Electrolytes. Properties of Solutions. Methods for Calculation of Multicomponent Systems and Experimental Data on Thermal Conductivity and Surface Tension

G. G. Aseyev
[redacted]
Khar'kov State Institute of Culture
Ukraine

Translated by:
Kirill Shakhlevich

BEGELL HOUSE INC. PUBLISHERS
New York

ASEYEV G. G.

ELECTROLYTES. PROPERTIES OF SOLUTIONS. METHODS FOR CALCULATION OF MULTICOMPONENT SYSTEMS AND EXPERIMENTAL DATA ON THERMAL CONDUCTIVITY AND SURFACE TENSION

Methods for calculation of the thermal conductivity and surface tension of multicomponent electrolyte solutions with minimum errors are presented. Related equations for calculation of the thermal conductivity of water at the saturation line in the temperature range 0–350°C, the activity of water, and the water vapor pressure over pure water in the temperature range 0–350°C and over a solution at the saturation line are also considered. Calculation coefficients for many electrolytes, obtained as a result of mathematical processing by the methods of regression analysis of experimental data available from the literature and measured by the author, are given. The material is illustrated by examples of calculation.

Tables of experimental data on the thermal conductivity and surface tension are presented for wide ranges of the mass contents of electrolytes in aqueous solutions, the temperatures, and pressures. The data were obtained as a result of mathematical processing of available reported information and experimental results determined by the author. The material is processed on computer.

This book gives data for a great number of electrolytes, which are most widely used in modern chemical technology, and is intended for scientific workers and engineers of chemical industry and allied industries.

Contents

Foreword

This book is the continuation of a number of the author's works dealing with study, representation, and methods of calculation of the physicochemical properties of binary and multicomponent electrolyte solutions [1–5].

Compared to [3], this book contains substantially revised and enlarged data on thermal conductivity, new experimental data on the surface tension of electrolyte solutions, and coefficients for calculation of the thermal conductivity and vapor pressure over a solution for many electrolytes. The coefficients are obtained as a result of mathematical processing of available experimental data by the methods of regression analysis. Experimental data for the most widely used electrolytes are given for high temperatures and pressure ranges.

Section I gives the methods for calculation of thermal conductivity and various coefficients for a wide range of electrolytes, which allow one to calculate multicomponent solutions with high accuracy. New regression equations for calculation of the thermal conductivity of water in the range 0–350°C, which are necessary for determination of the thermal conductivity of solutions, are proposed. An equation for calculation of the surface tension of binary and multicomponent systems, based on data on the water activity, is also presented. Approximation expressions for calculation of the vapor pressure over pure water and a solution, which are used to find the water activity, are also given.

The list of electrolytes in Section II is significantly longer than in [3] (see table index for Section II), and the data for the same electrolytes were revised. The logic sequence of reference data is identical to that in [3], and the maximum temperature range and mass content in a solution are given for each electrolyte. Considerable attention is given to high-temperature studies. Experimental data for many electrolytes were additionally obtained by the author, using original experimental techniques, which should make this book popular.

The following system of references is used in [1–3] and the next books [4, 5]. The complete references are given for each property and each electrolyte, and the absence of references means that original data are presented. Many data were refined by the author's experimental studies, and not all data from the references were mathematically processed.

The author will gratefully accept all comments and wishes of the reader.

Section I

1.1 Calculation of the Thermal Conductivity of Multicomponent Electrolyte Solutions

The thermal conductivity of multicomponent electrolyte solutions can be calculated by the formula [1–3]

$$\lambda = \lambda_0\left(1 + \sum_{i=1}^{k} \beta_i c_i\right) \qquad (1.1)$$

where λ is the thermal conductivity of solution, W/(m·K); λ_0 is the thermal conductivity of water, W/(m·K); β_i are coefficients obtained as a result of mathematical processing by the methods of regression analysis of available experimental data on thermal conductivity (Table 1.3); c_i is the mass content of electrolyte in the solution, %; and k is the number of components in the solution.

