CO_2 absorber pilot plant tests

Experimental matrix

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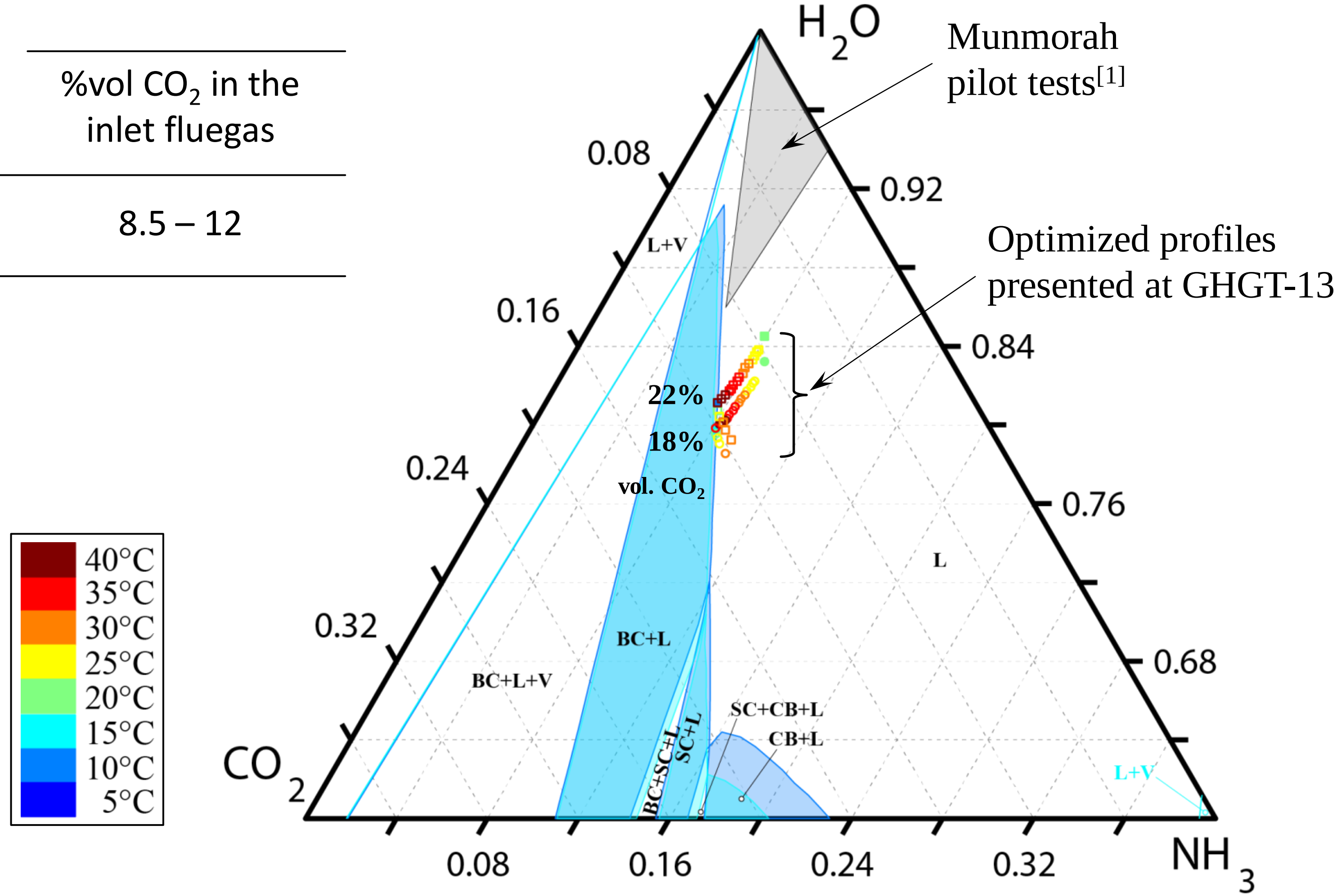
Experimental space

