

Journal of Molecular Liquids 118 (2005) 77-88



www.elsevier.com/locate/molliq

## Volumetric and thermal properties of some aqueous electrolyte solutions Part 5. Potassium bromide and potassium iodide 0.1, 0.5, and 1.0 mol kg<sup>-1</sup> solutions at temperatures from T=278.15 to 338.15 K

Alexander Apelblat<sup>a,\*</sup>, Emanuel Manzurola<sup>b</sup>

<sup>a</sup>Department of Chemical Engineering, Ben Gurion University of the Negev, Beer Sheva, 84105 Israel <sup>b</sup>Department of Research and Development, Negev Academic College of Engineering, Beer Sheva, 84100 Israel

Available online 1 September 2004

## Abstract

Precise densities of potassium bromide (0.10014, 0.49997, and 0.99962 mol kg<sup>-1</sup>) and potassium iodide (0.10008, 0.50551, and 0.99993 mol kg<sup>-1</sup>) aqueous solutions were determined at 1-K temperature intervals from T=278.15 to T=338.15 K, and they are compared with the literature data. Measured densities were expressed as polynomials of temperature, and these polynomials were used in an evaluation of the apparent molar volumes, the cubic expansion coefficients, the apparent molar expansibilities, and the second derivatives of volume with respect to temperature, which are interrelated with the derivatives of isobaric heat capacities with respect to pressure. In the framework of changes in the structure of water, these derivatives are discussed for potassium bromide and potassium iodide solutions.

© 2004 Elsevier B.V. All rights reserved.

Keywords: Potassium bromide; Potassium iodide; Electrolytes

## 1. Introduction

A quantitative description of the volumetric and thermal properties of water and aqueous solutions of electrolytes is of prime importance for various thermodynamic calculations connected with natural and industrial processes and helps in the elucidation of the structure of water and ion-water and ion-ion interactions. Extensive surveys on the subject (see, for example, International Critical Tables [1], Landolt–Börnstein [2], Lobo [3], and Aseyev–Zaytsev [4] tabulations) reveal that these properties are usually known as a function of concentration at one, sometimes at few fixed temperatures but not at constant molality m to permit direct differentiation with respect to temperature T. This situation is changed now,

\* Corresponding author.

*E-mail addresses:* apelblat@bgumail.bgu.ac.il (A. Apelblat), emanuel@nace.ac.il (E. Manzurola).

because volumetric properties via density determinations are easily available over a wide temperature range due to the appearance of commercial densimeters (vibrating tubes) equipped with a built-in thermoelectric Peltierelement module for continuous heating or cooling of the sample in a thermostated U-tube.

In a series of our papers [5–8], densities of water and aqueous solutions of electrolytes at fixed molalities 0.1, 0.5, and 1.0 mol kg<sup>-1</sup> were determined at closely spaced 1-K temperature intervals, usually from *T*=277.15 to 343.15 K (water, NaCl, and KCl [5], LiCl [6], NaBr [7], disodium and dipotassium tartrates [8], see also Ref. [9] for coefficients of the fitting equations of the type (1) for KBr, KI, and other solutions). From these densities,  $\rho(T;m)$ , the cubic expansion coefficients,  $\alpha(T;m)$ , the apparent molar volumes,  $V_{2,\phi}(T;m)$ , the apparent molar expansibilities,  $V_{2,E}(T;m)$ , and the second derivatives of volume with respect to temperature,  $[(\partial^2 V)/(\partial T^2)]_{P,m}$  were reported. The last quantity is directly related to the change of molar heat

<sup>0167-7322/</sup>\$ - see front matter © 2004 Elsevier B.V. All rights reserved. doi:10.1016/j.molliq.2004.07.017

Table 1 Experimental densities  $\rho(T;m)$  of aqueous solutions of potassium bromide and potassium iodide as a function of  $\theta=T/K-273.15$ 

