



Investigation of the suitability of aqueous sodium glycinate as a solvent for post combustion carbon dioxide capture on the basis of pilot plant studies and screening methods



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ABSTRACT

Post combustion CO₂ capture (PCC) through reactive absorption is a promising technology to tackle climate change. The application of new solvents enables a reduction in energy demand. This research work discusses the suitability of aqueous sodium glycinate (NaGly) as a CO₂ absorption solvent.

Laboratory studies show slow absorption kinetics and moderate CO₂ absorption capacities of aqueous NaGly. Results from pilot plant tests at the coal-fired power plant in Dürnrohr, Austria, with 15, 25 and 40 wt% NaGly are presented and discussed. Realistic industry conditions were achieved through the use of flue gas from the power plant and the well-conceived dimensions of the test facility. Low energy consumption of aqueous NaGly was mainly predicted by simulations in literature (~3 GJ/tCO₂). The measured energy consumption in the present work is much higher (> 5 GJ/tCO₂). This represents an increase of 40% with respect to 30 wt% monoethanolamine (MEA), not combined with enhanced system extensions. The low predicted optimal solvent flow rate could not be confirmed in the present work. The optimal liquid to gas ratio is in the range of 7–8 l/m³.

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1. Introduction

Post combustion CO₂ capture (PCC) is one way to remove carbon dioxide from flue gases. Compared to other technologies, this process affects the power plant operation only slightly. For low CO₂ partial pressures, especially amines are suitable for the absorption and desorption process (Kohl and Nielsen, 1997). However, the capital and operating costs of PCC are still high. These high costs complicate the implementation of the aqueous amine solution based absorption/desorption process for large scale PCC-plants (Davis, 2006).

The benchmark solvent for PCC is a 30 wt% aqueous solution of monoethanolamine (MEA). Extensions of the basic PCC-process,

such as vapor re-compression and absorber intercooling, decrease the required energy for solvent regeneration (Fisher et al., 2005; Knudsen et al., 2011). Nevertheless, the energy requirement for the process using MEA is still high (Mangalapally and Hasse, 2011). Moreover, MEA is corrosive and degrades under the influence of O₂, NO_x, SO₂ and heat (Notz, 2009). A further disadvantage of conventional amine based solvents is the additional process complexity needed to address solvent and degradation products volatility, including aerosols (Weiland et al., 2010a).

In order to improve the process, it is imperative to find new, more efficient, solvents. Thus, the performance of aqueous sodium glycinate (NaGly), an amino acid salt, as an alternative solvent was investigated. The main advantage of amino acid salts is their theoretical vapor pressure of zero, due to the non-volatility of the ionic structure. Amino acids are naturally occurring materials and highly resistant to oxidation (Weiland et al., 2010a). Additionally, amino acid salts have a higher CO₂ absorption capacity than MEA (Song et al., 2008).

Simulations with aqueous NaGly show consistently high energy savings compared to MEA (compare Section 2.3). Other amino acid

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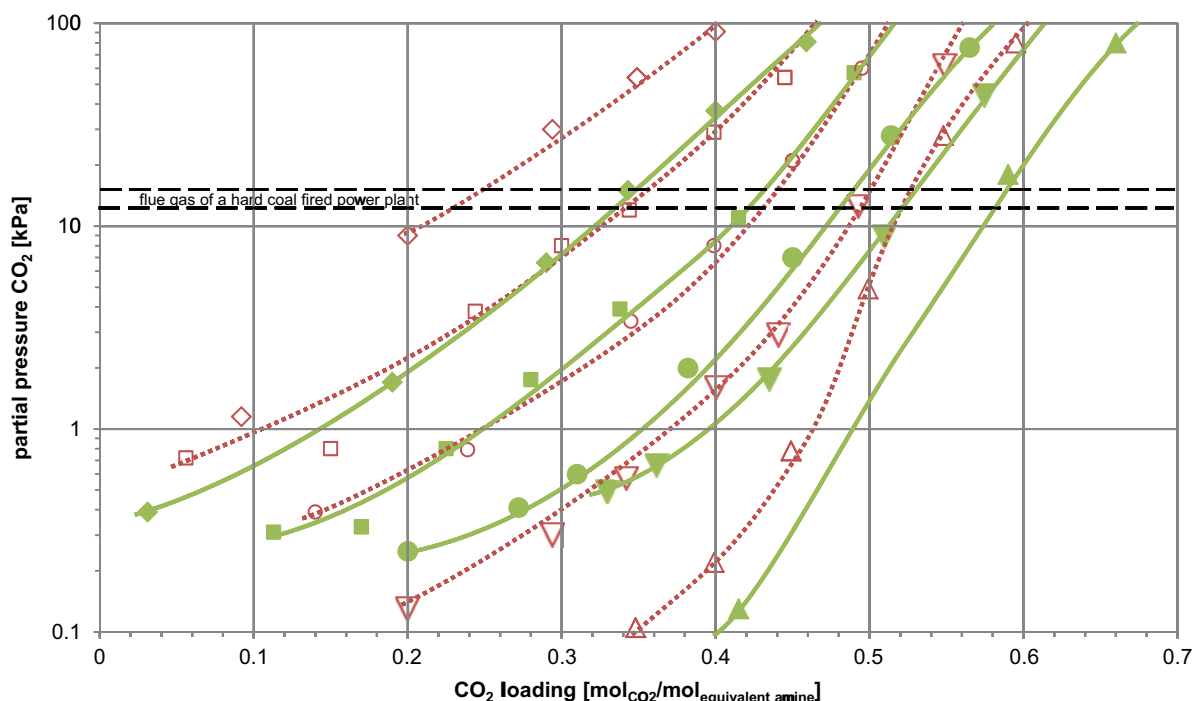


