Vapor Pressure Measurement of the Ternary Systems H_2O + LiBr + [Dmim]Cl, H_2O + LiBr + $[Dmim]BF_4$, H_2O + LiCl + [Dmim]Cl, and H_2O + LiCl + $[Dmim]BF_4$

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The aim of this work is to investigate improving the effects for adding ionic liquids (ILs) to the working fluids of absorption cycle, lithium bromide aqueous solution (H_2O + LiBr), and lithium chloride aqueous solution (H_2O + LiCl). 1,3-Dimethylimidazolium chloride ([Dmim]Cl) and 1,3-dimethylimidazolium tetrafluoroborate ($[Dmim]BF_4$) were selected to be additives. The vapor pressure data were measured for the H_2O + LiBr + [Dmim]Cl system (LiBr/[Dmim]Cl mass ratio = 3), H_2O + LiBr + $[Dmim]BF_4$ system (LiBr/$[Dmim]BF_4$ mass ratio = 2), H_2O + LiCl + [Dmim]Cl system (LiCl/[Dmim]Cl mass ratio = 2), and H_2O + LiCl + $[Dmim]BF_4$ system (LiCl/$[Dmim]BF_4$ mass ratio = 2) by means of the boiling point method, at temperatures from (303.60 to 439.42) K and the mass fraction of absorbent species from 0.20 to 0.70, respectively. The Antoine-type equation was used to correlate the experimental data of the ternary systems, and the agreements with the experimental data were excellent; that is, the average absolute relative deviations (ARDs) for pressure between experimental and calculated values were 1.05 %, 0.75 %, 0.63 %, and 0.92 % for the systems. Compared with traditional working fluids of absorption cycle, H_2O + LiBr and H_2O + LiCl, the promising results show that four ternary systems investigated in this work might be used as alternative working fluids to improve the performances of absorption cycles and liquid desiccant dehumidification systems.

Introduction

In recent years, the absorption cooling cycle has attracted considerable attention,[1,2] owing to the fact that they can be powered by low grade heat, for example, solar energy and waste heat and so on, to obtain cooling facility for refrigeration.[3] Absorption working fluids contain absorbents and refrigerants. As a performance request, the solution should have a much lower vapor pressure than the refrigerant at the same temperature. Water often used to be a refrigerant in the absorption cooling cycle, because it is nontoxic and owns a high enthalpy of evaporation. However, only lithium bromide aqueous solution (H_2O + LiBr) has been widely used in the absorption cooling cycle for air conditioning. Even the H_2O + LiBr system is limited because of its drawbacks, such as its crystallization and corrosion at high temperatures.[4]

On the side, lithium chloride aqueous solution (H_2O + LiCl) has been widely used as desiccant solution in the liquid desiccant dehumidification system.[5] The H_2O + LiCl system has a strong ability of water absorption. However, it has the same corrosion and crystallization problems as the H_2O + LiBr system.

Many scientists have tried to improve the H_2O + LiBr and H_2O + LiCl systems. Anticrystallization additives with a high boiling point and hygroscopic property were used to overcome the crystallization problem and ensure a safe cycle operation currently.[6,7] Some researchers have added some organic or inorganic salts to the binary systems H_2O + LiBr or H_2O + LiCl, and then the vapor pressures of ternary system and even a quaternary system have been measured. Donate et al.[8] selected sodium formate and potassium formate as additives for the H_2O + LiBr system, respectively, and they found that the cycle performance was improved through a thermodynamic evaluation. Park et al.[9] investigated the quaternary system water + lithium bromide + lithium nitrate + 1,3-propanediol. In the study, the mass fraction of the saturated solution could be reached 0.686 at 294.05 K. Lucas et al.[10] measured the vapor pressure of ternary systems water + lithium bromide + potassium acetate and water + lithium bromide + sodium lactate from (293.15 to 333.15) K. Kim et al.[11] studied the H_2O + LiBr system with ethanolamine ($H_2N(CH_2)_2OH$) as an additive and pointed out that the cycle performance was significantly improved. Ertas et al.[12] proposed adding calcium chloride ($CaCl_2$) to the H_2O + LiCl system, confirming that the optimum mass fraction ratio of LiCl/$CaCl_2$ was 1:1, and measuring the saturated vapor pressure, density, and viscosity of the mixture solution for the system.

