Basic Compound Synthesis for $^{14}$C Quality Verification Utilizing HANARO

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1. Introduction

$^{14}$C is a pure beta-emitting radioactive isotope that is the most commonly used in the form of a labeled compound with $^3$H. In addition, $^{14}$C is an isotope of carbon, a basic element of organic compounds, and be used as a radiotracer for physiological activity, metabolic tracing, and environmental change tracing in fields such as drug delivery systems, clinical research, and the environmental fields.

In particular, $^{14}$C-labeled compounds are widely used in new drug development and clinical research. Microdosing is a typical example, and this technology has the advantage of being able to check human metabolism by directly injecting it into the human body.

Despite a significant amount of $^{14}$C labeled compounds are being used in Korea, the production of labeled compounds is restricted because most of the basic raw materials, $^{14}$C, are imported and used from abroad. To overcome this problem, it is preparing to produce $^{14}$C using HANARO and will synthesize various basic compounds using $^{14}$C are produced.

In this study, several experiments were conducted with cold foam to verify the quality of $^{14}$C. Aluminum Nitride (AIN) not irradiated with neutrons recovers as BaCO$_3$ in carbonate form, and various basic compound synthesis experiments run using BaCO$_3$. Experimental equipment modifies to increase yield and quality, and it confirms quality through analysis equipment.

2. Methods

AIN is mainly used to produce $^{14}$C through nuclear reactions in nuclear reactors. AIN has a reasonably stable structure that does not cause thermal deformation or pyrolysis following neutron irradiation.

$^{14}\text{N} + ^1\text{n} \rightarrow ^{14}\text{C} + ^1\text{p}, \sigma=1.81 \text{b}, \tau(1/2) = 5,370 \text{ years}

Therefore, CO$_2$ generated by irradiating the AIN pellet target with neutrons was recovered in the form of BaCO$_3$, and conduct to synthesize and optimize various basic compounds, which are the previous steps of the labeling compound.

The experiment of irradiating the AIN pellet target and recovering it as BaCO$_3$ carries out as follows.

\[
\text{Al} + \text{N} + \text{H}_2\text{SO}_4 + \text{K}_2\text{Cr}_2\text{O}_7 \rightarrow \text{CO}_2
\]

<CO$_2$ generation process>

\[
2\text{NaOH} + \text{CO}_2 \rightarrow \text{Na}_2\text{CO}_3 + \text{NaHCO}_3
\]

\[
\text{Na}_2\text{CO}_3 + \text{NaHCO}_3 + \text{Ba(OH)}_2 \rightarrow \text{BaCO}_3
\]

3. Results

Among the various basic compounds synthesized through BaCO$_3$, sodium acetate was selected. The synthesis was carried out as follows through the cold foam experiment.

\[
\text{BaCO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{MeMgI} \rightarrow \text{Et}_2\text{O} \rightarrow \text{CH}_3\text{COO}^-\text{Na}^+
\]

A synthesis experiment was conducted based on the amount of BaCO$_3$ among the reagents used for sodium acetate synthesis. Table 1 summarizes the reagents used for the synthesis of sodium acetate. Fig 1 shows the synthesis equipment for sodium acetate.

$^3$H NMR, $^{13}$C NMR is used for the analysis.

Table 1 Reagents used in the synthesis of sodium acetate

<table>
<thead>
<tr>
<th>Reagents</th>
<th>Volume (g, ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BaCO$_3$(s)</td>
<td>1 g</td>
</tr>
<tr>
<td>H$_2$SO$_4$(l)</td>
<td>9 ml</td>
</tr>
<tr>
<td>MeMgI in ether (l)</td>
<td>3.2 ml</td>
</tr>
<tr>
<td>1N NaOH (l)</td>
<td>16.2 ml</td>
</tr>
<tr>
<td>Ag$_2$SO$_4$(s)</td>
<td>1.9 g</td>
</tr>
<tr>
<td>20% H$_2$SO$_4$(l)</td>
<td>8.8 ml</td>
</tr>
</tbody>
</table>

Fig 1 Sodium acetate synthesis equipment.

The $^{14}$C labeled compounds are commonly synthesized using BaCO$_3$ or basic compounds modified from BaCO$_3$. The amount of BaCO$_3$ produced from one AIN pellet target (size: φ 16mm, H: 8.85 mm) irradiated at HANARO was calculated 2.14 mg. And also, the amount of CO$_2$ gas generated from BaCO$_3$ was only 2.43 ml in STP. As such, a very small amount of $^{14}$C is produced, the tightness of synthetic equipment is paramount in order to enhance the synthetic yield of the basic compound. Most of the synthetic processes were carried out under vacuum, and the process optimization...
was carried out by changing the equipment and
adjusting the number of reagents through several
experiments.

At the beginning of the experiment, the yield was as
low as 50%. As the experiments conduct several times,
a high yield of 86% obtains by changing the
experimental equipment to suppress gas leakage and
increase the vacuum level. The expected yield was
0.352 g, but the amount obtained after the actual
experiment was 0.342 g. The synthesis results confirm
through NMR.

4. Conclusions

In this study, C was recovered in the form of BaCO₃,
and the sodium acetate synthesis process was optimized
to increase the yield and reduce waste, and the desired
results were obtained. Also, the synthesis of the desired
basic compound was confirmed through NMR analysis.
The optimal conditions will be applied to the synthesis
of basic compounds using ¹⁴C which will be produced
through HANARO in the future.

5. Acknowledgements

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