$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	1.0 <sup>f</sup>
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	1 11 50-
5 1.00866 1.04254 1.08275 1.01220 1.06071   6 1.00864 1.04243 1.08256 1.01217 1.06060   7 1.00859 1.04230 1.08236 1.01212 1.06045   8 1.00852 1.04214 1.08198 1.01201 1.06015   10 1.00834 1.04188 1.08173 1.01191 1.05996   11 1.00823 1.04170 1.08150 1.01180 1.05978   12 1.00812 1.04153 1.08127 1.01168 1.05978   13 1.00798 1.04135 1.08102 1.01154 1.05937   14 1.00767 1.04095 1.08050 1.01125 1.05892   16 1.00750 1.04073 1.08023 1.01048 1.05846   18 1.00715 1.04027 1.07967 1.01088 1.05846   18 1.00713 1.03977 1.01047 1.05793   20 1.00673 1.03947 1.07873	1.11.60.5
6 1.00864 1.04243 1.08256 1.01217 1.06060   7 1.00859 1.04230 1.08236 1.01212 1.06045   8 1.00852 1.04214 1.08214 1.01205 1.06030   9 1.00844 1.04205 1.08198 1.01201 1.06015   10 1.00834 1.04170 1.08150 1.01180 1.05978   12 1.00812 1.04135 1.08127 1.01168 1.05978   13 1.00798 1.04135 1.08102 1.01154 1.05937   14 1.00767 1.04095 1.08007 1.01139 1.05917   15 1.00767 1.04095 1.08023 1.01188 1.05869   17 1.00734 1.04027 1.07967 1.01069 1.05821   19 1.00694 1.04022 1.07937 1.01047 1.05793   20 1.00673 1.03977 1.07088 1.05766   21 1.00626 1.03921 1.07873	1.11.000
71.008591.042301.082361.012121.0604581.008521.042141.082141.012051.0603091.008441.042051.081981.012011.06015101.008341.041881.081731.011911.05996111.008231.041701.081501.011801.05978121.008121.041531.081271.011681.05978131.007981.041351.081021.011541.05937141.007841.040551.080771.011391.05917151.007671.040951.080501.011251.05892161.007501.040731.080231.011081.05869171.007341.040271.079671.010691.05821191.006941.040271.079371.010471.05793201.006731.039771.079081.010251.05766211.006661.039211.078421.009781.05706231.006031.038921.078081.009531.05676241.005801.038711.077791.008471.05541251.005531.038371.077441.008741.05544261.005251.038041.077831.008471.05541271.004991.037441.076381.007661.05442311.003731.036661.075191.007641.05405321.004451.0352	1.11681
8 1.00852 1.04214 1.08214 1.01205 1.06030   9 1.00844 1.04205 1.08198 1.01201 1.06015   10 1.00834 1.04170 1.08150 1.01180 1.05996   11 1.00823 1.04170 1.08150 1.01180 1.05978   12 1.00812 1.04135 1.08102 1.01154 1.05937   14 1.00784 1.04115 1.08077 1.01139 1.05917   15 1.00767 1.04095 1.08050 1.01125 1.05892   16 1.00750 1.04073 1.08023 1.0108 1.05869   17 1.00734 1.04027 1.07967 1.01069 1.05821   19 1.00649 1.03977 1.07908 1.01025 1.05766   21 1.00649 1.03947 1.07833 1.0102 1.05705   22 1.00630 1.03892 1.07842 1.00978 1.05676   24 1.00580 1.03893	1.11661
9 1.00844 1.04205 1.08198 1.01201 1.06015   10 1.00834 1.04188 1.08173 1.01191 1.05996   11 1.00823 1.04170 1.08150 1.01180 1.05978   12 1.00812 1.04153 1.08127 1.01168 1.05978   13 1.00798 1.04135 1.08077 1.01139 1.05917   15 1.00767 1.04095 1.08050 1.01125 1.05892   16 1.00750 1.04073 1.08023 1.01108 1.05869   17 1.00734 1.04052 1.07967 1.01069 1.05821   19 1.00694 1.04027 1.07967 1.01047 1.05793   20 1.00673 1.03977 1.07908 1.01025 1.05766   21 1.00649 1.03947 1.07873 1.01002 1.05766   23 1.00603 1.03892 1.07842 1.00978 1.05706   23 1.00553 1.03803 <td>1.11638</td>	1.11638