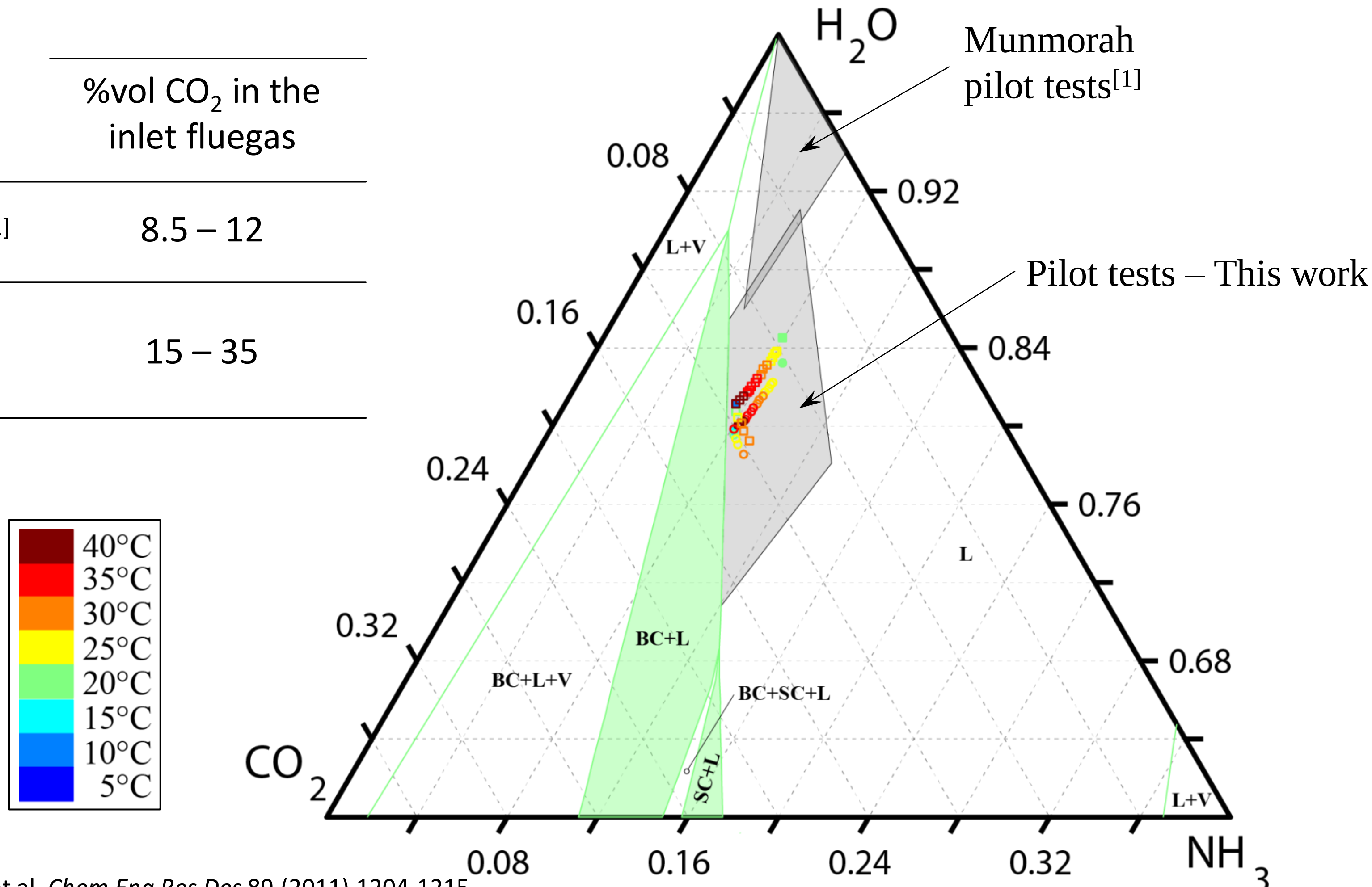
	%vol CO_2 in the inlet fluegas
Munmorah[1]	8.5 – 12



