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Anil K. Mehrotra, William Y. Svrcek, Loren G. Hepler, Yuming Xu, and Cheng Tze Fu

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CORRESPONDENCE

Comments on "Solubility of Carbon Dioxide in Tar Sand Bitumens: Experimental Determination and Modeling"

Sir: Deo et al. (1991) have reported results of their experimental investigations of solubilities of carbon dioxide in bitumens from three tar sand deposits, along with the viscosities of these same bitumens. They have also used equations of state to model their data for the solubility of CO_2 in bitumens.

Although Deo et al. (1991) did not cite any earlier studies of CO_2 solubility in bitumens, there have been many such investigations. We call specific attention to the substantial number of investigations concerning solubilities of gases (including CO_2) in Athabasca bitumen, and compare the results of some of these earlier investigations with the results reported by Deo et al. (1991).

Results of experimental studies, in Alberta (Canada), devoted to phase behavior measurements on gas–bitumen systems have been published by research groups at the University of Calgary (Mehrotra and Svrcek, 1982, 1984, 1985a–c, 1988a; Mehrotra et al., 1988, 1989a; Svrcek and Mehrotra, 1982, 1989), the University of Alberta (Lal et al., 1984; Xu and Hepler, 1990), and the Alberta Research Council (Fu et al., 1985, 1986a, 1988). In addition, Robinson (1984) has published results of his experimental investigations on phase equilibria of gas–bitumen mixtures. Results of related experimental investigations elsewhere have been reported by Quail et al. (1988) and Yu et al. (1989).

We also call attention to several publications concerning the use of an equation of state for correlating or predicting phase equilibria of gas–bitumen systems (Bishnoi et al., 1977; Eastick et al., 1992; Fu et al., 1985, 1986b, 1987, 1988; James and Mehrotra, 1988; Lu et al., 1986; Mehrotra and Svrcek, 1988b,c; Mehrotra et al., 1985, 1989a,b; Yu et al., 1989). This topic has also been reviewed by Lu and Fu (1989) in the AOSTRA Technical Handbook.

We have converted the solubilities of CO_2 in Athabasca bitumen that were reported as mole fractions by Deo et al. (1991) to solubilities as mass %; these mass % solubilities are displayed as circles in Figure 1. In Figure 1, we have also plotted (as triangles) the solubilities of CO_2 reported by Mehrotra et al. (1988), as measured by the Mehrotra–Svrcek group at the University of Calgary and by the Fu–Puttagunta group at the Alberta Research Council. The dotted lines in Figure 1 illustrate the solubilities that Deo et al. (1991) calculated by use of an equation of state. Note that their calculated solubilities agree much better with the solubilities measured by Mehrotra et al. (1988) than with their own measurements.

Although the temperatures used by Deo et al. (1991) were slightly higher than the temperatures used by Mehrotra et al. (1988), the solubilities reported by Deo et al. (1991) are larger than those reported by Mehrotra et al. (1988). Since the solubility of CO_2 surely decreases with increasing temperature, it must be concluded that at least one set of solubility data is in error; that is, either the solubilities reported by Deo et al. (1991) are too large or the solubilities reported by Mehrotra et al. (1988) are too small.

Support for the reliability of the two sets of solubility data reported by Mehrotra et al. (1988) has been provided
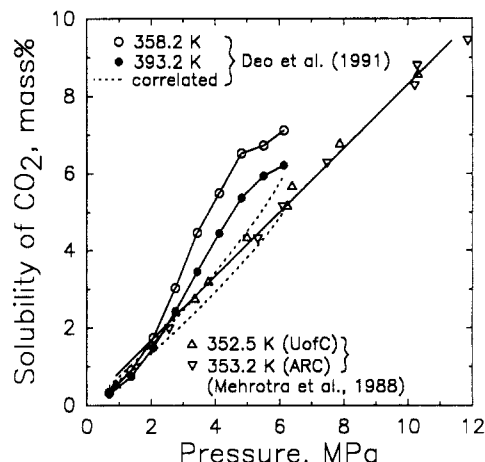

