Solubility and Density of Potassium Iodide in a Binary Propan-1-ol−Water Solvent Mixture at (298.15, 303.15, 308.15, and 313.15) K

Ramesh R. Pawar,* Sambhaji M. Golait, Mehdi Hasan, and Arun B. Sawant

P. G. Department of Physical Chemistry, MSG College Malegaon Camp, Pin 423105, India

The solubility of potassium iodide in a propan-1-ol + water binary solvent mixture was measured over the entire composition range from (0 to 1) mass fraction of propan-1-ol at (298.15, 303.15, 308.15, and 313.15) K. The densities of the saturated solutions are also reported. The equation given for the solubility of the saturated solutions is correlated with the mole fraction of propan-1-ol and the temperature and density of the solution.

Introduction

There has been considerable attention recently on solubility studies of electrolytes. These studies are extremely important for the design and simulation of unit operations. Important information can be obtained about the solution structure. The precipitation of inorganic salts from aqueous solutions by the addition of alcohols as cosolvents has several advantages over the standard crystallization technique:[1−3] for example, high yield and purity of the products, operation at ambient temperatures, and fitness for systems where the temperature has little effect on the solubility.[4]

Solubility data are generally available for many salts in aqueous systems.[5−8] Solubilities of potassium iodide in water−ethanol and water−propan-1-ol mixed solvents for a few compositions are available in Stephan and Stephen.[6] However, there is no data available for the solubility of potassium iodide in water−propan-1-ol for the complete binary water−propan-1-ol composition range. Therefore, in continuation of our work,[9] we have undertaken systematic measurements of solubilities and densities of potassium iodide in a propan-1-ol−water binary solvent over the entire composition range from (0 to 1) mass fraction of propan-1-ol at (298.15, 303.15, 308.15, and 313.15) K.

Experimental Section

Material. In all experiments, triply distilled water was used. Propan-1-ol was supplied by the Jiangyin Huaxi International Trade Co. of purity > 99.9 %. Potassium iodide (KI) was supplied by Qualigens Chemicals of purity > 99.8 %.

Apparatus and Procedure. The apparatus and procedures used for solubility and density measurement have been described earlier.[9−11]

Binary (propan-1-ol + water) mixtures were prepared by weight on an electronic balance (Shimadzu, Auxzzo) with an uncertainty of ± 0.1 mg. An excess amount of KI was added to the binary solvents in a specially designed 100 mL double-walled flask. Water was circulated at constant temperature between the outer and the inner walls of the flask. The temperature of the circulating water was controlled by a thermostat to within (± 0.1) K. The solution was constantly stirred using a magnetic stirrer. After attaining equilibrium, the stirrer was turned off to let the solution settle for 1 h. Then the supernatant liquid was taken in a weighing bottle. The weight of this sample was taken, and the sample was kept in an oven at 343 K until the whole solvent evaporated and the residue was completely dry. This was confirmed by weighing twice or thrice until constant weight was obtained after keeping the sample in an oven for another half hour every time. From the weight of solute (residue) and weight of solution, the solubility has been calculated. Each experimental value of solubility is an average of at least three different measurements, and the uncertainty of the experimental solubility value is ± 0.0001 g/100 g. The saturated mole fraction solubility (x_A) in binary water (B) + propan-1-ol (C) solvent mixtures can be obtained as follows

$$x_A = (m_A/M_A)/(m_A/M_A + m_B/M_B + m_C/M_C) \qquad (1)$$

Similarly, the mole fraction of propan-1-ol (x_C) is calculated using eq 2.

$$x_C = (m_C/M_C)/(m_A/M_A + m_B/M_B + m_C/M_C) \qquad (2)$$

where m_A, m_B, and m_C are the mass of solute, water, and propan-1-ol, respectively, and M_A, M_B, and M_C are the molecular weight of the solute, water, and propan-1-ol, respectively.