[1] Yu et al. *Chem Eng Res Des* 89 (2011) 1204-1215

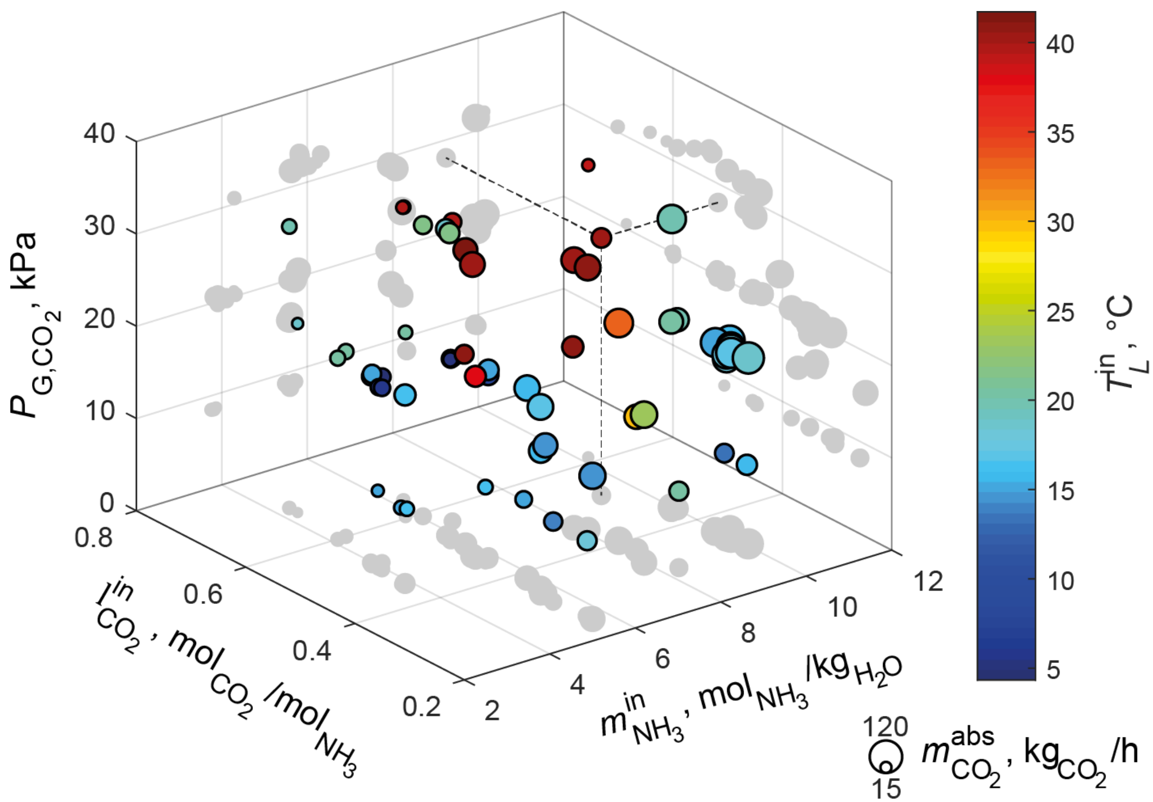
Experimental space

	%vol CO_2 in the inlet fluegas
Munmorah[1]	8.5 – 12
This work	15 – 35



[1] Yu et al. *Chem Eng Res Des* 89 (2011) 1204-1215

Experimental results after data reconciliation



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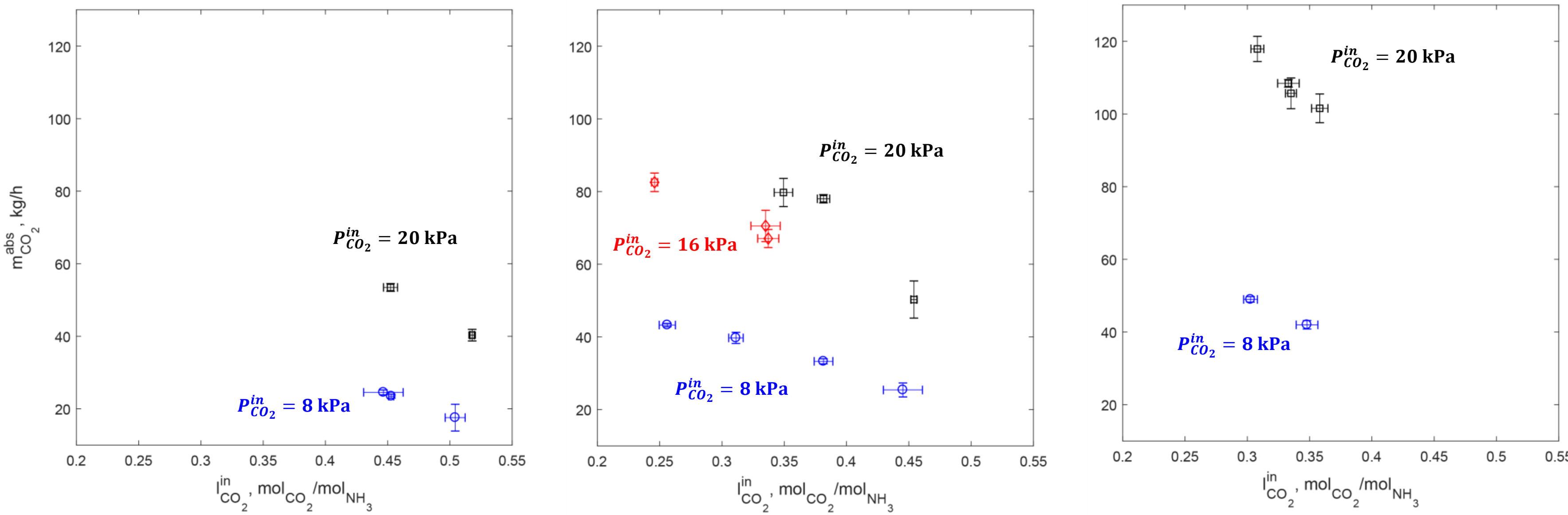
CO_2 absorber pilot plant tests

Sensitivity analysis on the experimental CO_2 absorption rate

CO_2 loading of the inlet liquid stream (1)

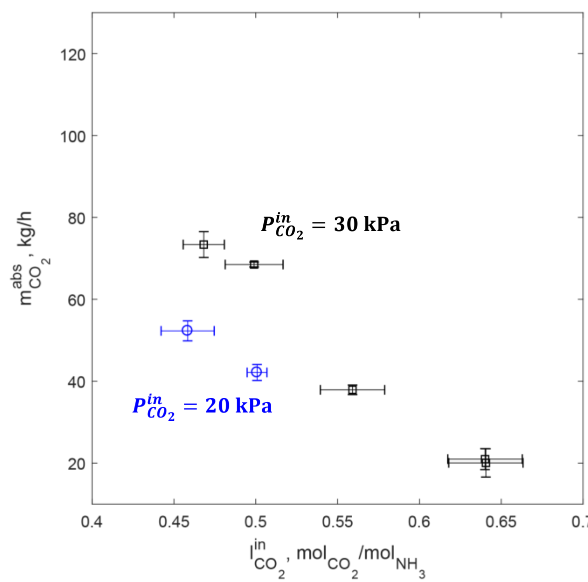
$m_{NH_3}^{in} = 4\ \mathrm{mol_{NH_3}/kg_{water}}$ | $m_{NH_3}^{in} = 6\ \mathrm{mol_{NH_3}/kg_{water}}$ | $m_{NH_3}^{in} = 10\ \mathrm{mol_{NH_3}/kg_{water}}$



