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STUDY OF DIRECT AIR CAPTURE (DAC) USING A KOH/K_2CO_3 ABSORBING SOLUTION FOR CO_2 CAPTURE

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Introduction

Using a KOH/K_2CO_3 blend solution to capture CO_2 from ambient air is an appealing approach to counteract the high corrosivity induced by KOH solutions. K_2CO_3 solutions could not be used alone, given the slow absorption kinetics and poor mass transfer performance. The point is thus to combine the ease of handling of K_2CO_3 solutions and the absorption performance of KOH solutions, the latter being used in the first pilot-scale DAC plant built by Carbon Engineering in 2015. This work aims to explore the first insights into assessing the potential of KOH/K_2CO_3 solutions for carbon capture in ambient air. A comparison between the utilisation of KOH and NaOH is also conducted, mainly based on the precipitation issues that may occur in both cases. All reasonings are based on the thermodynamic equilibria characterising the CO_2 absorption and hydration phenomena and assuming an ideal aqueous phase and ideally fast kinetics.

Objectives

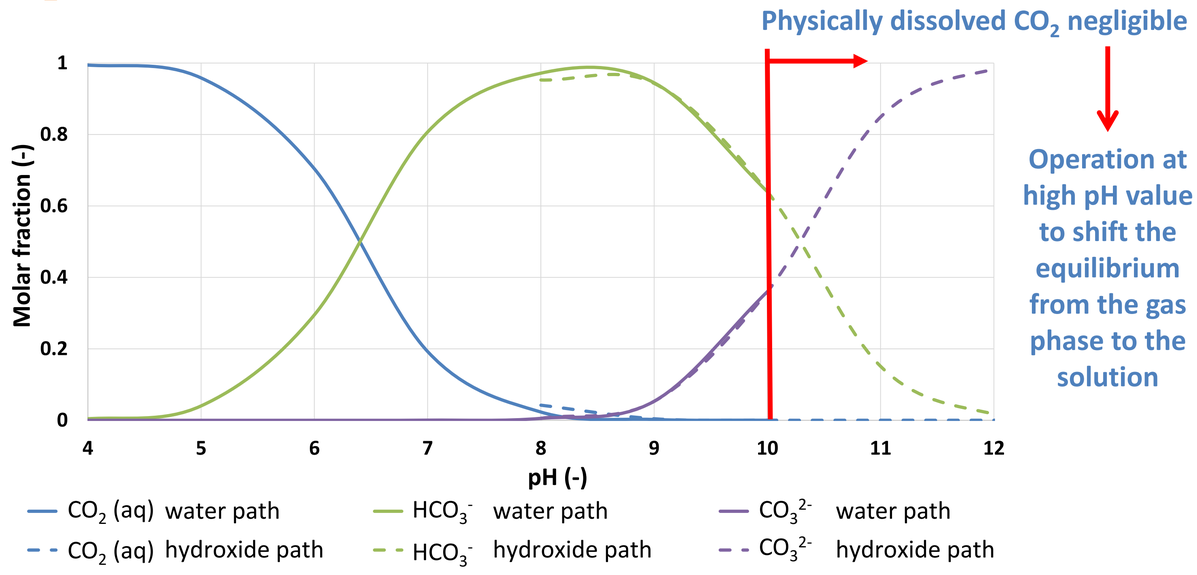
- Calculate CO_2 removal **efficiency** for various solvent pH values.
- Calculate the **ion product** of each salt present in the solution (**K_2CO_3, Na_2CO_3, $KHCO_3$, $NaHCO_3$**) and conclude on their precipitated state presence.

Methodology

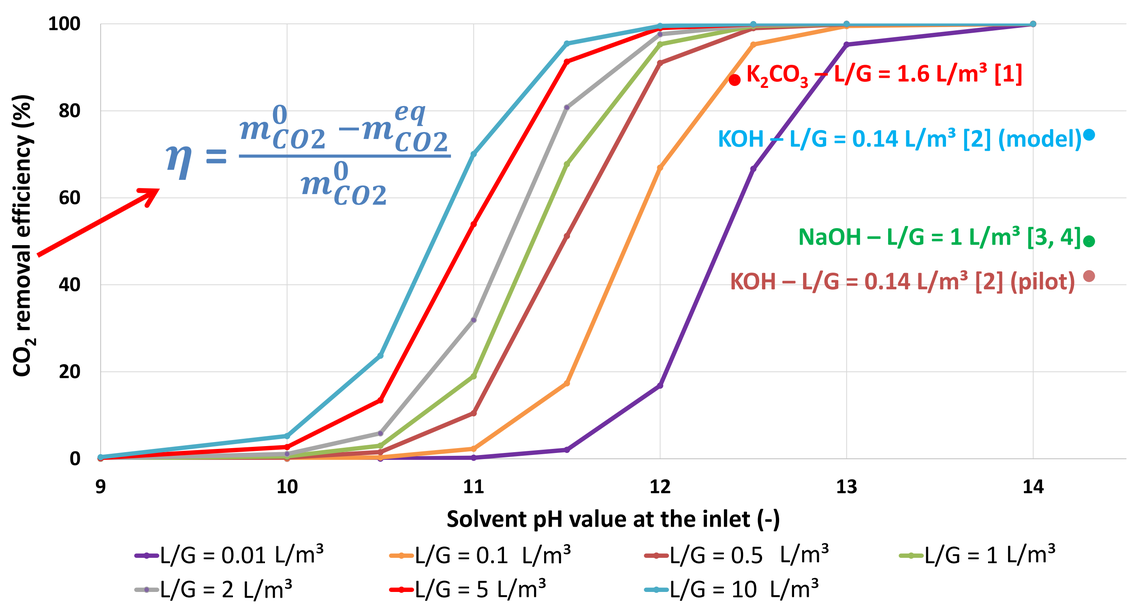
1. Calculate the **initial pH** value of the solution.
2. Calculate the **initial mass of CO_2** in the treated air.
3. Calculate the **mass of CO_2 absorbed** by the solution using the effective Henry's law.
4. Calculate the ions' **equilibrium concentration**.
5. Calculation of removal **efficiency** and **ion products**.

