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Experimental researches on characteristics of vapor–liquid equilibrium of NH_3–H_2O–LiBr system

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Abstract

An improved system of NH_3–H_2O–LiBr was proposed for overcoming the drawback of NH_3–H_2O absorption refrigeration system. The LiBr was added to NH_3–H_2O system anticipating a decrease in the content of water in the NH_3–H_2O–LiBr system. An equilibrium cell was used to measure thermal property of the ternary NH_3–H_2O–LiBr mixtures. The pressure–temperature data for their vapor–liquid equilibrium (VLE) data were measured at ten temperature points between 15–85 °C, and pressures up to 2 MPa. The LiBr concentration of the solution was chosen in the range of 5–60% of mass ratio of LiBr in pure water. The VLE for the NH_3–H_2O–LiBr ternary solution was measured statically. The experimental results show that the equilibrium pressures reduced by 30–50%, and the amount of component of water in the gas phase reduced greatly to 2.5% at $T=70$ °C. The experimental results predicted much better characteristics of the new ternary system than the NH_3–H_2O system for the applications.

Keywords: Absorption system; Ammonia-water; Additive; Heating; Lithium bromide; Experiment; Equilibrium; Vapour; Liquid

Recherches expérimentales sur les caractéristiques de l'équilibre vapeur/liquide d'un système NH_3-H_2O-LiBr

Mots clés : Système à absorption ; Ammoniac-eau ; Additif ; Chauffage ; Bromure de lithium ; Expérimentation ; Équilibre ; Vapeur ; Liquide

1. Introduction

The binary systems of NH_3–H_2O and H_2O–LiBr were well known as working fluid pairs to be applied both in absorption heat pumps and in absorption refrigerators currently [1]. Both mixtures had some disadvantages to limit their applications. The disadvantage of H_2O–LiBr system came from its negative pressure while the main disadvantage of the NH_3–H_2O system as the working fluid in heat pumps and heat transformers were its high water content in the vapor phase, resulting in a necessary requirement for an expensive dephlegmator, and resulting in the high vapor pressure at elevated temperatures for the NH_3–H_2O system. Due to the strong ability of absorbing water by LiBr, it was expected that the ternary NH_3–H_2O–LiBr system would have the lower vapor content inside the ternary system of ammonia. It was also expected that the

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Nomenclature

T	temperature (°C)	p	pressure (kPa)
X_{NH_3}	mass concentration of ammonia	m	mass in solution (kg)
X_{LiBr}	mass concentration of lithium bromide		

vapor pressure inside the system of LiBr would not be negative in the working situations.

The intention of our work was to obtain systematic information on the VLE in the temperature range of 15–85 °C and at pressures up to 2 MPa.

2. Experimental arrangements

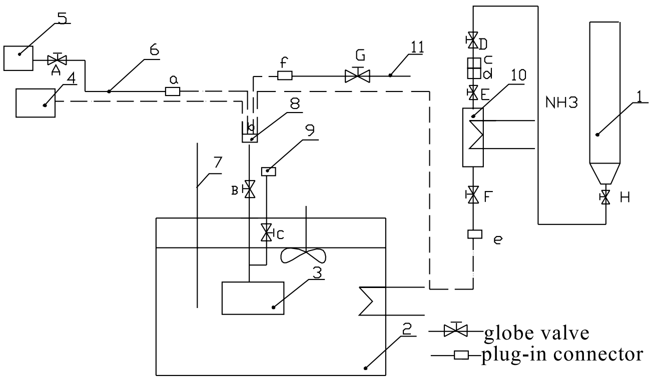
The applied working fluid in the experiments was NH_3–H_2O–LiBr. It had two disadvantages: corrosivity and ammonia's toxin. For the sake of safety, the experiment of the circulating type was unsuitable. The VLE-measurements were carried out by the static method.

As shown in Fig. 1, the experimental unit, measured the temperature–pressure characteristics of vapor–liquid equilibrium state of the NH_3–H_2O–LiBr system was composed of seven parts: an equilibrium cell (3), liquid thermostat (2), ammonia feeding circuit (include valve E, F, D, H, ammonia container (1), ammonia feeding bottle (10)) a LiBr–H_2O injection unit (5), a pressure transducer (9), a pressure and temperature computer data acquisition system and a gas chromatograph system (4). The equilibrium cell was the main experiment component which was fabricated by chromium–nickel steel, had a volume of 769 cm^3. The cell was submerged in the aqueous thermostat (2). An ammonia feeding bottle and a LiBr–H_2O injection unit were used to adjust the mass proportion of the mixture of ammonia lithium bromide and water.

During the preparation of the experiments, a vacuum pump, or the LiBr–H_2O solution feeding circuit, or the ammonia feeding circuit, or the sampling capillary column of the vapor phase would be connected with the equilibrium cell respectively by the plug-in connector (8). The schematic flow diagram is given in Fig. 1.

The procedures for preparing experiments were as follows: (1) First step was the lithium bromide aqueous solution's filling process. At first, the equilibrium cell was evacuated by the vacuum pump. Then closing the valve B, the container filled with the lithium bromide aqueous solution was then connected to the equilibrium cell. Secondly, opening the valves B and A, and the lithium bromide aqueous solution was then sucked in the equilibrium cell. The amount of the lithium bromide aqueous solution sucked in was determined by the container mass difference measured by an electric balance. Finally, after the filling process of the lithium bromide aqueous solution was finished, the valves B and A were then closed.

(2) The second step was the filling process of ammonia. At first, the ammonia container was then connected to the



1 ammonia container, 2 liquid thermostat, 3 equilibrium cell, 4 gas chromatograph system, 5 container of LiBr aqueous solution, 6 LiBr-H2O injection unit, 7 temperature transducer, 8 plug-in connector of the vacuum pump, of LiBr-H2O feeding, of gas chromatograph system, of discharge of the mixture, respectively, 9 pressure transducer, 10 ammonia feeding bottle, 11 discharge of the mixture.

A, B,C, D, E, F, G, H globe valve a, b, c, d, e, f plug-in connector

Fig. 1. Schematic flow diagram of the apparatus (excluding computer data acquisition).