Effect of Monoethanolamine on the Viscosity and CO₂ Absorption of Aprotic Heterocyclic Anion Ionic Liquids

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Carbon Capture and Storage

Powerplants, refineries, petrochemical plants etc.

Transportation Pipeline Conditions:
14 – 15 MPa
500 ppm H2O
Carbon Capture and Storage (CCS)
(Process simulation from waste flue gas to pipeline quality)

10 – 15 mol% CO₂ and 1 atm → CO₂ w/ 500 ppm water and 130 atm

Madugula et al. (2021) Chem Eng J Advances, 8, 100162
Carbon Capture Using Cyclic Absorption/Stripping

Amine Absorbents

- Established chemistry
- Established technology
- Industry ready

- High energy demand
- Amine degradation
  - Temperature
  - O₂, SOx, NOx

10 – 15 mol% CO₂
8 – 10 mol% H₂O
75 – 85 mol% N₂

95 mol% CO₂
5 mol% H₂O
Carbon Capture: Absorption Using MEA

Flue gas

30 wt % aqueous MEA

MEA, H₂O, CO₂
(to stripping column)

CO₂, H₂O, N₂

Monoethanolamine (MEA)

MW = 61.1
Density = 1.012 g/mL
T_melt = 50.5 °F (10.3 °C)
T_boil = 338 °F (170 °C)
T_degrade = 248 °F (120 °C)
VP = 64 Pa (20 °C)
Carbon Capture: Using Ionic Liquids

Ionic Liquid, CO$_2$ (to stripping column)

[NP][Inda]

[NP][2-CNPyr]

[NP][BnIm]

de Riva et al. (2018) Int. J. Greenhouse Gas Contrl
Parameters to Consider

Viscosity ↑, Diffusivity ↓
Temperature ↑, Viscosity ↓
Temperature ↑, Absorption Capacity ↓

Henry’s Law:

\[ D_{ij} = 1.173 \times 10^{-16} \left( \frac{T \times \sqrt{\varphi_j \times MW_j}}{\mu_j \times (V_{bi})^{0.6}} \right) \]

\[ P_{CO_2} = y_{CO_2}P = x_{CO_2}H(T) \]

Temperature ↑, Absorption Capacity ↓
Properties of Ionic Liquids

Can We Find a Compromise?

- Electrolytic Non-Random Two Liquid
- Redlich – Kwong Equation of State

Chemisorption Mechanism

\[
\ln(K_H) = A_{H,i} + \frac{B_{H,i}}{T}
\]

\[
\ln(K_{eq}) = A_{K,i} + \frac{B_{K,i}}{T}
\]

\[
\ln(K_{eq}) = \frac{\Delta S}{R} + \left(\frac{-\Delta H_{chem}^0}{RT}\right)
\]
Ionic Liquids Suited for Aqueous CO$_2$

Aprotic Heterocyclic Anion (AHA) – Small changes in viscosity with absorbed CO$_2$

Phosphorous – Good for high water concentrations
Absorption Profiles from Literature Data

[P2228][2-CNPyr]

[P66614][2-CNPyr]
Viscosity Profiles

Solvent A: [P2228][2-CNPyr]
Solvent B: [P66614][2-CNPyr]
Carbon Capture per mole MEA

[Graph showing CO₂ Capture per mole MEA as a function of Mole fraction of aqueous MEA in IL. The graph compares different solvents: Solvent A2 w/o CO₂ Loading (red dashed line), Solvent A2 w/ CO₂ Loading (red solid line), Solvent B2 w/o CO₂ Loading (blue dashed line), and Solvent B2 w/ CO₂ Loading (blue solid line).]
Absorber Temperature and Diffusivity

(a) Absorber Temperature vs. Mole fraction of aqueous MEA in IL

(b) Diffusivity vs. Mole fraction of aqueous MEA in IL
Next Steps

❖ Complete Optimization

❖ Perform Lifecycle Assessment