Densities were determined using a 15 cm^3 bicapillary pycnometer as described earlier.[9−11] The pycnometer was calibrated using triply distilled and degassed water with a density[12] of 0.99705 $g \cdot cm^{-3}$ at 298.15 K. The pycnometer filled with air-bubble-free experimental liquids was kept in a transparent walled water bath (maintained at a constant temperature ± 0.01 K) for (10 to 15) min to attain thermal equilibrium. The positions of the liquid levels in the two arms were recorded with the help of a traveling microscope, which could read to 0.01 mm. The estimated uncertainty of the density measurements of the solvent and binary mixtures was 0.1 $kg \cdot m^{-3}$. At least three to four measurements were made which had an average deviation of ± 0.1 $kg \cdot m^{-3}$.

Results and Discussion

The experimental values of solubility (x_A) and density (ρ) of the saturated solutions for potassium iodide + water + propan-1-ol and at (298.15, 303.15, 308.15, and 313.15) K are given in Table 1. The solubility data is visually shown in Figure 1.

* Corresponding author. E-mail: rameshpawar_09@rediffmail.com.

10.1021/je9006426
Published on Web 11/05/2009

Table 1. Solubility x_A and Density ρ of Potassium Iodide for Various Mole Fractions x_C of Propan-1-ol at (298.15, 303.15, 308.15, and 313.15) K

T					ρ	
K	w	x_C	x_A	$x_{A,cal}$	10^{-3} kg·m^{-3}	% relative error
298.15	0.0	0.0000	0.1393	0.1349	1.7160	3.1443
	0.1	0.0283	0.1234	0.1267	1.6277	−2.6509
	0.2	0.0621	0.1092	0.1136	1.4695	−3.9884
	0.3	0.1017	0.1010	0.1059	1.4083	−4.8083
	0.4	0.1253	0.0958	0.0981	1.3201	−2.3692
	0.5	0.2110	0.0851	0.0833	1.2183	2.1172
	0.6	0.2909	0.0623	0.0673	1.0876	−8.0595
	0.7	0.3918	0.0481	0.0538	1.0308	−11.8317
	0.8	0.5260	0.0354	0.0348	0.9377	1.7454
	0.9	0.7192	0.0143	0.0104	0.8525	27.4535
	1.0	0.9982	0.0018		0.8035	
303.15	0.0	0.0000	0.1428	0.1404	1.7224	1.6846
	0.1	0.0280	0.1322	0.1325	1.6391	−0.2179
	0.2	0.0617	0.1210	0.1203	1.4968	0.5463
	0.3	0.1005	0.1157	0.1129	1.4383	2.4492
	0.4	0.1494	0.1033	0.1014	1.3307	1.7915
	0.5	0.2086	0.0957	0.0905	1.2497	5.4031
	0.6	0.2868	0.0753	0.0751	1.1257	0.2799
	0.7	0.3860	0.0620	0.0601	1.0412	3.1612
	0.8	0.5218	0.0430	0.0412	0.9534	4.1020
	0.9	0.7168	0.0175	0.0158	0.8554	9.3261
	1.0	0.9981	0.0019		0.7998	
308.15	0.0	0.0000	0.1465	0.1461	1.7337	0.2640
	0.1	0.0278	0.1362	0.1377	1.6420	−1.1160
	0.2	0.0607	0.1289	0.1283	1.5424	0.4536
	0.3	0.1001	0.1207	0.1187	1.4497	1.6629
	0.4	0.1486	0.1076	0.1075	1.3469	0.0554
	0.5	0.2077	0.0994	0.0959	1.2537	3.4864
	0.6	0.2835	0.0859	0.0825	1.1572	3.9988
	0.7	0.3835	0.0683	0.0663	1.0555	2.9495
	0.8	0.5203	0.0459	0.0468	0.9588	−1.8785
	0.9	0.7155	0.0193	0.0210	0.8554	−8.9721
	1.0	0.9978	0.0022		0.7875	
313.15	0.0	0.0000	0.1497	0.1512	1.7329	−0.9692
	0.1	0.0277	0.1398	0.1431	1.6471	−2.3669
	0.2	0.0603	0.1347	0.1343	1.5572	0.2741
	0.3	0.0996	0.1253	0.1245	1.4604	0.6640
	0.4	0.1484	0.1089	0.1128	1.3491	−3.5447
	0.5	0.2070	0.1027	0.1016	1.2619	1.0925
	0.6	0.2823	0.0898	0.0879	1.1605	2.1696
	0.7	0.3824	0.0710	0.0726	1.0747	−2.3139
	0.8	0.5163	0.0531	0.0528	0.9683	0.5631
	0.9	0.7146	0.0205	0.0261	0..8541	−27.3170
	1.0	0.9977	0.0023		0.7721	

