Journal of Natural Gas Science and Engineering 55 (2018) 219–234

Contents lists available at ScienceDirect

Journal of Natural Gas Science and Engineering

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

Enhancement of CO_2 solubility in a mixture of 40 wt% aqueous N-Methyldiethanolamine solution and diethylenetriamine functionalized graphene oxide

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ARTICLE INFO

Keywords:
Gas sweetening
Amine solutions
Nanofluid
Graphene oxide
Diethylenetriamine

ABSTRACT

Graphene oxide functionalized by diethylenetriamine (DETA) was prepared and characterized with SEM, XRD, BET, TGA and IR spectroscopy techniques to find out its morphology, crystalline building, porous structure, thermal stability and functional groups. The CO_2 solubility in 40 wt% aqueous amine solution, 40 wt% aqueous amine solution + 0.1 wt% GO, and 40 wt% aqueous amine solution + 0.1 wt% DETA-GO is determined. The solubility measurements were performed at three temperature (303.15, 313.15 and 323.15 K) and CO_2 partial pressures up to 2200 kPa. Addition of GO and DETA-GO to MDEA (N-Methyldiethanolamine) solution enhanced the CO_2 adsorption capacity of the aqueous amine solution up to 7.5% and 12.5%, respectively. Increasing CO_2 partial pressure and decreasing temperature enhanced the CO_2 solubility.

1. Introduction

Greenhouse gas emissions are the main cause of global warming, which has made the scientists to develop low-cost methods for preventing and controlling it. One of the main components of greenhouse gas emissions is CO_2 (Kishor and Ghoshal, 2016; Liu et al., 2014; Mofarahi et al., 2008; Niu et al., 2016; Sim et al., 2015; Songolzadeh et al., 2014; Torralba-Calleja et al., 2013; Wang et al., 2016; Zhang et al., 2014a). Increasing carbon dioxide concentration due to human/industrial activities like combustion of fossil fuels, natural gas purification and other agents is recognized as the main cause of climate change and global warming (Barzagli et al., 2017; Ramezani et al., 2017). Natural gas extracted from underground gas reservoirs contains acid gases. These gases, mostly CO_2 and H_2S, could have undesirable and destructive consequences including: low heat value, equipment corrosion, etc. So, in order to diminish the mentioned effects, the acid gases should be eliminated (Vahidi et al., 2016b). There are several means for CO_2 capture, gas sweetening and separation. These methods are shown in Fig. 1 (Lee and Park, 2015).

Generally, membranes are of three types which include organic membranes like Polysulphone, Polyamide, Cellulose derivatives; inorganic membranes like Metallic, Ceramics, etc. and also enzymatic membranes (Lee and Park, 2015). Although membrane processes are immensely cost-effective and economical, they have disadvantages like low required CO_2 concentration (Brunetti et al., 2010). When applying membrane for CO_2 capture, its permeability is prior toward selectivity because of economics and financial reasons (Kai and Duan, 2014).

Adsorption is categorized into chemical and physical adsorption. Chemical adsorption is mainly carried out thorough metal oxides etc., while physical absorption including TSA, PSA (Liu and Green, 2014; Pirngruber et al., 2013; Pirngruber and Leinekugel-le-Cocq, 2013; Schell et al., 2013; Sculley et al., 2013) is accomplished through zeolites (Anbia and Lashgari, 2009), activated carbons (Anbia and Moradi, 2009) and Si/Al gel materials. The combination of the two methods makes the process of adsorption and recovery to occur at low temperatures and pressures. In order to enhance the adsorption capacity and selectivity of CO_2 capture, solid phase adsorbents are utilized. This aim is met thorough reaction between CO_2 and functional groups which have been grafted on the adsorbent surface (Auta et al., 2013; Hicks et al., 2008; Lee and Park, 2015; Nugent et al., 2013; Prenzel et al., 2014; Wei et al., 2012). Some of these adsorbents include Zeolites, Silica materials, Metal organic frameworks (MOFs), Alkali-based solid phase adsorbents (K, Na, etc.), Metal oxides-based adsorbents (CaO, MgO, etc.) (Lee and Park, 2015).