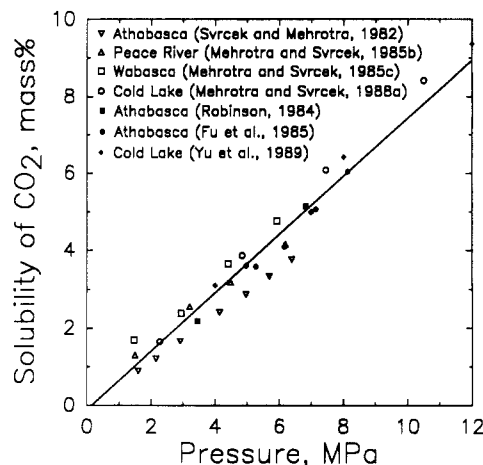**Figure 1.** Comparisons of solubilities of CO_2 in Athabasca bitumen.

Figure 2. Solubilities of CO_2 in several bitumens at 373 ± 5 K.

by Xu and Hepler (1990), whose measurements at low pressures led to Henry's law constants for CO_2 in Athabasca bitumen; these Henry's law constants are in satisfactory agreement with those calculated from the higher-pressure measurements reported by Mehrotra et al. (1988). Our calculations with the Krichevesky–Kasarnovsky equation (Lu et al., 1986) lead to questions about the reliability of the data reported by Deo et al. (1991).

Several published data sets for the solubility of CO_2 (expressed as mass %) in various bitumen samples, at 373 ± 5 K, are plotted against pressure in Figure 2. The linear dependence of CO_2 solubility on pressure, often observed over 0–12-MPa pressure range, is different from the non-linear results, shown in Figure 1, of Deo et al. (1991).

On the basis of the comparisons presented here and the usual dependence of gas solubilities on pressure and temperature, we suggest that the solubilities of CO_2 in Athabasca bitumen reported by Deo et al. (1991) are probably mistaken. This may also suggest that their data for the other two bitumens could also be mistaken.
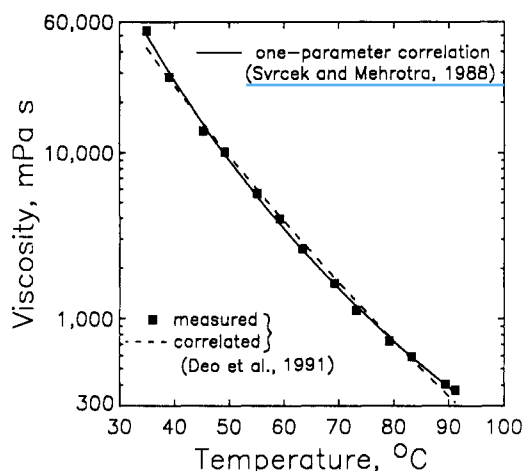
Figure 3. Correlations of viscosity–temperature for Athabasca bitumen.

Furthermore, Deo et al. (1991) have used the nearly-linear dependence of the logarithm of bitumen viscosity on reciprocal of absolute temperature (log μ against $1/T$) to correlate their measured viscosities and to interpolate these viscosities to other temperatures. Svrcek and Mehrotra (1988) have shown that a better correlation can be obtained by using another equation: $\log \log (\mu + 0.7) = b_1 - 3.63 \log (T)$. With the viscosity ($\mu$) in mPa s and temperature (T) in kelvin, we calculate parameter $b_1 = 9.706 \pm 0.003$ for Athabasca bitumen of Deo et al. (1991). The average absolute deviation for the correlation used by Deo et al. (1991) is 8.8% as compared to only 4.5% for the Svrcek–Mehrotra correlation. The two correlations and the data of Deo et al. (1991) for Athabasca bitumen are illustrated in Figure 3.

