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Representation of CO_2 absorption in sterically hindered amines

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Abstract

Post-combustion capture technology implemented at carbon-rich power plants offers an alternative for mitigating CO_2 emissions. Aqueous alkanolamines such as monoethanolamine and *N*-methyldiethanolamine are utilized to chemically absorb CO_2. However, current laboratory practice for evaluating new absorbents is laborious and time consuming. In this paper, we presented a possible relationship between acid dissociation constant, K_a and the CO_2 absorption affinity of sterically hindered amines. We demonstrated that addition of hydroxyl and methyl groups to AMP decreases the absorption affinity of sterically hindered amines towards CO_2. This finding adds to our understanding in trying to find a new and better CO_2 absorbent.

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Keywords: Carbon dioxide; sterically hindered amines; absorption equilibrium

1. Introduction

Combustion of fossil fuels releases carbon dioxide (CO_2) into the atmosphere. The high amount of CO_2 produced from human activities is considered to be one of the main contributors of greenhouse gas emission which could lead to the global warming phenomena [1]. CO_2 absorb some of the heat released by the Earth, and concurrently, the CO_2 molecules enter into excited mode and become unstable. The molecules released the extra energy back into the atmosphere, which could contribute to the rise in the Earth temperature i.e. global warming.

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In Nature, the production and consumption of CO_2 is balanced by microorganisms, plants and animals through the carbon cycle, as illustrated in Figure 1 [1]. Human activities altered the CO_2 balance by adding more CO_2 into the atmosphere, whilst influencing the removal of CO_2 from the atmosphere as exemplified by deforestation.

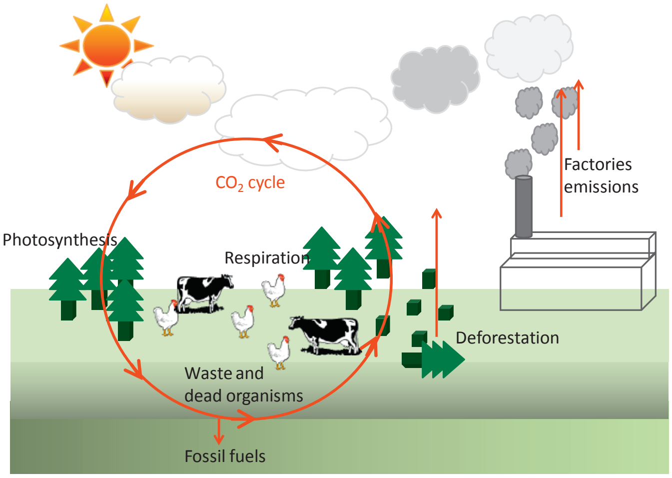

Fig. 1. The Carbon cycle.

The United Nations, through several of its treaties for example the Kyoto Protocol and Copenhagen Accord has recommended that countries are to contribute in minimizing the emission of greenhouse gases. One alternative to mitigate CO_2 emissions is to apply Carbon Capture and Storage (CCS) technology. In CCS, CO_2 is captured from power plants and then stored underground for long periods of time. There are three approaches to capture CO_2 generated from power plants activities i.e. pre-combustion, post-combustion and oxy-fuel combustion. The CO_2 present in synthesis gas is separated before the gas enters a combustion turbine in pre-combustion capture technology [2]. In post-combustion capture, CO_2 is separated from flue gas after complete burning of the fuel [3]. Finally, in oxy-combustion capture, the fuel is burned with O_2 separated from the air which results in a more 'clean' final flue gas, which contains H_2O and concentrated CO_2, where the condensation of H_2O renders pure CO_2 [4].

Post-combustion capture technology is important as it is compatible with the existing power plants without requiring substantial modifications to the plants. Several approaches for capturing CO_2 have been studied such as physical and chemical absorption, adsorption and membrane techniques. However, it is generally accepted that the chemical absorption technique is the most applicable for CO_2 capture, at least in the shorter term [5]. In this technique, a solution (solvent) is used to absorb CO_2 from the exhaust after combustion. The absorbed CO_2 is then liberated from the solvent before transportation and storage.

The most established class of solvent for CO_2 absorption is aqueous alkanolamines [5]. These amines contain at least one hydroxyl group, and are characterised based on the number of free hydrogen atom attached to the Nitrogen atom of the compound i.e. primary, secondary and tertiary. A list of commonly used alkanolamines is shown in Table 1.

Table 1. Commonly used alkanolamines for CO_2 absorption, as reported in the literature.

Name	Class	pK_a value (25 °C) [6]
Monoethanolamine (MEA)	1	9.45
Diethanolamine (DEA)	2	8.88
N-methyldiethanolamine (MDEA)	3	8.52
Diisopropanolamine (DIPA)	2	9.00
Diglycolamine (DGA)	1	9.46