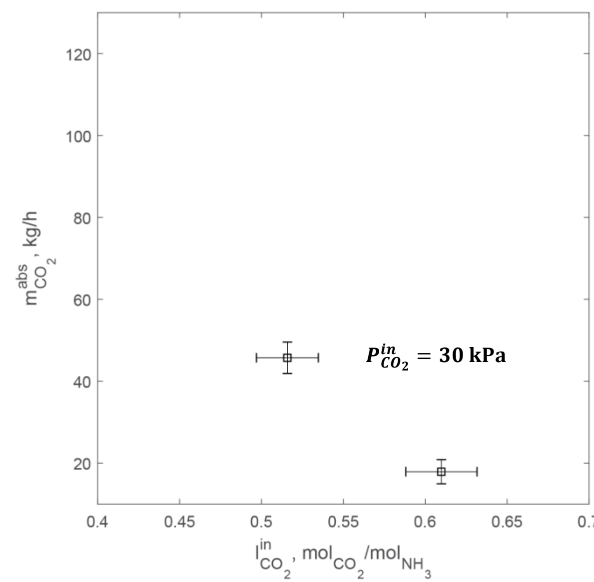
$$\frac{L^{in}}{G^{in}} = 8.5\,\frac{\mathrm{kg}}{\mathrm{kg}}\ ;\ T_L^{in} = 15°\mathrm{C}\ ;\ v_{S,G}^{in} = 1\,\frac{\mathrm{m}}{\mathrm{s}}$$

CO_2 loading of the inlet liquid stream (2)

$m^{in}_{NH_3} = 6\ \mathrm{mol_{NH_3}/kg_{water}}$



$m^{in}_{NH_3} = 10\ \mathrm{mol_{NH_3}/kg_{water}}$



$$\frac{L^{in}}{G^{in}} = 11\,\frac{\mathrm{kg}}{\mathrm{kg}}\,;\ T^{in}_{L} = 40°\mathrm{C}\,;\ v^{in}_{s,G} = 0.7\,\frac{\mathrm{m}}{\mathrm{s}}$$

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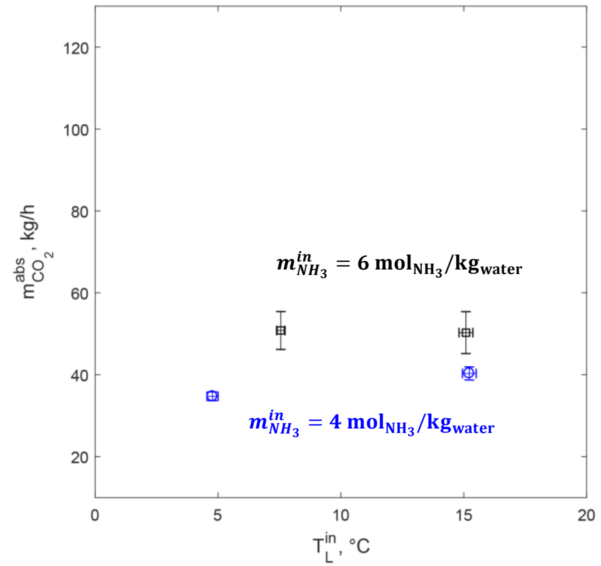
Temperature of the inlet liquid stream (1)



$$P^{in}_{CO_2} = 20\ \mathrm{kPa}\ ;\ \frac{L^{in}}{G^{in}} = 8.5\,\frac{\mathrm{kg}}{\mathrm{kg}}\ ;\ l^{in}_{CO_2} = 0.45 - 0.52\,\frac{\mathrm{mol_{CO_2}}}{\mathrm{mol_{NH_3}}}\ ;\ v^{in}_{s,G} = 0.7\,\frac{\mathrm{m}}{\mathrm{s}}$$