Registry No. CO_2, 124-38-9.

Literature Cited

Bishnoi, P. R.; Heidemann, R. A.; Shah, M. K. Calculation of Thermodynamic Properties of Bitumen Systems. In *CIM Special Volume 17*; Redford, D. A., Winestock, A. G., Eds.; CIM: Montreal, Canada, 1977; p 248.

Deo, M. D.; Wang, C. J.; Hanson, F. V. Solubility of Carbon Dioxide in Tar Sand Bitumens: Experimental Determination and Modeling. *Ind. Eng. Chem. Res.* 1991, *30*, 532.

Eastick, R. R.; Svrcek, W. Y.; Mehrotra, A. K. Phase Behaviour of CO_2-Bitumen Fractions. *Can. J. Chem. Eng.* 1992, *70*, 159.

Fu, C.-T.; Puttagunta, V. R.; Vilcsak, G. Vapor-Liquid Equilibrium Properties for Pseudo-Binary Mixtures of CO_2-Athabasca Bitumen and N_2-Athabasca Bitumen. *AOSTRA J. Res.* 1985, *2*, 73.

Fu, C.-T.; Puttagunta, V. R.; Vilcsak, G. Vapor-Liquid Equilibrium Properties for Gas-Cold Lake Bitumen. *Proc. 37th Pet. Soc. CIM Annu. Tech. Mtg*, Edmonton, Alberta, Canada; 1986a; paper no. 86-37-04.

Fu, C.-T.; Puttagunta, V. R.; Baumber, L.; Hsi, C. Pseudo-critical Properties of Heavy Oils and Bitumens. *Fluid Phase Equilib.* 1986b, *30*, 281.

Fu, C.-T.; Puttagunta, V. R.; Hsi, C. Sensitivities in Representing the Phase Behavior of Gas-Bitumen Systems. *Can. J. Chem. Eng.* 1987, *65*, 308.

Fu, C.-T.; Puttagunta, V. R.; Vilcsak, G. Gas Solubility of Methane and Ethane in Cold Lake Bitumen at In Situ Conditions. *J. Can. Pet. Technol.* 1988, *27* (4), 79.

James, N. E.; Mehrotra, A. K. V-L-S Multiphase Equilibrium in Bitumen-Diluent Systems. *Can. J. Chem. Eng.* 1988, *66*, 870.

Lal, D.; Otto, F. D.; Mather, A. E. Solubility of CO, H_2 and CO-H_2 Mixtures in Athabasca Bitumen. *Proc. 34th Can. Chem. Eng. Conf.*, Quebec, Canada, 1984; pp 510-513.

Lu, B. C.-Y.; Fu, C.-T. Phase Equilibria and PVT Properties. In *AOSTRA Technical Handbook on Oil Sands, Bitumens, and Heavy Oils*; Hepler, L. G., Hsi, C., Eds.; Alberta Oil Sands Technology and Research Authority (AOSTRA): Edmonton, Alberta, Canada, 1989; Chapter 6.

Lu, B. C.-Y.; Chung, W. K.; Adachi, Y.; Boublik, T. Correlation and Prediction of Solubilities of Gases in Athabasca Bitumen. *AOSTRA J. Res.* 1986, *2*, 139.

Mehrotra, A. K.; Svrcek, W. Y. Correlations for Properties of Bitumen Saturated with CO_2, CH_4 and N_2, and Experiments with Combustion Gas Mixture. *J. Can. Pet. Technol.* 1982, *21* (6), 95.

Mehrotra, A. K.; Svrcek, W. Y. Measurement and Correlation of Viscosity, Density and Gas Solubility for Marguerite Lake Bitumen Saturated with Carbon Dioxide. *AOSTRA J. Res.* 1984, *1*, 51.

