Solubilities of Sulfadiazine in Methanol, Ethanol, 1-Propanol, 2-Propanol, Acetone, and Chloroform from (294.15 to 318.15) K

Cong-Liang Zhang,* Bao-Ying Li, and Yan Wang

College of Chemical Engineering, Zhengzhou University, Zhengzhou, Henan 450002, P. R. China

---

The solubilities of sulfadiazine in methanol, ethanol, 1-propanol, 2-propanol, acetone, and chloroform have been determined with temperatures from (294.15 to 318.15) K by a static equilibrium method. The experimental data were correlated with the modified Apelblat equation.

Introduction

Sulfadiazine is member of the sulfonamides that are widely used in agriculture to prevent diseases in livestock and treat illness; therefore, soil and groundwater body have been badly contaminated. Its solubility plays a prominent role in the prediction of the environmental fate of chemicals and can characterize transportation through membranes and the topical activity of drugs.[1] In determining the transport of sulfadiazine in the environment and assessing its risk to terrestrial and aquatic ecosystems, it is necessary to know its solubilities in various solvents. However, only a limited amount of solubility data for sulfadiazine has been reported with temperatures from (298.15 to 313.15) K.[2−6] In this study, the solubilities of sulfadiazine in methanol, ethanol, 1-propanol, 2-propanol, acetone, and chloroform have been measured from (294.15 to 318.15) K. The experimental data were correlated with the modified Apelblat equation.[7,8]

Experimental Section

Materials. Sulfadiazine obtained from Daming Biotech was further purified by recrystallization from aqueous solutions. After filtration and drying, its mass fraction was determined by UV spectrometry (type UV-2401PC, Shimadzu), to be 0.996. All of the solvents selected for the present study were analytical grade reagents, which were obtained from Tianjin Kermel Chemical Reagent (China) and used without any further purification.

Apparatus and Procedure. The solubility was measured by a static equilibrium method.[9] Nearly 100 mg of sulfadiazine was added separately to 50 mL of each solvent in glass flasks. The mixtures were then stirred in a mechanical shaker for 1 h. Samples were then allowed to stand in water baths (type 501, Shanghai Laboratory Instrument Works) kept at the appropriate temperature (± 0.02 K). The equilibration of other sulfonamides has been reported to be achieved after 30 h. Therefore, in this work, the initial equilibration time of the saturated solution was 72 h; then, it was analyzed once every 5 h until the results were replicated three consecutive times. After this time, the supernatant solutions were filtered to ensure that they were free of particulate matter before sampling. We determined the concentrations by measuring UV absorbances after appropriate dilution and interpolation from previously constructed calibration curves for each system. To permit conversion between concentration and mole fraction, the density (ρ) of the saturated solutions listed in Table 1 was determined with a digital density meter. All of the solubility experiments were repeated at least three times, and the mean values were considered to be the measured results. As the solubilities are sensitive to temperature, it was controlled to ± 0.05 K. The reproducibility of mole-fraction measurements was $\pm\ 1 \cdot 10^{-8}$, and uncertainties of these were assumed to be less than $5 \cdot 10^{-8}$. The results showed that the deviation of the measured solubility from the literature values[3] was less than 1.1 %. Therefore, the reliability of the experimental apparatus was verified.

Table 1. Mole Fraction Solubilities (x) of Sulfadiazine in Water Compared with Literature Data at 298.15 K

system	$10^5\ x_{\mathrm{exptl}}$	$10^5\ x_{\mathrm{ref}}$	100 RD
sulfadiazine + water	0.4922[6]	0.4870[3]	1.07

Results and Discussion

The solubilities of sulfadiazine in water listed in Table 1 are measured to complete the data reported in literature.[3]

The temperature dependence of sulfadiazine solubility in methanol, ethanol, 1-propanol, 2-propanol, acetone, and chloroform has been described by the modified Apelblat equation[7,8]

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

where x is the mole fraction of sulfadiazine, T is the absolute temperature, and A, B, and C are constants determined by least-squares analysis. The values of these parameters are listed in Table 3. The relative deviations (RD values) between the experimental and the calculated values of solubilities are also calculated by eq 2 and are listed in Table 2.

