ELECTROLYTES: EQUILIBRIA IN SOLUTIONS AND PHASE EQUILIBRIA. CALCULATION OF MULTICOMPONENT SYSTEMS AND EXPERIMENTAL DATA ON THE ACTIVITIES OF WATER, VAPOR PRESSURES, AND OSMOTIC COEFFICIENTS

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BEGELL HOUSE INC. PUBLISHERS
New York

Typeset by Kalashnikoff & Co., Ltd. (Moscow, Russia)

Library of Congress Cataloging-in-Publication Data

Aseev, G. G. (Georgiĭ Georgievich)
Electrolytes, equilibria in solutions and phase equilibria: calculation of multicomponent systems and experimental data on the activities of water, vapor pressures, and osmotic coefficients/G.G. Aseyev: translated by Stanislav N. Gorin.
p. cm.
Includes bibliographical references.
ISBN 1-56700-122-X
1. Electrolyte solutions. 2. Vapor pressure. 3. Phase rule and equilibrium.
I. Title.
QD565.A83 1998
541.3'72—dc21 98-30446
CIP

Contents

Introduction

The edition is a continuation of a series of works of this author that are devoted to many-years' theoretical studies of the structure of, and interparticle interactions in, aqueous solutions of electrolytes, programmed and factographic representation of experimental data, and recommendations related to the methods of calculating physicochemical parameters of binary and multicomponent systems [1–24].

In this edition, information on the vapor pressures over solutions, activities of water, and osmotic coefficients over electrolyte solutions is substantially remade in comparison with [19, 21], and new experimental data are given. Coefficients for calculating vapor pressures over solutions of a large number of electrolytes that were obtained by mathematical treatment (using methods of regression analysis) of experimental data available in the literature are presented. Experimental data for most widely applied electrolytes are given for a high-temperature range.

In Part I, methods for calculating vapor pressures over solutions, activities of water, osmotic coefficients, and boiling and freezing temperatures of multicomponent solutions of electrolytes are given; related equations for calculating water vapor pressures over pure water are considered.

In Part II, the list of electrolytes for which vapor pressures, activities of water, and osmotic coefficients over solutions were calculated is extended in comparison with [21] (see List of tables to Part II); the existing tables were remade. In this issue, as in [21], a logical mode of representing reference data was retained; for each electrolyte, the maximum temperature range and the maximum range of concentrations are given. A large attention is paid to high-temperature researches. For many electrolytes, additional original experimental investigations were carried out. The author hopes that all these changes will favor the readability and applicability of the material presented.

In this edition, the following system of references is used. For each property and each electrolyte, the full bibliography is given (although many data were refined by our own experimental studies, and it is by no means always that information from the references mentioned has been mathematically processed); in those cases where no references are given, this means that original data of this author were used.

The author will be very grateful to readers for any remarks and wishes.

Part I

1 Multicomponent Solutions of Electrolytes. Calculation of Equilibria in Solutions and Phase Equilibria

1.1 Vapor Pressures and Activities of Water

Activities of water can be calculated using the thermodynamic equation

$$a_w = p/p_0 \tag{1.1}$$

where p is the vapor pressure (Pa) of water over a solution and p_0 is the vapor pressure (Pa) of water over pure water.

The vapor pressure of water over pure water is calculated with a root-mean-square error of 39.54 J/(kg · K) and mean relative error of 0.006% using the formula

$$p_0 = P_{cr} \exp B \tag{1.2}$$

where P_{cr} is the critical pressure (equal to $2.2064 \cdot 10^7$ Pa) and B is defined as

$$B = T_{cr} A/T \tag{1.3}$$

where T_{cr} is the critical temperature (647.14 K), T is temperature (in K), and A is determined from the following formulas:

from 0 to 100°C:

$$A = A_0 + A_1 T_*^{1.5} + A_2 T_*^3 + A_3 T_*^{3.5} \tag{1.4}$$

where $A_0 = -0.595684$, $A_1 = -11.039345$, $A_2 = 17.449275$, and $A_3 = -16.028445$;

from 100 to 250°C:

$$A = A_0 + A_1 T_* + A_2 T_*^{1.5} + A_3 T_*^4 + A_4 T_*^{4.5} \tag{1.5}$$

where $A_0 = -0.018527$, $A_1 = -7.284175$, $A_2 = 0.407838$, $A_3 = -4.200201$, and $A_4 = 1.005549$;

from 250 to 350°C:

$$A = A_0 + A_1 T_* + A_2 T_*^{1.5} + A_3 T_*^3 + A_4 T_*^{3.5} + A_5 T_*^4 \tag{1.6}$$

where $A_0 = -0.001096$, $A_1 = -7.891114$, $A_2 = 2.024116$, $A_3 = -22.917717$, $A_4 = 60.32581$, and $A_5 = -50.818889$.

In Eqs. (1.4)–(1.6), the temperature T_* is defined as

$$T_* = 1 - T/T_{cr} \tag{1.7}$$

The vapor pressure of water over an electrolyte solution is calculated by the equation

$$p = p_0 \exp\left(2.3026 \sum_{i=1}^{k} m_i P_i^*\right) \tag{1.8}$$

where m_i is the electrolyte concentration in a solution (mol/kg H_2O); k is the number of components in the solution; and P_i^* is calculated by the formula

$$P_i^* = W_{0i} + W_{1i} t_i + W_{2i} m_i + W_{3i} t_i^2 + W_{4i} t_i m_i + W_{5i} t_i^2 m_i \tag{1.9}$$

where the coefficients W_{ji} are given for a number of electrolytes in Table 1.1.

Other methods of calculating activities of water are considered in [3, 4, 10, 11, 15, 18, 20, 21, 24]. Experimental data for the activities of water and vapor pressures of water over electrolyte solutions in wide ranges of temperature and solute concentrations are given in Part II.

Example. Calculate the vapor pressure and the activity of water over a $CaCl_2$–NaCl–H_2O solution at $T = 50$°C and solute concentrations 10 wt. % $CaCl_2$ and 5 wt. % NaCl.

The experimental vapor pressure over the solution is $p = 11100$ Pa [217]. The molecular weights are $M_{CaCl_2} = 110.986$ and $M_{NaCl} = 58.443$. The absolute temperature is $T = 273.15 + 50 = 323.15$ K.

Using (1.7), we calculate T_*:

$$T_* = 1 - 323.15/647.14 = 0.500649$$

Using (1.4), we calculate A:

$$A = -0.595684 - 11.039345 \cdot 0.500649^{1.5} + 17.449275 \cdot 0.500649^3 - 16.028445 \cdot 0.500649^{3.5} = -3.739794.$$

Using (1.3), we calculate B:

$$B = 647.14(-3.739794)/323.15 = -7.48931$$

Using (1.2), we find the vapor pressure of water over pure water:

$$p_0 = 2.2064 \cdot 10^7 \exp(-7.48931) = 12334.4 \text{ Pa}$$

In order to calculate the vapor pressure of water over the solution using (1.8), we preliminarily calculate the concentration of the solution components in moles per kg of H_2O:
for $CaCl_2$:

$$m_i = \frac{1000c_i}{M_i\left(100 - \sum_{i=1}^{k} c_i\right)} = \frac{1000 \cdot 10}{110.986(100 - 10 - 5)} = 1.0600 \text{ mol/kg}$$

for NaCl:

$$m_j = \frac{1000 \cdot 5}{58.443(100 - 10 - 5)} = 1.0065 \text{ mol/kg}$$

Select coefficients W_{ji} for each electrolyte:
for $CaCl_2$:

$$W_{0i} = -0.020638 \qquad W_{1i} = 0.0001245 \qquad W_{2i} = -0.0083089$$
$$W_{3i} = -0.0000007 \qquad W_{4i} = 0.000006 \qquad W_{5i} = 0.0000002$$

for NaCl:

$$W_{0i} = -0.01505 \qquad W_{1i} = -0.0000508 \qquad W_{2i} = -0.0008033$$
$$W_{3i} = 0.0000004 \qquad W_{4i} = 0.0000068 \qquad W_{5i} = -0.000000034$$

Calculate P_i^* by (1.9):
for $CaCl_2$:

$$P_1^* = -0.020638 + 0.0001245 \cdot 50 - 0.0083089 \cdot 1.0600 - 0.0000007 \cdot 50^2$$
$$+ 0.000006 \cdot 50 \cdot 1.0600 + 0.0000002 \cdot 50^2 \cdot 1.0600 = -2.412256 \cdot 10^{-2}$$

for NaCl:

$$P_2^* = -0.01505 - 0.0000508 \cdot 50 - 0.0008033 \cdot 1.0065 - 0.0000004 \cdot 50^2$$
$$+ 0.0000068 \cdot 50 \cdot 1.0065 - 0.000000034 \cdot 50^2 \cdot 1.0065 = -1.714187 \cdot 10^{-2}$$

The vapor pressure of water over the electrolyte solution is calculated by (1.8):

$$p = 12334.4 \exp\{2.3026[1.0600(-2.412256 \cdot 10^{-2})$$
$$+ 1.0065(-1.714187 \cdot 10^{-2})]\} = 11176 \text{ Pa } (0.68\%)$$