In the previous decade, as a new solvent, ionic liquids (ILs) have gained more attention. Some ILs are very suitable to be used as absorbent species owing to their characteristics such as strong hydrophilicity, large solubility, noncorrosion, and so on.[13–15] Many kinds of ILs have been assessed for an alternative absorbent species, and thermophysical properties of the novel systems containing ILs have been studied. For example, Wang et al.[16] have measured the vapor pressures of the 1,3-dimethylimidazolium chloride aqueous solution ([Dmim]Cl + H_2O), and Kim et al.[17] have measured the vapor pressures of the 1-butyl-3-methylimidazolium bromide aqueous solution ([Bmim]Br + H_2O) and the 1-butyl-3-methylimidazolium tetrafluoroborate aqueous solution ($[Bmim]BF_4$ + H_2O), respectively.

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It should be pointed that the hydrophilic property of ILs was influenced by three factors: the organic cation, the length of the side chain, and the anion.[18] As we know, the imidazolium-based ILs and the pyridinium-based ILs are mainly in selected options of researchers. For a series of imidazolium-based ILs, the hydrophilic property increased with the length of its side chain decreasing; the smaller the anion, the stronger the hydrophilic property of IL has.[19,20] On the basis of the above principles, 1,3-dimethylimidazolium chloride ([Dmim]Cl) and 1,3-dimethylimidazolium tetrafluoroborate ($[Dmim]BF_4$) were selected to be additives in this work. To determine the mass ratio of LiBr to IL or LiCl to IL, a boiling point test was done. For the H_2O + LiBr + [Dmim]Cl system, the boiling points of the H_2O + LiBr + [Dmim]Cl system were measured at different mass ratios of LiBr to IL at the same atmospheric pressure. The higher the boiling point, the lower the vapor pressure of the system has. So the system has a stronger ability of water absorbing. Through the boiling point test, the optimum mass ratio of LiBr to [Dmim]Cl was found to be 3. Using the same method, the optimum mass ratio of LiBr to $[Dmim]BF_4$ was found to be 2, the optimum mass ratio of LiCl to [Dmim]Cl to be 2, and the optimum mass ratio of LiCl to $[Dmim]BF_4$ to be 2, respectively.

In this study, the alternative combinations with ILs [Dmim]Cl and $Dmim]BF_4$ as additives and four ternary systems for traditional binary systems H_2O + LiBr and H_2O + LiCl have been proposed, which are the H_2O + LiBr + [Dmim]Cl system (LiBr/[Dmim]Cl mass ratio = 3), the H_2O + LiBr + $[Dmim]BF_4$ system (LiBr/$[Dmim]BF_4$ mass ratio = 2), the H_2O + LiCl + [Dmim]Cl system (LiCl/[Dmim]Cl mass ratio = 2), and the H_2O + LiCl + $[Dmim]BF_4$ system (LiCl/$[Dmim]BF_4$ mass ratio = 2). The vapor pressures were measured by means of the boiling point method, at temperatures from (303.60 to 439.42) K and the mass fraction of absorbent species from 0.20 to 0.70, respectively.

Experimental Section

Materials. Lithium bromide ($w \geq 0.995$) and lithium chloride ($w \geq 0.995$) were supplied by Aladdin Chemistry Co., Ltd. and were used without further purification. 1,3-Dimethylimidazolium chloride ([Dmim]Cl) used was prepared and purified in the laboratory according to a method described in literature,[18] and the mass purity was more than 0.994 by differential scanning calorimetry (DSC). 1,3-Dimethylimidazolium tetrafluoroborate ($[Dmim]BF_4$, $w \geq 0.99$) was supplied by Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences. Sodium chloride ($w \geq 0.995$) was supplied by Beijing Chemical Works. Furthermore, all ILs were purified by vacuum evaporation to remove the residual volatile impurities before use.

All solutions were prepared with deionized water. The required concentrations of solution were obtained by weighing the corresponding quantity of salts on a precision balance (Mettler, AL204), with an accuracy of ± 0.0001 g.

Apparatus and Procedure. The detailed descriptions of the vapor pressure measurement apparatus and the operating procedures are presented in an earlier paper.[16] The vapor pressures were measured by the boiling point method. This method is valid because the vapor pressure of the absorbent species is neglectable compared with the vapor pressure of water. In this paper, the LiBr + IL and LiCl + IL are absorbent species, respectively.