The thermal conductivity of water from 0 to 135°C is approximated by the polynomial

$$\lambda_0 = 10^{-3}(L_0 + L_1T_* + L_2T_*^{1.5} + L_3T_*^{2.5} + L_4T_*^3) \qquad (1.2)$$

where

$$L_0 = 560.971778 \qquad L_1 = 178.153112 \qquad L_2 = 59.731618$$
$$L_3 = -245.008302 \qquad L_4 = 124.973313$$

from 135 to 350°C, by the polynomial

$$\lambda_0 = 10^{-3} (L_0 + L_1 T_*^{2.5} + L_2 T_*^{3.5} + L_3 T_*^4 + L_4 T_*^5) \tag{1.3}$$

where

$$L_0 = 689.135856 \qquad L_1 = -12.717225 \qquad L_2 = 32.337897$$
$$L_3 = -23.977428 \qquad L_4 = 2.002973$$

with the root-mean-square error of calculation $S_\lambda = 0.29$ W/(m·K) and the mean relative error of calculation $\Delta = 0.03\%$.

In all instances, $T_* = 0.01t$, where t is the temperature, °C.

Example. Calculate the thermal conductivity of a $CaCl_2$–NaCl–H_2O solution at t = 50.8°C and the mass content of $CaCl_2$ 15.75% and of NaCl 5.25%. The experimental thermal conductivity of the solution is 0.612 W/(m·K) [6].

According to formula (1.2), the thermal conductivity of water is

$$T_* = 0.01 \cdot 50.8 = 0.508$$

$$\lambda_0 = 10^{-3}(560.971778 + 178.153112 \cdot 0.508 + 59.731618 \cdot 0.508^{1.5}$$
$$- 245.008302 \cdot 0.508^{2.5} + 124.973313 \cdot 0.508^3) = 0.644 \text{ W/(m·K)}$$

Coefficients β_i from Table 1.3 are $-2.0856 \cdot 10^{-3}$ for $CaCl_2$ and $-1.9004 \cdot 10^{-3}$ for NaCl.

According to equation (1.1), the thermal conductivity of the solution is

$$\lambda_0 = 0.644\,(1 - 2.0856 \cdot 10^{-3} \cdot 15.75 - 1.9004 \cdot 10^{-3} \cdot 5.25) = 0.617 \text{ W/(m·K)}$$

The mean relative error of calculation is 0.82%.

1.2 Calculation of the Surface Tension of Multicomponent Solutions

The surface tension of a multicomponent solution can be calculated by the formula [1–3]

$$\sigma = \sigma_0 + 0.049(1 - a_w) \tag{1.4}$$

where σ is the surface tension of the multicomponent electrolyte solution, N/m; σ_0 is the surface tension of water, N/m; and a_w is the activity of water in the multicomponent solution.

The surface tension everywhere over the region of existence of water can be calculated from the data in [7] with high accuracy:

$$\sigma_0 = B\left(\frac{T_0 - T}{T_0}\right)^m \left[1 + b\left(\frac{T_0 - T}{T_0}\right)\right] \tag{1.5}$$

where

$$B = 235.6 \cdot 10^{-3} \qquad T_0 = 647.15 \qquad m = 1.256 \qquad b = -0.625$$

