Measurement of tritium with plastic scintillators in large vials of a low background LSC—an organic waste-less method—

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Past studies; how to use PS

PS=Plastic scintillator, which is an alternative material of liquid scintillator

PS-sheets for nonvolatile compounds

PS-pellets for HTO


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Past studies; plasma effects for PS-sheets

Plasma treatment effects were addition of a carbonyl group on the PS surface and at the same time, etching by DBD-plasma.
Past studies; detection limits

Both detection limits are not enough to measure environmental samples, directly.

\[ n_D = \frac{k^2}{2} \left[ \frac{1}{t_s} + \frac{1}{t_s^2 + \frac{4n_B}{k^2} \left( \frac{1}{t_s} + \frac{1}{t_B} \right)} \right] \]

\( k = 2 \)

PS-sheets in 20 mL vials

PS-pellets in 20 mL vials

Sample: 5\( \mu \)L, \( Eff=45\% \)

Sample: 50\( \mu \)L, \( Eff=25\% \)

\( t_B = 5 \text{ min} \)

\( t_B = 60 \text{ min} \)
Small ⇒ Large amounts

For example, pellets put in each vial are 15 g in 20mL vial, 97 g in 145 mL poly-vial, and 117 g in 100mL wide-mouth Teflon vial. One sheet size was increased 2 times and the sheet number was utmost 64 in a wide mouth Teflon vial.
Purpose

To confirm large vials with the plastic scintillators are effective for large volume

For some applications in the future
- Monitoring post,
- Plastic scintillation counter
  (Poster No119 on Tuesday)
- Expiration measurement apparatus
  (Friday, 2nd oral presentation in the morning)
Experimental

Factors to study

• Difference of plasma devices
• Protection/ damage from UV light
• Difference of vials
• Linearity and detection limits

Materials used

• Plastic scintillator; sheets of **BC-400** (Saint-Gobain, USA) and pellets of **EJ-200** (G-tech, Japan)
• Vials; Teflon (Sanplatec Co., Japan), Polyethylene (ZINSSER ANALYTIC, Germany) and its cap was uGV2-CAP (Meridian, UK)
• Plasma devices except for making by myself; PR-101 (Izumi Co., Japan), PCT (Tokyo Plasma Factory, Japan)
• UV auto-fade-meter; U48AUHB (Suga Test Instrument Co., Ltd. Japan)
• LSC; AccuFLEX LSC-LB7 (Hitachi Ltd., Japan)
• HTO and $^3$H-methionine (Moravek Biochemical Inc., USA)
• 5 mL liquid scintillator ACS-2 (GE Healthcare, UK) was used to get activity.
3H-methionine 100 μL/200 Bq applied to each PS-sheet. Non-treatment efficiency was approximately 14%. Triplicate samples were measured.

<table>
<thead>
<tr>
<th>Device</th>
<th>Source of plasma treatment</th>
<th>Etching</th>
<th>Sample Preparation</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 DBD</td>
<td>(myself)</td>
<td>Ar(He)</td>
<td>One by one</td>
<td>Yes</td>
</tr>
<tr>
<td>2 Low pressure</td>
<td>IP-220P</td>
<td>Air (compressor)</td>
<td>multiple</td>
<td>No</td>
</tr>
<tr>
<td>3 Low temperature</td>
<td>TPF</td>
<td>Air, Noble gas, N₂, O₂ (Mixture is possible.)</td>
<td>One by one</td>
<td>Maybe No</td>
</tr>
</tbody>
</table>
Implication of UV light irradiation

An UV auto-fade-meter

- Carbon arc lamp was used.
- Total irradiation time was 12h*365d.
- The irradiation was 500 W/m².
- Humidity in the irradiation room was 50%.
- 

The counting efficiency (%) of PS-pellets put under natural sunlight through a window glass among 1 year

<table>
<thead>
<tr>
<th>Vial</th>
<th>UV irradiation</th>
<th>non-irradiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyethylene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>145 mL</td>
<td>30.36 ± 1.01</td>
<td>34.65 ± 0.23</td>
</tr>
<tr>
<td>Teflon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 mL</td>
<td>39.61 ± 7.19</td>
<td>46.42 ± 0.90</td>
</tr>
</tbody>
</table>

HTO: 50μL/170 Bq
## Counting efficiency depending on vials

Counting efficiency (%) of tritiated water with PS-pellets filled full in each vial