$$\mathrm{RD} = \left(\frac{x - x_{\mathrm{c}}}{x}\right) \qquad (2)$$

where x and x_{c} are respectively the experimental and the calculated mole fraction of sulfadiazine. The average relative deviations (ARD values) for each system in this study are also calculated by eq 3 and are given in Table 3.

$$\mathrm{ARD} = \frac{1}{N} \sum_{i=1}^{N} \left| \frac{x_i - x_{\mathrm{c}i}}{x_i} \right| \qquad (3)$$

where x_i and $x_{\mathrm{c}i}$ are respectively the experimental and the calculated mole fraction of sulfadiazine at each experimental point. The data in Tables 2 and 3 indicate that the calculated solubilities show good agreement with the experimental data, which demonstrates that the modified Apelblat equation can be used to correlate the solubility data of sulfadiazine in different solvents. RD values among 36 data points for the studied

---

* Corresponding author. E-mail: zhangcl201@zzu.edu.cn.

10.1021/je900742p

Table 2. Solubility Data of Sulfadiazine in Different Solvents and the Regression Results Obtained Using the Modified Apelblat Equation

T/K	$10^5\,x$	100 RD	ρ/g·cm^{-3}	T/K	$10^5\,x$	100 RD	ρ/g·cm^{-3}
			Sulfadiazine + Methanol				
294.15	26.50	0.44	0.7933	308.15	34.31	0.26	0.7801
298.15	28.28	−0.57	0.7895	313.15	37.70	0.56	0.7754
303.15	31.12	−0.30	0.7848	318.15	40.87	−0.39	0.7707
			Sulfadiazine + Ethanol				
294.15	3.802	0.14	0.7891	308.15	7.005	0.26	0.7768
298.15	4.796	−0.23	0.7856	313.15	7.562	−0.10	0.7723
303.15	6.012	−0.046	0.7812	318.15	7.683	−0.0084	0.7679
			Sulfadiazine + 1-Propanol				
294.15	9.662	0.40	0.8035	308.15	20.85	1.1	0.7920
298.15	12.43	−0.58	0.8002	313.15	24.46	−0.43	0.7879
303.15	16.42	−0.42	0.7961	318.15	27.92	−0.014	0.7837
			Sulfadiazine + 2-Propanol				
294.15	6.525	0.15	0.7852	308.15	12.27	0.63	0.7732
298.15	8.177	−0.43	0.7818	313.15	13.45	−0.88	0.7688
303.15	10.35	0.22	0.7775	318.15	14.33	0.32	0.7644
			Sulfadiazine + Acetone				
294.15	5.963	0.10	0.7850	308.15	10.58	0.20	0.7728
298.15	7.345	−0.54	0.7815	313.15	11.45	−0.89	0.7684
303.15	9.173	0.72	0.7772	318.15	12.02	0.41	0.7640
			Sulfadiazine + Chloroform				
294.15	0.5473	−0.045	1.4881	308.15	2.150	0.032	1.4757
298.15	0.9256	−0.16	1.4846	313.15	2.572	−0.60	1.4712
303.15	1.539	0.47	1.4802	318.15	2.706	0.31	1.4668

Table 3. Parameters in the Modified Apelblat Equation for Different Systems

system	A	B	C	100 ARD
sulfadiazine + methanol	−55.324	686.32	7.8730	0.42
sulfadiazine + ethanol	1681.8	−79286	−250.26	0.13
sulfadiazine + 1-propanol	1103.8	−54139	−163.44	0.49
sulfadiazine + 2-propanol	1398.3	−66630	−207.85	0.44
sulfadiazine + acetone	1379.6	−65496	−205.26	0.48
sulfadiazine + chloroform	3704.4	−174302	−549.59	0.27

systems do not exceed 1.1 %, and the total average relative deviation is 0.37 %.

By using the data shown in Table 2, we plotted the solubility curves for the studied systems in Figure 1. It is evident that the solubility of each system is low. The solubility data of sulfadiazine in methanol, ethanol, 1-propanol, 2-propanol, acetone, and chloroform showed a flat uptrend when the temperature increased. Moreover, the structure of sulfadiazine indicates that the molecule is highly aromatic and the functional groups may not contribute much to the aqueous solubility. So, the solubility is at a minimum in chloroform and a maximum in methanol.

