Solubility of L-Lysine Hydrochloride in Dimethyl Sulfoxide, Methanol, Ethanol, Water, and Glycol between (283 and 323) K

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The solubility of L-lysine hydrochloride in dimethyl sulfoxide, methanol, ethanol, water, and glycol between (283 and 323) K was measured using a synthetic method at atmospheric pressure. The solubility of L-lysine hydrochloride in the above solvents increased in the order water > dimethyl sulfoxide > glycol > methanol > ethanol. A laser monitoring observation technique was used to determine the disappearance of the solid phase in a solid + liquid mixture. The experimental solubility data were correlated with an empirical equation.

Introduction

L-Lysine is one of the basic units of protein, which is one of the most important parts of biological organisms. L-Lysine can be generated by fermentation, but a long-term preservation is difficult because of the amino group. L-Lysine hydrochloride is relatively stable and easy for preservation.[1] So L-lysine hydrochloride is usually used in food, feed additives, and drug fields.[2] L-Lysine hydrochloride is separated and purified by extraction, decolorization, and crystallization in series. In the final purification step, the L-lysine hydrochloride is recrystallized from solution.[3] To determine the proper solvent and to design an optimized separation process, it is necessary to know its solubility in different solvents.[4] The solubility of L-lysine hydrochloride in water has been published. However no experimental solubility data of L-lysine hydrochloride in other solvents have been reported. In this paper, a laser monitoring observation technique was used to measure the solubilities of L-lysine hydrochloride in dimethyl sulfoxide, methanol, ethanol, water, and glycol. In this paper, a synthetic method was used to determine the solubility data of L-lysine hydrochloride.[5,6] By this method, solubility data can be obtained much faster and more readily than with an analytical method.[7−9]

Experimental Sections

Materials. White crystalline L-lysine hydrochloride powder ($C_6H_{14}N_2O_2 \cdot HCl$, CAS 657-27-2) was obtained from Huayang Chemical Co., Ltd., Jizhou Hebei, China, and had a melting point of 536.15 K. Its mass fraction purity, determined by HPLC according to USP27,[10] is higher than 99.5 %. It was dried under vacuum at 378 K for 24 h and stored in a desiccator. Dimethyl sulfoxide, methanol, ethanol, water, and glycol (obtained from Tianjin Chemical Reagent Co., Ltd., China) were analytical reagent grade and dehydrated with molecular sieves before use. The mass fraction purities of these five solvents, determined by gas chromatography, are higher than 99.5 %. L-Lysine hydrochloride is stable in these five solvents.

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Apparatus and Procedure. The solubility of L-lysine hydrochloride was measured using an apparatus the same as that described in the literature and described briefly here.[6,7] A laser monitoring observation technique was used to determine the disappearance of the last crystal particles in the solid + liquid mixture.[6] The laser set consists of a laser generator, a photoelectric transformer, and a digital display. The experiment was performed in a cylindrical double-jacketed glass vessel with a volume of 200 mL. This vessel was maintained at the desired temperature by circulating water from a water bath with a thermoelectric controller. A condenser was connected to the vessel to prevent the solvents from evaporating. A mercury-in-glass thermometer was inserted into the inner chamber of the vessel with an uncertainty of ± 0.05 K. An analytical balance (Metler Toledo AB204-N) with an uncertainty of ± 0.0001 g was used. The mixtures of solute and solvent in the vessel were stirred with a magnetic stirrer.

In the experiments, the solubility was determined by the last crystal disappearance method. This method is based on sequentially adding known masses of a solid to a stirred solution kept at a predetermined temperature. During the experiments, the glass vessel was monitored by a laser beam. When the solute dissolved completely, the solution was clear, and the laser intensity penetrating through the vessel reached its maximum. If the solute could not dissolve completely, then the laser beam was scattered by the undissolved solute particles in the solution, and the penetrating laser intensity was below the maximum. Predetermined amounts of solute and solvent were transferred into the inner chamber of the vessel. The solid + liquid mixture was stirred at a fixed temperature for 1 h. The quantity of solvent was a small excess. Then additional solute of known mass, from about (3 to 5) mg, was introduced into the vessel with continuous stirring. This procedure was repeated until the last addition of solute could not dissolve completely. The interval of addition was 0.5 h. This process lasted more than 6 h. Then the total amount of the solute used was recorded, and the solubility expressed in mole fraction was calculated. The uncertainty of the experimental solubility values is estimated to be 3 %.

Results and Discussion

The solubilities of L-lysine hydrochloride (x_i) in dimethyl sulfoxide, methanol, ethanol, water, and glycol at different temperatures are presented in Table 1 and more visually expressed in Figure 1.