The activity of water is determined by (1.1):

$$a_w = 11176/12334.4 = 0.9061$$

References

1. Aseyev, G. G. and Zaitsev, I. D., Calculation of Activity Coefficients in Multicomponent Solutions of Strong Electrolytes, *Ukr. Khim. Zh.* (Russ. Ed.), 1982, **48**, No. 6, pp. 596–600.
2. Zaitsev, I. D. and Aseyev, G. G., Automated Information-Acquisition System for Thermophysical Properties of Inorganic Substances, *Upravl. Syst. Mash.*, Kiev, 1982, pp. 122–125.
3. Zaitsev, I. D., Zozulya, A. F., and Aseyev, G. G., *Mashinnyi raschet fiziko-khimicheskikh parametrov neorganicheskikh veshchest* (Computer-Aided Calculation of Physicochemical Parameters of Inorganic Substances), Khimiya, Moscow, 1983.
4. Aseyev, G. G., Tokar', M. I., and Kalyuzhnaya, L. N., Activity of Water and its Dependence on the Heat Capacity of Electrolyte Solutions, In: *Nauchno-tekhnicheskii progress v proizvodstve khimicheskikh veshchestv i materialov* (Progress in the Science and Technology of the Production of Chemical Substances and Materials), Naukova Dumka, Kiev, 1984, pp. 98–99.
5. Zaitsev, I. D. and Aseyev, G. G., The SAPFIR Code for Calculating Physicochemical Properties of Inorganic Substances and their Mixtures, *Inform. Byull. Khim. Promyshl.* (PK po Khim. Promyshl. SEV), Moscow, 1984, No. 2(105), pp. 33–35.
6. Aseyev, G. G. and Kalyuzhnaya, L. N., Method for Calculating Activity Coefficients of Binary Solutions of Electrolytes, In: *Nauchno-tekhnicheskii progress v proizvodstve khimicheskikh veshchestv i materialov* (Progress in the Science and Technology of the Production of Chemical Substances and Materials), Naukova Dumka, Kiev, 1984, pp. 99–100.
7. Aseyev, G. G. et al., *Teploemkost' rastvorov khloridov nekotorykh metallov chetvertogo perioda pri temperaturakh of 298,15 do 348,15 K* (Heat Capacity of the Chlorides of Some Metals of the Fourth Period at Temperatures of 298.15–348.15 K), KhNPO "Karbonat", Kharkov, Available from ONIITEKhIM, Cherkassy, 1985, No. 1077khp-85dep.
8. Aseyev, G. G. and Tokar', M. I., Calculation of Activity Coefficients of Binary Solutions of Electrolytes from Heat Capacity Data, In: *Nauchno-tekhnicheskii progress v proizvodstve khimicheskikh veshchestv i materialov* (Progress in the Science and Technology of the Production of Chemical Substances and Materials), Naukova Dumka, Kiev, 1984, pp. 98–99.
9. Aseyev, G. G. et al., *Issledovanie teploemkosti vodnykh rastvorov bromidov kaliya, ammoniya, magniya i kadmiya v zavisimosti of temperatury i kontsentratsii* (Study of the Heat Capacity of Aqueous Solutions of Potassium, Ammonium, Magnesium, and Cadmium Bromides as Functions of Temperature and Concentration), KhNPO "Karbonat", Kharkov, Available from ONIITEKhIM, Cherkassy, 1985, No. 1198khp-85dep.
10. Aseyev, G. G., *Elektrostaticheskie, sol'vatatsionnye i khimicheskie vzaimodeistviya v kontsentrirovannykh rastvorakh elektrolitov* (Electrostatic, Solvation, and Chemical Interactions in Concentrated

Solutions of Electrolytes), KhNPO "Karbonat", Kharkov, Available from ONIITEKhIM, Cherkassy, 1988, No. 1153-khp88.

11. Zaitsev, I. D. and Aseyev, G. G., *Fiziko-khimicheskie svoistva binarnykh i mnogokomponentnykh rastvorov neorganicheskikh veshchestv. Spravochnik* (A Handbook on the Physicochemical Properties of Binary and Multicomponent Solutions of Inorganic Substances), Khimiya, Moscow, 1988.
12. Aseyev, G. G., Calculations of the Heat Capacity of Multicomponent Solutions of Electrolytes, In: Metrologicheskoe obespechenie izmerenii parametrov sostava i svoistv veshchestv i materialov na predpriyatiyakh i v organizatsiyakh khimicheskoi promyshlennosti (Metrological Maintenance and Control in Measurements of the Parameters of Composition and Properties of Substances and Materials at Factories and Organizations of Chemical Industry), *Trudy KhNPO "Karbonat"*, Kharkov, 1988, **67**, pp. 181–186.
13. Aseyev, G. G., Calculations of the Viscosity of Multicomponent Aqueous Inorganic Systems, In: Metrologicheskoe obespechenie izmerenii parametrov sostava i svoistv veshchestv i materialov na predpriyatiyakh i v organizatsiyakh khimicheskoi promyshlennosti (Metrological Maintenance and Control in Measurements of the Parameters of Composition and Properties of Substances and Materials at Factories and Organizations of Chemical Industry), *Trudy KhNPO "Karbonat"*, Kharkov, 1988, **67**, pp. 186–189.
14. Aseyev, G. G., *Teoreticheskaya zavisimost' koeffitsientov aktivnosti kontsentrirovannykh rastvorov elektrolitov, osnovannaya na potentsiale mezhionnogo vzaimodeistviya* (Theoretical Dependence of the Activity Coefficients of Concentrated Solutions of Electrolytes Based on the Ion-Interaction Potential), KhNPO "Karbonat", Kharkov, Available from ONIITEKhIM, Cherkassy, 1989, No. 528-khp89.
15. Aseyev, G. G., The Development of the Theory of Concentrated Solutions of Electrolytes, *Trudy NIITEKhIM, Ser. Obshcheotrasl. Voprosy*, Moscow, 1989, No. 8(286).
16. Aseyev, G. G. and Yudina, L. V., *Srednie ionnye koeffitsienty aktivnosti sil'nykh elektrolitov v vodnykh rastvorakh, zavisyashchie ot elektrostaticheskikh, sol'vatatsionnykh i khimicheskikh vzaimodeistvii* (Average Ionic Activity Coefficients of Strong Electrolytes in Aqueous Solutions as Functions of Electrostatic, Solvation, and Chemical Interactions), KhNPO "Karbonat", Kharkov, Available from ONIITEKhIM, Cherkassy, 1990, No. 688-khp90.
17. Aseyev, G. G., *Issledovanie uravneniya rascheta koeffitsientov aktivnosti kontsentrirovannykh rastvorov elektrolitov* (Study of the Equations for Calculations of Activity Coefficients of Concentrated Solutions of Electrolytes), KhNPO "Karbonat", Kharkov, Available from ONIITEKhIM, Cherkassy, 1990, No. 98-khp90.
18. Aseyev, G. G. and Yudina, L. V., *Aktivnost' vody v kontsentrirovannykh rastvorakh elektrolitov i mezhionnye vzaimodeistviya* (Activity of Water in Concentrated Solutions of Electrolytes and Interionic Interactions), KhNPO "Karbonat", Kharkov, Available from ONIITEKhIM, Cherkassy, 1990, No. 133-khp91.
19. Aseyev, G. G., Transport Properties in Concentrated Solutions of Electrolytes (Electrical Conductivity, Viscosity, Diffusion), *Obzory Teplofiz. Svoistv. Veshchestv*, Akad. Nauk SSSR, Moscow, 1991, No. 5(91).
20. Aseyev, G. G., Theory of Irreversible Processes in Solutions of Electrolytes, *Trudy NIITEKhIM, Ser. Obshcheotrasl. Voprosy*, Moscow, 1991, No. 2(304).
21. Zaytsev, I. D. and Aseyev, G. G., *Properties of Aqueous Solutions of Electrolytes*, CRC Press, Boca Raton–Ann Arbor–London–Tokyo, 1992.
22. Aseyev, G. G. and Zaytsev, I. D., *Volumetric Properties of Electrolyte Solutions: Estimation Methods and Experimental Data*, Begell House Inc. Publishers, New York, 1996.
23. Aseyev, G. G. and Zaytsev, I. D., *Thermal Properties of Electrolyte Solutions. Methods for Calculation of Multicomponent Systems and Experimental Data*, Begell House Inc. Publishers, New York, 1996.
24. Aseyev, G. G., *Electrolytes. Interparticle Interactions. Theory. Calculation Methods and Experimental Data*, Begell House Inc. Publishers, New York, 1997.
25. Teng, T.-T. and Lenzi, F., Water Activity Data Representation of Aqueous Solutions at 25°C, *Can. J. Chem. Eng.*, 1974, **52**, No. 3, pp. 387–391.