Figure 2 shows a comparison of our experimental values of solubility of potassium iodide in pure water with literature values.[5,7,8] It can be seen from the figure that our experimental values are slightly higher than literature values. The solubility of the potassium iodide solution appreciably decreases with the increasing mole fraction (x_C) of propan-1-ol, whereas there is little increase in solubility with an increase of temperature (T); the density of the saturated solution of KI is found to decrease with an increase of the weight fraction of propan-1-ol. The solubility data (except for pure propanol) is correlated with the mole fraction (x_C) of propan-1-ol and the temperature and density of solution by eq 3

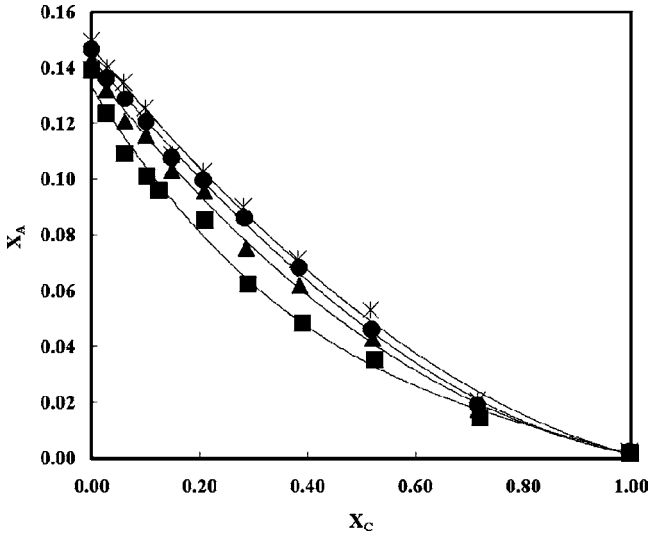

Figure 1. Solubility (s) vs mole fraction (x) of propan-1-ol at 298.15 K.

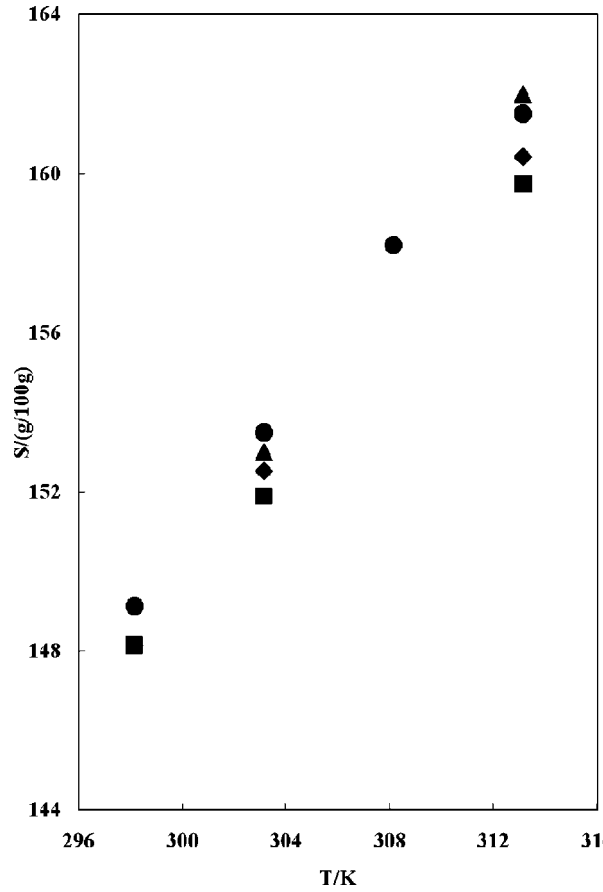

Figure 2. Solubility of KI in water as a function of temperature: ●, this study; ▲, ref 8; ■, ref 5; ◆, ref 7.