References

1. Zaitsev, I. D., Zozulya, A. F., and Aseev, G. G., *Computer Calculation of the Physic-Chemical Properties of Inorganic Substances*, Khimiya, Moscow, 1983.
2. Zaitsev, I. D., and Aseev, G. G., *Physic-Chemical Properties of Binary and Multicomponent Solutions of Inorganic Substances, Handbook*, Khimiya, Moscow, 1988.
3. Zaytsev, I. D., Aseyev, G. G., *Properties of Aqueous Solutions of Electrolytes*, CRC Press: Boca Raton–Ann Arbor: London–Tokyo, 1992.
4. Aseyev, G. G., Zaytsev, I. D., *Volumetric Properties of Electrolyte Solutions: Estimation Methods and Experimental Data*, Begell House Inc. Publishers, New York, 1996.
5. Aseyev, G. G., *Thermal Properties of Electrolyte Solutions, Methods for Calculation of Multicomponent Systems and Experimental Data*, Begell House Inc. Publishers, New York, 1996.
6. Verba, O. I., Gruzdev, V. A., Genrikh, V. N., et al., Thermophysical Properties of Mixed Calcium Chloride-Sodium Chloride Aqueous Solutions, In: *Issledovanie teplofizicheskikh svoistv zhidkostei* (Study of the Thermophysical Properties of Liquids), Novosibirsk, 1977, pp. 40–59.
7. Rivkin, S. L., and Aleksandrov, A. A., *Thermophysical Properties of Water and Water Vapor*, Energiya, Moscow, 1980.
8. Misnar, A., *Thermal Conductivity of Solids, Liquids, Gases, and their Compositions*, Mir, Moscow, 1968.
9. Janielson, D. T., Irving, J. B., Tudhope, J. S., *Liquid Thermal Conductivity: Data Survey to 1973*, Edinburg, 1975.
10. *International Critical Tables of Numerical Data. Physics, Chemistry, and Technology*, 1929, Vol. 5.
11. Wakeham, W. A., The Application of the Transient Hot-Wire Method to the Measurement of the Thermal Conductivity of Aqueous Salt Solutions, In: *Proc. 10-th int. conf. IAPS*, Moscow, 1984, Vol. 2, p. 219.
12. Assael, M. J., Chariditou, E., Stassis, J. C., Wakeham, W. A., Absolute Measurements of Thermal Conductivity of some Aqueous Chloride Salt Solutions, *Ber. Bunsen. Phys. Chem.*, 1989, **93**, No. 8, 887.
13. Beresz, E., Bader, I., Connection between Electric Conductivity and Viscosity Aqueous and Hydrochloric Metal Chloride Solutions, *Acta Chim. Ac. Sci. Hungar.*, 1979, **100**, No. 1–4, 243–256.
14. Magomedov, U. B., Thermal Conductivity of Aqueous Solutions of Calcium and Magnesium Chlorides at High Parameters, In: *Fazovye perekhody i teplofizicheskie svoistva mnogokomponentnykh sistem* (Phase Transformations and the Thermophysical Properties of Multicomponent Systems), Inst. Fiz. Dag. Fil. AN SSSR, 1990, pp. 65–75.
15. Sugawara, M., Inaba, H., Seki, N., Saito, H., Thermal Conductivity of Aqua-Solvent with Low Solidification Point, In: *Proc. 1-st Asian Conference on Thermophysical Properties*, 1986, pp. 409–414.
16. Abdulaev, K. M., El'darov, V. S., and Manafov, Sh. M., On the Effect of Pressure on the Thermal Conductivity of Aqueous Electrolyte Solutions, *Izv. Vyssh. Uchebn. Zaved.*, Energetika, 1981, No. 5, 67.