Mehrotra, A. K.; Svrcek, W. Y. Viscosity, Density and Gas Solubility Data for Oil Sand Bitumens. Part I: Athabasca Bitumen Saturated with CO and C_2H_6. *AOSTRA J. Res.* 1985a, *1*, 263.

Mehrotra, A. K.; Svrcek, W. Y. Viscosity, Density and Gas Solubility Data for Oil Sand Bitumens. Part II: Peace River Bitumen Saturated with N_2, CO, CH_4, CO_2 and C_2H_6. *AOSTRA J. Res.* 1985b, *1*, 269.

Mehrotra, A. K.; Svrcek, W. Y. Viscosity, Density and Gas Solubility Data for Oil Sand Bitumens. Part III: Wabasca Bitumen Saturated with N_2, CO, CH_4, CO_2 and C_2H_6. *AOSTRA J. Res.* 1985c, *2*, 83.

Mehrotra, A. K.; Svrcek, W. Y. Properties of Cold Lake Bitumen Saturated with Pure Gases and Gas Mixtures. *Can. J. Chem. Eng.* 1988a, *66*, 656.

Mehrotra, A. K.; Svrcek, W. Y. Correlation and Prediction of Gas Solubility in Cold Lake Bitumen. *Can. J. Chem. Eng.* 1988b, *66*, 666.

Mehrotra, A. K.; Svrcek, W. Y. Characterization of Athabasca Bitumen for Gas Solubility Calculations. *J. Can. Pet. Technol.* 1988c, *27* (6), 107.

Mehrotra, A. K.; Sarkar, M.; Svrcek, W. Y. Bitumen Density and Gas-Solubility Predictions using the Peng-Robinson Equation of State. *AOSTRA J. Res.* 1985, *1*, 215.

Mehrotra, A. K.; Svrcek, W. Y.; Fu, C.-T.; Puttagunta, V. R. Reconciliation of Bitumen Gas-Solubility Data. *AOSTRA J. Res.* 1988a, *4*, 237.

Mehrotra, A. K.; Nighswander, J. A.; Kalogerakis, N. Data and Correlation for CO_2-Peace River Bitumen Phase Behaviour at 22-200 °C. *AOSTRA J. Res.* 1989a, *5*, 351.

Mehrotra, A. K.; Patience, G. S.; Svrcek, W. Y. Calculation of Gas Solubility in Wabasca Bitumen. *J. Can. Pet. Technol.* 1989b, *28* (3), 81.

Quail, B.; Hill, G. A.; Jha, K. N. Correlations of Viscosity, Gas Solubility, and Density for Saskatchewan Heavy Oils. *Ind. Eng. Chem. Res.* 1988, *27*, 519.

Robinson, D. B. *The Thermodynamic and Transport Properties of Bitumens and Heavy Oils*; Alberta Oil Sands Technology and Research Authority (AOSTRA): Edmonton, Alberta, Canada, 1984; Chapter 4.

Svrcek, W. Y.; Mehrotra, A. K. Gas Solubility, Viscosity and Density Measurements for Athabasca Bitumen. *J. Can. Pet. Technol.* 1982, *21* (4), 31.

Svrcek, W. Y.; Mehrotra, A. K. One Parameter Correlation for Bitumen Viscosity. *Chem. Eng. Res. Des.* 1988, *66*, 323.

Svrcek, W. Y.; Mehrotra, A. K. Properties of Peace River Bitumen Saturated with Field Gas Mixtures. *J. Can. Pet. Technol.* 1989, *28* (2), 50.

Xu, Y.; Hepler, L. G. Henry's Law Constants and Thermodynamic Properties of Gases and Vapours in Bitumens. *Can. J. Chem. Eng.* 1990, *68*, 1024.

Yu, J. M.; Huang, S. H.; Radosz, M. Phase Behavior of Reservoir Fluids: Supercritical Carbon Dioxide and Cold Lake Bitumen. *Fluid Phase Equilib.* 1989, *53*, 429.

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