Equilibrium Solubility of CO2 in Alkanolamines

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Publication date: 2013

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
EQUILIBRIUM SOLUBILITY OF CO₂ IN ALKANOLAMINES

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Keywords: Equilibrium CO₂ solubility, Calorimeter, Post-combustion capture, Vapor liquid
equilibrium, Alkanolamines, Monoethanolamine (MEA), N,N-diethylethanolamine (DEEA)

Introduction

Post combustion carbon capture by absorption is one of the most common industrial technologies
available today. Recent techno-economic studies indicate that the technology will remain
competitive in the coming future. Alkanolamines are the most common chemical absorbents
used for capturing CO₂ from the flue gas streams. Aqueous solutions of monoethanolamine
(MEA), a primary alkanolamine, have been extensively studied for this purpose due to fast
reaction rate, low solvent cost, ease of reclamiation and relatively low solubility of hydrocarbons
in the solutions. The disadvantages are high heat of absorption due to formation of stable
carbamate leading to high energy consumption for solvent regeneration in the desorber,
formation of degradation products, solvent losses due to high vapor pressure, relatively high
corrosiveness and the limit of loading capacity of up to 0.5 mol CO₂/ mol amine [1]. On the other
hand, aqueous solutions of N,N-diethylethanolamine (DEEA), a tertiary alkanolamine, have high
loading capacity (1.0 mol CO₂/ mol amine) [2] and low heat of absorption due to formation of
carbonates leading to low desorption energy. The major disadvantage of DEEA is the slow rate
of reaction. However, DEEA can be blended with a suitable promoter to get reasonably fast
reaction rate along with other favorable properties required for the cost effective CO₂ capture.

Experimental data on the equilibrium solubility of CO₂ in aqueous alkanolamine solutions are
necessary for the design of unit operation in the carbon capture process. Equilibrium cells are
generally used for the measurement of vapor-liquid equilibrium (VLE) of CO₂ over aqueous
amine solutions [3-7]. Extensive CO₂ solubility data are available in the literature for various
amine systems measured with different equilibrium cells. This work exhibits experimental measurement of solubility of CO₂ in aqueous solutions of MEA and DEEA using a calorimeter. Calorimeters are generally used for the measurements of heat of absorption. But in the present work, besides heat of absorption data which was presented earlier [2], VLE of CO₂ over aqueous MEA and DEEA solutions were measured. To validate the method, the measured CO₂ solubility data were compared with the data available in the literature obtained from different vapor-liquid equilibrium cells. The method has an advantage of measuring both heat of absorption and CO₂ equilibrium solubility over aqueous amine solutions at the same time.

Experimental

The vapor liquid equilibrium of CO₂ in aqueous solutions of MEA and DEEA was conducted in a reaction calorimeter (model CPA 122 from ChemiSens AB, Sweden). The equipment was previously described by Kim and Svendsen [1]. The 2-L mechanically agitated reactor is attached to the CO₂ storage cylinders through a mass flow controller, a vacuum pump, feed solution bottle and data acquisition unit. Sample solution was fed to the reactor and CO₂ was injected to the reactor in several small steps. The experiments were conducted in an isothermal mode while the total pressure inside the vessel varied from the amine plus water vapor pressure before the first loading of CO₂ at the start of experiment to a maximum total pressure (amine + water vapor + CO₂) of ~ 6 bars during the last loading. The system continuously logged all the necessary parameters (reactor temperature and pressure, CO₂ storage cylinders pressure etc.) as a function of time. The CO₂ added in each feeding interval was calculated using the Peng-Robinson equation of state. The measurements were performed at temperature ranging from 40 to 120°C.

The solubility of CO₂ in 30 mass % MEA solutions were measured and presented in Figure 1 and Figure 2 respectively for 40 and 120°C. The measured data in this work (using calorimeter) are in good agreement with the literature data [3-7] obtained from different vapor-liquid equilibrium cells. Similarly, the equilibrium solubility of CO₂ with 5M DEEA was also measured at temperature ranging from 40 to 120°C and compared with the data available in the literature.

Acknowledgement

Financial support from European Commission 7th Framework Program (Grant Agreement No. 241393) through the iCap project is greatly acknowledged.
Figure 1: Equilibrium solubility of CO$_2$ in 30% MEA at 40°C from this work and data available in literature.

Figure 2: Equilibrium solubility of CO$_2$ in 30% MEA at 120°C from this work and data available in literature.
References