17. White, W. R., et al., Computer-Controlled Measurement of Thermal Conductivities of Aqueous Salt Solutions, *J. Solut. Chem.*, 1975, **4**, No. 7, 557–570.
18. Losenicky, Z., The Thermal Conductivity of Aqueous Solutions of Alkali Hydroxides, *J. Phys. Chem.*, 1969, **73**, No. 2, 451–452.
19. Baruel, P., *On Transient Hot-Wire Measurements of the Thermal Conductivity of Electrolyte Solutions*, 1972.
20. Medzhidov, R. A., Thermal Conductivity of Hydrochloric Acid, In: *Teplofizicheskie svoistva chistykh veshchestv i vodnykh rastvorov elektrolitov* (Thermophysical Properties of Pure Substances and Aqueous Electrolyte Solutions), 1987, pp. 56–60.
21. Magomedov, U. B., Thermal Conductivity of Aqueous Electrolyte Solutions at High Pressures, In: *Geotermiya* (Geothermy), 1989, pp. 103–109.
22. Kalaev, S. N., Thermal Conductivity of Nitric Acid Aqueous Solutions, *Zh. Fiz. Khim.*, 1987, No. 12, 3332–3333.
23. Kalaev, S. N., Thermal Conductivity of Solutions in the HNO_3–H_2O System, In: *Teplofizicheskie svoistva chistykh veshchestv i vodnykh rastvorov elektrolitov* (Thermophysical Properties of Pure Substances and Aqueous Electrolyte Solutions), Makhachkala, 1987, p. 37.
24. Guseinov, G. G., Experimental Study of the Thermal Conductivity of Aqueous Solutions of Orthophosphoric and Orthoboric Acids at 293–368 K and 0.1 MPa, In: *Teplofizicheskie svoistva chistykh veshchestv i vodnykh rastvorov elektrolitov* (Thermophysical Properties of Pure Substances and Aqueous Electrolyte Solutions), Makhachkala, 1987, pp. 51–55.
25. Blankshtein, V. A., et al., Study in the Thermal Conductivity of Orthophosphoric Acid, *Vestnik MGU, Khimiya*, 1973, Ser. 2, **14**, No. 3, 365.
26. Rasulov, S. M., and Abdulkadirova, Kh. S., Thermal Conductivity of Sulfuric Acid Aqueous Solutions, In: *Geotermiya* (Geothermy), 1989, pp. 97–102.
27. Smirnova, E. G., Thermophysical Properties of K_2CO_3 and its Aqueous Solutions, *Available from VINITI*, 1978, No. 3240–78.
28. Davis, P. S., et al., Non-Steady-State, Hot Wire, Thermal Conductivity Apparatus, *J. Chem. Phys.*, 1971, **55**, No. 10, 4776–4783.
29. Nagasaka, Y., Suzuki, J., Nagashima, A., The Thermal Conductivity of Aqueous KCl Solutions at Pressures up to 40 MPa, In: *Proc. 10-th int. conf. IAPS*, Moscow, 1984, Vol. 2, p. 203.
30. Pepinov, R. I., and Guseinov, G. M., Thermal Conductivity of Potassium Chloride Aqueous Solutions at 20–340°C, *Inzh. Fiz. Zhurn.*, 1991, **60**, No. 5, 742.
31. Pepinov, R. I., and Guseinov, G. M., Experimental Study into the Thermal Conductivity of Potassium Chloride Aqueous Solutions at High Temperatures, *Teplofiz. Vys. Temp.*, 1991, **29**, No. 3, 605–607.
32. Alloush, A., Gosney, W. B., Wakeham, W. A., A Transient Hot-Wire Instrument for Thermal Conductivity Measurements in Electrically Conducting Liquids at Elevated Temperatures, *Int. J. Thermophys.*, 1982, **3**, No. 3, 225–235.
33. Kawamata, K., Nagasaka, Y., Nagashima, A., Measurements of the Thermal Conductivity of Aqueous LiBr Solutions at Pressures up to 40 MPa, *Int. J. Thermophys.*, 1988, **9**, No. 3, 317–329.
34. Dembecki, F., Gazinski, B., Formuly aproksymacyjne opisujace fizyczne wlasnosci wodnego roztworu bromsku litu, *Archiwum termodynamiki*, 1980, **1**, No. 3–4, 211–224.
35. Rastorguye, V. Yu. L., et al., Thermal Conductivity of Aqueous Solutions of Alkali Metals Halides, In: *Proc. 10-th int. conf. IAPS*, Moscow, 1984, Vol. 2, p. 210.
36. Magomedov, U. B., Thermal Conductivity of Aqueous Solutions of Magnesium and Zinc Sulfates at High Temperatures, In: *Termodinamika fazovykh ravnovesii i kriticheskie yavleniya* (Thermodynamics of Phase Equilibria and Critical Phenomena), Makhachkala, 1991, pp. 37–43.
37. Sehneider, W., Muller, H., Morke, K., Spezifische warme und warmeitfahigkeit des systems $(NH_4)_2SO_4$–H_2O, *Chem. Techn.*, 1982, **34**, No. 1, 31–32.
38. El'darov, V. S., Thermal Conductivity of Aqueous Solutions of Sodium Salts, *Zh. Fiz. Khim.*, 1986, No. 3, 603–605.
39. Nagasaka, Y., Nagashima, A., Absolute Measurement of the Thermal Conductivity of Electrically Conducting Liquids by the Transient Hot-Wire Method (Thermal Conductivity of an Aqueous NaCl Solution at High Pressure, *Thermal conductivity*, Plenum Press, **17**, No. 4, 1983, 307–314.
40. Nagasaka, Y., et al., Measurements of the Thermal Conductivity of Aqueous NaCl Solutions at Pressures up to 40 MPa, *Ber. Bunsenges. Phys. Chem.*, 1983, No. 87, 859–866.
41. Ozbek, H., Phillips, S. L., Thermal Conductivity of Aqueous Sodium Chloride Solutions from 20 to 330°C, *J. Chem. Eng. Data*, 1980, **25**, No. 3, 263.
42. Yusufova, V. D., Pepinov, R. I., et al., Thermal Conductivity of Aqueous NaCl Solutions, *Inzh. Fiz. Zh.*, 1975, **24**, No. 4, 600–605.