The schematic diagram of the apparatus is shown in Figure 1. The apparatus is composed of an equilibrium vessel with a volume of 500 cm^3, an oil bath, a condenser cooled by refrigerant, a temperature sensor, and a temperature transmitter calibrated with the uncertainty of ± 0.05 K, a U-tube mercury manometer with the minimum calibration of 1 mm, a magnetic stirrer, and a set of vacuum system. The atmospheric pressure was measured with a calibrated barometer with a minimum calibration of 0.1 kPa, which is comparable with the accuracy of the U-tube mercury manometer.[16] The condenser was cooled with an aqueous alcohol solution to make a sufficiently cooled temperature (270.15 K) to minimize the amount of condensed vapor because the evaporation of water can vary the initial concentration of the sample solution.

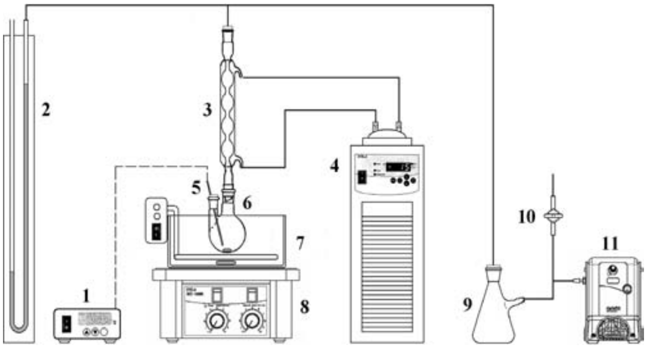

Figure 1. Schematic diagram of the experimental apparatus for the measurement of saturated vapor pressure: 1, temperature transmitter; 2, U-tube mercury manometer; 3, condenser; 4, refrigerator; 5, temperature sensor; 6, equilibrium vessel; 7, constant temperature bath; 8, magnetic stirrer; 9, pressure buffer; 10, vacuum control valve; 11, vacuum pump.

Validity of the Method. To check the reliability of the experimental apparatus used in this work, the vapor pressures of pure water and NaCl aqueous solution (mass fraction of NaCl was 0.25) were measured. The results were compared with the literature data.[21,22] The average absolute relative deviations (ARDs) were 0.43 % and 0.52 % in the vapor pressure of water and NaCl aqueous solution, respectively. It is shown that the data measured in this work are in very good agreement with literature data and indicates that the experimental apparatus is reliable and applicable for the measurement of the vapor pressures for the H_2O + LiBr + IL system and the H_2O + LiCl + IL system.

Results and Discussion

The vapor pressure data for the four ternary systems H_2O + LiBr + [Dmim]Cl (LiBr/[Dmim]Cl mass ratio = 3), H_2O + LiBr + $[Dmim]BF_4$ (LiBr/$[Dmim]BF_4$ mass ratio = 2), H_2O + LiCl + [Dmim]Cl (LiCl/[Dmim]Cl mass ratio = 2), and H_2O + LiCl + $[Dmim]BF_4$ (LiCl/$[Dmim]BF_4$ mass ratio = 2) were measured at temperatures from (303.60 to 439.42) K and the mass fraction of absorbent species from 0.20 to 0.70, respectively. The experimental results for the four systems were listed in Tables 1 to 4, respectively.

The vapor pressure results were correlated with an Antoine-type equation, which expresses vapor pressure as a function of temperature and concentration:

$$\log(p/\text{kPa}) = \sum_{i=0}^{3}\left[A_i + \frac{1000B_i}{T/\text{K} - 43.15}\right]w^i \qquad (1)$$

where p and T denote the vapor pressure in kPa and temperature in K and w is the mass fraction of absorbent species. The parameters A_i and B_i were determined by the least-squares method, and the results are listed in Table 5. The experimental

Table 1. Vapor Pressures of the H_2O (1) + LiBr (2) + [Dmim]Cl (3) (LiBr/[Dmim]Cl Mass Ratio = 3) Ternary System