Fig. 1. Solubility of carbon dioxide in 30 wt% NaGly (filled symbols) and 30 wt% MEA (unfilled symbols). Experimental data from Song et al. (2008) for 40 (Δ), 60 (∇), 80 (\circ), 100 (\square) and 120 (\diamond) °C.

solvents exhibit similar simulation results, such as potassium tauurate. One can take advantage of the precipitation of the pure amino acid, resulting in a reduction of the energy consumption to 2.4 GJ per ton separated CO₂ (Brouwer et al., 2005; Fernandez et al., 2013). On the pilot plant at E.ON's coal-fired power plant Staudinger, the energy requirement could be reduced to 2.7 GJ per ton separated CO₂ by using amino acid solvents (Jockenhövel and Schneider, 2011). As with amines, a blend of primary and secondary amino acid salts enables the preparation of interesting solvents (Siemens AG, 2011).

The measurements were performed at a pilot plant at the EVN power plant in Dürnröhr, Austria. The post combustion capture test facility, known as CO₂SEPPL (CO₂ SEPARation PLant), was Austria's first carbon dioxide removal plant for flue gases originating from the thermal conversion of fossil fuels. With the test facility having an absorber height of 12 m and operating with flue gases from an industrial boiler, the pilot plant provides industry-related measuring conditions. Prior to the pilot plant tests, chemical and physical properties of the aqueous NaGly solutions were investigated. The suitability of aqueous NaGly as a solvent for CO₂ post combustion absorption was determined with bench-scale units.

2. Aqueous sodium glycinate as a solvent for CO₂ absorption

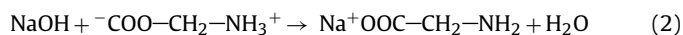
Amino acid salts have been used for acid gas removal since the 1930s. The Alkazid[®] process developed by BASF uses the potassium salts of N,N-dimethylaminoacetic acid and N-methylalanine. This process is widely used throughout Europe, especially in Germany (Weiland et al., 2010a,b). In the recent past, sodium glycinate in glycerol within an immobilized liquid membrane, was used for removal of carbon dioxide from atmosphere in closed-loop life support systems, like in spacecraft or space suits (Chen et al., 2000; Murdoch et al., 2001; Sirkar et al., 2002). For some years, there is an interest in the usage of glycine for CO₂ capture (Weiland et al., 2010b).

2.1. Chemical basics of the CO₂ absorption in aqueous sodium glycinate

Glycine, the simplest primary amino acid, exists in aqueous solution as zwitterion (1).



The amino group is protonated, meaning it is completely non-reactive toward CO₂. When the acid group is titrated (neutralized) with sodium hydroxide (NaOH), the amino group deprotonates (2), and a primary amine is formed (Weiland et al., 2010a,b). Further reaction chain is described in various literature (i.e. Posch, 2012).



2.2. Investigation of the properties of aqueous sodium glycinate

Physical properties of aqueous NaGly have been investigated by Lee et al. (2005), Park et al. (2006) and Harris et al. (2009). Lee et al. (2005) discussed CO₂ unloaded solutions for different NaGly concentrations (10–50 wt%) and temperatures (30–80 °C), and subsequently offered values for density, viscosity, surface tension, alkalinity and hydrogen ion activity (pH-value). Harris et al. (2009) investigated the density of aqueous NaGly before and after CO₂ absorption for a concentration range of 1–30 wt% within a temperature range of 25–80 °C. In Section 3, the results of these papers will be compared partially with the measured values of the present work.

The solubility of carbon dioxide in an aqueous NaGly solution was studied by Song et al. (2008, 2006) and Harris et al. (2009). Song et al. (2006) provided VLE data (vapor–liquid equilibrium) for 10, 20 and 30 wt% NaGly for temperatures of 30, 40 and 50 °C. Harris et al. (2009) investigated mainly CO₂ partial pressures in the excess pressure range. Within the range of overlap between the two studies, the data, in parts, vary widely. Song et al. (2008) investigated the solubility of CO₂ in 30 wt% NaGly over a wider temperature range (Fig. 1). Several large deviations exist between the VLE data

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