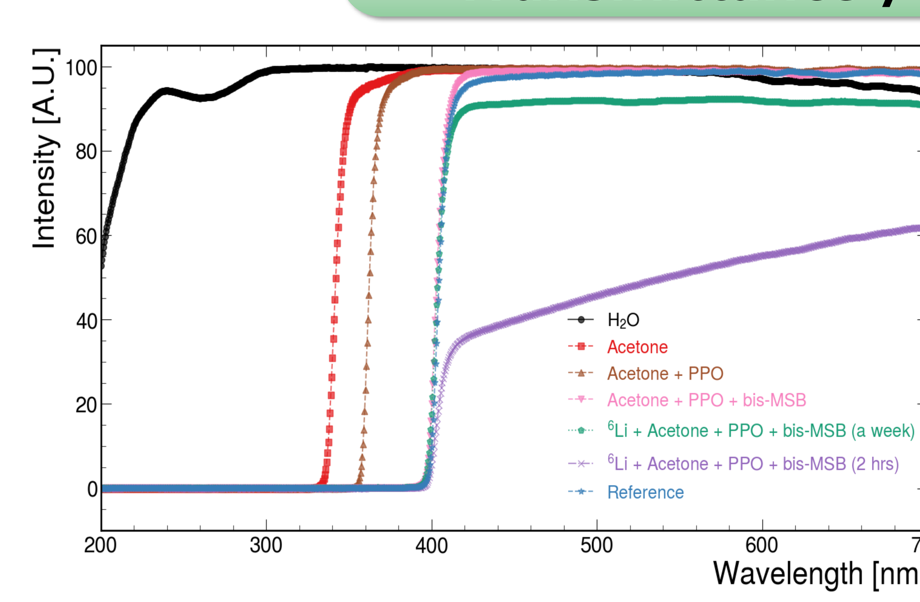
Lithium samples from XRD measurement

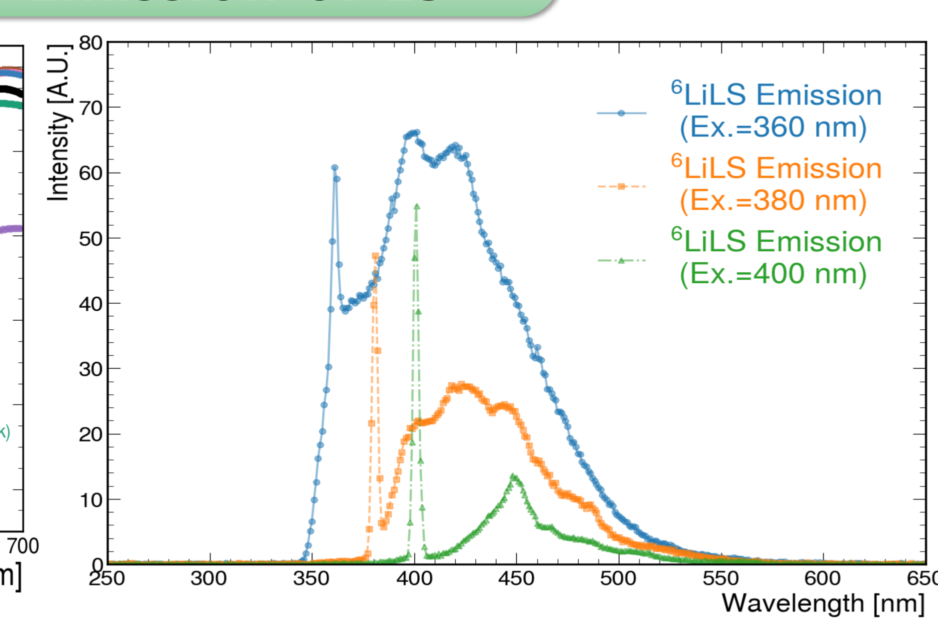




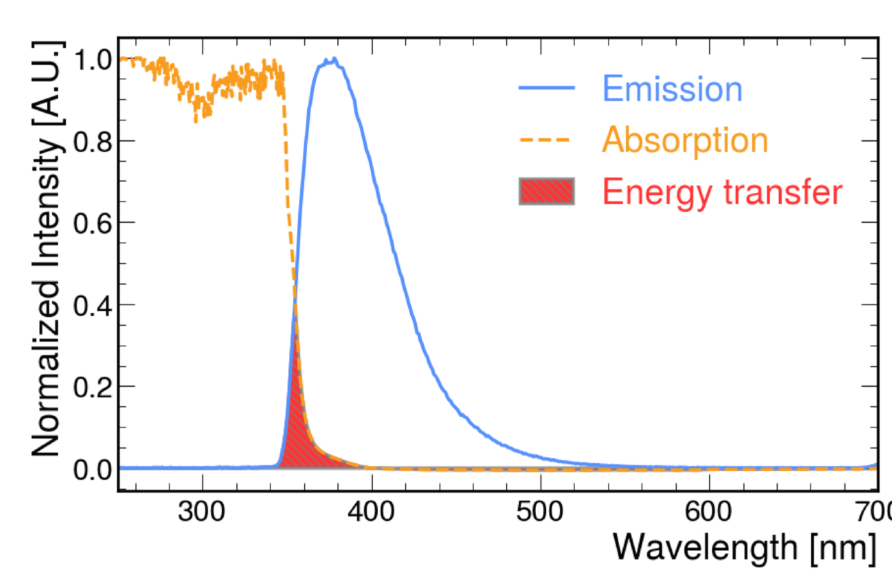
- Our sample has monoclinic crystal system.
- Using X-ray Diffraction, verified the purity of the sample by confirming the match of its crystal system.
- The mass-to-charge ratio spectrum of the sample, the m/z ratio is high at 6.
- The sample consists of over 90% lithium with a mass number 6.

Transmittance / Emission of LS





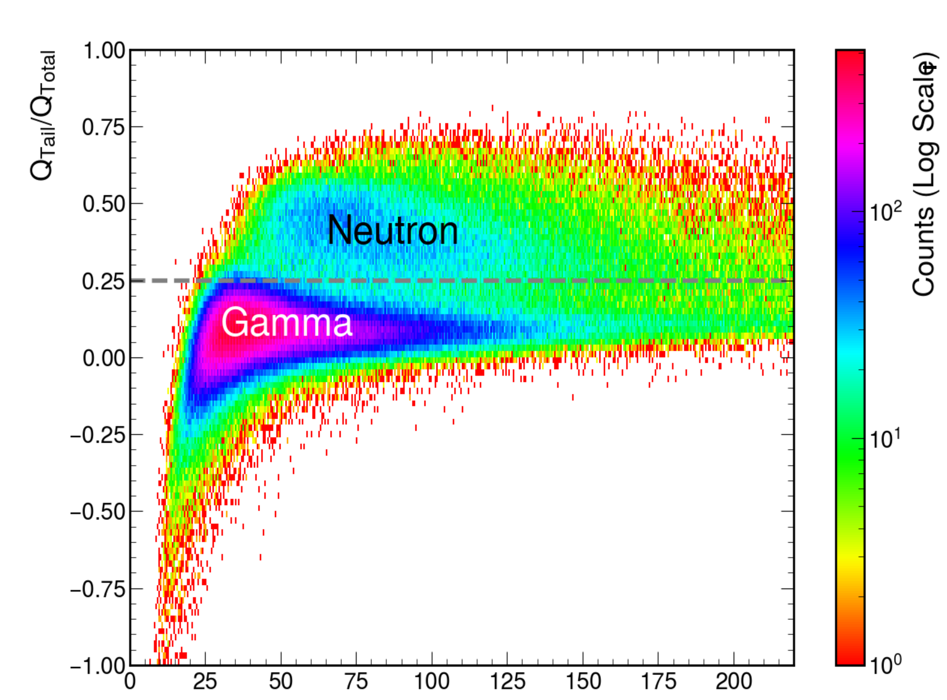
- The [T] of our final sample synthesized ~2 hours appears relatively low
- The [T] of our final sample mixed about a week does not differ significantly from that of other samples
- The excitation wavelength was increased from 360 and 400nm.



Absorption and emission spectrum as a function of wavelength on one plot.

- There is overlap of absorption and emission spectra in our sample
- The absorption spectrum of the base solvent matches well with the emission spectrum of fluorescence.

Pulse shape discrimination of LS



Q_{tail}/Q_{total} value of the sample using the PSD method as a function of energy. The sample enables a marginal discrimination of neutron (n) and gamma ray signals. The horizontal dotted line represents the boundary line between n and gamma ray. It is marginally possible to separate between the neutron and gamma ray in the sample. .

Summary & Future Plan

- Obtained promising results regarding the possibility of synthesizing LS without surfactants using acetone.
- Further optimization is necessary to simultaneously enhance stability and efficiency.

Reference: Kim, B.C., Choi, J.Y., Joo, K.K., Park, S.Y., Song, Y.S., & Woo, H.J. (2021). Development of an Alcohol-based Liquid Scintillator and its Application. New Physics: Sae Mulli, 71(1), 21-28.