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Measuring and correlating solubility of hydrogen sulfide in aqueous solution of 2-((2 aminoethyl)amino)ethanol

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ABSTRACT

The solubility of hydrogen sulfide (H_2S) in aqueous solution of 2-((2-aminoethyl)amino)ethanol (AEEA) at low and medium pressures was determined for two different concentrations (*i.e.* 10 and 30 wt%). The experimental total pressure varied from (9.5 to 1594) kPa and the experimental temperature was set to (313.2, 328.2, 343.2 and 358.2) K. The experimental data are presented as the total pressure against acid gas loading (mole H_2S per mole of AEEA). The Deshmukh-Mather model and Peng-Robinson equation of state were used for the liquid and vapour phase, respectively, to correlate the solubility of H_2S in aqueous solutions of AEEA. The average absolute deviation percent (*AAD%*) in calculating the total pressure as a function of H_2S loading obtained 5.0% for (AEEA– H_2O–H_2S) ternary system at the four values of temperature. The enthalpy change of the absorption of H_2S in the 10 and 30 wt% aqueous solution of AEEA was also estimated with the tuned model.

1. Introduction

Gas sweetening by aqueous alakanolamines is a well-known process [1] to eliminate acid gases from sour gas feed streams in the oil and gas industry. Ma'mun et al. [2] have found that net cyclic capacity AEEA is significantly higher than the common alkanolamine solutions such as monoethanolamine (MEA) and diethanolamine (DEA) for CO_2 absorption. AEEA is a di-amine that may be a potentially very good absorbent in gas sweetening of natural gas process itself or in mixture with other alkanolamines. Zoghi et al. studied the performance of addition of different alkanolamines in aqueous solution of MDEA, they have shown that AEEA could be better than piperazine under the testing condition [3]. On the other hand there are few experimental reports on solubility and absorption rate of acid gases in aqueous solution of AEEA at different temperatures and pressures [2,4–8]. All experimental results show that AEEA offers a high absorption rate combined with high net cyclic capacity for the case of CO_2. Recently Zoghi and Shokouhi have been reported experimental data on H_2S solubility in mixture of MDEA and AEEA aqueous solutions [9]. In order to design a sweetening process based on alkanolamines, an appropriate model which has been already tuned in wide range of temperature and pressure as well as in wide range of different compositions is vital demand. In order to extend the knowledge of equilibrium solubility behaviour of H_2S in aqueous AEEA at different ranges of temperature, pressure and concentration in the present work, the H_2S solubility in aqueous solution of AEEA at low and medium pressures are obtained. In the present work, two different concentrations of aqueous solution of AEEA equal to 10 and 30 wt%, have been studied. The low concentration level (10 wt%) corresponds to situations where AEEA plays the role of additive in an amine formulation, while the high concentration level (30 wt%) is considered for cases where it plays the role of the main amine constituent of the solution/formulation.

The experimental total pressure varied from (9.5 to 1594) kPa and the experimental temperature was set to (313.2, 328.2, 343.2 and 358.2) K. The experimental results are presented as the total pressure against acid gas loading (mol H_2S per total mol of AEEA). Experimental measurements have been carried out using isochoric saturation method, which has been extensively used for measuring the gas solubility in physical and chemical solvents [3,6,7,9–14]. The experimental values were correlated by using the Deshmukh-Mather model as well [9,15,16].

2. Experimental

2.1. Materials

Distilled deionized water, which used for preparing solutions, was degassed in an ultrasonic bath (FUNGILAB, model UA10MFD)

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Table 1
Specifications and sources of chemicals used in this work.

Chemical Name	Source	Purity*	Analysis Method	CAS Registry Number
Hydrogen sulfide	Roham Gas Co.	99.95 (mol%)	GC[a]	[7783–06–4]
2-((2-aminoethyl)amino)ethanol	Sigma-Aldrich Co.	>99 (wt%)	GC	[111–41–1]

[a] Gas Chromatography.
* The analysis is provided by supplier.

at temperature 353.2 K and wave frequency of 50 kHz about half an hour before use. The specifications and sources of the chemicals used in this work are summarized in Table 1. All the materials were reagent grade and used without further purification.

2.2. Apparatus and procedure

In the present work, the solubility measurements were carried out using a constant volume static apparatus that has been already used by Mazloumi et al. and Zoghi and Shokouhi [9,14]. The apparatus used in this work is shown in Fig. 1. The volume of autoclave is $(1.17 \times 10^{-4} \pm 7\times10^{-7})$ m^3 and it is made of SS 304. A magnetic stirrer is used for efficient mixing of vapour and liquid phases. A pressure transducer sensor in the range (0–3000) kPa with the accuracy of ±0.05% of full scale (Keller-Druck PA-33X) is used for measuring the pressure of the autoclave. A thermostatic water bath (Thomson 2000, accuracy ±0.1 K) is utilized for controlling and monitoring of temperature of the autoclave. The H_2S is injected into the equilibrium cell by a gas container with a volume of 5×10^{-5} m^3. The gas container is connected to gas storage cylinder. A pressure transducer (Keller-Druck PA-33X) with a range of (0–4000) kPa and an accuracy of ±0.05% of full scale is used to measure the gas container pressure. An electronic mass balance (Mettler Model AE200, Switzer with precision of $\pm1\times10^{-7}$ kg) is used for preparing the aqueous solutions.

