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Design of reactive spray absorption column for decarbonization of flue gas

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Absorption is a separation method in which one or more gaseous components are selectively transferred into a liquid phase through gas–liquid contact. Key performance factors include interfacial area, mass transfer coefficients in both phases, and the concentration or pressure gradient of the absorbed components. In practice, several types of absorption columns exist, with the most common being packed bed columns, bubble columns, and spray towers.

This project focuses on developing a mathematical model for a one-dimensional NaOH spray tower absorber. In this setup, NaOH–water solution droplets fall under gravity through an upward-flowing, CO_2-rich gas stream. Each droplet is modelled as a small reactor, with its size, temperature, and composition tracked as it absorbs CO_2, evaporates water, and reacts to form Na_2CO_3.

The core of the model consists of a system of ordinary differential equations (ODEs) that describe droplet motion, mass transfer of CO_2 and water, heat balance (including reaction and evaporation), and the chemical reaction between CO_2 and NaOH. The gas-phase composition is also updated along the tower height to reflect CO_2 depletion and water vapor enrichment. This problem is formulated as a boundary value problem (BVP), with conditions specified at both the top and bottom of the tower.

The model equations were solved numerically. By varying parameters such as tower height, initial droplet size and number, and NaOH concentration in the feed, the model predicts CO_2 removal efficiency and the extent of NaOH conversion to carbonate.

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