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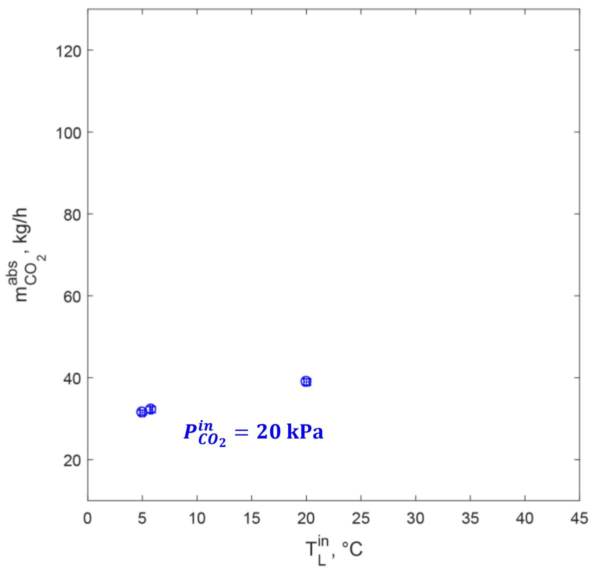
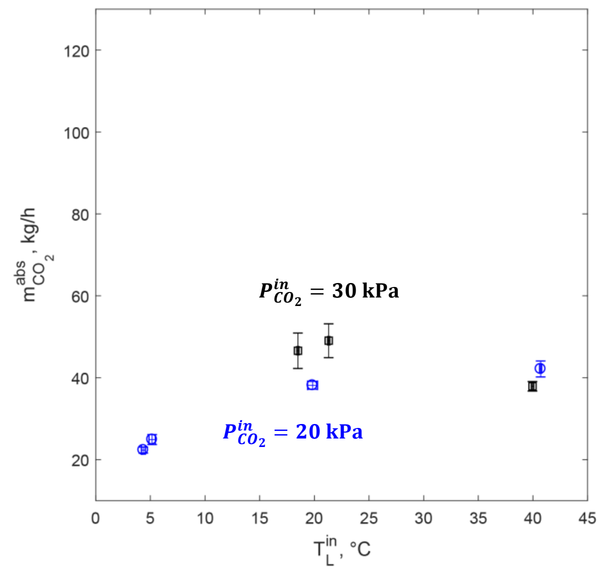
Temperature of the inlet liquid stream (2)

$m_{NH_3}^{in} = 4\ \mathrm{mol_{NH_3}/kg_{water}}$



$m_{NH_3}^{in} = 6\ \mathrm{mol_{NH_3}/kg_{water}}$



$$\frac{L^{in}}{G^{in}} = 11\,\frac{\mathrm{kg}}{\mathrm{kg}}\,;\ l_{CO_2}^{in} = 0.5 - 0.55\,\frac{\mathrm{mol_{CO_2}}}{\mathrm{mol_{NH_3}}}\,;\ v_{S,G}^{in} = 0.7\,\frac{\mathrm{m}}{\mathrm{s}}$$

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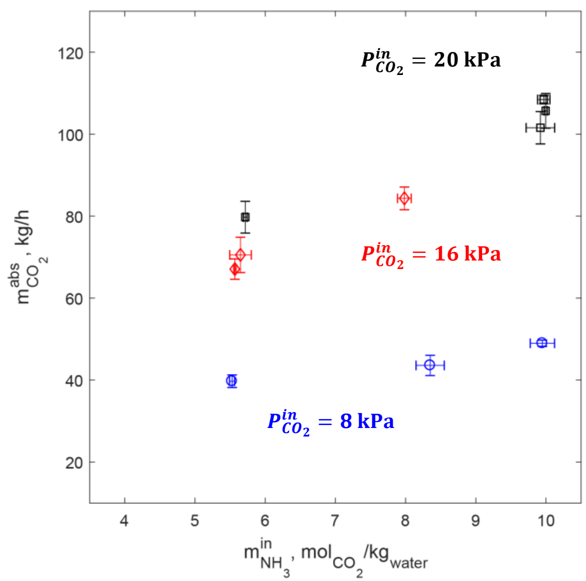
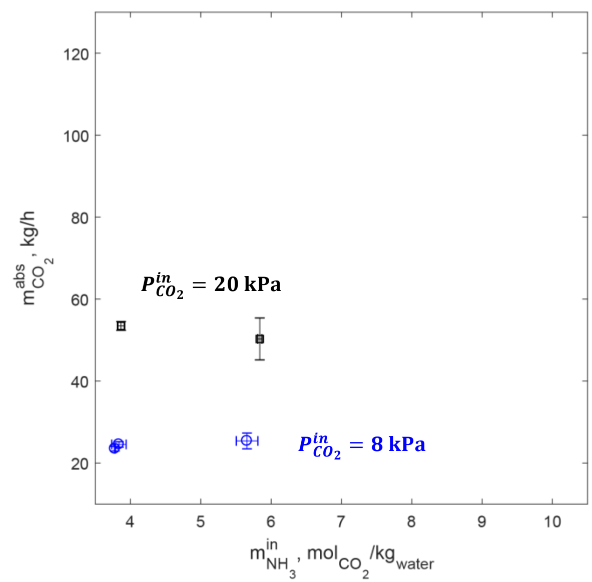
NH_3 concentration in the inlet liquid stream (1)

$l_{CO_2}^{in} = 0.325\ \mathrm{mol_{CO_2}/mol_{NH_3}}$



$l_{CO_2}^{in} = 0.45\ \mathrm{mol_{CO_2}/mol_{NH_3}}$



$$\frac{L^{in}}{G^{in}} = 8.5\,\frac{\mathrm{kg}}{\mathrm{kg}}\,;\ T_L^{in} = 15°\mathrm{C}\,;\ v_{s,G}^{in} = 1\,\frac{\mathrm{m}}{\mathrm{s}}$$