101.008341.041881.081731.011911.05996111.008231.041701.081501.011801.05978121.008121.041531.081271.011681.05937141.007981.041351.080771.011391.05917151.007671.040951.080501.011251.05892161.007501.040731.080231.011081.05869171.007341.040521.079961.010881.05846181.007151.040271.079671.010691.05821191.006941.040221.079371.010471.05793201.006731.039771.079081.010251.05766211.006491.039471.078731.010021.05735221.006261.039211.078421.009781.05706231.006031.038921.078081.009281.05649251.005531.038681.077791.009281.05649251.005531.038041.077081.008741.05584271.004991.037441.076731.008471.05581281.004701.037441.076731.008471.05551281.004701.037441.07581.007561.05477301.004051.036611.074811.006591.05331341.002781.035321.074021.006591.05331341.002781.03	1.11611
111.008231.041701.081501.011801.05978121.008121.041531.081271.011681.05958131.007981.041351.081021.011541.05937141.007841.041151.080771.011391.05917151.007671.040951.080501.011251.05892161.007501.040731.080231.011081.05869171.007341.040521.079671.010691.05821191.006941.040271.079671.010471.05793201.006731.039771.079081.010251.05766211.006491.039471.078731.010021.05735221.006261.039211.078421.009781.05706231.006031.038921.078081.009781.05649251.005531.038681.077791.009281.05649251.005531.038041.077081.008741.05584271.004991.037441.076731.008471.05551281.004701.037441.076731.008471.05541291.004351.037081.075581.007861.05477301.004051.036611.074811.006591.05331341.002781.03521.074021.006591.05331341.002781.035321.074021.006591.05255361.00241.034	1.11591
121.008121.041531.081271.011681.05958131.007981.041351.081021.011541.05937141.007841.041151.080771.011391.05917151.007671.040951.080501.011251.05892161.007501.040731.080231.011081.05869171.007341.040521.079961.010881.05846181.007151.040271.079671.010691.05821191.006941.040021.079371.010471.05793201.006731.039771.079081.010251.05766211.006491.039471.078731.010021.05735221.006261.039211.078421.009781.05706231.006031.038921.078081.009781.05649251.005531.038681.077791.009281.05649251.005531.038041.077081.008741.05584271.004991.037441.076731.008471.05551281.004701.037441.076381.008181.05517291.004351.036611.074811.006921.05331341.002781.035221.074021.006591.05331341.002781.035211.074221.006591.05255351.002431.034511.072771.005161.05213381.001511.0	1.11563
131.007981.041351.081021.011541.05937141.007841.041151.080771.011391.05917151.007671.040951.080501.011251.05892161.007501.040731.080231.011081.05869171.007341.040521.079961.010881.05846181.007151.040271.079671.010691.05821191.006941.040021.079371.010471.05793201.006731.039771.079081.010251.05766211.006491.039471.078731.010021.05735221.006261.039211.078421.009781.05706231.006031.038921.078081.009281.05649251.005531.038371.077441.009021.05616261.005251.038041.077081.008741.05584271.004991.037441.076731.008471.05551281.004701.037441.076381.008181.05517291.004351.036611.075951.007861.05477301.004051.036611.074811.006921.05331341.002781.035221.074021.006591.05255351.002431.034511.072771.005161.05251381.001701.034151.072771.005161.05251381.001311.0	1.11537 1.11510
141.007841.041151.080771.011391.05917151.007671.040951.080501.011251.05892161.007501.040731.080231.011081.05869171.007341.040521.079961.010881.05846181.007151.040271.079671.010691.05821191.006941.040021.079371.010471.05793201.006731.039771.079081.010251.05766211.006491.039471.078731.010021.05735221.006261.039211.078421.009781.05676241.005801.038681.077791.009281.05649251.005531.038371.077441.009021.05616261.005251.038041.077081.008741.05584271.004991.037441.076731.008471.05551281.004701.037441.076381.008181.05517291.004351.036611.075951.007861.05477301.004051.036611.07581.006251.05295311.003731.036361.075191.006251.05295351.002431.035321.074021.006591.05331341.002781.035321.074021.005531.05251381.001311.03731.072331.004791.05130391.00241.0345	1.11310