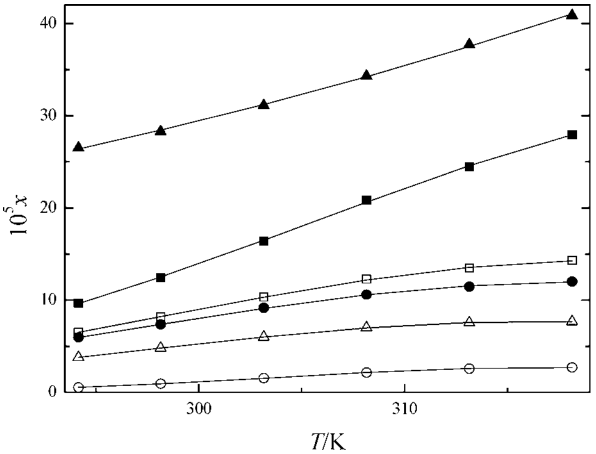

Figure 1. Solubilities of sulfadiazine in studied solvents: ▲, sulfadiazine + methanol; △, sulfadiazine + ethanol; ■, sulfadiazine + 1-propanol; ■, sulfadiazine + 2-propanol; ●, sulfadiazine + acetone; ○, sulfadiazine + chloroform; —, calculated from eq 1.

Conclusions

Using a static equilibrium method, we experimentally determined the solubilities of sulfadiazine in methanol, ethanol, 1-propanol, 2-propanol, acetone, and chloroform with temperatures from (294.15 to 318.15) K. The experimental data were correlated with the modified Apelblat equation. The calculated results show good agreement with the experimental data.

Literature Cited

(1) Picó, Y.; Andreu, V. Fluoroquinolones in soil-risks and challenges. *Anal. Bioanal. Chem.* **2007**, *387*, 1287–1299.

(2) Martinez, F.; Gomez, A. Thermodynamic study of the solubility of some sulfonamides in octanol, water, and the mutually saturated solvents. *J. Solution Chem.* **2001**, *30*, 909–923.

(3) Martinez, F.; Avila, C. M.; Gomez, A. Thermodynamic study of the solubility of some sulfonamides in cyclohexane. *J. Braz. Chem. Soc.* **2003**, *14*, 803–808.

(4) Hanaee, J.; Jouyban, A.; Dastmalchi, S.; Adibkia, K.; Mirzazadeh, A.; Barzegarjalali, M. Solubility prediction of sulfonamides at various temperatures using a single determination. *Daru, J. Fac. Pharm., Tehran Univ. Med. Sci.* **2005**, *13*, 37–45.

(5) Mauger, J. W.; Paruta, A. N.; Gerraughty, R. J. Solubilities of sulfadiazine, sulfisomidine and sulfadimethoxine in several normal alcohols. *J. Pharm. Sci.* **1972**, *61*, 94–97.

(6) Zhang, C. L.; Wang, F. A.; Wang, Y. Solubilities of sulfadiazine, sulfamethazine, sulfadimethoxine, sulfamethoxydiazine, sulfamonomethoxine, sulfamethoxazole, and sulfachloropyrazine in water from (298.15 to 333.15) K. *J. Chem. Eng. Data* **2007**, *52*, 1563–1566.

(7) Apelblat, A.; Manzurola, E. Solubility of oxalic, malonic, succinic, adipic, maleic, malic, citric, and tartaric acids in water from 278.15 to 338.15 K. *J. Chem. Thermodyn.* **1987**, *19*, 317–320.

(8) Jia, Q.; Ma, P.; Yi, S.; Wang, Q.; Wang, C.; Li, G. Solubilities of benzoic acid, *p*-methylbenzoic acid, *m*-methylbenzoic acid, *o*-methylbenzoic acid, *p*-hydroxybenzoic acid, and *o*-nitrobenzoic acid in 1-octanol. *J. Chem. Eng. Data* **2008**, *53*, 1278–1282.

(9) Martinez, F.; Avila, C. M.; Gomez, A. Thermodynamic study of the solubility of some sulfonamides in cyclohexane. *J. Braz. Chem. Soc.* **2003**, *14*, 803–808.

Received for review September 23, 2009. Accepted January 25, 2010. Financial assistance from the Henan Province Natural Science Fund of P. R. China (Grant No. 0611033400) is gratefully acknowledged.

JE900742P