43. Ganie, V. Y. A., et al., The Thermal Conductivity of Water and Aqueous Solutions of NaCl in the Range of Temperatures 20–400°C and Pressures up to 100 MPa, In: *12 conf. of IAPS*, Prague, 1988, pp. 132–138.
44. Yusufova, V. D., et al., Thermal Conductivity of Aqueous NaCl Solutions, *Zh. Fiz. Khim.*, 1975, **49**, No. 10, 2677.
45. Ghosh, L., Das, K. P., Chattoraj, D. K., Thermodynamics of Adsorption of Inorganic Electrolytes at Air/Water and Oil/Water Interfaces, *J. Coll. Inter. Sci.*, 1988, **121**, No. 1, 278–288.
46. Weast, R. C., ed., *Handbook of Chemistry and Physics, 70-th edition*, CRC Press Inc., 1990, p. F–33.
47. Shevchuk, V. G., and Lebedinskii, B. I., The Li_2O_4–$Al_2(SO_4)_3$–H_2O System, *Zh. Neorg. Khim.*, 1967, **12**, No. 4, 1103–1105.
48. *International Critical Tables*, Ed. by Washburn, E. W., New York, 1928, pp. 463–474.
49. Nikol'skii, B. N., et al., Eds., Second Edition, *Handbook of Chemist*, Khimiya, Moscow, 1964, Vol. 3, pp. 726–727.
50. Gal'perin, N. I., Gurovich, B. M., and Dubinchik, K. Kh., Surface Tension of Aqueous KCl, $BaCl_2$, and $MgCl_2$ Solutions as a Function of the Temperature and Concentration, *Zh. Prikl. Khim.*, 1972, **45**, No. 6, 1354–1355.
51. Bellard, R. E., Jones J., Read, D., et. al., The He (I) Photoelectron Spectra of Aqueous Solution of Calcium Salts, *Chem. Phys. Lett.*, 1987, **134**, No. 2, 177–180.
52. Bogatykh, S. A., Evnovich, I. D., and Sidorov, V. M., Study of the Surface Tension of Aqueous LiCl, LiBr, and $CaCl_2$ Solutions under the Conditions of Gas Desiccation, *Zh. Prikl. Khim.*, 1966, **39**, No. 11, 2590–2591.
53. Bogatykh, S. A., Dependences for Calculation of the Physical Properties of Aqueous Solutions of Moisture Absorbents such as LiCl, LiBr, and $CaCl_2$, *Zh. Prikl. Khim.*, 1974, **47**, No. 11, 2553–2554.
54. Gurovich, B. M., Gorelov, A. Ya, and Mezheritskii, S. M., *Tables of the Thermophysical Properties of Aqueous Solutions of Some Inorganic Substances*, Second Edition, Tashkent, 1987.
55. Gurovich, B. M., et al., *Tables of the Thermophysical Properties of Aqueous Solutions of Some Inorganic Substances*, TPI, Tashkent, 1975.
56. Celeda, J., Skramovsky, S., Zilkova, J., The Metachors of Polyvalent and Associated Electrolytes in Aqueous Solutions, *Collect. Czech. Chem. Commun.*, 1984, **49**, No. 5, 1079–1089.
57. Levichev, S. A., and Kiseleva, T. E., Surface Tension of Aqueous Solutions of Sodium Dodecylsulfate and Cobalt Sulfate, *Vestnik MGU*, Ser., 4, **3**, No. 18, 114–116.