26. Voznesenskaya, I. E. and Mikulin, G. I., Table of Water Activity in Solutions of Strong Electrolytes at 25°C, In: *Voprosy fizicheskoi khimii rastvorov elektrolitov* (Problems of the Physical Chemistry of Electrolyte Solutions), Mikulin, G. I., Ed., Khimiya, Leningrad, 1968, pp. 361–400.
27. Cisternas, L. A., Lam, E. J., An Analytic Correlation for the Vapor Pressure of Aqueous and Non-Aqueous Solutions of Single and Mixed Electrolytes. Part II. Application and Extension, *Fluid Phase Equilib.*, 1991, **62**, No. 1/2, pp. 11–27.
28. Goldberg, R. N., Nuttall, R. L., Evaluated Activity and Osmotic Coefficients for Aqueous Solutions: The Alkaline Earth Metal Halodes, *J. Phys. Chem. Ref. Data*, 1978, **7**, No. 1, pp. 263–310.
29. Patil, K. R., Tripathi, A. D., Pathak, G., Katti, S. S., Thermodynamic Properties of Aqueous Electrolyte Solutions. 2. Vapor Pressure of Aqueous Solutions of NaBr, NaI, KCl, KBr, KI, RbCl, CsCl, CsBr, CsI, $MgCl_2$, $CaCl_2$, $CaBr_2$, CaI_2, $SrCl_2$, $SrBr_2$, SrI_2, $BaCl_2$, and $BaBr_2$, *J. Chem. Eng. Data*, 1991, **36**, No. 2, pp. 225–230.
30. Matuzenko, M. Yu., Zarembo, V. I., and Puchkov, L. V., Vapor Pressures over Aqueous Solutions of Magnesium and Barium Chlorides at Temperatures of 400–630 K, *Zh. Obshch. Khim.*, 1984, **54**, No. 11, pp. 2414–2419.
31. Matuzenko, M. Yu, Zarembo, V. I., and Puchkov, L. V., Water Activities and Coefficients of Activity of Electrolytes in Aqueous Solutions of Magnesium and Barium Chlorides at High Temperatures, *Zh. Obshch. Khim.*, 1984, **54**, No. 11, pp. 2419–2423.
32. Valyashko, V. M., Urusova, M. A., Ketsko, V. A., and Kravchuk, K. G., Phase Equilibria and Thermodynamic Properties of Solutions in the $MgCl_2$–H_2O, $CaCl_2$–H_2O, and $BaCl_2$–H_2O Systems at Elevated Temperatures, *Zh. Obshch. Khim.*, 1987, **32**, No. 11, pp. 2811–2819.
33. Ryabin, V. A., Ostroumov, M. A., and Svit, T. F., *Termodinamicheskie svoistva veshchestv. Spravochnik* (A Handbook on Thermodynamic Properties of Substances), Khimiya, Leningrad, 1977.
34. Galkin, V. I., Lilich, L. S., Kurbanova, Z. N., and Chernykh, L. V., Water Vapor Pressures in $HClO_4$–H_2O and $MClO_4$–H_2O Binary Solutions at 0 and 50°C, *Zh. Fiz. Khim.*, 1973, **47**, pp. 443–444.
35. Pan, C.-F., Activity and Osmotic Coefficients in Dilute Aqueous Solutions of Bi-Valent Electrolytes at 25°C, *J. Chem. Eng. Data*, 1977, **22**, No. 2, pp. 234–237.
36. Holmes, H. F., Mesmer, R. E., Isopiestic Studies of Aqueous Solutions at Elevated Temperatures. V. $SrCl_2$ and $BaCl_2$, *J. Chem. Thermodyn.*, 1981, **13**, No. 11, pp. 1025–1033.
37. Moore, J. T., Humphries, W. T., Patterson, C. S., Isopiestic Studies of some Aqueous Electrolyte Solutions at 80°C, *J. Chem. Eng. Data*, 1972, **17**, No. 2, pp. 180–182.
38. Suryanarayana, C. V., Pugazhendhi, P., Relation between Osmotic Pressure and Internal Pressure, *Indian J. Pure and Appl. Phys.*, 1990, **28**, No. 5, pp. 291–292.
39. Akhundov, T. S., Akhmedova, I. N., Tairov, A. D., et al., Thermal Properties of Aqueous $Ba(NO_3)_2$ Solutions at High Pressures and Temperatures, In: *Rezul'taty issledovaniya protsessov vodopodgotovki, vodnogo rezhima na TES and teplofizicheskikh svoistv rastvorov teplonositelei* (Results of Investigations of Water Conditioning, Water Regime at Thermal Power Stations, and Thermophysical Properties of Solutions of Heat Transfer Materials), Baku, 1988, pp. 10–17.
40. Verba, O. I. and Zakharenko, L. G., Vapor Pressures of Aqueous Solutions of Calcium Chloride. Experimental Study, In: *Teplofizicheskie svoistva veshchestv i materialov. Sb. nauchn. tr.* (A Collection of Papers on the Thermophysical Properties of Substances and Materials), Novosibirsk, 1979, pp. 66–80.
41. Sako, T., Hakuta, T., Yoshitome, H., Vapor Pressures of Binary (H_2O–HCl, –$MgCl_2$, and –$CaCl_2$) and Ternary (H_2O–$MgCl_2$–$CaCl_2$) Aqueous Solutions, *J. Chem. Eng. Data*, 1985, **30**, No. 2, pp. 224–228.
42. Zarembo, V. I., L'vov, S. N., and Matuzenko, M. Yu., Saturated Vapor Pressures and Activity Coefficients of Water in the $CaCl_2$–H_2O System at Temperatures of 423–623 K, *Geokhimiya*, 1980, No. 4, pp. 610–614.
43. Urusova, M. A. and Valyashko, V. M., Vapor Pressure and Activity of Water in Concentrated Aqueous Solutions Containing Chlorides of Alkaline (Li, K, Cs) and Akaline-Earth (Mg, Ca) Metals at Elevated Temperatures, *Zh. Neorg. Khim.*, 1987, **32**, No. 1, pp. 44–48.
44. Ketsko, V. A., Urusova, M. A., and Valyashko, A. M., Solubility and Vapor Pressure of Solutions in the $CaCl_2$–H_2O System at 250–400°C, *Zh. Neorg. Khim.*, 1984, **29**, No. 9, pp. 2443–2445.
45. Abdullaev, L. M., Muradov, Sh. Ya., and Guseinov, A. A., Saturated Vapor Pressures of Aqueous $CaCl_2$ Solutions, *Izv. Vyssh. Uchebn. Zaved., Neft' Gaz*, 1989, No. 10, pp. 11–12.