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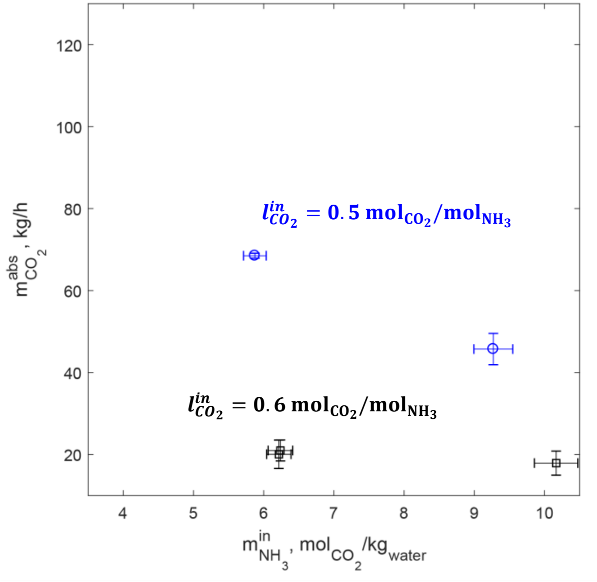
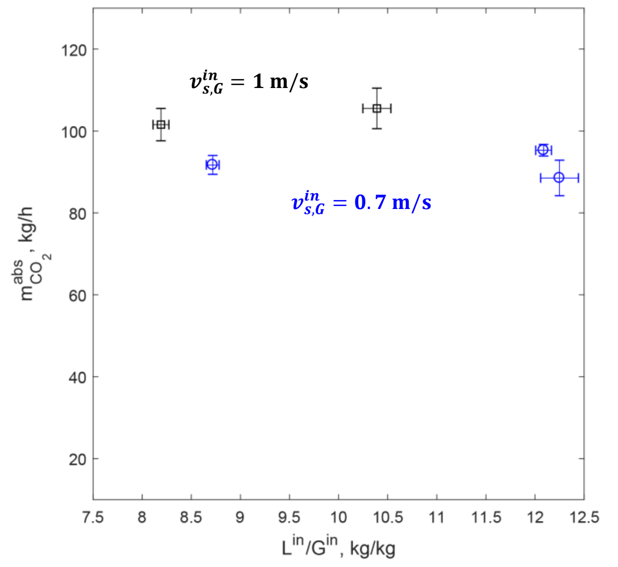
NH_3 concentration in the inlet liquid stream (2)



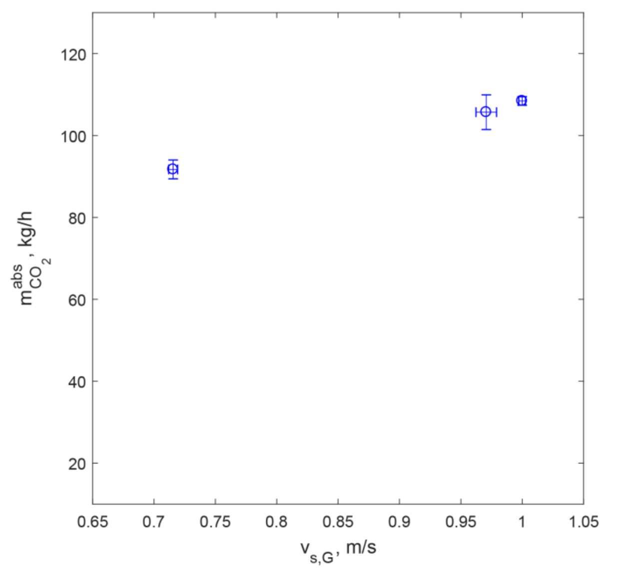
$$P^{in}_{CO_2} = 30\ \text{kPa}\ ;\ \frac{L^{in}}{G^{in}} = 11\,\frac{\text{kg}}{\text{kg}}\,;\ T^{in}_L = 40°\text{C}\ ;\ v^{in}_{S,G} = 0.7\,\frac{\text{m}}{\text{s}}$$

Inlet liquid-to-gas flowrate ratio



$$P_{CO_2}^{in} = 20 \text{ kPa} \; ; \; l_{CO_2}^{in} = 0.35 \frac{\text{mol}_{\text{CO}_2}}{\text{mol}_{\text{NH}_3}} \; ; T_L^{in} = 15°\text{C} \; ; \; m_{NH_3}^{in} = 10 \frac{\text{mol}_{\text{NH}_3}}{\text{kg}_{\text{water}}}$$

Inlet gas superficial gas velocity



$$P^{in}_{CO_2} = 20\ \text{kPa}\ ;\ l^{in}_{CO_2} = 0.35\,\frac{\text{mol}_{\text{CO}_2}}{\text{mol}_{\text{NH}_3}}\ ;\ T^{in}_L = 15\text{°C}\ ;\ m^{in}_{NH_3} = 10\,\frac{\text{mol}_{\text{NH}_3}}{\text{kg}_{\text{water}}}\ ;\ \frac{L^{in}}{G^{in}} = 8.5$$