151.007671.040951.080501.011251.05892161.007501.040731.080231.011081.05869171.007341.040521.079961.010881.05846181.007151.040271.079671.010691.05821191.006941.040021.079371.010471.05793201.006731.039771.079081.010251.05766211.006491.039471.078731.010021.05735221.006261.039211.078421.009781.05676241.005801.038681.077791.009281.05649251.005531.038371.077441.009021.05616261.005251.038041.077081.008741.05584271.004991.037741.076731.008471.05551281.004701.037441.076381.008181.05517291.004351.036611.075951.007861.05477301.004051.036711.075881.007241.05405311.003731.036661.074421.006591.05331341.002781.035321.074021.006591.05255361.002441.03731.072771.005161.05173381.001311.03731.072331.004791.05130391.000541.032491.070991.003621.05043411.000551.032	1.11453
16 $1.00750$ $1.04073$ $1.08023$ $1.01108$ $1.05869$ $17$ $1.00734$ $1.04052$ $1.07996$ $1.01088$ $1.05846$ $18$ $1.00715$ $1.04027$ $1.07967$ $1.01069$ $1.05821$ $19$ $1.00694$ $1.04002$ $1.07937$ $1.01047$ $1.05793$ $20$ $1.00673$ $1.03977$ $1.07908$ $1.01025$ $1.05766$ $21$ $1.00649$ $1.03947$ $1.07873$ $1.01002$ $1.05735$ $22$ $1.00626$ $1.03921$ $1.07842$ $1.00978$ $1.05706$ $23$ $1.00603$ $1.03892$ $1.07808$ $1.00953$ $1.05676$ $24$ $1.00580$ $1.03868$ $1.07779$ $1.00928$ $1.05649$ $25$ $1.00553$ $1.03837$ $1.07744$ $1.00902$ $1.05616$ $26$ $1.00525$ $1.03804$ $1.07708$ $1.00874$ $1.05584$ $27$ $1.00499$ $1.03744$ $1.07673$ $1.00847$ $1.05551$ $28$ $1.00470$ $1.03744$ $1.07638$ $1.00818$ $1.05517$ $29$ $1.00435$ $1.03671$ $1.07588$ $1.00756$ $1.05442$ $31$ $1.00373$ $1.03661$ $1.07191$ $1.00724$ $1.05405$ $32$ $1.00341$ $1.03601$ $1.07481$ $1.00692$ $1.05371$ $33$ $1.00309$ $1.03522$ $1.07402$ $1.00659$ $1.05255$ $36$ $1.00243$ $1.03451$ $1.07217$ $1.00516$ $1.05255$ $36$	1.11423
18 1.00715 1.04027 1.07967 1.01069 1.05821   19 1.00694 1.04002 1.07937 1.01047 1.05793   20 1.00673 1.03977 1.07908 1.01025 1.05766   21 1.00649 1.03947 1.07873 1.01002 1.05735   22 1.00626 1.03921 1.07842 1.00978 1.05706   23 1.00603 1.03892 1.07808 1.00973 1.05676   24 1.00580 1.03868 1.07779 1.00928 1.05649   25 1.00553 1.03837 1.07744 1.00902 1.05616   26 1.00525 1.03804 1.07708 1.00874 1.05584   27 1.00499 1.03744 1.07673 1.00847 1.05551   28 1.00470 1.03744 1.07588 1.00756 1.05442   31 1.00405 1.03661 1.07588 1.00756 1.05442   31 1.00373 1.03636 <td>1.11392</td>	1.11392
191.006941.040021.079371.010471.05793201.006731.039771.079081.010251.05766211.006491.039471.078731.010021.05735221.006261.039211.078421.009781.05706231.006031.038921.078081.009531.05676241.005801.038681.077791.009281.05649251.005531.038371.077441.009021.05616261.005251.038041.077081.008741.05584271.004991.037741.076731.008471.05551281.004701.037441.076381.008181.05517291.004351.037081.075951.007861.05442311.003731.036611.075191.007241.05465321.003411.036011.074811.006921.05367331.002781.035221.074021.006591.05255361.002431.034511.072771.005161.05211371.001701.034151.072771.005161.05173381.001311.032911.071441.004031.05043411.000541.032911.071441.004031.05043411.00151.032491.070991.003621.05043411.00151.032491.070991.002801.04958430.999331.031	1.11362