58. Kochurova, N. N., Rusanov, F. I., and Mishukov, V. F., Dynamic Surface Tension of NaCl and CsCl Aqueous Solutions, *Dokl. Akad. Nauk SSSR*, 1976, **229**, No. 5, 1152–1154.
59. Komarova, T. A., and Akhutin, A. V., Presolidification State of Cesium Chloride in Aqueous Solutions, *Zh. Fiz. Khim.*, 1973, **47**, No. 12, 3059–3062.
60. Jones G., Ray, W. A., The Surface Tension of Solutions of Electrolytes as a Function of the Concentration, a Differential Method for Measuring Relative Surface Tension, *J. Amer. Chem. Soc.*, 1937, **59**, 187–198.
61. Levichev, S. A., and Lomovtsev, Yu. O., Surface Tension of Aqueous Solutions of Sodium Dodecylsulfate and Copper Sulfate, *Vestnik MGU*, 1987, Ser., 4, **2**, No. 11, 115–118.
62. Shchedrina, A. P., Mel'nichenko, L. M., and Ozerova, M. P., The $FeCl_2$–$MgCl_2$–H_2O System at 70°C, *Zh. Neorg. Khim.*, 1970, **25**, No. 9, 2504–2506.
63. Hard, S., Johansson, K., The Surface Tension of Concentrated Aqueous Solutions of 1.1 – Electrolytes Measured by Means of Wilhelmy and Laser Light Scattering Methods, *J. Colloid and Interface Sci.*, 1977, **60**, No. 3, 467–472.
64. Granzhan, V. A., and Laktionov, S. K., Density, Viscosity, and Surface Tension of Nitric Acid Aqueous Solutions, *Zh. Fiz. Khim.*, 1975, **49**, No. 9, 2461.
65. Gruzdev, V. A., and Kiselev, E. Ya., Experimental Study into the Surface Tension of Aqueous Electrolyte Solutions, In: *Issledovanie teplofizicheskikh svoistv* (Study into Thermophysical Properties), Kutateladze, S. S., Ed., Novosibirsk, 1974, pp. 37–52.
66. Aveyard R., Saleem, S. M., Interfacial Tensions of Alkaline Aqueous Electrolyte Solutions, *J. Chem. Soc. Faraday Trans. I*, 1976, **72**, No. 7, 1609–1617.
67. Lakinskaya, N. M., Surface Tension of Aqueous Solutions of Inactivated Substances, *Izv. Vyssh. Uchebn. Zaved., Khim. i Khim. Tekhn.*, 1961, **4**, No. 4, 604–610.
68. Karov, Z. G., Mirzoev, R. S., Kyarov, A. A., et al., The K_2MoO_4–KBr–H_2O System at 25°C, *Zh. Neorg. Khim.*, 1989, **34**, No. 10, 2668–2673.
69. Gurovich, B. M., Frolova, T. M., and Mezheritskii, S. M., Coefficient of Surface Tension of Aqueous K_2CO_3, KOH, $(NH_4)_2SO_4$, and NH_4NO_3 Solutions, *Zh. Prikl. Khim.*, 1983, **56**, No. 11, 2612–2614.
70. Celeda, J., Zilkova, J., Surface Tension as Evidence for Complex Formation in Strongly Concentrated Electrolyte Solutions, *Collect. Czech. Chem. Commun.*, 1977, **42**, No. 9, 2728–2736.

