Experiments on saturated vapor pressure of aqueous lithium bromide solution at high temperatures

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A B S T R A C T

This work mainly focuses on the determination of the saturated vapor pressure of LiBr aqueous solution with mass fraction ranging from 43.14 to 65.26 wt% at high temperature experimentally. First, the measurement of the saturation vapor pressures is conducted in deionized water as well as in LiBr aqueous solution at a lower temperature. The experimental result has a good agreement with the literature value, which verified the reliability and accuracy of the experimental apparatus. Second, measurement of the saturated vapor pressure of LiBr aqueous solution with mass fraction ranging from 43.14 to 65.26 wt% is systematically carried out in the 156.06~257.84 °C temperature range. Based on the saturated vapor pressure data at lower temperature, a correlation for predicting the saturated vapor pressure data of the LiBr aqueous solution is obtained, which is also available for high temperature condition. Therefore, this work will be very helpful for the modeling and design of high temperature LiBr/H$_2$O absorption heat transformers.

Expérience sur la pression de vapeur saturée d'une solution aqueuse de bromure de lithium à haute température

1. Introduction

Thermodynamic performance and efficiency of absorption heat pump or refrigerant system are highly dependent on the properties of the working fluids. Many working fluid pairs have been considered for absorption system. Nowadays, LiBr aqueous solution has a very extensive application in absorption systems due to its advantage of high latent heat. The thermodynamic properties of LiBr aqueous solution are very necessary for the industrial applications of the heat pump, and the saturated

vapor pressure data are one of the most important basic properties (McNeely, 1979). Iyoki and Uemura (1989) measured the vapor pressures of the LiBr aqueous solution system in the range of temperatures from 93.9 to 181.7 °C and concentrations from 38.9 to 70.3 wt%. They also measured the vapor pressures of the water–lithium bromide–zinc bromide–lithium chloride system in the range of temperatures from 99.9 to 150.3 °C and concentrations from 50.8 to 63.6 wt% by using static-equilibrium method. The experimental data for the four-component system agreed well with the extrapolated values of Takigawa's equation, which was obtained at a low

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Table 1 – Experimental reagents information.

Chemical name	Purity	Manufacturer
Lithium bromide (powder)	≥99.9%	Aladdin Industrial Corporation
Dichlorofluorescein	≥80%	The Third Shenyang Reagent Co., Ltd
AgNO$_3$	≥99.8%	Sinopharm Chemical Reagent Co., Ltd

temperature. Lenard et al. (1992) measured the vapor pressures of concentrated LiBr aqueous solution at temperatures ranging from 120 to 210 °C and salt mass fraction ranging from 43.7 to 65.2 wt%. They also developed a novel representation of the vapor pressure over a large range of temperature and concentrations using a minimum number of parameters. The results would allow the development of more reliable P-T-X charts for LiBr aqueous solution over a large range of conditions. Feuerecker et al. (1994) measured the vapor pressure of LiBr aqueous solution at concentrations from 40 to 75 wt% and temperature up to 190 °C with an accuracy of typically 0.2 K. Using previous measured data of vapor pressure and heat capacity, Kaita (2001) developed the equations which could calculate the vapor pressure, enthalpy and entropy of LiBr aqueous solution at such high temperatures. The developed equations are valid from concentrations of 40 to 65 wt% and also from temperatures of 40 to 210 °C. These equations were very helpful for modeling and designing triple-effect LiBr–water chillers. Recently emerging LiBr/H$_2$O absorption heat transformers operate at higher temperatures and pressures, which is usually more than 200 °C and 500 kPa than traditional heat transformers (Chen et al., 2009; Hao et al., 2012, 2013, 2014; Ma et al., 2003, 2012). Being one of the basic and important property of the LiBr aqueous solution system, the saturated vapor pressure data would be impotent in the design of industry process.

The purpose of this work is to experimentally measure the saturated vapor pressure of LiBr aqueous solution at the concentration ranging from 40 to 75 wt% with temperature up to 250 °C, and to develop correlations for calculating saturation pressure of LiBr aqueous solution at high temperatures.

2.   Experimental section

2.1.   Chemicals

The sample of lithium bromide, which was an analytically pure agent of 99.9% purity level, produced by Aladdin Industrial Corporation, was used in this work. The concentration of the LiBr aqueous solution was analyzed by a titrimetric method of AgNO$_3$ solution at known concentrations using dichlorofluorescein as an adsorption indicator. The measurement uncertainty of LiBr concentration was ± 0.07 wt.% in this experiment. The details of the agents are shown in Table 1.

2.2.   Apparatus

The experimental schematic diagram and photograph of the experimental setup are shown in Figs. 1 and 2. Vapor pressure of the LiBr aqueous solution is measured by boiling point method, which is based on the static vapor liquid equilibrium principle. The main components of the experimental

apparatus include a sample equilibrium cell with a volume of 1 L, a high accuracy digital pressure gauge, a platinum resistance thermometer, and an electrical heater. The LiBr aqueous solution equilibrium cell is the major part of the system, which is constructed of stainless steel (type 316L). The uncertainty of the inner volume of the cell is 1.84 cm^3. In order to transmit pressure from the cell to the digital pressure, a tube made of 3 mm ID tubing is connected from equilibrium cell to digital pressure gauge. Deionized water is used as the pressure transmitting fluid to prevent condensation of water vapor in the manifold parts of the system. Pressures in the equilibrium cell are continuously measured by a high accuracy digital pressure gauge (Model 745-300A High Accuracy Laboratory Standard, Paroscientific) with a resolution better than 0.0001% full scale and an accuracy better than 0.008% full scale. Its range is from 0 to 2.07 MPa and the experimental uncertainty of pressure is estimated to be 165.6 Pa. The temperature inside the equilibrium cell is measured with a platinum resistance thermometer (Model WZPB-2, Fangda Corporation, China), which has been calibrated by the National Metrical Laboratory of China. The experimental uncertainty of temperature is estimated to be 0.01 K for the test standard of the platinum resistance thermometer (Grade II). Experimental data are collected with an Agilent 34970A data acquisition system and a computer.

In this way, the real-time data profiles were directly displayed on the computer monitor. The equilibrium cell was cleaned with deionized water over times and baked to remove the impurity which could affect the measurements, before
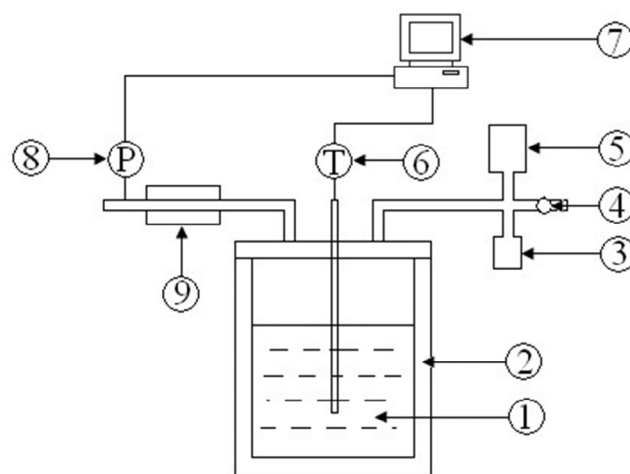

Fig. 1 – Schematic of the static VLE apparatus. ① LiBr; ② electrical heater; ③ pressure gauge; ④ needle valve; ⑤ safety valve; ⑥ platinum resistance thermometer; ⑦ computer; ⑧ high accuracy digital pressure gauge; ⑨ ice bath.