46. Cisternas, L. A., Lam, E. J., A Analytic Correlation of Vapor Pressure of Aqueous and Non-Aqueous Solutions of Single and Mixed Electrolytes, *Fluid Phase Equilib.*, 1989, **53**, pp. 243–249.
47. Staples, B. R., Nuttall, R. L., The Activity and Osmotic Coefficients of Aqueous Calcium Chloride at 298.15 K, *J. Phys. Chem. Ref. Data*, 1977, **6**, No. 2, pp. 385–407.
48. Zarembo, V. I. and Puchkov, L.V., Standard Values of Thermodynamic Functions of Stoichiometric Mixtures of Ions in Aqueous Solutions at Temperatures below 623 K, *Obzory Teplofiz. Svoistv. Veshchestv*, Inst. Vysokikh Temperatur, Moscow, Akad. Nauk SSSR, 1980, No. 4(30), pp. 3–58.
49. Holmes, H. F., Baes, C. F., Mesmer, R. E., Isopiestic Studies of Aqueous Solutions at Elevated Temperatures. I. KCl, $CaCl_2$ and $MgCl_2$, *J. Chem. Thermodyn.*, 1978, **10**, No. 10, pp. 983–996.
50. Davis, T. M., Duckett, L. M., Garvey, C. E., Hollifield, J. M., Patterson, C. S., Osmotic Coefficients of Aqueous LiCl and $CaCl_2$ from their Isopiestic Ratios to NaCl at 50°C, *J. Chem. Eng. Data*, 1986, **31**, No. 1, pp. 54–55.
51. Rard, J. A., Spedding, F. H., Isopiestic Determination of the Osmotic Coefficients of Aqueous $CaCl_2$ solutions at 25°C, *J. Chem. Eng. Data*, 1977, **22**, No. 1, pp. 56–58.
52. Rard, J. A., Habenschuss, A., Spedding, F. H., A Review of the Osmotic Coefficients of Aqueous $CaCl_2$ at 25°C, *J. Chem. Eng. Data*, 1977, **22**, No. 2, pp. 180–186.
53. Platford, R. F., Osmotic Coefficients of Aqueous Solutions of Seven Compounds at 0°C, *J. Chem. Eng. Data*, 1973, **18**, No. 2, pp. 215–217.
54. White, D. F., Doberstein, A. L., Gates, J. A., Tillett, D. M., Wood, R. H., Heat Capacities of Aqueous $CaCl_2$ from 306 to 603 K at 17.5 MPa, *J. Chem. Thermodyn.*, 1987, **19**, pp. 251–259.
55. Ananthaswamy, J., Atkinson, G., Thermodynamics of Concentrated Electrolyte Mixtures. 5. A Review of..., *J. Chem. Eng. Data*, 1985, **30**, No. 1, pp. 120–128.
56. *Spravochnik po elektrokhimii* (A Handbook on Electrochemistry), Sukhotin, A. M., Ed., Khimiya, Leningrad, 1981, pp. 114–119.
57. Filippov, V. K., Agafonova, K. A., Makarevskii, V. M., and Yakimov, M. A., Thermodynamic Study of the LiCl–$CdCl_2$–H_2O Ternary System at 25°C, *Zh. Prikl. Khim.*, 1975, **48**, No. 2, pp. 313–318.
58. Goldberg, R. N., Evaluated Activity and Osmotic Coefficients for Aqueous Solutions: Bi-Univalent Compounds of Zinc, Cadmium, and Ethylene Bis(Trimethylammonium) Chloride and Iodide, *J. Phys. Chem. Ref. Data*, 1981, **10**, No. 1, pp. 1–55.
59. Matuzenko, M. Yu., Zarembo, V. I., Puchkov, L. V., and Gilyarov, V. N., Standard Thermodynamic Functions of Magnesium and Cadmium Sulfates in Aqueous Solutions at Elevated Temperatures, *Zh. Prikl. Khim.*, 1982, **55**, No. 4, pp. 770–775.
60. Matuzenko, M. Yu, Zarembo, V. I., Puchkov, L. V., and Gilyarov, V. N., Tensiometric Investigation of the $MgSO_4$–H_2O and $CdSO_4$–H_2O Systems at Temperatures of 383–444 K, *Zh. Prikl. Khim.*, 1982, **55**, No. 4, pp. 816–820.
61. Lobo, V. M. M., Part A., Lobo, V. M. M. and Quaresma, J. L., *Part B. Handbook of Elektrolite Solutions*, Physical Sciences Data Series, Elsevier, Amsterdam–Oxford–New York–Tokyo, Vol. 41, 1989.
62. Goldberg, R. N., Nuttall, R. L., Staples, B. R. Evaluated Activity and Osmotic Coefficients for Aqueous Solutions: Iron Chloride and the Bi-Univalent Compounds of Nickel and Cobalt, *J. Phys. Chem. Ref. Data*, 1979, **8**, No. 4, pp. 923–1003.
63. Sadowska, T., Libus, W., Thermodynamic Properties and Solution Equilibria of Aqueous Bivalent Transition Metal Nitrates and Magnesium Nitrate, *J. Solution Chem.*, 1982, **11**, No. 7, pp. 457–468.
64. Filippov, V. K. and Nokhrin, V. I., Li_2SO_4–MSO_4–H_2O Systems (M = Mn, Co, Cu) at 25°C, *Zh. Neorg. Khim.*, 1985, **30**, No. 2, pp. 513–516.
65. Awakura, Y., Park, S.-K., Majima, H., Activities of Water and Solutes in the Solution System H_2SO_4–$Cr_2(SO_4)_3$–H_2O, *Metall. Trans. B*, 1989, **20B**, No. 6, pp. 763–771.
66. Vlasov, Yu. G. and Seleznev, B. L., Activity of Water, Osmotic Coefficients and Coefficients of Activity of CsI and CsBr in Aqueous Solutions at 25°C, *Zh. Fiz. Khim.*, 1972, **46**, No. 9, pp. 2387–2388.
67. Hamer, W. J., Wu, Y.-C., Osmotic Coefficients and Mean Activity Coefficient of Uni-Univalent Electrolytes in Water at 25°C, *J. Phys.Chem. Ref. Data*, 1972, **1**, No. 4, pp. 1048–1099.
68. Rard, J. A., Miller, D. G., Isopiestic Determination of the Osmotic and Activity Coefficients of Aqueous CsCl, $SrCl_2$, and Mixtures of NaCl at 25°C, *J. Chem. Eng. Data*, 1982, **27**, No. 2, pp. 169–173.
69. Holmes, H. F., Mesmer, R. E., Isopiestic Studies of Aqueous Solutions at Elevated Temperatures. VI. LiCl and CsCl, *J. Chem. Thermodyn.*, 1981, **13**, No. 11, pp. 1035–1046.

70. Lilley, T. H., Scott, R. P., The Osmotic Coefficients of Aqueous Solutions of Caesium Vhloride at the Freezing Temperatures of the Solutions, *J. Chem. Thermodyn.*, 1974, **6**, No. 10, pp. 1015–1017.
71. Holmes, H. F., Mesmer, R. E., Thermodynamic Properties of Aqueous Solutions of Alkali Metal Chlorides to 250°C, *J. Phys. Chem.*, 1983, **87**, No. 7, pp. 1242–1255.
72. Goldberg, R. N., Evaluated Activity and Osmotic Coefficients for Aqueous Solutions: Bi-Univalent Compounds of Lead, Copper, Manganese, and Uranium, *J. Phys.Chem. Ref. Data*, 1979, **8**, No. 4, pp. 1005–1050.
73. Miller, D. G., Rard, J. A., Eppstein, L. B., and Robinson, R. A., Mutual Diffusion Coefficients, Electrical Conductances, Osmotic Coefficients, and Ionic Transport Coefficients I_{ij} for Aqueous $CuSO_4$ at 25°C, *J. Solut. Chem.*, 1980, **9**, No. 7, pp. 467–496.
74. Susarev, M. P., Gorelik, L. I., Toikka, A. M., et al., Vapor Pressure of Water over Iron Chloride Solutions, *Zh. Prikl. Khim.*, 1976, **49**, No. 5, pp. 1045–1048.
75. Perry, R. H., ed., Perry's Chemical Engineers Handbook, 6th ed., McGraw-Hill, New York, 1984, pp. 3–73.
76. Hala, E., Wichterle, I., Polak, J., Boublik, T., *Vapor-Liquid Equilibrium Data at Normal Pressures*, Pergamon Press, Oxford–Coudon, 1968, pp. 457–485.
77. Lyudmirskaya, G. S., Barsukova, T. A., and Bogomol'nyi, V. M., *Ravnovesie zhidkost'–par* (A Handbook on the Liquid-Vapor Equilibria), Bogomol'nyi, A. M., Ed., Khimiya, Leningrad, 1987, p. 17.
78. Freier, R. K., Aqueous Solutions Data for Inorganic and Organic Compounds, Berlin, New York, 1978, Vol. 2, pp. 51–54, 56.
79. Sako, T., Hakuta, T., Yoshitome, H., Salt Effects on Vapor-Liquid Equilibria for Volatile Strong Electrolyte-Water Systems, *J. Chem. Eng. Jpn.*, 1984, **17**, No. 4, pp. 381–388.
80. Kao, J. T. F., Vapor-Liquid Equilibrium of Water-Hydrogen Chloride System, *J. Chem. Eng. Data*, 1970, **15**, No. 3, pp. 362–367.
81. Gibbons, R. M., Laughton, A. P., An Equation of State for Hydrochloric Acid Solutions, *Fluid Phase Equilib.*, 1984, **18**, pp. 61–68.
82. Hanson, D. R., Mauersberger, K., HCl/H_2O Solid-Phase Vapor Pressures and HCl Solubility in ICl, *J. Phys. Chem.*, 1990, **94**, No. 11, pp. 4700–4705.
83. Hanson, D., Mauersberger, K., Solubility and Equilibrium Vapor Pressures of HCl Dissolved in Polar Stratyspheric Cloud Materials: ICl and the Trihydrate of Nitric Acid, *Geophys. Res. Lett.*, 1988, **15**, No. 13, pp. 1507–1510.
84. Liu, Y., Gren, U., Description of Vapor-Liquid Equilibrium of the HCl/H_2O System Using an Activity-Coefficient Model, *Fluid Phase Equilib.*, 1991, **63**, No. 1/2, pp. 49–63.
85. Holmes, H. F., Busey, R. H., Simonson, J. M., et al., The Enthalpy of Dilution of HCl(aq) to 648 K and 40 MPa. Thermodynamic Properties, *J. Chem. Thermodyn.*, 1987, **19**, No. 8, pp. 863–890.
86. Miki, N., Maeno, M., Maruhashi, K., Ohmi, T., Vapor-Liquid Equilibrium of the Binary System $HF–H_2O$ Extending to Extremely Anhydrous Hydrogen Fluoride, *J. Electrochem. Soc.*, 1990, **137**, No. 3, pp. 787–790.
87. Lemire, R. J., Brown, C. P., Campbell, A. B., Vapor Pressures of Nitric Acid and Water in the Systems HNO_3 and $HNO_3–Th(NO_3)_4–H_2O$ at 50°C, *J. Chem. Eng. Data*, 1985, **30**, No. 4, pp. 421–424.
88. Clegg, S. L., Brimblecombe, P., Equilibrium Partial Pressures and Mean Activity and Osmotic Coefficients of 0–100% Nitric Acid as a Function of Temperature, *J. Phys. Chem.*, 1990, **94**, No. 13, pp. 5369–5380.
89. Hanson, D., Mauersberger, K., Vapor Pressures of HNO_3/H_2O Solutions at Low Temperatures, *J. Phys. Chem.*, 1988, **92**, No. 21, pp. 6167–6170.
90. Tang, I. N., Munkelwitz, H. R., Lee, J. H., Vapor-Liquid Equilibrium Measurements for Dilute Nitric Acid Solutions, *Atmosph. Environm.*, 1988, **22**, No. 11, pp. 2579–2585.
91. Bolsaitis, P., Elliott, J. F., Thermodynamic Activities and Equilibrium Partial Pressures for Aqueous Sulfuric Acid Solutions, *J. Chem. Eng. Data*, 1990, **35**, No. 1, pp. 69–85.
92. Wilson, R. W., Stein, F. P., Correlation of Sulfuric Acid-Water Partial Pressures, *Fluid Phase Equilib.*, 1989, **53**, pp. 279–288.
93. Ayers, G. P., Gillett R. W., Gras, J. L., On the Vapor Pressure of Sulfuric Acid, *Geophys. Res. Lett.*, 1980, **7**, No. 6, pp. 433–436.
94. Staples, B. R., Activity and Osmotic Coefficients of Aqueous Sulfuric Acid at 298.15 K, *J. Phys. Chem. Ref. Data*, 1981, **10**, No. 3, pp. 778–798.

