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Advancement and new perspectives of using formulated reactive amine blends for post-combustion carbon dioxide (CO_2) capture technologies

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ABSTRACT

Chemical absorption using amine–based solvents have proven to be the most studied, as well as the most reliable and efficient technology for capturing carbon dioxide (CO_2) from exhaust gas streams and synthesis gas in all combustion and industrial processes. The application of single amine–based solvents especially the very reactive monoethanolamine (MEA) is associated with a parasitic energy demand for solvent regeneration. Since regeneration energy accounts for up to three–quarters of the plant operating cost, efforts in its reduction have prompted the idea of using blended amine solvents. This review paper highlights the success achieved in blending amine solvents and the recent and future technologies aimed at increasing the overall volumetric mass transfer coefficient, absorption rate, cyclic capacity and greatly minimizing both degradation and the energy for solvent regeneration. The importance of amine biodegradability (BOD) and low ecotoxicity as well as low amine volatility is also highlighted. Costs and energy penalty indices that influences the capital and operating costs of CO_2 capture process was also highlighted. A new experimental method for simultaneously estimating amine cost, degradation rate, regeneration energy and reclaiming energy is also proposed in this review paper.

Contents

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1. Introduction

The capture of carbon dioxide (CO_2) has taken the center stage globally due to the increasing adverse effects of CO_2 emissions. These emissions are generated from anthropogenic activities during the utilization of fossil fuels for electric power generation, transportation, as well as for heating/cooling purposes in residential and office buildings. According to the International Energy Agency, based on total global emissions in 2013, coal and crude oil emitted the most CO_2 when compared to natural gas (coal > crude oil > natural gas) [1]. Also, through the use of these fossil fuels, the generation of electricity was the sector that generated the most CO_2 emissions. Due to the relatively cheap cost and global availability, coal specifically will most likely be the preferred fossil fuel for electricity production in the coming decades [2], thereby constituting the highest source of CO_2 emissions. Hence, it is imperative to capture the CO_2 from such fossil fuel power generation plants to limit its adverse effects. The process of combusting fossil fuels for electric power generation and removing CO_2 afterwards before releasing the exhaust gas can be classified into post–combustion, pre–combustion and oxy–fuel combustion CO_2 capture. In terms of industry and commercially applied and mostly studied, they can be ranked as follows post–combustion > pre–combustion > oxy–fuel combustion.

1.1. Post–combustion CO_2 capture

In the post–combustion CO_2 capture, the flue gas (containing CO_2) is produced from combusting fossil fuels (coal or natural gas) with air for power generation as seen in Eq. (1) [3]. The flue gas CO_2 concentration from this combustion process is usually between 10 and 15% for coal fired power plants and 3–8% for natural gas fired power plants [4–9]. The second step is the capture of CO_2 from the flue gas produced. Fig. 1 displays post–combustion CO_2 capture process.

$$C_xH_y + z(O_2 + 3.76N_2) \rightarrow aCO_2 + bH_2O + cO_2 + dN_2 \quad (1)$$

'z' is the stoichiometric coefficient of air. The stoichiometric coefficients of the products (a, b, c, d) will depend on those of the reactants (x, y, z).

The combustion reaction in Eq. (1) produces mainly nitrogen (N_2), CO_2, water (H_2O), and unreacted oxygen (O_2). However, due

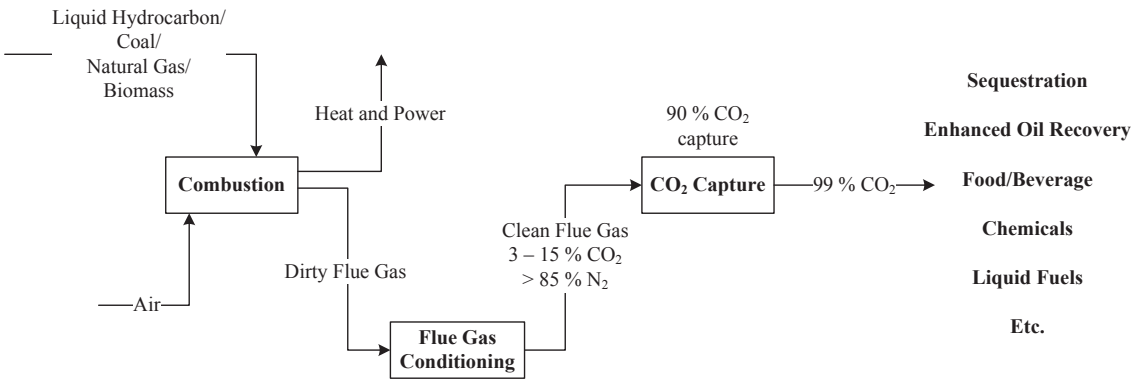

Fig. 1. Integrated post–combustion CO_2 capture process.

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