71. Karov, Z. G., Ashkhotov, V. G., and Semenova, S. B., The K_2CO_3–K_2MoO_4–H_2O System (25°C), *Zh. Neorg. Khim.*, 1970, **25**, 2580–2585.
72. Celeda, J., Skramovsky, S., The Metachor as a Characteristic of the Association of Electrolytes in Aqueous Solutions, *Collect. Czech. Chem. Commun.*, 1984, **49**, No. 5, 1061–1078.
73. Johansson, K., Eriksson, J. S., *Y* and *dY/dT* Measurements on Aqueous Solutions of 1.1 – Electrolytes, *J. Colloid and Interface Sci.*, 1974, **49**, No. 3, 469–480.
74. Faktor, E. A., and Rusanov, A. I., Thermodynamic Study of the Surface Layers of Liquid Solutions, V. The NaCl–H_2O, NaI–H_2O, KCl–H_2O, and KI–H_2O Systems, *Kolloidn. Zh.*, 1973, **35**, No. 5, 928–934.
75. Jarvis, N. L., Scheiman, M. A., Surface Potentials of Aqueous Electrolyte Solutions, *J. Phys. Chem.*, 1968, **72**, No. 1, 74–78.
76. Tornberg, E., A Surface Tension Apparatus According to the Drop Volume Principle, *J. Coll. Interf. Sci*, 1977, **60**, No. 1, 50–53.
77. Bhuiyan, L. B., Bratko, D., Outhwaite, C. W., Electrolyte Surface Tension in the Modified Poisson-Boltzmann Approximation, *J. Phys. Chem.*, 1991, **95**, No. 1, 336–340.
78. Jones G., Frizzell, L. D., A Theoretical and Experimental Analysis of the Capillary Rise Method for Measuring the Surface Tension of the Solutions of Electrolytes, *J. Chem. Phys.*, 1940, **8**, 986–997.
79. Kochurova, N. N., and Grebenshchikov, N. R., Study into the Dynamic Surface Tension of Aqueous Solutions of Sodium and Potassium Iodides, *Vestn. Leningr. Univ.*, 1985, No. 11, 104–107.
80. Ripoche, P., Rolin, M., Determination des caracteristiques physicochimiques des solution aqueuses concentrees d'hydroxyde de potassium jusqu'a 180°C, III. Les tensions superficielles et la solubilite de l'oxygene, *Bull. Soc. Chim. France*, 1980, No. 9–10, I-386 – I-392.
81. Karov, Z. G., Perel'man, F. M., and Rogozhina, G. N., The $NaNO_3$–Na_2WO_4–H_2O System at 25°C, *Zh. Neorg. Khim.*, 1965, 10, No. 5, 1233–1236.
82. Karov, Z. G., Khochuev, I. Yu., Lepeshkov, I. N., and Karaeva, L. N., Solubility and Some Properties of Saturated Solutions in the K_2WO_4–KOH–H_2O System at 25°C, *Zh. Neorg. Khim.*, **34**, No. 11, 2942–2947.
83. Feldkamp, K., Die Oberflachenspannung wassriger NaOH- und KOH-Losungen, *Chem. Ing. Techn.*, 1969, **45**, No. 21, 1181–1183.
84. Yao, W., Bjurstrom, H., Setterwall, F., Surface Tension of Lithium Bromide Solutions with Heat-Transfer Additives, *J. Chem. Eng. Data*, 1991, **36**, 96–98.
85. Zyukanov, V. M., Baranenko, A. V., and Orekhov, I. I., Surface Tension of an Aqueous Lithium Bromide Solution with a Surfactant, In: *Kholodil'nye mashiny i transformatory, Termogazodinamicheskie protsessy kholodil'nykh mashin* (Refrigerating Machines and Transformers, Thermal and Gas-Dynamic Processes in Refrigerating Machines), Leningrad, 1984, pp. 3–7.
86. Faktor, E. A., and Rusanov, A. I., Thermodynamic Study into the Surface Layers of Liquid Solutions, V. The LiCl–H_2O and NH_4Cl–H_2O Systems, *Kolloidn. Zh.*, 1973, **35**, No. 6, 1117–1122.
87. Vemyra, T., Hasaba, S., Studies of the Lithium-Bromide-Water Absorption Refrigerating Machine, *Techn. Reports of Kansai University*, 1964, **6**, 31–55.
88. Ershov, Yu. G., and Rudakov, S. V., On the Determination of the Surface Tension of Solutions, *Izv. Vyssh. Uchebn. Zaved., Khim. i Khim. Tekhn.*, 1978, **21**, No. 7, 1076–1077.
89. Jones, G., Ray, W. A., The Surface Tension of Solutions of Electrolytes as a Function of the Concentration, IV. Magnesium Sulfate, *J. Amer. Chem. Soc.*, 1942, **64**, 2744–2745.
90. Konig, An., Emons, H. H., Crystallization Kinetic of $MgSO_4 \cdot 7H_2O$ in Presence of Tenside, *Cryst. Res. Technol.*, 1988, **23**, No. 3, 319–326.
91. Lowry, S. A., et al., Surface Tension Measurements of Aqueous Ammonium Chloride (NH_4Cl), *J. Cryst. Growth*, 1989, **96**, No. 4, 774–776.
92. Karov, Z. G., Khochuev, I. Yu., Kyarov, A. A., and Mirzoev, R. S., Solubility and the Physico-Chemical Properties of Saturated Solutions in the Na_2MoO_4–NaBr–H_2O System at 25°C, *Zh. Neorg. Khim.*, 1988, **33**, No. 3, 780–785.
93. Boucher, E. A., Grinchuk, T. M., Zettlemoyer, A. C., Measurement of Surface Tension of Surfactant Solutions, *J. Colloid and Surface Sci.*, 1967, **23**, No. 3, 600–603.
94. Gel'perin, N. I., Gurovich, B. M., and Dubinchik, K. Kh., Surface Tension of Aqueous Solutions of Some Inorganic Substances as a Function of the Concentration and Temperature, *Zh. Prikl. Khim.*, 1969, **42**, No. 1, 214–216.
95. Jones, G., Ray, W. A., The Surface Tension of Solutions of Electrolytes as a Function of the Concentration, III. Sodium Chloride, *J. Amer. Chem. Soc.*, 1941, **63**, No. 12, 3262–3.
96. Karov, Z. G., Kyarov, A. A., Urusova, R. Kh., and Shakov, Z. M., Phase Equilibrium and the Properties of Saturated Solutions in the $NaMoO_4$–NaI–H_2O System at 25°C, *Zh. Neorg. Khim.*, 1987, **32**, No. 2, 473–479.

