Comments on "Solubility and Dissolution Thermodynamic Data of Cefpiramide in Pure Solvents and Binary Solvents"

William E. Acree, Jr.

Department of Chemistry, 1155 Union Circle Drive #305070, University of North Texas, Denton, TX 76203, USA

Abstract

Errors are found in the mathematical correlation based on the combined Jouyban-Acree and Modified Apelblat model for describing the variation in the mole fraction solubility of cefpiramide with temperature and solvent composition for the binary aqueous-ethanol solvent system. The equation coefficients given by Tang and coworkers, when substituted into the model equation, do not yield the authors' calculated mole fraction solubilities of cefpiramide.

Key Words and Phrases: cefpiramide solubility; binary aqueous-ethanol solvent mixtures; binary aqueous-2-propanol solvent mixtures; mathematical representation of solubility data in binary solvent mixtures

_____

*To whom correspondence should be addressed. (E-mail: acree@unt.edu); fax: 940-565-4318.

In a recent paper appearing in *This Journal* Tang and coworkers [1] reported the solubility of cefpiramide in five neat mono-solvents (water, ethanol, 1-propanol, 1-butanol and 2-propanol) and in two binary aqueous-organic solvent mixtures. The two organic solvents were ethanol and 2-propanol. Solubilities were measured at six temperatures from 278.2 K to 303.2 K using a spectroscopic method of chemical analysis. The authors used the combined Jouyban-Acree and Modified Apelblat models:

$$\ln(x_A)_{m,T} = A_1 + \frac{A_2}{T} + A_3 \ln T + A_4 x_B^o + A_5 \frac{x_B^o}{T} + A_6 \frac{(x_B^o)^2}{T} + A_7 \frac{(x_B^o)^3}{T} + A_8 \frac{(x_B^o)^4}{T} + A_9 x_B^o \ln T \quad (1)$$

to describe how the measured mole fraction solubility of cefpiramide, $(x_A)_{m,T}$, varied with both temperature, T, and initial mole fraction composition of the binary solvent mixture, x_B^o. The curve-fit equation coefficients, A_i, were determined by regressing the experimental mole fraction solubility data in accordance with Eqn. 1. The authors tabulated the calculated curve-fit equation coefficients in Table 8 of their published paper [1]. Only the statistically significant coefficients were tabulated. The authors stated in the manuscript that Eqns. 2 and 3 below (Eqns. 15 and 16 in the published paper):

$$\ln(x_A)_{m,T} = A_1 + A_3 x_B^o + A_5 \frac{(x_B^o)^2}{T} + A_7 \frac{(x_B^o)^3}{T} + A_8 \frac{(x_B^o)^4}{T} \quad (2)$$

$$\ln(x_A)_{m,T} = A_1 + A_3 x_B^o + A_5 \frac{x_B^o}{T} + A_6 \frac{(x_B^o)^2}{T} + A_7 \frac{(x_B^o)^3}{T} + A_8 \frac{(x_B^o)^4}{T} + A_9 x_B^o \ln T \quad (3)$$

were the final equations for predicting the solubility of cefpiramide in binary aqueous-ethanol and aqueous-2-propanol solvent mixtures in the solvent mole fraction composition range from $x_B^o = 0.0$ to $x_B^o = 0.9$, respectively.

The purpose of this commentary is to alert journal readers to several errors in the authors' mathematical correlations. Careful examination of Eqns. 1 - 3 reveals that the curve-fit equation coefficients are identified differently in Eqn. 1 than in Eqns. 2 and 3. The A_3 equation coefficient in Eqn. 1 corresponds to the coefficient in the $A_3 \ln T$ term, whereas in Eqns. 2 and 3 the A_3 coefficient corresponds to the $A_3 x_B^o$ term. There is a similar problem with the A_5 coefficient in Eqns. 1 and 2. The change in symbolism can lead to confusion when it comes to substituting the numerical values for the equation coefficients. For example, in Table 7 of the published paper [1] the authors gave numerical values of A_1 = -93.252; A_3 = 13.927; A_5 = 3559.445; A_7 = 10448.710 and A_8 = 8314.726 as the coefficients for binary aqueous-ethanol solvent mixture. Does one substitute the numerical values into Eqn. 1 to give:

$$\ln(x_A)_{m,T} = -93.252 + 13.927 \ln T + 3559.445 \frac{x_B^o}{T} + 10448.710 \frac{(x_B^o)^3}{T} + 8314.726 \frac{(x_B^o)^4}{T} \quad (4)$$

or does one substitute the numerical values into Eqn 2 to yield:

$$\ln(x_A)_{m,T} = -93.252 + 13.927 x_B^o + 3559.445 \frac{(x_B^o)^2}{T} + 10448.710 \frac{(x_B^o)^3}{T} + 8314.726 \frac{(x_B^o)^4}{T} \quad (5)$$

