

Experimental Determination and Modelling of Reaction Kinetics for the Desorption of CO₂ from Aqueous MEA

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ABSTRACT

The world's ever growing need for energy, and the rising standard of living in developing countries like China and India puts a great strain on the climate of the Earth. Also, the growing need for energy in already established industrial nations like the United States and Russia adds to the pressure on the climate. Carbon dioxide, released by the burning of fossil fuels, is a major contributor to the rising emission of greenhouse gasses and must be reduced in order to mitigate the climate changes. One technology that can be applied to capture the CO₂ is post-combustion capture. The advantage when using post-combustion as a way to reduce CO₂ emissions is that it is applicable to the majority of already existing coal fired power plants. This means, that post-combustion presents us with the greatest near-term potential for reducing emission, because it can be retrofitted to existing power plants. The post-combustion capture of CO₂ is most often done by reversible absorption with aqueous amine, because CO₂ and amines react to form water soluble compounds. The amine-CO₂ solution is then passed through a desorption unit, where the CO₂ is separated from the amine, which is in turn regenerated and recycled.

A major issue, however, is the reduced efficiency of a power plant with a post combustion CO₂ capture unit. The capture unit itself requires a significant amount of energy, which would increase the cost of electricity by as much as 20%. This is caused by the great amount of heat required for solvent regeneration, CO₂ compression and purchasing of construction materials. It is therefore of great importance to develop carbon capture units that are energy efficient and relatively simple to construct. This project focuses on the desorption part of a post-combustion carbon capture unit. The long-term goal is to provide an effective design proposal for the implementation of a desorber into the existing CO₂ absorption section of the carbon capture pilot plant at The Technical University of Denmark (DTU).

Experiments with a heated pressure cell and subsequent mathematical modelling have been utilized to investigate the reaction kinetics of desorption of carbon dioxide from an aqueous monoethanolamine (MEA) solution. Through 43 experiments using 30 wt% MEA with an approximate CO₂ loading of 0.3 a mathematical mass balance model based on the carbamic acid reaction mechanism has been constructed in order to evaluate the reaction kinetics. The experiments cover a pressure range from 1 bar abs. to 5 bar abs. and a temperature span from 353 Kelvin to 393 Kelvin. The amount of CO₂ in the exit gas from the pressure cell was measured and the Barium chloride method was used to analytically determine the concentration of CO₂-MEA complex in the aqueous mixture before and after each experiment. The key findings in this project are; the reaction order and reaction rate coefficient for the liquid phase reaction.

Prior to the collection of experimental data a versatile and simple experimental setup for measuring the desorption of CO₂ from various solutions of different alkanolamines was constructed. The majority of the results obtained from kinetic data indicate a reaction order of approximately 1. However, some data for lower temperature experiments (363 K) indicates a higher reaction order of magnitude 3. The reaction rate constant was found to increase with temperature from 5.72E-5 at 353 K to 1.4E-3 at 393 K, but to be unaffected by the pressure.