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Vapor pressure above concentrated aqueous solution of lithium bromide at subzero temperatures

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ABSTRACT

The property of vapor pressure above aqueous solution of lithium bromide has been extensively studied, but the experimental data are mostly limited to temperature range above 0°C. During recent years novel applications of hygroscopic solutions at subzero temperatures were proposed; thus more accurate data of vapor pressure are anticipated. In this paper the equilibrium vapor pressure above aqueous LiBr solution was measured with static method in the temperature range from 217K to 273K. The molality of LiBr varied from 8.62 to 11.51 mol kg^{-1}. The measured data were compared with the calculated values of an existing formulation (Pátek and Klomfar in 2006), and a mean deviation of 35.85% was found. If the data were correlated with a modified Antoine equation, a mean deviation of 2.81% could be obtained. In order to estimate the hygroscopic potential of low temperature aqueous LiBr solution as compared to cold surface, the temperature differences between the solution and the ice at the same vapor pressures were estimated.

Pression de vapeur au-dessus d'une solution aqueuse concentrée de bromure de lithium à des températures inférieures à zéro

Mots clés : Solution aqueuse de LiBr ; Pression de vapeur saturée ; Mesure expérimentale ; Équation d'Antoine modifiée

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Nomenclature

A_0~A_4, B_0~B_4, C_0~C_4	polynomial term
m	molality [mol kg^{-1}]
p	pressure [Pa]; in equation (2): pressure [torr]; in equation (3): pressure [kPa]
T	temperature [K]; in equation (2): temperature [°C]
w	mass fraction

Subscripts

exp	experimental
cal	calculated
modified	modified value of vapor pressure
0,sub	pure water, calculated with Murphy's equation
0,patek	pure water, calculated with Pátek's equation
patek	calculated with Pátek's equation

1. Introduction

The saturated vapor pressure above LiBr–water solution is one of the most important basic properties for the research and design of absorption refrigerating machines and liquid desiccant dehumidification systems. The measurements of the vapor pressure of LiBr–water solutions are driven by the applications of this solution. Many researchers have conducted studies on this topic and those cited and applied most frequently are listed in Table 1. In addition to measuring the vapor pressure experimentally, correlation with better accuracy and consistency also plays an important role.

During recent years some novel systems which incorporate LiBr–water solution were proposed to address the issue of energy saving. Nevertheless the solution temperatures in these systems exceed traditional ranges as listed in Table 1. Ma (2012) put forward a high temperature double effect absorption heat transformer (HDAHT) to recover high temperature waste heat, and they measured the vapor pressure of LiBr–water solution in the temperature range of 429–531 K in order to optimize the design of HDAHT (Ding, 2013). Li and Chen et al. raised a frost-free air-source heat pump (FFASHP) which utilized hygroscopic solutions (LiBr–water solution, LiCl–water solution, etc.) to absorb sensible and latent heat from humid air in winter, not only improving the quantity of heat collected from unit mass of air, but also remedying the necessity of defrosting (Guo et al., 2008). Peng et al. proposed a heat driven freeze dryer (HDFD) in which hygroscopic solutions were used to absorb water vapor produced from materials to be freeze dried (Peng et al., 2013). In HDAHT and HDFD, the temperatures of LiBr–water solutions fell below 273K, of which temperature range the thermophysical property data are scarce. Thus, the aim of this work is to obtain the saturated vapor pressures of LiBr–water solutions below 273K. Experimental measurements and data correlation will be carried out.

2. Materials, preparations and methods

2.1. *Materials*

Solutions were prepared with distilled water. Analytical grade LiBr (≥99.5%) was purchased from Urchem Ltd. (Shanghai, China) and used directly without further purification. An electronic balance (AL104, Mettler Toledo) with a precision of ±0.1 mg was used for weighing. Five different concentrations of LiBr–water solutions were prepared. Their molality was 8.62, 9.05, 9.93, 10.42 and 11.51 mol kg^{-1} respectively.

2.2. *Degassing*

Many literatures pointed out that the main sources of error in the measurement of low vapor pressure were the air and volatile impurities dissolved in the solution (Fernicola et al., 2012). Therefore, it is necessary and crucial to degas the solution, usually using the method of freezing (Fernicola et al., 2012). The principle of this method is to reduce the solubility of the gases in the solution by freezing with liquid nitrogen, and to remove the gases by vacuum pumps. As for this circumstance, the solutions were degassed twice at 10^{-1} Pa lasting 30 s and four times at 10^{-3} Pa lasting 30 s. The solution concentration after vapor pressure measurement was checked by heating the solution sample to over 150°C and weighing the residual solute.

2.3. *Vapor pressure measurement*

The experimental device is shown in Fig. 1, employing the static method for vapor pressure measurement (Fernicola et al., 2012).

Table 1 – Previous typical studies on the vapor pressure of LiBr–water solution.

Author(s)	Year	Experiment/Correlation	Range of values (Range of applicability for fittings)	
			Temperature (K)	Mass fraction (wt%)
Löwer, 1960	1960	Experiment and correlation	273–403	0–70
McNeeley, 1978	1976	Correlation	278–453	45–70
Lee et al., 1990	1992	Experiment and correlation	393–483	43.8–65.2
Feurecker et al., 1993	1993	Experiment and correlation	318–463	40.4–70.3
Zhe, 2005	2005	Correlation	278–523	0–76
Kim and Ferreira, 2006	2005	Correlation	273–483	0–70
Pátek and Klomfar, 2006a	2006	Correlation	273–503	0–75