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## Using pre-treated carbon steel for post-combustion carbon capture infrastructure

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### Abstract

The reduction of capital cost in building post-combustion CO<sub>2</sub> capture is necessary to realize its widespread use. Cheaper steels, *e.g.* carbon steel, are attractive but lack the necessary corrosion resistance. To protect from corrosion, one approach is to implement a protective coating on the surface. Particularly, a coating like siderite (FeCO<sub>3</sub>) is appealing because it can be formed by amines and therefore could be regenerated. This study investigates the formation, over seven days at 40 and 80 °C, of such siderite layers formed in methyldiethanolamine (MDEA), 2-amino-2-methyl-1-propanol (AMP), and a K<sub>2</sub>CO<sub>3</sub> solution. When tested against 2.5 M monoethanolamine for 28 days, the coatings formed at 80 °C in MDEA and AMP appear the most resilient. There is a substantial siderite crystal layer remaining on the surface and only minimal weight loss.

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*Keywords:* post-combustion capture, corrosion, carbon steel, siderite, monoethanolamine, methyldiethanolamine, 2-amino-2-methyl-1-propanol

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### 1. Introduction

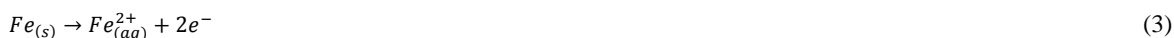
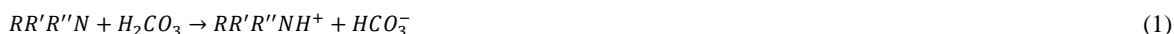
Reduction of the capital costs associated with the construction of post-combustion CO<sub>2</sub> capture (PCCC) infrastructure is essential to the future large-scale worldwide deployment of this technology. In demonstration facilities, stainless steels remain the construction material of choice due to their robustness against corrosion from CO<sub>2</sub>-loaded aqueous amine solvents. However, the high cost of this material and the popularity of amine solvents

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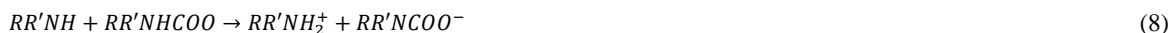
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are incompatible. As such, the use of less expensive steels which resist corrosion is essential and is the long-term goal of this work. The approach presented herein uses the pre-treatment of carbon steel with siderite ( $\text{FeCO}_3$ ), which can be formed in some aqueous amine solution environments. The crystalline siderite layer offers protection to the surface of the metal. In this study, the siderite-producing amine solution is replaced with an alternative amine solution which shows corrosive behaviors.

Amines are not inherently corrosive, but rather some show corrosive behaviours in the presence of  $\text{CO}_2$  [1,2]. Previous research has demonstrated that tertiary ( $3^\circ$ ) (e.g. methyldiethanolamine, MDEA) and sterically-hindered (SH) (e.g. 2-amino-2-methyl-1-propanol, AMP)  $\text{CO}_2$ -loaded amines form siderite crystals on the surface of carbon steel at  $80^\circ\text{C}$  [3-6]. This results from the indirect (*via* hydrolysis) reaction of the amine with  $\text{CO}_2$  which causes the formation of bicarbonate ions (Equation 1). The conversion of bicarbonates to carbonates occurs readily (Equation 2). In the presence of Fe oxidized at the surface of the metal (Equation 3), the carbonate or bicarbonate reacts to form siderite (Equation 4).



Ionic solutions, such as  $\text{K}_2\text{CO}_3$ , are also viable to create an excess of bicarbonate into solution. Such solutions can even serve as an alternative to amines, particularly given their resistance to degradation [7]. By contrast, primary ( $1^\circ$ ) (e.g. monoethanolamine, MEA) (Equations 5 and 6) and secondary ( $2^\circ$ ) amines (Equations 7 and 8) do not have the same propensity to produce bicarbonate ions when reacted with  $\text{CO}_2$ .



While more corrosive, these amines demonstrate significantly more rapid  $\text{CO}_2$  capture kinetics. As such, their use is often preferred but could be cycled with another amine in the hopes of regularly regenerating the protective siderite layer and while still maintaining some  $\text{CO}_2$  capture.

#### Nomenclature

$1^\circ$	primary amine
$2^\circ$	secondary amine
$3^\circ$	tertiary amine
SH	sterically-hindered amine
MEA	monoethanolamine
MDEA	methyldiethanolamine
AMP	2-amino-2-methyl-1-propanol
SEM	Scanning electron microscopy
EDX	Energy dispersive X-ray
XRD	X-ray Diffraction
MSCR	mass size change rate ( $\text{mm y}^{-1}$ )
$m$	mass
$\rho$	density
$A$	exposed surface area

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