95. Rard, J. A., Hobenschuss, A., Spedding, F. H., A Review of the Osmotic Coefficients of Aqueous H_2SO_4 at 25°C, *J. Chem. Eng. Data*, 1976, **21**, No. 3, pp. 374–379.
96. Rard, J. A., Isopiestic Determination of the Osmotic Coefficients of Aqueous H_2SO_4 at 25°C, *J. Chem. Eng. Data*, 1983, **28**, No. 4, pp. 384–387.
97. L'vov, S. N., Antonov, N. A., and Fedorov, M. K., Saturated Vapor Pressures of Aqueous KBr and KI Solutions at Temperatures of 150–350°C, *Zh. Prikl. Khim.*, 1976, **49**, No. 5, pp. 1048–1051.
98. Fanghanel, Th., Grjotheim, K., Thermodynamics of Aqueous Reciprocal Salt Systems. III. Isopiestic Determination of Osmotic and Activity Coefficients of Aqueous $MgCl_2$, $MgBr_2$, KCl and KBr at 100.3°C, *Acta Chem. Scand.*, 1990, **44**, No. 9, pp. 892–895.
99. Akhundo, V. T. S., Imanova, M. V., Tahiro, V. A. D., Thermal Properties of High Temperature Aqueous Electrolyte Solutions, In: The Properties of Steam, *Proc. 10th Int. Conf.*, Moscow, 1984, Vol. 2, pp. 316–323.
100. Pan, C.-F., Activity and Osmotic Coefficients in Dilute Aqueous Solutions of the Uni-Univalent Electrolytes at 25°C, *J. Chem. Eng. Data*, 1981, **26**, No. 2, pp. 183–184.
101. Puchkov, L. V., Kurochkina, V. V., and Matveeva, R. P., *Plotnost' i davlenie nasyshchennogo para vodnykh rastvorov uglekislogo kaliya pri temperaturakh do 315°C* (Density and Saturated Vapor Pressures of Aqueous Solutions of Potassium Carbonate at Temperatures up to 315°C), Available from VINITI, 1976, No. 3476–76.
102. Korzhavina, N. A. and Novikov, B. E., Saturated Vapor Pressures over Aqueous Solutions of Potassium Carbonate at Temperatures of 25 to 400°C and Concentrations to 80 wt.%, In: *Tables of Recommended Reference Data*, GSSSD P242–87, Moscow, Available from VNIIKI, 1987, No. 452-kk87.
103. Roy, R. N., Gibbons, J. J., Williams, R., et al., The Thermodynamics of Aqueous Carbonate Solutions. II. Misxtures of Potassium Carbonate, Bicarbonate, and Chloride, *J. Chem. Thermodyn.*, 1984, **16**, No. 4, pp. 303–315.
104. Sarbar, M., Covington, A. K., Nuttall, R. L., Goldberg, R. N., Activity and Osmotic Coefficients of Aqueous Potassium Carbonate, *J. Chem. Thermodyn.*, 1982, **14**, No. 7, pp. 695–702.
105. Novikov, B. E., Korzhavina, N. A., Volumetric Properties of Liquid and Vapor K_2CO_3 Solutions at Phase Equilibrium, In: The Properties of Steam, *Proc. 10th Int. Conf.*, Moscow, 1984, Vol. 2, pp. 190–195.
106. Novikov, B. E. and Korzhavina, N. A., Thermodynamic Investigation of Aqueous and Steam Solutions of K_2CO_3 at Phase Equilibria in Wide Ranges of Temperatures and Concentrations, *Teplofiz. Vys. Temp.*, 1987, **25**, No. 3, pp. 475–480.
107. Puchkov, L. V., Kurochkina, V. V., and Matveeva, R. P., *Plotnost' i davlenie nasyshchennogo para vodnykh rastvorov K_2CO_3 pri temperaturakh do 315°C* (Density and Saturated Vapor Pressures of Aqueous Solutions of Potassium Carbonate at Temperatures up to 315°C), Available from VINITI, 1976, No. 3476–76.
108. Hovey, J. K., Pitzer, K. S., Tanger, J. C., Bischoff, J. L., Rosenbauer, R. J., Vapor-Liquid Phase Equilibria of Potassium Chloride-Water Mixtures: Equation-of-State Representation for KCl–H_2O and NaCl–H_2O, *J. Phys. Chem.*, 1990, **94**, No. 3, pp. 1175–1179.
109. Zarembo, V. I., Antonov, N. A., Gilyarov, V. N., and Fedorov, M. K., On the Coefficients of Activity of KCl in the KCl–H_2O System at Temperatures of 150–350°C and Pressures to 1500 kgf/cm^2, *Zh. Prikl. Khim.*, 1976, **49**, No. 6, pp. 1221–1225.
110. Thiessen, D. B., Wilson, A. J., An Isopiestic Method for Measurement of Electrolyte Activity Coefficients, *Aiche J.*, 1987, **33**, No. 11, pp. 1926–1929.
111. Vega, R., Vera, J. H., Phase Equilibria of Concentrated Aqueous Solutions Containing Native Strong Electrolytes, *Can. J. Chem. Eng.*, 1976, **54**, No. 3, pp. 245–248.
112. Snipes, H. P., Manly, C., Ensor, D. D., Heats of Dilution of Aqueous Electrolytes: Temperature Dependence, *J. Chem. Eng. Data*, 1975, **20**, No. 3, pp. 287–291.
113. Davis, T. M., Duckett, L. M., Owen, J. F., Patterson, C. S., Saleeby, R., Osmotic Coefficients of Aqueous LiCl and KCl from their Isopiestic Ratios to NaCl at 45°C, *J. Chem. Eng. Data*, 1985, **30**, No. 4, pp. 432–434.
114. Gomez-Estevez, J. L., Osmotic Coefficients of Aqueous NaCl and KCl Solutions, *J. Chem. Soc. Faraday Trans. I*, 1986, **82**, pp. 2167–2174.
115. Ninkovic, R. R., Radovanovic, D. N., Osmotic and Activity Coefficients of the Aqueous Mixtures KCl–$MgSO_4$ and K_2SO_4–$MgCl_2$ at 25°C, *J. Serb. Chem. Soc.*, 1991, **56**, No. 3, pp. 151–160.

116. Manohar, S., Ananthaswamy, J., Thermodynamic Properties of Electrolyte Solutions: An EMF Study of the Activity Coefficients of KCl in the System KCl–KNO_3–H_2O at 25, 35 and 45°C, *J. Solution Chem.*, 1990, **19**, No. 11, pp. 1125–1135.

117. Chinnappa, R. D., Ananthaswamy, J., Thermodynamic Properties of Aqueous Electrolyte Solutions: An E.M.F. Study of {KCl(Ma) + $SrCl_2$(Mb)}(aq) at the Temperatures 298.15 K, 308.15 K, and 318.15 K, *J. Chem. Thermodyn.*, 1990, **22**, No. 10, pp. 1015–1023

118. Iminova, M. V., Experimental Investigation of Thermal Properties of Aqueous Solutions of Potassium Chloride, *Izv. Vyssh. Uchebn. Zaved., Neft' Gaz*, 1985, No. 4, pp. 61–3.

119. Pabalan, R. T., Pitzer, K. S., Apparent Molal Heat Capacity and other Thermodynamic Properties of Aqueous KCl Solutions to High Temperatures and Pressures, *J. Chem. Eng. Data*, 1988, **33**, No. 3, pp. 354–362.

120. Goldberg, R. H., Evaluated Activity and Osmotic Coefficients for Aqueous Solutions: Thirty-Six Uni-Bivalent Electrolytes, *J. Phys. Chem. Ref. Data*, 1981, **10**, No. 3, pp. 671–764.

121. Reznik, F. Ya., Viteeva, L. N., and Voskresenskaya, I. E., Thermodynamic Characteristics of Aqueous Solutions of KH_2PO_4, K_2HPO_4, and K_3PO_4, *Tr. Nauchn.-issled. i Proektn. Inst. Osnov. Khimii*, 1974, No. 34, pp. 79–81.

122. Egorov, V. Ya., Zarembo, V. I., Soboleva, N. G., and Puchkov, L. V., Activity of Water and Coefficients of Activity of Dissolved Electrolytes in Aqueous Solutions of Alkaline-Metal Nitrates at Temperatures of 423–623 K, *Zh. Prikl. Khim.*, 1981, **54**, No. 6, pp. 1247–1250.

