Feasibility Study on Hydrogen Isotope Exchange Reaction by Ultraviolet Light

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1. Introduction

The methods of tritiated wastewater treatment, which has been studied so far, are composed of a combined process of electrochemistry, catalyst, metal materials, and laser technology [1]. Among them, hydrogen isotope exchange reaction has been known an efficient method for treating tritiated wastewater [2-3]. For this reason, most of study has been mainly directed toward increasing the efficiency of hydrogen isotope exchange. Until now, the most economical separation method for the tritium is known to be the liquid catalytic exchange reaction. However, since this method has to be operated at high temperature (> 80°C) and to be carried out under deaerated condition, it needs lots of energy and complicated system for the treatment of tritiated wastewater.

In present work, we analyzed the principle of the liquid catalytic exchange reaction and then modified it as introducing UV light instead of platinum catalyst. This article mentions about the feasibility of this modified technique.

2. Feasibility of Hydrogen Isotope Exchange Under Ultraviolet Light Conditions

2.1 Experimental

The experimental equipment for the hydrogen isotope exchange reaction consists of a reaction vessel, UVC lamps (254 nm, 24 W × 2), and a hydrogen gas (H₂) supply unit. The basic configuration of the experiment is shown in Fig. 1.

![Fig. 1. Experiment system of UV-based the hydrogen exchange reaction.](image)

The tritium radioactivity of the solution used for the experiment was in the range of 300 - 500 Bq·g⁻¹. Hydrogen gas (99.999 vol%) was supplied to the bottom of the solution with 200 mL·min⁻¹ of the flow rate.

2.2 Results

The experiments were conducted to confirm the hydrogen isotope exchange reaction between hydrogen in water molecules and gaseous hydrogen atoms under UV light conditions. Under non-irradiated condition, only the hydrogen gas was
supplied in the solution. Table 1 shows the comparison of the reduction of tritium radioactivity with and without UV light. Without UV light, the tritium radioactivity little changed after supplying hydrogen gas. With UV light, the radioactivity decreased significantly after supplying hydrogen gas.

Table 1. Reduction of tritium radioactivity in the solution at the room temperature

<table>
<thead>
<tr>
<th>Reaction time (h)</th>
<th>w/o UV (Bq/g)</th>
<th>with UV (Bq/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>452.13</td>
<td>403.42</td>
</tr>
<tr>
<td>3</td>
<td>451.99</td>
<td>401.75</td>
</tr>
<tr>
<td>6</td>
<td>450.97</td>
<td>398.63</td>
</tr>
</tbody>
</table>

At our experimental condition, as UV light and hydrogen gas supply conditions are constant, the isotope exchange reaction may follow the first order reaction rate as follow:

$$\ln \frac{[C_a]}{[C_{a0}]} = -kt$$

Where, $C_a$ is the tritium concentration at time $t$, $C_{a0}$ is the initial concentration of tritium, $k$ is the reaction rate constant, and $t$ is reaction time.

Using the equation 1, we plotted the data denoted in Table 1 as shown in Fig. 2. We confirmed that the decrease of radioactivity follows the first order reaction rate under UV light condition. And the reaction rate was calculated to be 0.0038 Bq·g⁻¹·h⁻¹. We confirmed that the hydrogen isotope exchange reaction could be possible by UV light.

3. Conclusion

The feasibility experiments of hydrogen isotope exchange reaction were carried out under UV light conditions. With UV light, the decrease of tritium radioactivity follows the first order reaction rate. The reaction rate was calculated to be 0.0038 Bq·g⁻¹·h⁻¹. We confirmed that the hydrogen isotope exchange reaction is feasible under UV light condition.

REFERENCES