What I have done is to calculate the solubility of cefpiramide for the binary aqueous-ethanol solvent system at T = 298.2 K using both Eqns. 4 and 5. The results of my calculations are summarized in the third and fourth columns of Table 1 of this commentary, along with the calculated values that the authors gave in Table 1 of their published paper for water and for the five binary solvent compositions studied. According to the headings in Table 3 of the published paper [1] the authors' calculated values are presumably based on Eqn. 5 (which would be Eqn. 15 in the published paper with the coefficients inserted). Careful examination of the numerical entries in the last three columns of Table 1 reveals that neither Eqn. 4 nor Eqn. 5 reproduce the authors'

calculated values. In the case of Eqn. 5 the calculated mole fraction solubility of cefpiramide would be the same at all six temperatures for $x_B^o = 0.0$ as only the first term would contribute to the calculation. The remaining four terms would equal zero at $x_B^o = 0.0$. Equation 4 on the other hand gives a calculated value of $10^6 x (x_A)_{m,T}^{calc}$ close to the value reported by the authors for $x_B^o = 0.0$; however, calculated values at the larger mole fractions of solvent component B exceed unity. Mole fraction compositions cannot exceed unity. There is clearly problems with the A_i equation coefficients given in the paper by Tang and coworkers [1] for the aqueous-ethanol solvent system. I suspect that one of the authors' tabulated equation coefficients (perhaps the A_7 coefficient) is missing a negative sign.

Table 1. Comparison between the experimental mole fraction solubilities of cifpiramide, $(x_A)_{m,T}$, calculated values reported by Tang and coworkers [1], and calculated values based on Eqns. 4 and 5.

x_B^o	$10^6 x (x_A)_{m,T}^{exp}$	$10^6 x (x_A)_{m,T}^{calc,eq.4}$	$10^6 x (x_A)_{m,T}^{calc,eq.5}$	$10^6 x (x_A)_{m,T}^{calc,authors}$
0.0000	0.8495	0.9197	$3.171 \ x \ 10^{-35}$	0.9175
0.1007	2.873	3.180	$1.512 \ x \ 10^{-34}$	2.952
0.2010	9.941	14.09	$1.174 \ x \ 10^{-33}$	7.957
0.4008	20.83	2156	$1.123 \ x \ 10^{-30}$	23.61
0.6010	21.44	$9.172 \ x \ 10^7$	$7.798 \ x \ 10^{-25}$	22.63
0.8011	19.92	$8.459 \ x \ 10^{16}$	$3.050 \ x \ 10^{-14}$	19.03
0.8994	29.65	$4.180 \ x \ 10^{23}$	$1.348 \ x \ 10^{-6}$	30.03

There is also an error in the symbolism associated with the equation coefficients for the binary aqueous-2-propanol solvent mixture reported in reference 1. The numerical value for the A_3 coefficient should pertain to the $A_3 \ln T$ term, and not the $A_3 x_B^o$ term as implied by Eqn. 16 in the authors' published paper [1]. If the A_3 coefficient were to apply to the $A_3 x_B^o$ term then the calculation would yield $\ln (x_A)_{m,T} = -89.733$ at $x_B^o = 0.0$, which would correspond to an aqueous mole fraction solubility of $(x_A)_{m,T} = 1.07 \times 10^{-39}$ for all six temperatures studied. The authors' calculated value for T= 298.2 K is much larger, e.g., $10^6 x (x_A)_{m,T}^{calc,authors} = 0.9568$. As an informational note the authors' tabulated coefficients (using A_3 for the $A_3 \ln T$ term) for the binary aqueous-2-propanol system are much better at reproducing the calculated mole fraction solubilities at T = 298.2 K reported in Table 4 of the published paper. I only checked the calculations for T = 298.2 K.

References

1.   Tang, F., Wu, S., Zhao, S.: Solubility and dissolution thermodynamic data of cefpiramide in pure solvents and binary solvents. J. Solution Chem. **46**, 1556-1574 (2017).