97. Protsenko, P. I., et al., Solubility and the Properties of Solutions in the KNO_2–K_3PO_4–H_2O and $NaNO_2$–Na_3PO_4–H_2O Systems at 25°C, *Zh. Prikl. Khim.*, 1975, No. 5, 1055–1059.
98. Glazyrina, L. N., and Katyshev, S. F., Density and the Surface Tension of Aqueous Sodium Sulfide Solutions, *Zh. Prikl. Khim.*, 1986, **59**, No. 3, 665–667.
99. Novoselov, A. G., et al., Study into the Physical Properties of Aqueous Sodium Sulfite Solutions, *Zh. Prikl. Khim.*, 1989, No. 5, 1144.
100. Vyaseleva, G. Ya., Gvozdeva-Karelina, A. E., and Barabanov, V. P., On the Effect of Electrolysis on the Surface Tension and the Physico-Chemical Properties of Aqueous Salt Solutions, *Elektrokhimiya*, 1988, **24**, No. 6, 813–815.
101. Skramovsky, S., Celeda, J., Metachors and Dissociation of Salts of Oxo Acids of Group VI Heavy Metals in Aqueous Solutions, *Collect. Czech. Chem. Commun.*, 1985, **50**, No. 9, 1917–1927.
102. Pepinov, R. I., and Zokhrabbekova, G. Yu., Surface Tension of Aqueous Sodium Sulfate Solutions, In: *Teplofizicheskie svoistva rabochikh tel energetichaskikh ustanovok* (Thermophysical Properties of Working Fluids in Power Plants), ENIN, Moscow, No. 61, 1977, 95–98.
103. Levichev, S. A., and Erokhina, L. Yu., Surface Tension of Aqueous Solutions of Sodium Dodecylsulfate and Nickel Sulfate, *Vestnik MGU*, Ser. 4, 1988, **2**, No. 11, 102–105.