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# Measurement of solubility and density of water + lithium bromide + lithium chloride and water + lithium bromide + sodium formate systems

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## ARTICLE INFO

### Article history:

Received 3 January 2015

Received in revised form

1 April 2015

Accepted 3 April 2015

Available online 14 April 2015

### Keywords:

Solubility measurement

Density measurement

Absorption chiller

Lithium bromide

Absorbent mixture

## ABSTRACT

Solubility of aqueous solutions containing lithium bromide + lithium chloride and lithium bromide + sodium formate were measured ( $\text{LiBr}/\text{NaHCO}_2 = 2$  and  $\text{LiBr}/\text{LiCl} = 2$  by mass ratio) at different temperatures. Visual polythermal method was used in the temperature range of (283.15–340.15) K and mass fraction range of (0.4–0.8). Also density of mentioned systems was reported in the temperature range of (288.15–333.15) K. Each set of experimental measurements were correlated using least-square regression as a function of temperature. Our results indicate that solubility of  $\text{LiBr} + \text{LiCl}$  is higher than  $\text{LiBr}$  and its density is lower than density of aqueous solution of  $\text{LiBr}$ .

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# Mesure de la solubilité et de la densité des systèmes eau + bromure de lithium + chlorure de lithium et eau + bromure de lithium + formate de sodium

Mots-clés : Mesure de solubilité ; Mesure de densité ; Refroidisseur à absorption ; Bromure de lithium ; Mélange d'absorbant

## 1. Introduction

Lithium bromide solution is used as absorbent in absorption chillers because of its thermo physical properties such as low heat capacity and high water absorption capacity. Absorption

chiller is one of the best alternatives to vapor compression cooling cycle because of low electricity consumption and possibility of coupling with solar systems. However, there are some problems that hinder the widespread use of absorption chillers. The most important problem is crystallization of  $\text{LiBr}$  that impedes proper performance of chillers. This

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<http://dx.doi.org/10.1016/j.ijrefrig.2015.04.002>

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**Nomenclature**

LiBr	Lithium Bromide
NaHCO <sub>2</sub>	Sodium Formate
LiCl	Lithium Chloride
H <sub>2</sub> O	Water
$\rho$	Density
$\rho_w$	Density of water
W	mass fraction
T	Temperature
A <sub>n</sub>	Equation Constant
RMSD	Root Mean Square Deviation
$\mu$	Chemical potential
$\mu^0$	Standard chemical potential
$\gamma$	Activity coefficient
R	Gases global constant
m	molality
M	Cation
A	anion
aq	aqueous
s	Solid
l	Liquid
C <sub>p</sub>	heat capacity
H	enthalpy
G	Gibbs free energy
T <sub>0</sub>	Standard temperature

phenomenon mostly occurs in absorber which operates at higher concentration levels (Izquierdo et al., 2004). A lot of researches have focused on improvement of absorbent to increase the efficiency of the system and eliminate the crystallization problem (Iyoki et al., 1993a; Kim et al., 1996, 1997; Kim and Lee, 2002; Koo and Lee, 1998; Lee et al., 2000; Donate et al., 2006; De Lucas et al., 2008; Salavera et al., 2004). Solubility of the mixture is the most important property in this regard, higher solubility means lower crystallization problem. Density and viscosity of the working fluid also influence the electricity consumption as well as efficiency of the absorption chillers. Heat capacity is also an essential parameter since it determines the heat absorbed in generator and evaporator. A series of experimental data have been presented by various researchers to find the best working mixtures for absorption chillers. Solubility and vapor pressure of the (water + lithium bromide + lithium iodide) system were measured by Iyoki et al. (Iyoki et al., 1993a). Jin soo Kim applied visual polythermal method to measure solubility of lithium bromide + ethanolamine in water (Kim et al., 1996) and heat capacity of mixtures containing lithium bromide plus ethanolamine and 1,3-propanediol (Kim et al., 1997). Lithium bromide solution in the presence of ethanolamine and 1,3-propanediol was tested in a wide range of operational condition in an air-cooled cycle. In another work, Lee measured the surface tension of an aqueous solution containing lithium bromide, lithium iodide and 1,3-propanediol (Kim and Lee, 2002). Koo et al. measured solubilities, vapor pressures, densities, and viscosities of the aqueous solution including lithium bromide, lithium iodide and lithium chloride (Koo and Lee, 1998). Later, they reported same physical properties for

aqueous solution containing lithium bromide, lithium iodide, and lithium nitrate and lithium chloride (Lee et al., 2000). They found that the suggested working fluids have higher COP, lower crystallization temperature and sufficient cooling capacity. Rodriguez et al. suggested a mixture of lithium bromide and organic salts of sodium and potassium (formate, acetate and lactate) as alternative absorbents (Donate et al., 2006). They measured vapor pressure, densities, and viscosities of the aqueous solution containing lithium bromide + potassium acetate and lithium bromide + sodium lactate (De Lucas et al., 2008). Salavera reported solubility, heat capacity, and density of aqueous solution of lithium bromide + lithium iodide + lithium nitrate + lithium chloride at several compositions and temperatures (Salavera et al., 2004).

In this article, aqueous solutions containing lithium bromide + lithium chloride and lithium bromide + sodium formate have been selected for possible application in absorption chillers. Solubilities and densities of mentioned systems have been measured and reported over a wide range of temperatures and mass fractions. Finally experimental values have been correlated using proper equations. Presented experimental data can be helpful to find the best working fluid.

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## 2. Experimental procedure

### 2.1. Materials

LiBr (99.9%, mass%), LiCl (99+%, mass%) and NaHCO<sub>2</sub> (99+%, mass%) were supplied by Merck Co. All the reagents were used without further purification. All solutions were prepared with distilled and de-ionized water.

### 2.2. Apparatus and procedure

#### 2.2.1. Solubility

Visual polythermal method was used to measure the solubility of salts in water. The apparatus consists of a Pyrex glass vessel (50 cm<sup>3</sup>), a thermometer (with 0.1 K precision) which is connected to a constant temperature bath (Lauda Alpha RA8) with the accuracy of 0.1 K, a circulator, cooling and heating media and a magnetic stirrer. Each sample was accurately prepared by weighing each component with a precision balance (Precisa, xt220A with 0.001g precision). The prepared sample solution (approximately 30 cm<sup>3</sup>) was placed in a vessel and stirred using magnetic stirrer. The solution was heated above the estimated saturation temperature to dissolve all the salts. Then the temperature was lowered slowly to settle a small amount of salt. The temperature of the solution was lowered and raised at a slow rate (nearly 0.1 K min<sup>-1</sup>). Through a series of dissolving and precipitation process, the temperature at which all the salts disappeared was taken as the dissolution temperature of the solution. Each test was repeated with the same composition to ensure that the right dissolution temperature is recorded. Also, accuracy of the apparatus and the procedure was checked with binary solutions such as water + lithium bromide and water + lithium

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