T/K	p/kPa	T/K	p/kPa	T/K	p/kPa	T/K	p/kPa	T/K	p/kPa
$w_{2+3} = 0.30$		$w_{2+3} = 0.40$		$w_{2+3} = 0.50$		$w_{2+3} = 0.60$		$w_{2+3} = 0.69$	
308.63	4.9	309.76	4.2	314.74	3.7	327.80	3.4	352.15	3.7
315.78	6.9	319.94	6.8	325.56	6.2	342.05	6.6	364.33	6.4
322.89	9.7	327.01	9.6	333.57	8.9	350.27	9.5	372.22	9.0
329.42	13.4	333.93	13.3	340.73	12.3	360.01	14.7	383.13	14.3
336.53	18.5	341.16	18.3	347.63	16.6	368.23	20.5	393.14	21.4
342.28	23.8	348.76	25.4	354.55	22.3	377.30	29.1	401.98	29.7
349.36	32.2	356.41	34.8	361.56	29.6	386.31	40.7	411.48	41.4
356.90	43.8	363.65	46.2	368.39	38.8	396.28	57.5	421.49	58.4
366.37	63.0	373.16	65.8	375.09	49.6	413.90	102.0	439.42	101.8
379.82	102.5	385.61	102.1	381.44	62.3				
				396.05	102.5				

Table 2. Vapor Pressures of the H_2O (1) + LiBr (2) + [Dmim]BF_4 (3) (LiBr/[Dmim]BF_4 Mass Ratio = 2) Ternary System

T/K	p/kPa	T/K	p/kPa	T/K	p/kPa	T/K	p/kPa	T/K	p/kPa
$w_{2+3} = 0.30$		$w_{2+3} = 0.40$		$w_{2+3} = 0.50$		$w_{2+3} = 0.60$		$w_{2+3} = 0.70$	
316.33	7.5	310.65	4.7	310.88	3.7	331.49	6.1	354.32	7.5
322.23	9.9	322.75	8.7	321.96	6.5	342.84	10.3	366.63	12.7
330.65	14.8	331.74	13.4	332.31	10.5	352.00	15.3	377.20	19.5
339.92	22.5	340.44	19.8	340.49	15.2	361.91	23.0	387.18	28.3
346.38	29.7	346.51	25.8	350.40	23.3	369.79	31.2	396.83	40.3
355.18	42.8	355.36	37.2	358.25	31.9	379.04	43.9	406.44	56.3
364.44	61.4	364.95	54.2	367.87	46.3	387.44	59.4	416.86	79.9
373.39	85.7	374.54	77.5	375.38	61.0	398.04	84.5	424.02	100.1
378.24	101.5	382.24	100.6	385.41	86.5	403.41	100.1		
				390.02	100.7				

Table 3. Vapor Pressures of the H_2O (1) + LiCl (2) + [Dmim]Cl (3) (LiCl/[Dmim]Cl Mass Ratio = 2) Ternary System

T/K	p/kPa	T/K	p/kPa	T/K	p/kPa	T/K	p/kPa	T/K	p/kPa
$w_{2+3} = 0.20$		$w_{2+3} = 0.30$		$w_{2+3} = 0.40$		$w_{2+3} = 0.50$		$w_{2+3} = 0.55$	
303.60	3.6	309.15	3.8	321.83	4.7	337.99	5.6	334.63	3.4
310.56	5.4	316.80	5.8	330.69	7.3	346.64	8.4	345.17	5.7
318.26	8.0	331.28	11.6	344.01	13.3	359.26	14.7	356.03	9.4
327.83	12.7	342.71	19.4	353.59	20.2	367.20	20.4	366.34	14.7
337.88	20.1	351.24	27.8	361.56	27.9	375.29	28.3	375.28	21.2
346.10	28.6	360.22	39.9	371.22	40.8	385.17	41.2	383.14	28.9
354.46	40.5	368.88	55.6	379.80	56.0	394.04	56.8	392.59	41.2
363.34	57.2	379.05	80.3	390.08	80.8	411.15	101.2	401.88	57.4
372.63	81.5	385.53	100.1	396.83	101.1			411.99	80.7
378.57	99.8							419.26	101.7

Table 4. Vapor Pressures of the H_2O (1) + LiCl (2) + [Dmim]BF_4 (3) (LiCl/[Dmim]BF_4 Mass Ratio = 2) Ternary System

