Journal of Environmental Chemical Engineering 11 (2023) 110188

Contents lists available at ScienceDirect

Journal of Environmental Chemical Engineering

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

A review of catalytically enhanced CO_2-rich amine solutions regeneration

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A R T I C L E I N F O

Editor: Javier Marugan

Keywords:
CO_2 desorption
Solvent regeneration
Nanomaterials
Catalytic enhancement

A B S T R A C T

Global warming, primarily caused by greenhouse gas emissions, is a serious issue, and carbon capture from point sources is gaining attention as a potential solution. Carbon Capture and Storage (CCS) using amine-based absorption is a mature industrial technique for capturing anthropogenic and native CO_2, but its energy-intensive nature and high costs limit its widespread implementation. Despite extensive research on amine-based chemical absorption for CO_2 capture, there is little information about the energy-intensive solvent regeneration process. A potential solution to minimize the energy requirement for solvent regeneration is the use of nano-catalytic materials in solvents. Experimental studies have shown that nano-catalysts can increase CO_2 desorption and decrease solvent regeneration energy costs. Therefore, a review of catalytically enhanced CO_2 desorption with efficient solvent blends is necessary. This study aims to review the physicochemical properties of different catalysts and recent advances in nanomaterials for catalyst-assisted solvent regeneration. It also reviews the basics of the regeneration mechanism for catalyzing CO_2 desorption using different materials based on their textural characteristics. The advantages, disadvantages, and challenges of each heterogeneous catalysts are explored in depth, and a clear pathway for future research is presented. Additionally, the study discusses identifying or producing new nanomaterials and determining the optimal solvent blends to enhance CO_2 desorption catalytically while consuming minimal energy for solvent regeneration. By exploring these aspects, this study aims to provide valuable insights for researchers and engineers working towards the development of more efficient and cost-effective carbon capture and storage technologies.

1. Introduction

As a result of the greenhouse effect, global warming has become one of the biggest concerns of our time. CO_2 is one of the most important greenhouse gases (GHGs) released into the atmosphere every year, and its level is steadily increasing [1]. As of 2020, the concentration of CO_2 in the atmosphere is 412 parts per million (ppm), up from 280 ppm in 1750 [2]. Two hundred countries signed a global agreement in 2015 under the name the Paris Agreement, where they agreed to limit global temperature increases to below 2 °C by reducing CO_2 emissions [3]. Steel, cement, ammonia, and fertilizer production is necessary and not possible without emitting significant quantities of CO_2 [4]. The combustion of fossil fuels such as coal, natural gas, and oil also releases CO_2 [5]. As a result of the rising demand of industrial commodities and the lack of alternative renewable systems, CO_2 capturing and mitigation strategies are under development, to make processes sustainable and environmentally friendly [6]. It is important to reduce CO_2 emissions from conventional channels without shutting them down altogether to reduce GHG emissions [7]. Furthermore, chemically converting captured CO_2 allows valuable chemicals and fuels to be created without the use of fossil fuels [8]. However, technologies for the sequestration of CO_2, either directly from spot sources or indirectly from the environment, could partially mitigate CO_2 emissions [9]. It is essential to understand that there are three major approaches to capturing CO_2 through carbon capture, utilization, and storage processes (CCUS), as shown in Fig. 1 below: (1) post-combustion, (2) pre-combustion, and (3) oxyfuel-generated. Pre-combustion gasification uses the well-known water-gas shift reaction to convert CO into CO_2 and H_2 (syngas) [10]. Oxy-combustion refers to the process of burning fuel in pure oxygen, and the exhaust gases are recycled [11]. CO_2 is captured from the exhaust after fuel is completely burned in post-combustion [12]. Depending on the source and CO_2 concentration in the treated gas, chemical absorption (e.g., amine-based absorption) [13], solid adsorbents (e.g., N-functionalized slid adsorbents (NFSAs)) and physical separation methods (e.g., membrane separation) are generally employed to separate out the CO_2 [14]. Aqueous amines-based approach is a proven

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https://doi.org/10.1016/j.jece.2023.110188
Received 15 March 2023; Received in revised form 21 May 2023; Accepted 22 May 2023
Available online 23 May 2023