EFFECT OF AGITATION RATE ON OXIDATIVE DEGRADATION OF MONOETHANOLAMINE

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Abstract

To mitigate the problems caused by CO₂ emissions, post-combustion capture using monoethanolamine (MEA) is one of the most appropriate solutions. In addition to the large energy penalty, one of the most important issues that prevent a large deployment of this technology is the oxidative degradation of MEA. A pilot plant sample showed degradation of MEA after 45 days when treating a flue gas containing about 5% O₂, at 40°C and atmospheric pressure[1].

In order to study the various aspects related to the mechanism of degradation of the MEA within a reasonable time, operating conditions especially agitation rate are better controlled. This allows us to observe a significant degradation with similar reaction pathways compared to the real case (pilot plant).

Industrial vs. laboratory conditions

- A base case is identified for the study of MEA degradation under accelerated conditions (Table 1).
- By increasing the agitation rate, we could reduce the experiment duration for similar degradation rate (figure 1).
- Degradation products obtained at lab scale are similar to industrial scale (figure 2) and accelerated lab-scale degradation follows the same reaction pathways as degradation at industrial scale. This confirms the relevance of accelerated degradation experiments.

Table 1. Comparison between industrial and lab scale conditions

<table>
<thead>
<tr>
<th>Unit</th>
<th>Industrial conditions</th>
<th>Lab conditions (G.L.Leonard[2])</th>
<th>Lab conditions (base case)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>days</td>
<td>45</td>
<td>7</td>
</tr>
<tr>
<td>Degradation rate</td>
<td>Wt% / day</td>
<td>0,026</td>
<td>0,9</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>Pa</td>
<td>6000</td>
<td>25000</td>
</tr>
<tr>
<td>T</td>
<td>°C</td>
<td>40-60</td>
<td>120</td>
</tr>
<tr>
<td>Agitation rate</td>
<td>RPM</td>
<td>-</td>
<td>600</td>
</tr>
<tr>
<td>Kₐa</td>
<td>s⁻¹</td>
<td>0,01&lt;Kₐa&lt;0,04</td>
<td>~0,003</td>
</tr>
<tr>
<td>Gas feed</td>
<td>%</td>
<td>6%O₂/68%H₂O/14%CO₂/12%H₂O</td>
<td>5%O₂/95%N₂</td>
</tr>
</tbody>
</table>

Figure 1. Influence of the agitation rate on the degradation of the MEA over time.

Figure 2. Comparison of GC-FID spectra between samples degraded at lab scale (BC DTR) and at industrial scale (pilots1 and 2).

Kinetics of MEA degradation

- We propose a kinetic model of the MEA degradation under two different agitation rate (800 and 1000 rpm).

Case 1: 800 rpm

\[-r_{MEA} = 3.9 \times 10^5 e^{-48.116/R\sigma} [O_2]^{1}\]

Case 2: 1000 rpm

\[-r_{MEA} = 5.3 \times 10^5 e^{-48.116/R\sigma} [O_2]^{1}\]

- Larger agitation rate → higher overall mass transfer coefficient.
- As a consequence, more oxygen is transferred to the gas/liquid interface → acceleration of the degradation (figure 3).

Figure 3. Influence of temperature and agitation rate on degradation rate of MEA.

Conclusion and perspective

- In addition to the temperature and the pressure, the improvement of the gas / liquid transfer also accelerates the degradation.
- Based on the results, the goal of the next study is to establish a kinetic model that considers both the chemical and the physical kinetics separately instead of usual apparent kinetics

\[r = k_0 \cdot e^{-\frac{E_a}{RT}} \left(1 + \frac{2K_L a - k_0 \cdot e^{-\frac{E_a}{RT}}}{2K_L a + k_0 \cdot e^{-\frac{E_a}{RT}}} \right)[O_2]^n\]

References