T/K	p/kPa	T/K	p/kPa	T/K	p/kPa	T/K	p/kPa	T/K	p/kPa
$w_{2+3} = 0.20$		$w_{2+3} = 0.30$		$w_{2+3} = 0.40$		$w_{2+3} = 0.50$		$w_{2+3} = 0.57$	
299.93	3.3	311.73	4.6	320.29	4.6	325.84	3.6	339.73	4.9
309.30	5.2	322.27	7.9	328.38	7.2	337.08	6.4	350.14	8.5
318.67	8.2	332.05	12.5	339.88	12.2	350.24	11.8	362.49	14.2
328.57	13.3	342.39	19.9	350.49	19.4	360.81	18.4	371.97	21.1
338.40	20.8	351.41	29.2	359.85	28.6	370.54	27.5	380.43	29.3
347.46	30.8	360.37	41.9	369.17	41.3	380.49	40.4	389.92	41.9
357.14	45.8	369.92	60.3	378.60	58.7	389.55	56.3	399.36	57.9
366.34	65.3	379.43	85.1	388.74	83.9	399.97	80.8	409.30	81.0
374.91	90.0	384.62	101.7	394.41	101.5	406.68	100.4	416.47	100.6
378.60	101.6								

data almost coincide with the calculated values predicted by eq 1. The ARDs for the vapor pressure between experimental and calculated values were found to be 1.05 % for the H_2O + LiBr + [Dmim]Cl system, 0.75 % for the H_2O + LiBr + [Dmim]BF_4 system, 0.63 % for the H_2O + LiCl + [Dmim]Cl system, and 0.92 % for the H_2O + LiCl + [Dmim]BF_4 system, respectively.

The vapor pressure data of the ternary systems H_2O + LiBr + [Dmim]Cl (LiBr/[Dmim]Cl mass ratio = 3) and H_2O + LiBr + [Dmim]BF_4 (LiBr/[Dmim]BF_4 mass ratio = 2) measured by this work and H_2O + LiBr + $H_2N(CH_2)_2OH$ (LiBr/$H_2N(CH_2)_2OH$ mass ratio = 3.5) taken from literature[11] at an absorbent species mass fraction of 0.60 were compared in Figure 2. It is shown that the vapor pressure of the H_2O + LiBr + [Dmim]Cl system is lower than the H_2O + LiBr + $H_2N(CH_2)_2OH$ (ethanolamine) system, but the vapor pressure of the H_2O + LiBr + [Dmim]BF_4 system is higher than the H_2O + LiBr + $H_2N(CH_2)_2OH$ system, at the same absorbent species mass fraction of 0.60. It is obvious that the adding effect of [Dmim]Cl is the best for the binary system H_2O + LiBr, but the adding effect of [Dmim]BF_4 is not better than $H_2N(CH_2)_2OH$.

To compare the effect of four absorbent species on the vapor pressure lowering of water at the same conditions, the vapor pressures of four ternary systems at an absorbent species mass fraction of 0.50 were compared in Figure 3. It is shown that the effect of absorbent species on the vapor pressure lowering of water follows the order LiCl + [Dmim]Cl > LiCl + [Dmim]BF_4 > LiBr + [Dmim]Cl > LiBr + [Dmim]BF_4, which is consistent with the IL sizes, and the law of the hydrophilicity of LiCl is stronger than LiBr.

Furthermore, the initial mass fraction of LiBr in the H_2O + LiBr system is usually 0.50 for lithium bromide absorption

Table 5. Correlation Parameters of Equation 1 for Four Ternary Systems

parameters	H_2O (1) + LiBr (2) + [Dmim]Cl (3)	H_2O (1) + LiBr (2) + [Dmim]BF_4 (3)	H_2O (1) + LiCl (2) + [Dmim]Cl (3)	H_2O (1) + LiCl (2) + [Dmim]BF_4 (3)
A_0	7.50618	7.64174	7.17024	7.02538
A_1	−1.65494	−2.26113	−1.20249	−0.22158
A_2	−1.33746	0.46489	0.66971	−0.08364
A_3	4.28939	2.06903	2.42692	1.14385
B_0	−1.59359	−1.75266	−1.77531	−1.72948
B_1	−1.21829	−0.15696	1.02194	0.71585
B_2	4.78511	2.12543	−2.59398	−2.36090
B_3	−5.71179	−3.16220	0.45908	1.04511
ARD^a for p	1.05 %	0.75 %	0.63 %	0.92 %
Application Range	$0.3 \leq w_{2+3} \leq 0.69$	$0.3 \leq w_{2+3} \leq 0.7$	$0.2 \leq w_{2+3} \leq 0.55$	$0.2 \leq w_{2+3} \leq 0.57$

^{a} ARD = $100\Sigma_{i=1}^{N}|(\exp_i - \text{cal}_i)/\exp_i|/N$; N = number of measurement points, exp$_i$ = experimental value, cal$_i$ = calculated value.

