Amino Acid Solvents for CO₂ Absorption

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Abstract

Amino acid solvents were tested for CO₂ capture performance at optimized absorber conditions. The solvents are: 6 m potassium glycine (GlyK), 6.5 m potassium β-alanine (β-AlaK), 3 m / 5 m potassium taurine / homotaurine (TauK/HtauK), 6 m potassium sarcosine (SarK), and 4.5 m sodium sarcosine (SarNa). A Wetted Wall Column (WWC) was used to measured the absorption/desorption rates and CO₂ solubility of each solvent at variable CO₂ loadings and temperatures (40°C, 60°C, 80°C, 100°C). Solvents are analyzed at coal fired power plant flue gas conditions and gas turbine combined cycle (GTCC) plant conditions. The operation lean/rich CO₂ loading is assumed to correspond to CO₂ equilibrium partial pressures of 500 Pa / 5000 Pa for coal, and 100 Pa / 1000 Pa for GTCC. The absorption/desorption rates, cyclic capacity, and heat of CO₂ absorption are reported for each solvent at both conditions and compared against 7 m monoethanolamine (MEA). All amino acid solvents have low capacities at 0.2-0.3 mol CO₂/mol alk, which is 50% of 7 m MEA. The absorption rate of 6 m SarK is competitive against 7 m MEA. 3 m / 5 m TauK / HtauK has an attractive high heat of absorption at 80 kJ/mol.

Key words: Amino acid; Solvent screening; Natural gas; Absorption/desorption rates; Cyclic capacity; Heat of CO₂ absorption

1. Introduction

Amino acid solvents are attractive for post combustion CO₂ absorption because of their low environmental impact, with characteristics such as zero volatility, low ecotoxicity, and high biodegradability [1]. To absorb CO₂, amino acids must be activated in water with the addition of an equi-molar amount of base. In the presence of added base, the amino group on the amino acid reacts with CO₂ like amines [2,3]. Potassium (K⁺) was used as the base in four tested solvents: 6 m SarK, 6.5 β-AlaK, 6 m GlyK, and 3 m/5 m TauK/HtauK; sodium (Na⁺) was used for 4.5 m SarNa. Many amino acid solvents precipitate with CO₂ loadings [4,5]. As aqueous solvents, this physical property limits solvent cyclic capacity and the potential for flexible operation at rich loadings.

Typical coal fired power plants generate flue gas with 12% CO₂ and 5-8% O₂. GTCC plants with similar power capacity generate flue gas with 3% CO₂, 15% O₂, and twice the molar flow rate of coal flue gas. These differences in flue gas properties results in changes in solvent performance. When used for GTCC, desirable solvent properties include: stability towards oxidative degradation, good absorption performance at lean CO₂ loadings, and low volatility.
2. Experimental Method and Data Analysis

Experimental data were collected using a WWC, the same as the apparatus and method used by Chen [6] and Dugas [7]. The absorption/desorption rates are reported using liquid film mass transfer coefficients (k_g'). A semi-empirical VLE model (Equation 1) is used to model experimental data and represent solvent CO₂ solubility (Figure 1).

\[
P_{\text{CO}_2}^* = a + b/T + c \cdot \alpha + d \cdot \alpha/T + e \cdot \alpha^2
\]

This model is used to calculate solvent capacity and heat of CO₂ absorption (Figure 2).

\[\text{Figure 1: CO}_2\text{ solubility in 6.5 m } \beta\text{-alaK. Filled points: measured data. Solid lines: model prediction (Eq.1). Dashed lines: 7 m MEA model, Ref [6]}\]

\[\text{Figure 2: Cyclic capacity and heat of CO}_2\text{ absorption analysis for 6.5 m } \beta\text{-alaK}\]

3. Results

Table 1: Summary of absorption properties of tested amino acid solvents, compared against 7 m MEA [7].

<table>
<thead>
<tr>
<th>Amino acid (m)</th>
<th>CO₂ Capacity (mol CO₂/kg Solution)</th>
<th>(k_g')_{avg}) (@40°C) (x 10⁻⁷ mol CO₂/s Pa m²)</th>
<th>Mid (\Delta H_{abs}) (kJ/mol)</th>
<th>(P^{*}_{\text{CO}_2}) (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GlyK (3.55)</td>
<td>Coal 0.25 Gas 0.25</td>
<td>Coal 3 Gas 10.2</td>
<td>Coal 64 Gas 64*</td>
<td></td>
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<tr>
<td>GlyK (6)</td>
<td>Coal 0.35* Gas 0.35</td>
<td>Coal 0.2* Gas 3.2</td>
<td>Coal 64* Gas 64*</td>
<td></td>
</tr>
<tr>
<td>SarK (6)</td>
<td>Coal 0.22 Gas 0.236</td>
<td>Coal 5 Gas 18.9</td>
<td>Coal 56.5 Gas 64</td>
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<tr>
<td>Tau/Htau (3/5)</td>
<td>Coal 0.195* Gas 0.23</td>
<td>Coal 2.2* Gas 10.3</td>
<td>Coal 74.5* Gas 80</td>
<td></td>
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<tr>
<td>(\beta) AlaK (6.5)</td>
<td>Coal 0.25* Gas 0.29</td>
<td>Coal 2* Gas 7.4</td>
<td>Coal 64* Gas 67</td>
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<tr>
<td>MEA (7)</td>
<td>Coal 0.47 Gas 0.55</td>
<td>Coal 4.3 Gas 11.7</td>
<td>Coal 82 Gas 83</td>
<td></td>
</tr>
</tbody>
</table>

4. References


