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Investigating the corrosion due to high capacity and uptake promoter amine blends on carbon steel

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Abstract

The continued development of amine solvents for post-combustion CO₂ capture is essential to the large-scale success of this technology, with particular interest in high capacity and uptake promoter blends. Some of these solutions also show reduced corrosive tendencies in the presence of carbon steel, a significantly cheaper alternative to the stainless steels generally employed. Optimization of the solution composition and reduced corrosion could yield both a decrease in capital and operating costs. Solutions (30 % by weight) of monoethanolamine (MEA) or piperazine (PZ) were blended with either methyldiethanolamine (MDEA) or 2-amino-2-methyl-1-propanol (AMP). At 120 °C, Solutions containing PZ outperformed those with MEA showing the formation of good protective siderite (FeCO₃) crystal layers, reducing continued oxidation of Fe from the surface and therefore corrosion.

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1. Introduction

The emission of greenhouse gases, in particular CO₂, can be mitigated using well developed post-combustion CO₂ capture technology (PCCC). In addition to its status as a relatively mature technology, from extensive

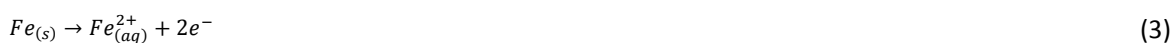
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experience in natural gas sweetening operations, the infrastructure is relatively straightforward to retrofit onto existing plants and power stations. While improvements continue to be made, one remaining challenge to large-scale deployment is the capital investment required to build this amine scrubbing unit. To reduce capital costs, construction materials cheaper than the stainless steels currently employed must be established. Stainless steel has been used due to its relatively impervious nature, where it has been shown to resist significant corrosion in the relevant aqueous amine environments. Inherently, amines are not particularly corrosive. The corrosive tendencies are from the interaction of amines with CO₂. In fact, even the presence of CO₂ in water alone can prove to be highly corrosive.

Recent literature has demonstrated that the corrosivity of CO₂-loaded aqueous amine solutions is not consistent. Crucially, amine chemical structure determines whether or not corrosion is generally observed [1]. Primary (1°) and secondary (2°) amines, show significant corrosive tendencies in most circumstances. By contrast tertiary (3°) and sterically-hindered (SH) amines do not [2]. The relative lack of corrosion is attributed to the mechanism by which these species interact with CO₂ (Equation 1). Particularly, the reaction results in the formation of bicarbonates (which can be converted to carbonates, Equation 2).



The presence of bicarbonates is highly favorable as they react readily with Fe ions oxidized at the surface of the steel substrate (Equations 3 and 4). In this reaction a crystalline FeCO₃ (siderite) is formed, which potentially protects, and even passivates, the surface reducing further oxidization of the metal and the ingress of solvent from the aqueous amine solution [3-5].

The use of 3° and SH amines alone are appealing because of their high CO₂ capacity and lower heat of adsorption (lowering regeneration energy) [6]. However, the slow reaction kinetics makes them impractical. When blended with a rate promoter, a 1° or 2° amine, this problem is mitigated [7,8]. As such, blends of this type have become increasingly popular. While these solutions were developed for optimal operations, initial studies have indicated that such blends could prove to be effective in the development of protective siderite layers [2].

Herein, this study presents the use of two rate promoters: monoethanolamine and piperazine blended with methyldiethanolamine and 2-amino-2-methyl-1-propanol. These solutions are tested at 120 °C, relevant to the stripper (and reboiler), to establish their corrosive nature.

Nomenclature

1°	primary amine
2°	secondary amine
3°	tertiary amine
SH	sterically-hindered amine
MEA	monoethanolamine
PZ	piperazine
MDEA	methyldiethanolamine
AMP	2-amino-2-methyl-1-propanol
GCTCD	Gas chromatography – thermal conductivity detector
ICPOES	Inductively coupled plasma – optimal emissions spectroscopy
SEM	Scanning electron microscopy
EDX	Energy dispersive X-ray
XRD	X-ray Diffraction

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