CO_2 absorber pilot plant tests

Sensitivity analysis on the overall gas phase mass transfer coefficient for CO_2

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Simplified equation of the CO_2 absorption rate

$$N_{CO_2} = K_{G,CO_2} V A_{int} (P_{CO_2} - P^*_{CO_2})$$

N_{CO_2} — **Experimental value** from pilot tests

$A_{int} = f(\text{hydrodynamics})$ — **Rochelle model** to compute the **effective G-L interfacial area**

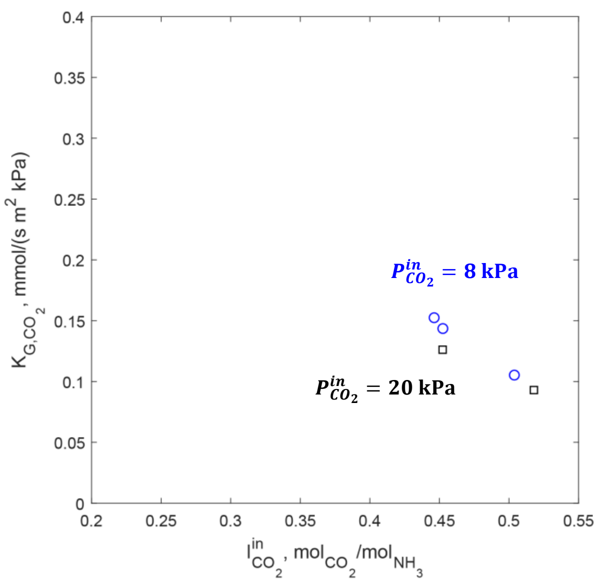
$(P_{CO_2} - P^*_{CO_2}) = f(\text{thermodynamics})$ — **Thomsen** thermodynamic **model** to compute the **driving force**

$K_{G,CO_2} = f\begin{pmatrix}\text{physical mass transfer} \\ \text{reaction kinetics in the L} - \text{phase}\end{pmatrix}$ — **Computed from CO_2 absorption rate experimental results**

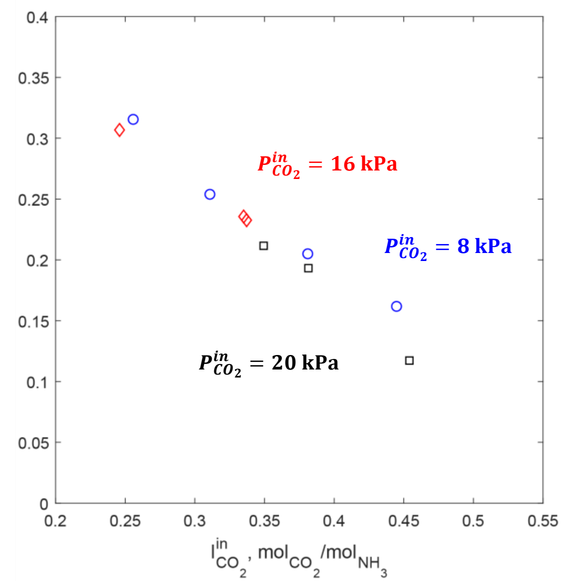
CO_2 loading of the inlet liquid stream

(exemplary sensitivity analysis)

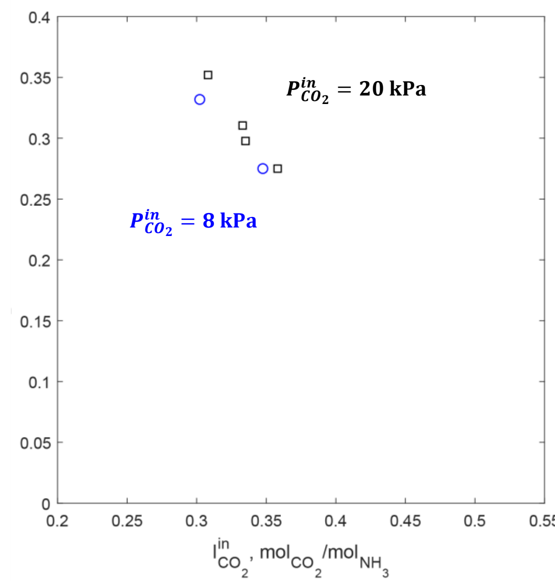
$m_{NH_3}^{in} = 4\ \mathrm{mol_{NH_3}/kg_{water}}$



$m_{NH_3}^{in} = 6\ \mathrm{mol_{NH_3}/kg_{water}}$



$m_{NH_3}^{in} = 10\ \mathrm{mol_{NH_3}/kg_{water}}$



$$\frac{L^{in}}{G^{in}} = 8.5\,\frac{\mathrm{kg}}{\mathrm{kg}}\,;\ T_L^{in} = 15°\mathrm{C}\,;\ v_{S,G}^{in} = 1\,\frac{\mathrm{m}}{\mathrm{s}}$$