<table>
<thead>
<tr>
<th>HTO volume</th>
<th>20 mL glass vial</th>
<th>Polyethylene vial 145 mL</th>
<th>Teflon vial normal cap</th>
<th>100 mL wide mouth a special cap in a bag</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 μL</td>
<td>46.4 ± 1.0</td>
<td>38.9 ± 3.5</td>
<td>-</td>
<td>69.0 ± 3.3</td>
</tr>
<tr>
<td>25 μL</td>
<td>36.0 ± 0.4</td>
<td>36.3 ± 0.3</td>
<td>-</td>
<td>62.5 ± 0.8</td>
</tr>
<tr>
<td>50 μL</td>
<td>22.3 ± 0.4</td>
<td>35.8 ± 0.1</td>
<td>46.4 ± 0.9</td>
<td>43.8 ± 0.4</td>
</tr>
<tr>
<td>100 μL</td>
<td>13.0 ± 0.1</td>
<td>32.1 ± 0.4</td>
<td>-</td>
<td>37.1 ± 0.3</td>
</tr>
<tr>
<td>500 μL</td>
<td>3.1 ± 0.1</td>
<td>7.4 ± 0.1</td>
<td>-</td>
<td>20.3 ± 0.4</td>
</tr>
<tr>
<td>1 mL</td>
<td>-</td>
<td>6.5 ± 0.1</td>
<td>5.8 ± 0.1</td>
<td>11.1 ± 0.1</td>
</tr>
<tr>
<td>3 mL</td>
<td>-</td>
<td>2.6 ± 0.1</td>
<td>2.3 ± 0.1</td>
<td>3.7 ± 0.1</td>
</tr>
<tr>
<td>5 mL</td>
<td>-</td>
<td>1.6 ± 0.1</td>
<td>-</td>
<td>1.3 ± 0.1</td>
</tr>
<tr>
<td>7 mL</td>
<td>-</td>
<td>1.2 ± 0.1</td>
<td>-</td>
<td>1.0 ± 0.1</td>
</tr>
<tr>
<td>10 mL</td>
<td>-</td>
<td>0.80 ± 0.1</td>
<td>-</td>
<td>0.6 ± 0.1</td>
</tr>
<tr>
<td>full**</td>
<td>0.085 ± 0.014</td>
<td>0.14±0.0035</td>
<td>0.18±0.0047</td>
<td>-</td>
</tr>
</tbody>
</table>

**full**: Sample was 9 mL in a 20 mL glass vial, 52 mL in a polyethylene vial, and 46 mL in a Teflon vial.

By LS, it was approx. 39%.

Weight of PS-pellets

<table>
<thead>
<tr>
<th></th>
<th>15.5 g</th>
<th>97 g</th>
<th>117 g</th>
<th>72.5 g</th>
</tr>
</thead>
</table>

*counting efficiency (%) = cpm/dpm×100

**Special cap is appeared at the “Tritium study”, tomorrow morning, 2nd.*
Quantitative analysis is possible with plastic scintillator using LSC-LB7.

In the case of 1 mL*8 sheets.

PS-pellets filled full in each vial.

Bq mL⁻¹

with PS-pellets.
Detection limits of PS method

$$n_D = \frac{k^2}{2} \left[ \frac{1}{t_S} + \sqrt{\frac{1}{t_S^2} + \frac{4n_B}{k^2} \left( \frac{1}{t_S} + \frac{1}{t_B} \right)} \right]$$

Both were measured in the 100 mL Teflon vials; 1 mL/ 1 PS-sheet applied to.
Summary

For low energy beta emitters measurement, plastic scintillators (PS) are useful:

- Usage of PS is same with that of liquid scintillator use.
- The counting efficiency is approximately same as that of liquid scintillator use.
- The PS-sheets are suited for non-volatile compound, and the PS-pellets are suited for volatile compound.
- The plasma treatment for PS-sheets are useful especially for tritium, because the wide contact area is effective for short range beta-rays.
- It is necessary to avoid UV-light for stocking the PSs.
- The PSs uses are organic waste-less methods.
- Large vials with wide mouth for LSC-LB7 are useful to get low detection limits.
Thank you for your attention!!

Please check a poster No.119.
Please watch the second oral presentation on Friday.