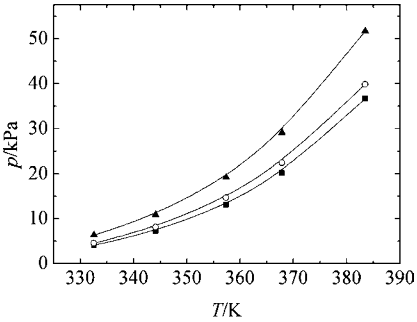

Figure 2. Vapor pressure comparison of the ternary systems H_2O + LiBr + [Dmim]Cl (LiBr/[Dmim]Cl mass ratio = 3), H_2O + LiBr + [Dmim]BF_4 (LiBr/[Dmim]BF_4 mass ratio = 2), and H_2O + LiBr + $H_2N(CH_2)_2OH$ (LiBr/$H_2N(CH_2)_2OH$ mass ratio = 3.5) at an absorbent species mass fraction of 0.60: ▲, H_2O + LiBr + [Dmim]BF_4 (0.60 mass fraction of LiBr + [Dmim]BF_4); ○, H_2O + LiBr + $H_2N(CH_2)_2OH$ (0.60 mass fraction of LiBr + $H_2N(CH_2)_2OH$);[11] ■, H_2O + LiBr + [Dmim]Cl (0.60 mass fraction of LiBr + [Dmim]Cl).

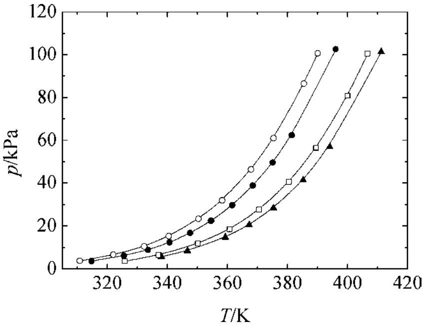

Figure 3. Vapor pressure comparison of four ternary systems at an absorbent species mass fraction of 0.50: ○, H_2O + LiBr + [Dmim]BF_4 (LiBr/[Dmim]BF_4 mass ratio = 2, 0.50 mass fraction of LiBr + [Dmim]BF_4); ●, H_2O + LiBr + [Dmim]Cl (LiBr/[Dmim]Cl mass ratio = 3, 0.50 mass fraction of LiBr + [Dmim]Cl); □, H_2O + LiCl + [Dmim]BF_4 (LiCl/[Dmim]BF_4 mass ratio = 2, 0.50 mass fraction of LiCl + [Dmim]BF_4); ▲, H_2O + LiCl + [Dmim]Cl (LiCl/[Dmim]Cl mass ratio = 2, 0.50 mass fraction of LiCl + [Dmim]Cl).

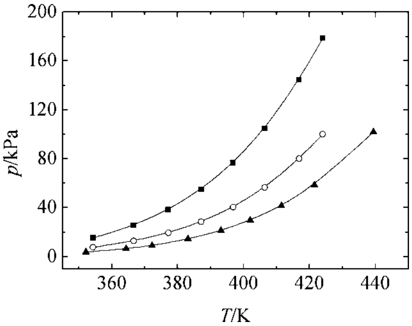

Figure 4. Vapor pressure comparison of different ILs added to the H_2O + LiBr system: ■, the H_2O + LiBr system (0.50 mass fraction of LiBr);[24] ○, the H_2O + LiBr + [Dmim]BF_4 system (LiBr/[Dmim]BF_4 mass ratio = 2, 0.70 mass fraction of LiBr + [Dmim]BF_4); ▲, the H_2O + LiBr + [Dmim]Cl system (LiBr/[Dmim]Cl mass ratio = 3, 0.69 mass fraction of LiBr + [Dmim]Cl).

