Abstract

Limiting global average temperature increase to 1.5°C by 2100 will likely require large-scale adoption of carbon dioxide removal (CDR). Direct air capture (DAC) is one such process, in which carbon dioxide (CO_2) is extracted from atmospheric air and permanently sequestered. DAC capacity is expected to rapidly increase in the coming decades and will likely need chemical engineers to address the challenge of sustainable scale-up. Demand for climate change mitigation technology is growing and CO_2 absorption is a well-researched process, but it is still not typical for the core curriculum of this discipline to include climate change mitigation processes. The chemical engineering curriculum has faced criticism for not keeping pace with technological development and shifting priorities towards sustainability, motivating this work to design an absorption experiment in a laboratory course.

The new DAC experiment was modeled after a real industrial process, coupled with a process model used to apply chemical engineering theory. The absorber and its model were tested over the following parameter ranges: air flow rate [1-4 SCFM], liquid flowrate [0.1-0.72 L/min], and NaOH concentration [0.0001-0.01 kmol/m^3]. Data collected over this range was interpreted using the two-film mass transfer theory and pseudo first order enhancement factor model. The experimental values for overall mass transfer coefficient K_{OV} [kmol/m^2/kPa/s] measured 19% deviation from theoretical values, ranging from 1.13E-5 to 1.58E-4 [kmol/m^2/kPa/s]. These experimental values matched with the process model well, with steady state log mean pressure difference [kPa] within 3.4% error and transient CO_2 mole fraction [-] and reservoir hydroxide concentration [kmol/m^3] profiles within 17% and 5% error respectively. Thus, the methods and model created for this experiment accurately interpreted and predicted absorption rates in a retrofitted absorber. Overall, this study qualifies this absorber set-up and

process model for use as educational tools to enable evolving undergraduate experimentation in DAC and maintain relevant climate change-related content in the chemical engineering curriculum.