Absorption is classified to chemical and physical absorption. Chemical absorption is mainly taken place by amines and caustics while physical absorption by selexol and rectisol. In the absorption process, CO_2 gas is dissolved in amine solution through reaction and the

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https://doi.org/10.1016/j.jngse.2018.04.032
Received 11 December 2017; Received in revised form 20 March 2018; Accepted 27 April 2018
Available online 03 May 2018
1875-5100/

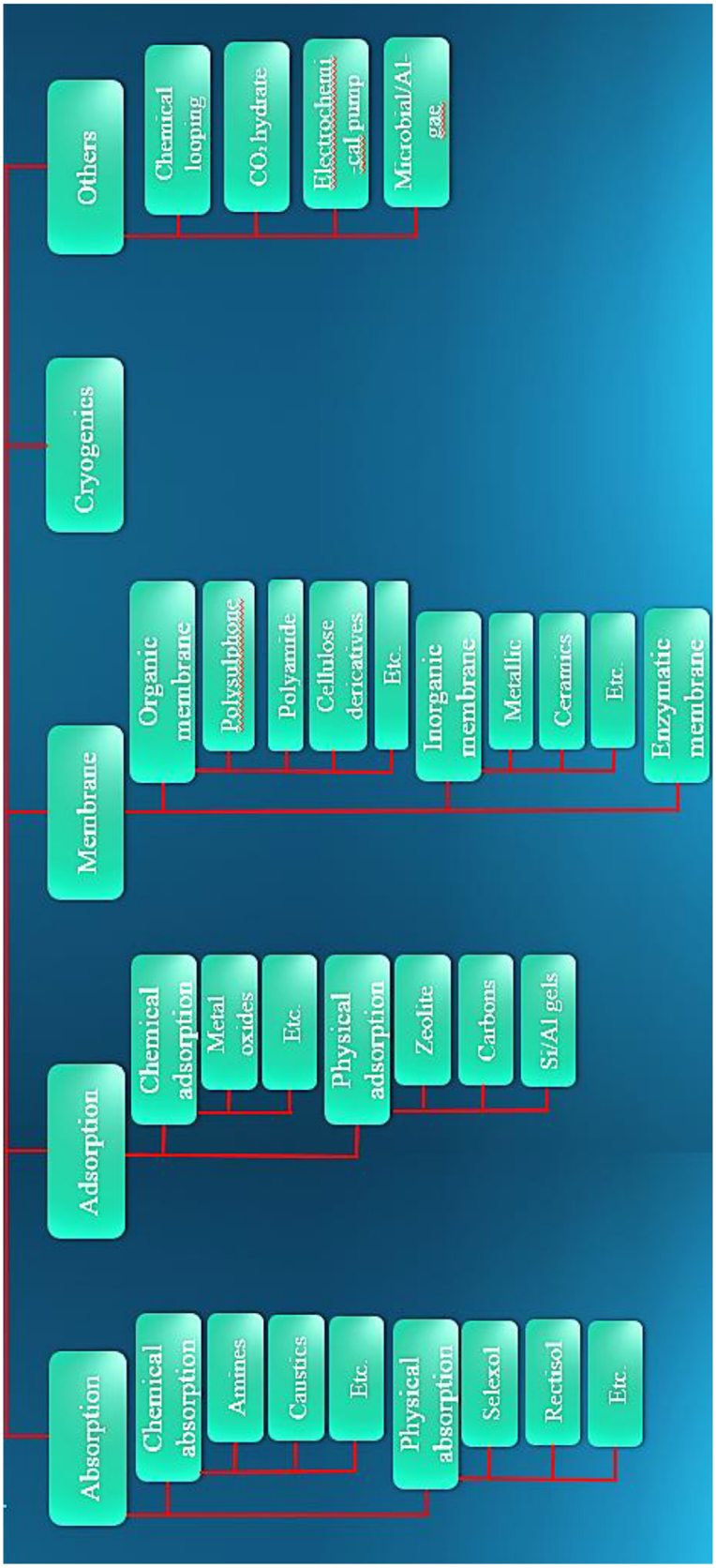

Fig. 1. The methods of gas sweetening and separation.

formation of chemical bonding which further causes the CO_2 absorption (Rahman et al., 2017). Different amine solutions were examined for this purpose which are subdivided to primary amine, monoethanolamine (MEA); secondary amine, diethanolamine (DEA); tertiary amine, methyldiethanolamine (MDEA) (Samanta et al., 2012).

In the primary amines e.g. MEA, according to reaction (1), CO_2