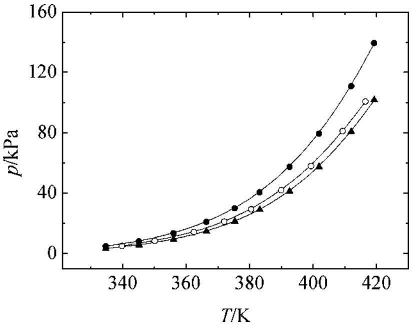

Figure 5. Vapor pressure comparison of different ILs added to the H_2O + LiCl system: ●, the H_2O + LiCl system (0.40 mass fraction of LiCl);[26] ○, the H_2O + LiCl + [Dmim]BF_4 system (LiCl/[Dmim]BF_4 mass ratio = 2, 0.57 mass fraction of LiCl + [Dmim]BF_4); ▲, the H_2O + LiCl + [Dmim]Cl system (LiCl/[Dmim]Cl mass ratio = 2, 0.55 mass fraction of LiCl + [Dmim]Cl).

chillers.[23] In Figure 4, the vapor pressures of the ternary systems H_2O + LiBr + [Dmim]Cl (0.69 mass fraction of LiBr + [Dmim]Cl) and H_2O + LiBr + [Dmim]BF_4 (0.70 mass fraction of LiBr + [Dmim]BF_4) were compared with that of the H_2O + LiBr system (0.50 mass fraction of LiBr), which were taken from literature.[24] Besides, in the liquid desiccant system, the mass fraction of LiCl in the H_2O + LiCl system is generally not more than 0.40.[25] In Figure 5, the vapor pressures of the ternary systems H_2O + LiCl + [Dmim]Cl (0.55 mass fraction of LiCl + [Dmim]Cl) and H_2O + LiCl + [Dmim]BF_4 (0.57 mass fraction of LiCl + [Dmim]BF_4) were compared with that of the H_2O + LiCl system (0.40 mass fraction of LiCl), which were taken from literature.[26] Obviously, Figures 4 and 5 show that the vapor pressures of ternary systems H_2O + LiBr + [Dmim]Cl (0.69 mass fraction of LiBr + [Dmim]Cl) and H_2O + LiBr + [Dmim]BF_4 (0.70 mass fraction of LiBr + [Dmim]BF_4) were lower than the binary system H_2O + LiBr (0.50 mass fraction of LiBr), and the vapor pressures of the ternary systems H_2O + LiCl + [Dmim]Cl (0.55 mass fraction of LiCl + [Dmim]Cl) and H_2O + LiCl + [Dmim]BF_4 (0.57 mass fraction of LiCl + [Dmim]BF_4) were lower than the binary system H_2O + LiCl (0.40 mass fraction of LiCl), respectively. It indicates that, compared with traditional binary systems, the water absorption ability of the ternary systems studied in this work is significantly improved through adding ILs. The choice of [Dmim]Cl and [Dmim]BF_4 as additives is reasonable. In addition, Figures 4 and 5 show that the improving effect of adding [Dmim]Cl is superior to that of adding [Dmim]BF_4.

Conclusions

The vapor pressure data of four ternary systems H_2O + LiBr + [Dmim]Cl (LiBr/[Dmim]Cl mass ratio = 3), H_2O + LiBr + [Dmim]BF_4 (LiBr/[Dmim]BF_4 mass ratio = 2), H_2O + LiCl + [Dmim]Cl (LiCl/[Dmim]Cl mass ratio = 2), and H_2O + LiCl + [Dmim]BF_4 (LiCl/[Dmim]BF_4 mass ratio = 2) were measured by means of the boiling point method, at temperatures from (303.60 to 439.42) K and the mass fraction of absorbent species from 0.20 to 0.70, respectively. The results indicate that the effect of four absorbent species on the vapor pressure lowering of water follows the order LiCl + [Dmim]Cl > LiCl + [Dmim]BF_4 > LiBr + [Dmim]Cl > LiBr + [Dmim]BF_4. Using ILs as additives to the LiBr aqueous solution and LiCl aqueous solution, the adding effect of [Dmim]Cl is superior to [Dmim]BF_4. Compared with traditional working fluids H_2O + LiBr and H_2O + LiCl, the improving effect exhibits promising results. It shows that four ternary systems investigated in this work as alternative working fluids might be used to improve the performances of absorption cycles and liquid desiccant dehumidification systems upon more research.

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