Different strategies for accelerated CO₂ absorption in packed columns by application of the biocatalyst carbonic anhydrase

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There is a critical need to reduce emissions of carbon dioxide (CO₂), in order to achieve the targeted reductions in GHG emissions by 2020. While CO₂ separation by means of chemical absorption using aqueous amine solutions (e.g. monoethanolamine (MEA)) in packed columns is the state-of-the-art approach (Rochelle, 2009), industrial application of CO₂ capture from power plant flue gas is still restricted. The main reason for this is the significant reduction of power plant efficiency caused by the high amount of energy necessary for the absorbent regeneration. Consequently, there is a severe need of energy efficient concepts for carbon capture. Especially solvent regeneration in the desorption step accounts for 80 % of the total capture costs for the MEA process, resulting in a loss in overall power plant efficiency of up to 15 % (Neveux et al., 2013). Consequently, solvent regeneration represents the bottleneck of the reactive absorption/desorption process, which is practically not considered for large scale industrial application (Mondal et al., 2012). A lot of research effort is carried out in order to overcome this restriction with a focus on more energy efficient solvents. However, solvents that need less energy for regeneration, especially due to reduced absorption enthalpies, are often less efficient concerning kinetics. Consequently, the advantage from the energetic point of view is challenged for such solvents by the potential increase in the required equipment size due to the decrease in absorption rates. Therefore, the aim of this work is to find a solution for the trade-off between reduced energy for desorption and reduced absorption/desorption rate by applying catalysts which are known to enhance the reaction rate drastically. This work specifically shows how enzymes can contribute as non-volatile and biodegradable biocatalysts to such systems and enhance the competitiveness of the system.

In specific the combination of an energetically favourable aqueous N-Methyldiethanolamine (MDEA) solution and the enzyme carbonic anhydrase is investigated. The use of aqueous MDEA solution for CO₂ separation is already known from natural gas applications, for which an increased driving force due to the higher partial pressures of CO₂ decreases kinetic limitations. The objective of the addition of carbonic anhydrase is to compensate for the loss of efficiency caused by the lower driving force in CO₂ capture from power plant flue gases. Hence, carbonic anhydrase acts as a key enabler to make the energetic advantage of these solvent systems accessible. However, application of the enzyme also poses restrictions on the process. Especially compliance with the enzyme stability limits is challenging for desorption, which is generally performed at high temperatures.

In order to determine an optimal implementation of the enzyme into the process the current work presents different strategies how to apply CA as a biocatalyst in reactive absorption processes and shows how absorption efficiency is influenced. Therefore, absorption performance of the solvent system without any enzyme is determined first in order to further compare it to the enzyme accelerated processes. For applying the enzyme to a packed column two major approaches are investigated in this study. The simplest way of application is to dissolve the enzyme in the solvent. This allows the enzyme to work exactly where the major mass transfer resistance can be found, in
the liquid boundary layer. However, due to the temperature sensitivity of the enzyme (Gundersen et al., 2014) an additional enzyme recovery step prior to the desorber might be necessary if desorption is to be performed at high temperatures. The immobilization of the enzyme inside the absorption column presents an alternative to prevent this additional separation, but may cause additional mass transfer limitations at the solid particles in which the enzyme is immobilized. The immobilization and the necessity of a suitable packing in which the enzyme particles can be filled, also makes this strategy more complicated but allows placing the enzyme at a location of most suitable process conditions in the column. But most importantly it completely avoids that the enzymes experience high temperature in the desorber. In this work, a systematic comparison of these different strategies is presented based on experimental investigations in order to determine the most suitable strategy for application and evaluate the potential benefit of process intensification by means of an energetically favourable solvent in combination with the enzyme.

REFERENCES

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