123. Puchkov, L. V., Chakhal'yan, O. Kh., and Kebe, M., Vapor Pressures and Boiling Temperatures of Alkaline-Metal Hydroxide Solutions, *Zh. Prikl. Khim.*, 1978, **51**, No. 11, pp. 1442–2446.

124. Zarembo, V. I., Matuzenko, M. Yu., and Egorov, V. Ya., Activities of Water and Coefficients of Activity of Dissolved Electrolytes in Li_2SO_4–H_2O, Na_2SO_4–H_2O, and K_2SO_4–H_2O Systems, *Zh. Prikl. Khim.*, 1981, **54**, No. 4, pp. 918–920.

125. Puchkov, L. V., Kurochkina, V. V., and Matveeva, R. P., *Plotnost' i davlenie nasyshchennogo para vodnykh rastvorov uglekislogo kaliya pri temperaturakh do 315°C* (Density and Saturated Vapor Pressures of Aqueous Solutions of Potassium Carbonate at Temperatures up to 315°C), Available from VINITI, 1976, No. 3476–76.

126. Holmes, H. F., Mesmer, R. E., Isopiestic Studies of Aqueous Solutions at Elevated Temperatures. VIII. The Alkali-Metal Sulfates, *J. Chem. Thermodyn.*, 1986, **18**, No. 3, pp. 263–275.

127. Gruzdev, V. A., Verba, O. I., and Seryakov, A. V., Equilibrium Vapor Pressures of Aqueous Solutions of Lithium Chloride at High Concentrations, In: *Teplofizicheskie svoistva veshchestv i rastvorov* (Thermophysical Properties of Substances and Solutions), Sb. Nauchn. Trudov, Novosibirsk, 1988, pp. 70–81.

128. Richardson, C. B., Kurtz, C. A., A Novel Isopiestic Measurement of Water Activity in Concentrated and Supersaturated Lithium Halide Solutions, *J. Am. Chem. Soc.*, 1984, **106**, No. 22, pp. 665–668.

129. Borita, D. A., Maas, A. J., Grant, C. B., Vapor Pressure-Temperature-Concentration Relationship for System Lithium Bromide and Water (40–70% Lithium Bromide), *J. Chem. Eng. Data*, 1975, **20**, No. 3, pp. 316–319.

130. Fedorov, M. K., Antonov, N. A., and L'vov, S. N., Saturated Vapor Pressures of Aqueous Solutions of LiCl, LiBr, and LiI and the Thermodynamic Characteristics of Dissolution Processes in these Systems at Temperatures of 150–350°C and Pressures up to 1500 bar, *Zh. Prikl. Khim.*, 1976, **49**, No. 6, pp. 1226–1232.

131. Patil, K. R., Tripathi, A. D., Pathak, G., Katti, S. S., Thermodynamic Properties of Aqueous Electrolyte Solutions: 1. Vapor Pressure of Aqueous Solutions of LiCl, LiBr, and LiI, *J. Chem. Eng. Data*, 1990, **35**, No. 2, pp. 166–168.

132. Voigt, W., Dittrich, A., Hausdal, B., Crjotheim, K., Thermodynamics of Aqueous Reciprocal Salt Systems: II. Isopiestic Determination of the Osmotic and Activity Coefficients in $LiNO_3$–NaBr–H_2O and LiBr–$NaNO_3$–H_2O at 100.3°C, *Acta Chem. Scand.*, 1990, **44**, No. 1, pp. 12–17.

133. Gruzdev, V. A., Verba, O. I., and Seryakov, A. V., Equilibrium Vapor Pressures and Thermodynamic Properties of Aqueous Solutions of Lithium Chloride, In: *Teplofizicheskie svoistva individual'nykh veshchestv i rastvorov* (Thermophysical Properties of Individual Substances and Solutions), Sb. Nauchn. Trudov, Novosibirsk, 1986, pp. 51–64.

134. Gibbard, H. F., Jr., Scarchard, G., Liquid-Vapor Equilibrium of Aqueous Lithium Chloride, from 25°C to 100°C and from 1.0 to 18 Molal, and Related Properties, *J. Chem. Eng. Data*, 1973, **18**, No. 3, pp. 293–298.

135. Gruzdev, V. A. and Verba, O. I., Equilibrium Vapor Pressures of Aqueous Solutions of Lithium Chloride, In: *Teplofizicheskie svoistva veshchestv* (Thermophysical Properties of Substances), Proc. VIII All-Union Conf., Novosibirsk, 1989, Part I, pp. 53–58.

136. Grjotheim, K., Voigt, W., Hausdal, B., Dittrich, A., Isopiestic Determination of Osmotic Coefficients at 100°C by Means of a Simple Apparatus, *Acta Chem. Scand.*, 1988, **42A**, No. 8–9, pp. 470–476.

137. Filippov, V. K. and Nokhrin, V. I., Li_2SO_4–MSO_4–H_2O (M = Mg, Ni, Zn) Systems at 25°C, *Zh. Neorg. Khim.*, 1985, **30**, No. 2, pp. 501–505.

138. Urusova, M. A. and Valyashko, V. M., Vapor Pressures and Thermodynamic Properties of Aqueous Solutions of Magnesium Chloride at 250°C, *Zh. Neorg. Khim.*, 1984, **29**, No. 9, pp. 2437–2439.

139. Urusova, M. A. and Valyashko, V. M., Solubility, Vapor Pressure, and Thermodynamic Properties of Solutions in the $MgCl_2$–H_2O System at 300–350°C, *Zh. Neorg. Khim.*, 1983, **28**, No. 7, pp. 1845–1849.

140. Rard, J. A., Miller, D. G., Isopiestic Determination of the Osmotic and Activity Coefficients of Aqueous $MgCl_2$ Solutions at 25°C, *J. Chem. Eng. Data*, 1981, **26**, No. 1, pp. 38–43.

141. Filippov, V. K. and Charykov, N. A., Phase Equilibria in the Na^+, Mn^{++}‖Cl^-, SO_4^-:H_2O System at 25°C, *Zh. Neorg. Khim.*, 1989, **34**, No. 6.

142. Valyashko, V. M., Urusova, M. A., Voigt, W., and Emons, H.-H., Properties of Solutions in the $MgCl_2$–H_2O System in Wide Ranges of Temperatures and Concentrations, *Zh. Neorg. Khim.*, 1988, **33**, No. 1, pp. 228–232.

143. Emons, H.-H., Voigt, W., Wollny, F.-W., Dampfdruckenessungen am System Magnesiumchlorid-Wasser, *Z. Phys. Chem.* (DDR), 1986, Bd. **267**, S. 1–8.

144. Roux, A., Musbally, G. M., Perron, G., et al., Apparent Molal Heat Capacities and Volumes at 25°C: $NaClO_3$, $NaClO_4$, $NaNO_3$, $NaBrO_3$, $NaIO_3$, $KClO_3$, $KBrO_3$, KIO_3, NH_4NO_3, NH_4Cl and NH_4ClO_3, *Can. J. Chem.*, 1978, **56**, No. 1, pp. 24–28.

145. Phutela, R., Pitzer, K. S., Heat Capacity and other Thermodynamic Properties of Aqueous Magnesium Sulfate to 473 K, *J. Phys. Chem.*, 1986, **90**, pp. 895–901.

146. Filippov, V. K., Shestakov, N. E., and Charykova, M. V., Thermodynamic Calculation of Phase Equilibria in the Na, K, Mg‖SO_4–H_2O System at 30°C, In: *Khimiya i termodinamika rastvorov* (Chemistry and Thermodynamics of Solutions), Izd. Leningrad. Univ., Leningrad, 1986, No. 6, pp. 167–185.

147. Holmes, H. F., Mesmer, R. E., Isopiestic Studies of Aqueous Solutions at Elevated Temperatures. VII. $MgSO_4$ and $NiSO_4$, *J. Chem. Thermodyn.*, 1983, **15**, No. 8, pp. 709–720.

148. Rard, J. A., Miller, D. G., Isopiestic Determination of the Osmotic Coefficients of Aqueous Na_2SO_4, $MgSO_4$, and Na_2SO_4–$MgSO_4$ at 25°C, *J. Chem. Eng. Data*, 1981, **26**, No. 1, pp. 33–38.

149. Rard, J. A., Miller, D. G., Isopiestic Determination of the Osmotic and Activity Coefficients of Aqueous $MnCl_2$, $MnSO_4$ and RbCl at 25°C, *J. Chem. Eng. Data*, 1984, **29**, No. 4, pp. 443–446.

150. Deckwer, W. D., Density, Viscosity, Vapor Pressure, and Hydrogen Solubility of Aqueous $MnSO_4$ Solutions, *J. Chem. Eng. Data*, 1980, **25**, No. 1, pp. 75–76.

151. Thiesen, W. E., Simonson, J. M., Enthalpy of Dilution and the Thermodynamics of NH_4Cl(aq) to 523 K and 35 MPa, *J. Phys. Chem.*, 1990, **94**, No. 20, pp. 7794–7800.

152. Bonner, O. D., The Osmotic and Activity Coefficients of some Salts Having Relatively Large Molar Volumes, *J. Chem. Eng. Data*, 1976, **21**, No. 4, pp. 498–499.

