International Journal of Greenhouse Gas Control 31 (2014) 214–228

Contents lists available at ScienceDirect

International Journal of Greenhouse Gas Control

journal homepage: www.elsevier.com/locate/ijggc

Degradation study of piperazine, its blends and structural analogs for CO_2 capture: A review

Shaukat A. Mazari, Brahim Si Ali*, Badrul M. Jan, Idris Mohamed Saeed

Department of Chemical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:
Received 23 December 2013
Received in revised form 8 October 2014
Accepted 10 October 2014

Keywords:
Piperazine
Monoethanolamine
CO_2 absorption
Degradation
Blends
Nitrosamine

ABSTRACT

Postcombustion carbon dioxide (CO_2) capture using amine scrubbing is an emerging technology to mitigate CO_2 emissions. Benchmark amines used in this technology are monoethanolamine (MEA), methyldiethanolamine (MDEA), and diethanolamine (DEA). Amines undergo irreversible reactions, resulting degradation of the solvent under process operating conditions. Degradation of solvent may create environmental concerns, increased costs as well as corrosion in the process equipment. Piperazine (PZ) has been investigated as a novel amine solvent for CO_2 capture. It has high CO_2 capture capacity and absorption rate with thermal and oxidative degradation resistance. This study discusses the thermal and oxidative degradation of PZ under process operating conditions. A critical review of various parameters, such as the effect of temperature, amine concentration, CO_2 loading (α), partial pressure of oxygen (O_2) and presence of metal ions on rate of degradation has been reported. Chemistry of degradation products and mechanisms of degradation of PZ are reported for better understanding of PZ degradation kinetics. In addition, degradation of PZ blends, structural analogs, and diamines is focused, and behavior of their degradation is highlighted. Furthermore, kinetics of formation and degradation of nitrosamines through PZ is also discussed.

1. Introduction

Amines usage for gas sweetening started in early 1930s (Bottoms, 1933). During last few decades, CO_2 emissions increased globally which have enhanced the development of postcombustion CO_2 capture (PCC) technology (Rochelle, 2009). Amine-based CO_2 capture using amine scrubbing technology is known as one of the promising technologies for CO_2 capture (MacDowell et al., 2010; Mangalapally et al., 2009). Expected energy required for an advanced amine systems for CO_2 capture is about 220 kilowatt hour per ton (kWh/ton) CO_2 removed (Rochelle et al., 2011). The most conventional amines used in this technology are monoethanolamine (MEA), methyldiethanolamine (MDEA), and diethanolamine (DEA) (Dumée et al., 2012; Lowe et al., 2009; MacDowell et al., 2010). These amines undergo irreversible reactions due to reactions with acidic gases (CO_2, H_2S, COS, CO, SOx, and NOx), elevation of temperature, and oxidation (Freeman et al., 2010a; Goff and Rochelle, 2006; Islam et al., 2010, 2011; Lepaumier et al., 2009; Wang et al., 2011). Estimations show that the solvent (MEA) make up accounts for around 10% of the total CO_2 capture cost (Rao and Rubin, 2002).

Efficient use of the technology primarily depends on the selection of viable solvent. The suitable solvent should have high CO_2 capture capacity, high CO_2 absorption rate, low thermal and oxidative degradation rate, and low volatility with appropriate physical characteristics (Boot-Handford et al., 2014; Freeman and Rochelle, 2012b). A number of new amines and their blends have been examined under different conditions to recognize a stable solvent system with promising CO_2 capture properties (Hilliard, 2008; Idem et al., 2005; Namjoshi et al., 2013). PZ and its blends have been found as effective and stable amine solvents as that of alkanolamines and others (Dugas and Rochelle, 2009; Freeman, 2011; Freeman and Rochelle, 2011, 2012b; Li et al., 2013b; Namjoshi et al., 2013; Rochelle et al., 2011).

Previously, PZ has been used as a CO_2 capture promoter in blends with different amines in small concentrations (Bishnoi and Rochelle, 2002; Cullinane and Rochelle, 2006; Zhang et al., 2001). However, at present it is established that PZ alone can be used as an alternative to MEA due its favorable CO_2 capture properties and thermal and oxidative degradation resistance (Freeman et al., 2009, 2010a,b). PZ has exhibited thermal stability up to 150 °C and oxidation stability in the presence of O_2, CO_2, and metal ions, like Fe^{2+}, Cr^{3+}, and Cu^{2+} (Alawode, 2005; Li et al., 2013b; Freeman,

* Corresponding authors. Tel.: +60 3 7967 6896; Fax: +60 3 7967 5319.
E-mail address: brahim@um.edu.my (B.S. Ali).

http://dx.doi.org/10.1016/j.ijggc.2014.10.003
1750-5836/