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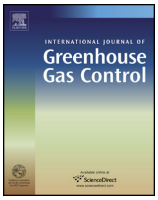

Review

Carbon dioxide absorption into promoted potassium carbonate solutions: A review

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ABSTRACT

The emission of carbon dioxide into the atmosphere is recognized as a significant driver for climate change. Carbon capture and storage (CCS) techniques are efficient and effective ways to reduce these emissions to the atmosphere. However, the cost of any carbon capture technique has to be reduced to manageable levels before it can be deployed at an industrial scale. Several methods for capturing carbon dioxide, such as absorption, adsorption, membrane techniques and cryogenic separation have been proposed, of which absorption is the closest to commercial reality. Potassium carbonate is a good solvent for carbon dioxide capture because of its low regeneration energy, low degradation rates and low corrosivity. However, one shortcoming of potassium carbonate in CO_2 absorption is that it has relatively slow reaction kinetics with CO_2 resulting in the need for large absorption equipment. The most efficient method for improving the absorption kinetics is to add promoters into the potassium carbonate solutions. There have been a number of promoters studied over the last decades, including inorganic promoters such as arsenate, boric acid and vanadate, organic promoters such as different amines and amino acids, enzymatic promoters such as carbonic anhydrase and metal compounds mimicking carbonic anhydrase. In this paper, different promoters for CO_2 absorption in potassium carbonate solutions are reviewed and their performance summarized. Additionally, a CO_2 hydration promoting mechanism of deprotonation, followed by intermediate formation and then promoter regeneration is presented.

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1. Introduction

The emission of carbon dioxide into the atmosphere is recognized as a significant driver for climate change. Carbon capture and storage (CCS) techniques are efficient and effective ways to reduce carbon dioxide emissions to the atmosphere. However, the cost of any carbon capture technique has to be reduced to manageable levels before it can be deployed at an industrial scale.

1.1. Reducing carbon dioxide from the atmosphere

The emission of carbon dioxide into the atmosphere is recognized as the main reason for climate change effects including global warming, changes in sea levels, extreme hot summers and cold winters, and agricultural problems (Chu and Majumdar, 2012; Hegerl and Stott, 2014; Howard-Grenville et al., 2014; Motz et al., 2001; Rutgersson et al., 2014). As fossil fuels will continue to be a source of energy in the near future (Bachu, 2008), it is inevitable that the emissions of carbon dioxide to the atmosphere will continue, which leads to further climate change effects. Therefore, devising an economical, stable and environmentally friendly way to reduce these effects is essential.

1.2. Techniques for carbon dioxide reduction

Carbon dioxide capture and storage (CCS) (Chu, 2009) is an efficient way to reduce carbon dioxide emissions into the atmosphere and several methods for capturing carbon dioxide such as absorption (Endo et al., 2011), adsorption (Lee et al., 2006), membrane (Khalilpour et al., 2015; Trachtenberg et al., 2009), cryogenic separation (a single process of capture and compression) (Scholes et al., 2013) and a combination of these techniques (Masoumi et al., 2013; Tuinier et al., 2011) have been proposed. Of these technologies, absorption is currently the closest to being commercially realised.

1.3. Solvent absorption for capturing carbon dioxide

The absorption of carbon dioxide into an aqueous solvent was initially developed for purifying gases such as hydrogen gas, natural gas and synthesis gas (Shrier and Danckwerts, 1969), and more recently has been investigated for CO_2 capture from fossil fuel emission sources (Lee et al., 2006). Many solvents have been investigated for the absorption of CO_2, including monoethanolamine (MEA), diamines and tertiary amines (Zhou et al., 2010) such as piperazine and its derivatives (Bishnoi and Rochelle, 2002; Freeman et al., 2009; Li et al., 2014), ammonia (Collett et al., 2011), amino acid salts (Aronu et al., 2010), ionic liquids (Bates et al., 2002; Blanchard et al., 1999), Deep eutectic solvents (DESs) (Mirza et al., 2015), and their blends (Aroonwilas and Veawab, 2004; Bishnoi and Rochelle, 2002; Closmann et al., 2009; Dugas and Rochelle, 2009). MEA is regarded as the industry benchmark as it is the most widely used solvent. However, MEA has some disadvantages such as a high energy penalty for solvent regeneration, high degradation rate and corrosivity (Goff and Rochelle, 2004; Lim et al., 2014; Wang et al., 2015). Research has been conducted to reduce energy costs, such as utilising solar energy with the amine absorption process to supplement the total energy requirements (Zhao et al., 2014), however, full scale implementation has not occurred and the drawbacks of solvent degradation, solvent volatility and corrosion still need to be addressed.

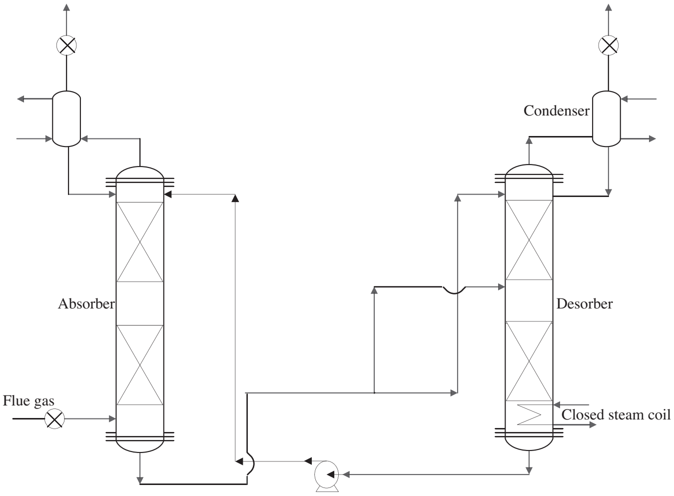

Fig. 1. Flow diagram of a K_2CO_3 solvent absorption process.

1.4. Potassium carbonate system for carbon dioxide capture

Aqueous potassium carbonate is a good solvent for carbon dioxide capture because of its low regeneration energy, low degradation and low corrosivity (Anderson et al., 2013). The CO_2 absorption process using potassium carbonate solutions was first developed as the "Hot Potassium Carbonate (Benfield) Process" (Benson and Field, 1959; Benson et al., 1954).

Potassium carbonate solutions have been widely used for synthesis gas purification and more recently research has been conducted to assess its suitability for CO_2 absorption from power station flue gas (Mumford et al., 2011). A potassium carbonate solvent absorption process flow diagram is shown in Fig. 1. The main parts of this process are the absorber and desorber. The flue gas is fed into the absorber counter-currently to the solvent for absorption of CO_2. The loaded solvent is then sent into a desorber, where CO_2 is stripped from the solvent by increasing the temperature or decreasing the pressure of the desorber. This desorbed CO_2 will then be compressed and liquefied for utilization or storage, and the regenerated solvent can be channelled back to the absorber for reuse in the absorption process.

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