153. Sorina, G. A., Blinova, M. B., and Tsekhanskaya, Yu. V., The Boiling Temperature of Aqueous Solutions of Ammonium Nitrate under Pressure, *Zh. Prikl. Khim.*, 1983, **56**, No. 8, pp. 1878–1881.

154. Filippov, V. K., Charykova, M. V., and Trofimov, Yu. N., Thermodynamic Study of the Na^+, NH_4^+‖SO_4^-:H_2O and Na^+, NH_4^+‖$H_2PO_4^-$:H_2O Systems at 25°C, *Zh. Prikl. Khim.*, 1987, **60**, No. 2, pp. 257–262.

155. Akhundov, G. S., Imanova, M. V., and Tairov, A. D., Termal Properties of Aqueous Solutions of Sodium Bromide, In: *Teplofizicheskie svoistva veshchestv i materialov* (Thermophysical Properties of Substances and Materials), GSSSD, Izd. Standardov, Moscow, 1984, No. 21, pp. 60–71.

156. Mashovets, V. P., Zarembo, V. I., and Fedorov, M. K., Saturated Vapor Pressures of Aqueous Solutions of NaCl, NaBr, and NaI at Temperatures of 150–300°C, *Zh. Prikl. Khim.*, 1973, **46**, No. 3, pp. 650–652.

157. Imanova, M. V., Iskenderov, A. N., and Akhundov, T. S., *P–ρ–T* and *Ps–Ts* Dependences for High-Temperature Electrolytes, In: *Obrabotka vysokomineralizovannykh vodi teplofizicheskie svoistva* (Conditioning of Highly Mineralized Waters and Thermophysical Properties), Baku, 1985, pp. 99–102.
158. Archer, D. G., Thermodynamic Properties of the NaBr + H_2O system, *J. Phys. and Chem. Ref. Data*, 1991, **20**, No. 3, pp. 509–555
159. Puchkov, L. V. and Kurochkin, V. V., Densities and Saturated Vapor Pressures of Aqueous Solutions of Sodium Carbonate at Temperatures to 320°C, In: *Issledovaniya v oblasti neorganicheskoi tekhnologii* (Investigations in the Field of Neorganic Technology), Nauka, Moscow, 1972, pp. 263–267.
160. Peiper, J. C., Pitzer, K. S., Thermodynamics of Aqueous Carbonate Solutions Including Mixtures of Sodium Carbonate, Bicarbonate, and Chloride, *J. Chem. Thermodyn.*, 1982, **14**, No. 7, pp. 613–638.
161. Khvorostin, Ya. S., Filippov, V. K., and Reshetova, L. I., Determining Coefficients of Activity of Sodium Carbonate at 25°C by the Isopiestic Method, *Zh. Fiz. Khim.*, 1975, **49**, No. 5, pp. 1271–1272.
162. Clerke, E. C. W., Glew, D. N., Evaluation of the Thermodynamic Functions for Aqueous Sodium Chloride from Equilibrium and Calorimetric Measurements below 154°C, *J. Phys.Chem. Ref. Data*, 1985, **14**, No. 2, pp. 489–610.
163. Aqueous and Vapor-Gas Solutions. The Water-Sodium Chloride System, In: *Tablitsy termodinamicheskikh svoistv gazov i zhidkostei* (Tables of Thermodynamic Properties of Gases and Liquids), Izd. Standartov, Moscow, 1980, No. 6.
164. Valyashko, V. M., Dibrov, I. A., Puchkov, L. A., et al., Thermophysical Properties of the NaCl–H_2O System in a Wide Range of the Parameters of State, In: *Obzory Teplofiz. Svoistv. Veshchestv*, Inst. Vysokikh Temperatur, Moscow, Akad. Nauk SSSR, 1986, No. 4(60), pp. 3–112.
165. Bischoff, J. L., Rosenbauer, R. J., Pitzer, K. S., The system NaCl–H_2O; Relations of Vapor-Liquid Near the Critical Temperature of Water and of Vapor-Liquid-Halite from 300 to 500°C, *Geochimica et Cosmochimica Acta*, 1986, **50**, pp. 1437–1444.
166. Bodnar, R. J., Burnham, C. W., Sterner, S. M., Synthetic Fluid Inclusions in Natural Quartz. III. Determination of Phase Equilibrium Properties in the System H_2O–NaCl to 1000°C and 1500 Bars, *Geochimica et Cosmochimica Acta*, 1985, **49**, pp. 1861–1873.
167. Urusova, M. A., Phase Equilibria and Thermodynamic Characteristics of Solutions in the NaCl–H_2O and NaOH–H_2O Systems at Temperatures of 350–550°C, *Geokhimiya*, 1974, No. 9, pp. 1360–1366.
168. Urusova, M. A., Phase Equilibria in Sodium Hydroxide-Water and Sodium Chloride–Water Systems at 350–550°C, *Zh. Neorg. Khim.*, 1974, **19**, No. 3, pp. 828–833.
169. Parisod, C. J., Plattner, E., Vapor-Liquid Eqilibria of the NaCl–H_2O System in the Temperature Range 300–440°C. *J. Chem. Eng. Data*, 1981, **26**, No. 1, pp. 16–20.
170. Gibbard, H. F., Jr., Scatchard, G., Rousseau, R. A., Creek, J. L., Liquid-Vapor Equilibrium of Aqueous Sodium Chloride, from 298 to 373 K and from 1 to 6 mol/ kg, and Related Properties, *J. Chem. Eng. Data*, 1974, **19**, No. 3, pp. 281–288.
171. Marshall, W. L., Critical Curves of Aqueous Electrolyte Related to Ionization Behaviour: New Temperatures for Sodium Chloride Solutions, *J. Chem. Soc. Faraday Trans.*, 1990, **86**, No. 10, pp. 1807–1814.
172. Tanger, J. C. T., Pitzer, K. S., Thermodynamics of NaCl–H_2O: A New Equation of State for the Near-Critical Region and Comparisons with other Equations for Adjoining Regions, *Geochim. et Cosmochim. Acta*, 1989, **53**, No. 5, pp. 973–987.
173. Bischoff, J. L., Rosenbauer, R. J., Liquid-Vapor Relations in the Critical Region of the System NaCl–H_2O from 380 to 415°C: A Refined Determination of the Critical Point and Two-Phase Boundary of Seawater, *Geochim. et Cosmochim. Acta*, 1988, **52**, No. 8, pp. 2121–2126.
174. Rosenbauer, R. J., Bischoff, J. L., Pressure-Composition Relations for Coexisting Gases and Liquids and the Critical Points in the System NaCl–H_2O at 450, 475, and 500°C, *Geochim. et Cosmochim. Acta*, 1987, **51**, pp. 2349–2354.
175. Bischoff, J. L., Pitzer, K. S., Liquid-Vapor Relations for the System NaCl–H_2O: Summary of the *P–T–x* Surface from 300 to 500°C, *Am. J. Sci.*, 1989, **289**, pp. 217–248.
176. Pitzer, K. S., Tanger, J. C., Near-Critical NaCl–H_2O: An Equation of State and Discussion of Anomalous Properties, *Int. J. Thermophys.*, 1988, **9**, No. 5, pp. 635–648.
177. Pitzer, K. S., Bischoff, J. L., Rosenbauer, R. J., Critical Behavior of Dilute NaCl in H_2O, *Chem. Phys. Lett.*, 1987, **134**, No. 1, pp. 60–63.