$$H'_{CO2} = H_{CO2}\left(1 + \frac{K_3 10^{-14}}{[H^+]} + \frac{K_3 K_4 10^{-28}}{[H^+]^2}\right)$$

CO_2 species in aqueous solutions

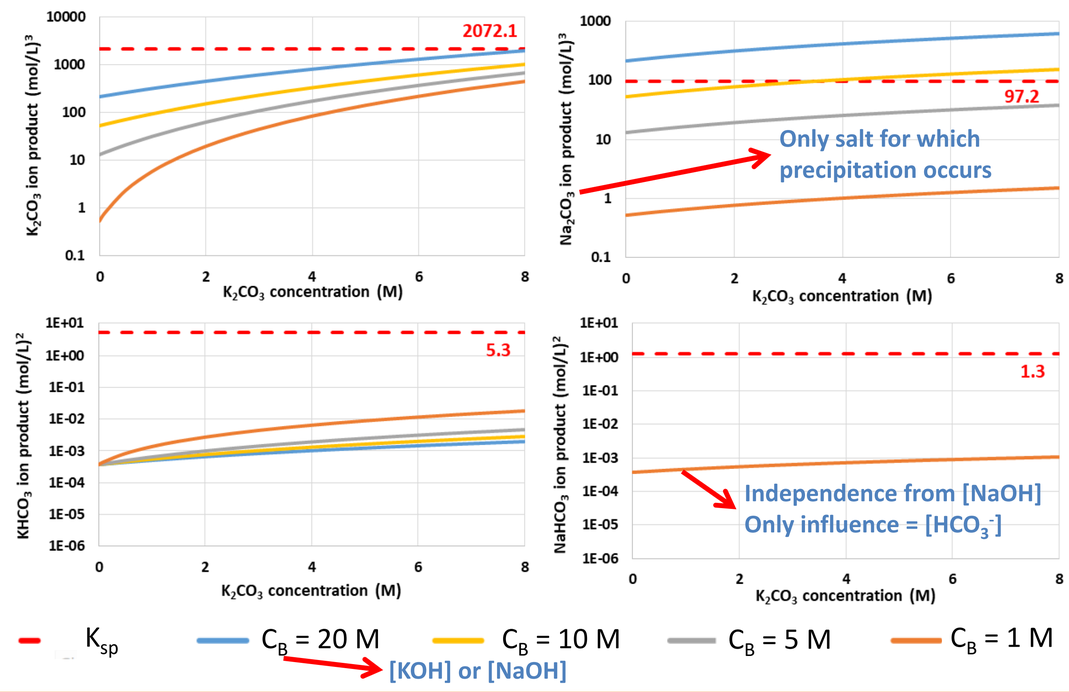


CO_2 removal efficiency compared with experimental data from the literature



Main assumption: capture takes place in a column with a solvent flow rate ***L*** and a gas flow rate ***G***

Study of potential salt precipitation in a KOH/K_2CO_3 (left) or NaOH/K_2CO_3 (right) solution



Conclusion

This work shows that a 100% removal efficiency is theoretically achievable with a KOH/K_2CO_3 blend solution, based on equilibrium considerations and assuming an ideal aqueous phase. However, the comparison of the results with literature data highlights the importance of kinetic limitations within the studied solution. It is also shown that using a KOH/K_2CO_3 solution does not yield any precipitation problems for various operating conditions, whereas Na_2CO_3 precipitation may occur with a NaOH/K_2CO_3 solution for extreme concentration values. The absorption kinetics and the non-idealities of the aqueous phase should be considered to refine the results. Nevertheless, the results highlight thermodynamic limits that make the first step towards an efficient design of CO2 capture systems with K_2CO_3-based blends.

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