10.1021/je900022k CCC: $40.75
Published on Web 06/09/2009

Table 1. Mole Fraction Solubility x of L-Lysine Hydrochloride in Pure Solvents

T/K	10^3x_i	RD	T/K	10^3x_i	RD	T/K	10^3x_i	RD
				Water				
283.0	49.7	0.805	288.1	54.3	1.84	292.9	58.7	2.90
298.1	61.8	0	302.8	62.7	6.53	308.0	70.7	4.10
313.3	83.3	1.92	317.9	92.5	2.70	323.0	102	0.98
328.2	111	2.70						
				Dimethyl Sulfoxide				
282.8	17.9	8.38	288.2	24.3	0.412	293.0	30.1	2.99
298.1	35.7	3.92	303.3	39.1	0.767	308.4	43.2	1.85
312.8	46.9	1.49	318.1	51.6	0.775	323.2	52.9	1.51
328.3	56.1	1.25						
				Ethylene Glycol				
282.9	7.69	2.34	288.0	10.8	0	293.1	14.6	0.685
298.2	18.3	0.546	303.2	22.0	0.909	307.9	25.9	0
312.9	29.8	0.671	318.0	32.6	1.23	322.7	35.4	0.282
328.1	37.7	0.531						
				Ethanol				
288.1	0.00671	2.95	292.8	0.00831	2.39	298.1	0.00991	3.30
303.0	0.0109	1.56	308.1	0.0122	3.95	312.7	0.0141	0.355
318.2	0.0163	2.21	322.9	0.0176	0.398	328.3	0.0192	0.678
				Methanol				
297.9	0.283	2.47	303.0	0.368	1.63	308.1	0.433	0.23
312.8	0.501	1.40	318.1	0.550	0.909	323.0	0.592	1.35
327.8	0.637	0.942						

The temperature dependence of L-lysine hydrochloride solubility in pure solvents was described by the modified empirical equation[11,12]

$$\ln x = A + \frac{B}{(T/\mathrm{K})} + C\ln(T/\mathrm{K}) \quad (1)$$

where x is the mole fraction solubility of L-lysine hydrochloride; T is the absolute temperature; and A, B, and C are the parameters. The experimented solubility values of L-lysine hydrochloride (x_i) are also given in Table 1. The values of the relative deviation (RD) are also given in Table 1. The RD is defined as eq 2.

$$\mathrm{RD} = \frac{|x_i - x_i^{\mathrm{calcd}}|}{x_i}\cdot 100 \quad (2)$$

where x_i^{calcd} represents the solubilities calculated from eq 1; and x_i represents the experimental values of solubility. The values

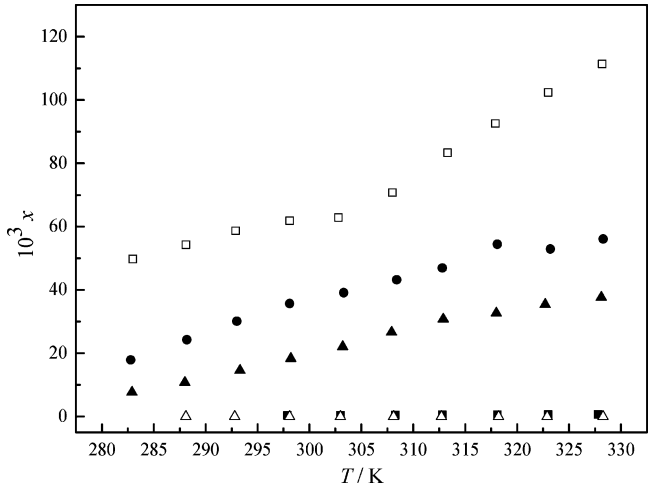

Figure 1. Mole fraction solubility of L-lysine hydrochloride x in different solvents: □, water; ●, dimethyl sulfoxide; ▲, glycol; △, ethanol; ■, methanol.

Table 2. Parameters of Equation 1 for L-Lysine Hydrochloride in Pure Solvents

solvent	A	$B/10^4$	C	10^2rmsd
water	−242.9	0.9457	36.58	2.913
dimethyl sulfoxide	482.8	−2.385	−72.29	3.198
ethylene glycol	684.6	−3.392	−100.9	0.9516
methanol	741.8	−3.687	−109.9	1.506
ethanol	180.0	−1.080	−27.27	2.327

of parameters A, B, and C and the root-mean-square deviations (rmsd) are listed in Table 2. The rmsd is defined as the following

$$\mathrm{rmsd} = \left\{\frac{\sum_{i=1}^{N}[(\ln x_i^{\mathrm{calcd}} - \ln x_i)]^2}{N}\right\}^{1/2} \quad (3)$$

where N is the number of experimental points; x_i^{calcd} represents the solubilities calculated from eq 1; and x_i represents the experimental values of solubility. From Table 1 and Table 2, we can draw the following conclusions: (1) the solubilities of L-lysine hydrochloride in dimethyl sulfoxide, methanol, ethanol, water, and glycol all increase with increasing temperature. (2) The solubility of L-lysine hydrochloride in the above solvents increased in the order water > dimethyl sulfoxide > glycol > methanol > ethanol. (3) These experimental data were able to be regressed by eq 1 for each solvent.

Acknowledgment

We are very grateful to Huayang Chemical Co., Ltd., Jizhou Hebei, China, for supplying L-lysine hydrochloride.

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Received for review January 7, 2009. Accepted March 16, 2009.

JE900022K