178. Harvey, A. H., Levelt Sengers, J. M. H., On the NaCl–H_2O Coexistence Curve Near the Critical Temperature of H_2O, *Chem. Phys. Lett.*, 1989, **156**, No. 4, pp. 415–417.
179. Pitzer, K. S., Tanger, J. C., Critical Exponents for the Coexistence Curves for NaCl–H_2O Near the Critical Temperature of H_2O, Reply to Comment by A. N. Harvey and J. M. H. Levelt Sengers, *Chem. Phys. Lett.*, 1989, **156**, No. 4, pp. 418–419.
180. Thurmond, V. L., Brass, G. W., Activity and Osmotic Coefficients of NaCl in Concentrated Solutions from 0 to 40°C, *J. Chem. Eng. Data*, 1988, **33**, No. 4, pp. 411–414.
181. Filippov, V. K. and Charykova, M. V., Phase Equilibria in the $Na^+||Cl^-$, SO_4^-, H_2PO_4:H_2O System at 25°C, *Zh. Prikl. Khim.*, 1991, **64**, No. 1, pp. 3–7.
182. Pitzer, K. S., Peiper, J. C., Busey, R. H., Thermodynamic Properties of Aqueous Sodium Chloride Solutions, *J. Phys. Chem. Ref. Data*, 1984, **13**, No. 1, pp. 1–102.
183. Holmes, H. F., Mesmer, R. E., Isopiestic Studies of Aqueous Solutions at Elevated Temperatures. 10. $(1 - y)$NaCl + yCsCl(aq), *J. Phys. Chem.*, 1990, **94**, No. 20, pp. 7800–7805.
184. Sarada, S., Ananthaswamy, J., Thermodynamic Properties of Electrolyte Solutions: EMF Study of the System NaCl–Na_2SO_4–H_2O at 25, 35 and 45°C, *J. Chem. Soc. Faraday Trans.*, 1990, **86**, No. 1, pp. 81–84.
185. Schonert, H., The Debye-Huckel Theory for Hydrated Ions: I. Osmotic and Activity Coefficients of Binary Aqueous Solutions of Some 1:1 Electrolytes at 25°C., *Ber. Bunsenges. Phys. Chem.*, 1990, **94**, No. 6, pp. 658–664.
186. Partanen, J. I., Minkkinen, P. O., Activity and Osmotic Coefficients of Dilute Sodium Chloride Solutions at 273 K, *J. Chem. Eng. Data*, 1991, **36**, No. 4, pp. 432–435.
187. Akhundov, T. S., Imanov, M. V., and Ismail-zade, Sh. M., Thermal Properties of Aqueous Solutions of Sodium Chloride at Concentrations of 100 and 300 gel, *Izv. Vyssh. Uchebn. Zaved., Neft' Gaz*, 1985, No. 2, pp. 58–60.
188. Akhundov, T. S. and Imanova, M. V., Thermal Properties of an Aqueous Solution of Sodium Chloride at a Concentration of 200 gel, *Inzh.-Fiz. Zh.*, 1984, No. 6, pp. 957–959.
189. Knight, C. L., Bodnar, R. J., Synthetic Fluid Inclusions: IX. Critical *PVTx* Properties of NaCl–H_2O Solutions, *Geochim. et Cosmochim. Acta*, 1989, **53**, No. 1, pp. 3–8.
190. Gallagher, J. C., Levelt Sengers, J. M. H., Modeling the Thermodynamic Properties of Sodium Chloride in Steam through Extended Corresponding States, *Int. J. Thermophys.*, 1988, **9**, No. 5, pp. 649–661.
191. Valyashko, V. M., et al., Thermophysical Properties of the NaCl–H_2O System in a Wide Range of the Parameters of State, In: *Obzory Teplofiz. Svoistv. Veshchestv*, Inst. Vysokikh Temperatur, Moscow, Akad. Nauk SSSR, 1986, No. 4 (60).
192. Gates, J. A., Tillett, D. M., et al., Apparent Molar Heat Capacities of Aqueous NaCl Solutions from 0, 0.5 to 3.0 mol/kg, 350 to 600 K and 2 to 18 MPa, *J. Chem. Thermodyn.*, 1987, **19**, No. 2, pp. 131–146.
193. Akhundov, T. S., Iskenderov, A. I., Imanova, M. V., and Ishkhanov, N. B., Experimental Study of the Thermal Properties of Aqueous Solutions of Sodium Fluoride, *Zh. Fiz. Khim.*, 1988, **62**, No. 7, pp. 1932–1933.
194. Guseinov, A. G., Iskenderov, A. I., Akhundov, R. T., Agaeva, D. A., and Akhundov, T. S., *P*–ρ–v and *Ps*–*Ts* Dependences for Aqueous Solutions of Sodium Fluoride, In: *Termodinamicheskie i perenosnye svoistva veshchestv* (Thermodynamic and Transport Properties of Substances), Baku, 1989, pp. 14–20.
195. Sarbar, M., Covington, A. K., Nuttall, R. L., Goldberg, R. N., The Activity and Osmotic Coefficients of Aqueous Sodium Bicarbonate Solutions, *J. Chem. Thermodyn.*, 1982, **14**, No. 10, pp. 967–976.
196. Akhundov, T. S., Imanova, M. V., Tairov, A. D., and Ismail-zade, Sh. M., Experimental Studies of *P*–*V*–*T* and *Ps*–*Ts* Dependences for Aqueous Solutions of Sodium Iodide, In: *Teplofizicheskie svoistva vysokokipyashchikh zhidkostei* (Thermophysical Properties of High-Boiling Liquids), AzINEFTEKhiM, Baku, 1983, pp. 3–10.
197. Akhundov, T. S., Imanova, M. V., and Ismail-zade, Sh. M., Thermal Properties of an Aqueous Solution of Sodium Iodide at a Concentration of 200 gel, *Izv. Vyssh. Uchebn. Zaved., Energet.*, 1984, No. 1, pp. 95–97.
198. Akhundov, T. S. and Imanova, M. V., Thermal Properties of an Aqueous Solution of Sodium Iodide at a Concentration of 200 gel, *Inzh.-Fiz. Zh.*, 1983, **45**, No. 1, pp. 140–142.
199. Akhundov, T. S., Imanova, M. V., and Arutunyan, G. S., Thermal Properties of Aqueous Solutions of Sodium Iodide at Concentrations of 20 and 50 gel, *Dokl. Akad. Nauk SSSR*, 1983, **271**, No. 5, pp. 1146–1149.

200. Akhundov, T. S., Imanova, M. V., and Tairova, A. D., Thermal Properties of an Aqueous Solution of Sodium Iodide at a Concentration of 400 gel, *Dokl. Akad. Nauk AzSSR*, 1983, **39**, No. 7, pp. 40–43.
201. Staples, B. R., Activity and Osmotic Coefficients of Aqueous Alkali Metal Nitrites, *J. Phys. Chem. Ref. Data*, 1981, **10**, No. 3, pp. 765–777.
202. Wu, Y. C., Hamer, W. J., Comments. Revised Values of the Osmotic Coefficients and Mean Activity Coefficients of Sodium Nitrate in Water at 25°C, *J. Phys.Chem. Ref. Data*, 1980, **9**, No. 2, pp. 513–518.
203. Allred, G. C., Wooley, E. M., Heat Capacities of Aqueous HCl, NaOH and NaCl at 283.15, 298.15 and 313.15 K: C_p for Ionization of Water, *J. Chem. Thermodyn.*, 1981, **13**, pp. 147–154.
205. Krey, J., Dampfdruck und Dichte des systems H_2O–NaOH, *Z. Phys. Chem. N. F.*, 1972, Bd. 81, No. 5/6, S. 252–273.
206. Martynova, O. I., Androsov, V. I., and Vospennikov, V. V., Thermodynamic Properties of the Sodium Hydroxide-Water System, In: *Obzory Teplofiz. Svoistv. Veshchestv*, Inst. Vysokikh Temperatur, Akad. Nauk SSSR, Moscow, 1982, No. 4(36), pp. 1–108.
207. Androsov, V. I., Vospennikov, V. V., The Thermodynamic Properties of Sodium Hydroxide – Water System, In: Properties of Steam, *Proc. 10th Intern. Conf.*, Moscow, 1984, pp. 165–169.
208. Campbell, A. N., Bhatnagar, O. N., Osmotic and Activity Coefficients of Sodium Hydroxide in Water from 150 to 250°C, *J. Chem. Eng. Data*, 1984, **29**, No. 2, pp. 166–168.
209. Filippov, V. K., Veretennikova, G. A., and Nokhrin, V. N., A Thermodynamic Study of the Na_2SO_4–$NiSO_4$–H_2O System at 25°C, *Zh. Prikl. Khim.*, 1984, **57**, No. 9, pp. 1938–1943.
210. Pabalan, R., Pitzer, K. S., Heat Capacity and other Thermodynamic Properties of Na_2SO_4(aq) in Hydrothermal Solutions and the Solubilities of Na_2SO_4-Minerals in the System Na–Cl–SO_4–OH–H_2O to 300°C, *Geochim. Cosmochim. Acta*, 1988, **92**, No. 10, pp. 2393–2404.
211. Rard, J. A., Isopiestic Determination of the Osmotic and Activity Coefficients of Aqueous $NiCl_2$, $Pr(NO_3)_3$, and $Ln(NO_3)_3$ and Solubility of $NiCl_2$ at 25°C, *J. Chem. Eng. Data*, 1987, **32**, No. 3, pp. 334–341.
212. Holmes, H. F., Mesmer, R. E., Isopiestic Studies of Aqueous Solutions at Elevated Temperatures. IV. $NiCl_2$ and $CoCl_2$, *J. Chem. Thermodyn.*, 1981, **13**, No. 2, pp. 131–137.
213. Sarbar, M., Covington, A. K., Nuttall, R. L., and Goldberg, R. N., Activity and Osmotic Coefficients of Aqueous Nickel(II)Nitrate Solutions, *J. Chem. Thermodyn.*, 1982, **19**, No. 6, pp. 573–545.
214. Urusova, M. A., Vapor Pressure in the $SrCl_2$–H_2O System at Temperatures above 250°C, *Zh. Neorg. Khim.*, 1986, **31**, No. 7, pp. 1916–1917.
215. Rard, J. A., Miller, D. G., Isopiestic Determination of the Osmotic and Activity Coefficients of $ZnCl_2$(aq) at 298.15 K, *J. Chem. Thermodyn.*, 1989, **21**, pp. 463–482.
216. Verba, O. I., Gruzdev, V. A., Genrikh, V. N., et al., Thermophysical Properties of Mixed Aqueous Solutions of Calcium Chloride and Sodium Chloride, In: *Issledovanie teplofizicheskikh svoistv zhidkostei* (Studies of Thermophysical Properties of Liquids), Novosibirsk, 1977, pp. 40–59.