Table 2. Coefficients of Model Equation 3

a	b	c	d
$-9.9111\cdot10^{-2}$	$1.1025\cdot10^{-3}$	$6.1701\cdot10^{-2}$	−0.2727

$$x_A = \exp(ax_C + bT + c\rho + d) \quad (3)$$

The percent relative error is calculated using eq 4

$$\%\ \text{relative error} = [(y_{exp} - y_{calc})/(y_{exp})]100 \quad (4)$$

The values of % relative error and y_{cal} ($x_{A,cal}$) are given in Table 1. Values of coefficients of eq 3 are presented in Table 2.

Conclusions

This paper reports experimental data for the solubility and density of potassium iodide in propan-1-ol + water mixed solvent from (298.15 to 313.15) K. A simple method for measuring solubility and density was found to be very precise. The data of solubility were correlated with the mole fraction of propan-1-ol (x_C) and the temperature and density of solution by eq 3. The solubilities calculated using eq 3 are in good agreement with experimental values.

Nomenclature

x_C	mole fraction of propan-1-ol
x_A	solubility in mole fraction of KI
w	weight fraction of propan-1-ol
ρ	density of solution, kg/m^3
T	temperature
S	solubility in g/100 g
a, b, c, d	coefficients of eq 1

Literature Cited

(1) Lozano, J. A. F. Recovery of Potassium Magnesium Sulfate Double Salt from Seawater Bittern. *Ind. Eng. Chem. Process Des. Dev.* **1976**, *15*, 445–447.

(2) Mydlarz, J.; Jones, A. G. Solubility and Density Isotherms for Magnesium Sulfate Heptahydrate-Water-Propan-1-ol. *J. Chem. Eng. Data* **1991**, *36*, 119–121.

(3) Fleischmann, W.; Mersman, A. In *Industrial Crystallisation 84*; Jancic, S., de Jong, J., Eds.; Elsevier Science Publisher: Amsterdam, 1984; pp 165−168.

(4) Carton, A.; Sobron, F.; Bolado, S.; Tabares, J. Composition and Density of Saturated Solution of Lithium Sulphate + Water + Propan-1-ol. *J. Chem. Eng. Data* **1994**, *39*, 61–62.

(5) Stephan, H., Stephen, T., Eds. *Solubilities of Inorganic and Organic, Compounds, Binary Systems, Part-1*; Pergamon Press: Oxford, U.K., 1963; Vol. 1, p 154.

(6) Stephan, H.; Stephen, T., Eds. *Solubilities of Inorganic and Organic Compounds, Ternary Systems, Part-1*; Pergamon Press: Oxford, U.K., 1964; Vol. 2, pp 337−338.

(7) Lide, D. R. *CRC Handbook of Chemistry and Physics*, 79th ed.; CRC Press: Boca Raton, FL, 1998; pp 8−105.

(8) Dean, J. A., Ed. *Langes Handbook of Chemistry*, 13th ed.; McGraw-Hill International: New York, 1987; pp 10−16.

(9) Pawar, R. R.; Nahire, S. B.; Hasan, M. Solubility and Density of Potassium Iodide in Binary Ethanol-Water Solvent Mixture at (298.15, 303.15, 308.15, and 313.15) K. *J. Chem. Eng. Data* **2009**, *54*, 1935–1937.

(10) Kadam, U. B.; Hiray, A. P.; Sawant, A. B.; Hasan, M. Density, Viscosities, and Ultrasonic Velocity Studies of Binary Mixtures of Chloroform with Propan-1-ol and Butan-1-ol at (303.15 and 313.150) K. *J. Chem. Eng. Data* **2006**, *51*, 60–63.

(11) Hasan, M.; Shirude, D. F.; Hiray, A. P.; Kadam, U. B.; Sawant, A. B. Densities, Viscosities and Speed of Sound Studies of Binary Mixtures of Methylbenzene with Heptan-1-ol, Octan-1-ol and Decan-1-ol at (303.15 and 313.15) K. *J. Chem. Eng. Data* **2006**, *51*, 1922–26.

(12) Marsh, K. N. *Recommended Reference Materials for the Realisation of Physicochemical Properties*; Blackwell Scientific Publications: Oxford, U.K., 1987.

Received for review July 28, 2009. Accepted October 24, 2009.

JE9006426