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CO_2 absorber pilot plant tests

Sensitivity analysis on the enhancement factor (E) of the physical mass transfer in the liquid due to chemical reaction

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Mass transfer resistance

$$\frac{1}{K_{G,CO_2}} = \frac{RT}{k_{g,CO_2}} + \frac{H^m_{CO_2}}{E k^0_{l,CO_2}}$$

k_{g,CO_2} — **Rochelle model** to compute the **gas-film mass-transfer coefficient**

k^0_{l,CO_2} — **Rochelle model** to compute the **liquid-film mass-transfer coefficient**

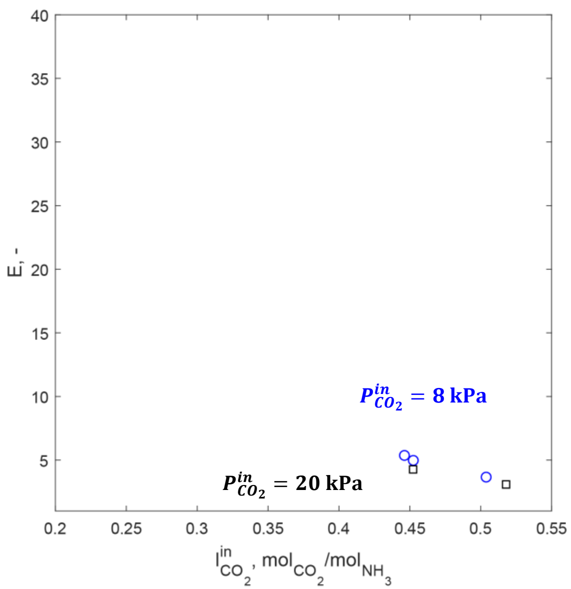
$H^m_{CO_2}$ — **Partition coefficient** computed by **Thomsen model**

E — **Enhancement factor** due to chemical reaction **computed from the overall CO_2 mass transfer resistance**

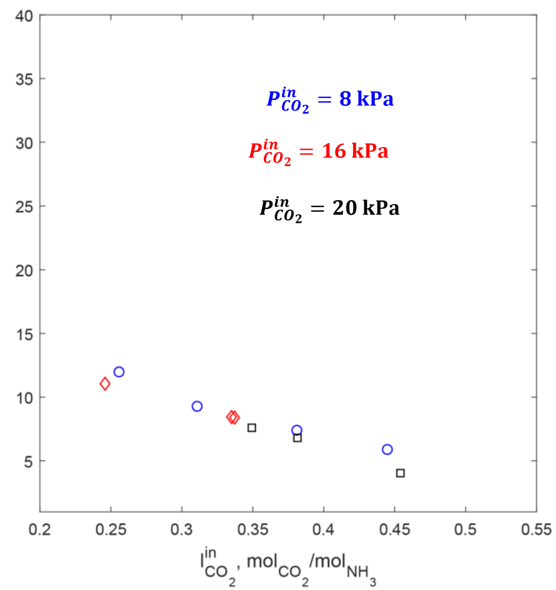
CO_2 loading of the inlet liquid stream

(exemplary sensitivity analysis)

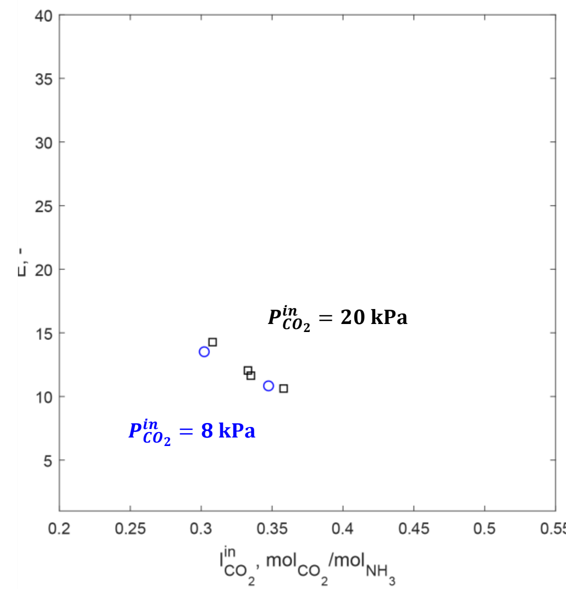
$m_{NH_3}^{in} = 4\ \mathrm{mol_{NH_3}/kg_{water}}$



$m_{NH_3}^{in} = 6\ \mathrm{mol_{NH_3}/kg_{water}}$



$m_{NH_3}^{in} = 10\ \mathrm{mol_{NH_3}/kg_{water}}$



$$\frac{L^{in}}{G^{in}} = 8.5\,\frac{\mathrm{kg}}{\mathrm{kg}}\,;\ T_L^{in} = 15°\mathrm{C}\,;\ v_{S,G}^{in} = 1\,\frac{\mathrm{m}}{\mathrm{s}}$$