The following procedure was used for obtaining the experimental data. First the equilibrium cell was evacuated for several minutes by using a vacuum pump. In the next step, the prepared aqueous amine solution was degassed in an ultrasonic bath for 0.25 h. In each experiment certain volume of the alkanolamine solution (approximately 25–30 cm^3) was injected into the cell under vacuum. The temperature was controlled to the desired set point by using a thermostatic water bath that circulated the water through the autoclave jacket. A certain amount of the hydrogen sulfide (H_2S) was fed to the equilibrium cell. The injected number of moles is obtained by the pressure change of gas container with the known volume and the ambient temperature before and after H_2S injection. A thermocouple with precision ±0.1 K was used for measuring the ambient temperature. The mechanical stirrer was used to ensure the liquid and vapour phases contacted well. The vapour-liquid equilibrium was achieved for about 2 h when pressure and temperature reach to constant value. The equilibrium condition (temperature and pressure) were then recorded. The amount of H_2S injected into the equilibrium cell was calculated with procedure adopted by Park and Sandall [17], Hosseini Jenab et al. [18] and Zoghi et al. [7,9] in which accurate *PVT* data were obtained from the National Institute of Standards and Technology

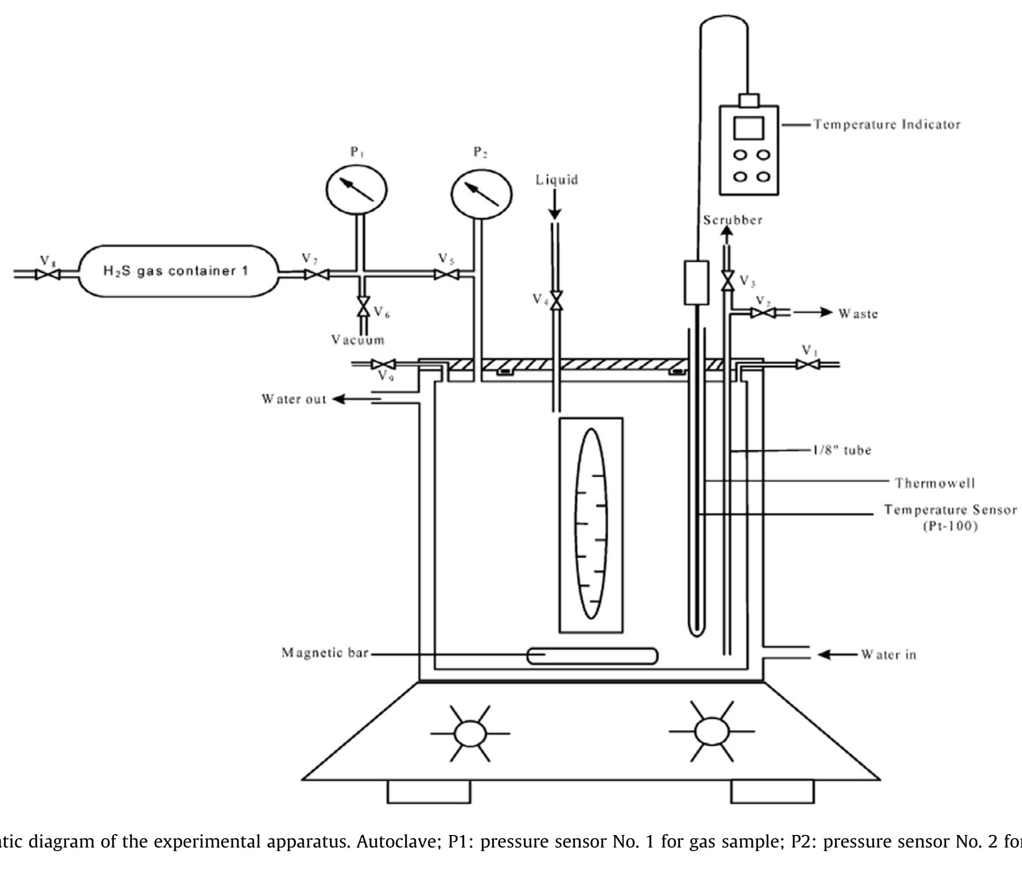

Fig. 1. Schematic diagram of the experimental apparatus. Autoclave; P1: pressure sensor No. 1 for gas sample; P2: pressure sensor No. 2 for autoclave [14].