201.006731.039771.079081.010251.05766211.006491.039471.078731.010021.05735221.006261.039211.078421.009781.05706231.006031.038921.078081.009531.05676241.005801.038681.077791.009281.05649251.005531.038371.077441.009021.05616261.005251.038041.077081.008741.05584271.004991.037741.076731.008471.05551281.004701.037441.076381.008181.05517291.004351.036711.075581.007861.05477301.004051.036711.075581.007661.05442311.003731.036611.074811.006921.05367331.003091.035661.074421.006591.05331341.002781.035321.074021.006591.05255361.002041.034511.072771.005161.05173381.001311.033311.071891.004411.05086401.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05043411.00151.032491.070991.003621.05043411.00151.032491.070661.002801.04958430.999331.031	1.11329
211.006491.039471.078731.010021.05735221.006261.039211.078421.009781.05706231.006031.038921.078081.009531.05676241.005801.038681.077791.009281.05649251.005531.038371.077441.009021.05616261.005251.038041.077081.008741.05584271.004991.037741.076731.008471.05551281.004701.037441.076381.008181.05517291.004351.037081.075951.007861.05477301.004051.036711.075581.007561.05442311.003731.036361.075191.007241.05405321.003411.036011.074811.006921.05367331.002781.035321.074021.006591.05255361.002041.034511.072771.005161.05173381.001311.033731.072331.004791.05130391.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070561.002201.04958430.999331.031631.070061.002801.04910440.998921.031191.069601.002381.04864	1.11296
221.006261.039211.078421.009781.05706231.006031.038921.078081.009531.05676241.005801.038681.077791.009281.05649251.005531.038371.077441.009021.05616261.005251.038041.077081.008741.05584271.004991.037741.076731.008471.05551281.004701.037441.076381.008181.05517291.004351.037081.075951.007861.05477301.004051.036711.075581.007561.05442311.003731.036361.075191.007241.05405321.003411.036011.074811.006921.05367331.003091.035661.074421.006591.05255361.002041.034511.072771.005161.05173381.001311.033731.072331.004791.05130391.000921.033111.071891.004411.05086401.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070561.002211.04958430.999331.031631.070061.002801.04910440.998921.031191.069601.002381.04864	1.11262
231.006031.038921.078081.009531.05676241.005801.038681.077791.009281.05649251.005531.038371.077441.009021.05616261.005251.038041.077081.008741.05584271.004991.037741.076731.008471.05551281.004701.037441.076381.008181.05517291.004351.037081.075951.007861.05477301.004051.036711.075581.007561.05442311.003731.036361.075191.007241.05405321.003411.036011.074811.006921.05367331.003091.035661.074421.006591.05331341.002781.035321.074021.005531.05255361.002041.034511.072771.005161.05173381.001311.033731.072331.004791.05130391.000921.033111.071891.004411.05086401.000541.032911.071441.004031.05043411.000151.032491.070991.003211.04958430.999331.031631.070661.002801.04910440.998921.031191.069601.002381.04864	1.11224
241.005801.038681.077791.009281.05649251.005531.038371.077441.009021.05616261.005251.038041.077081.008741.05584271.004991.037741.076731.008741.05551281.004701.037441.076381.008181.05517291.004351.037081.075951.007861.05477301.004051.036711.075581.007561.05442311.003731.036361.075191.007241.05405321.003411.036011.074811.006921.05367331.003091.035661.074421.006591.05295351.002431.034941.073621.005891.05255361.002041.034511.072771.005161.05173381.001311.033731.072331.004791.05130391.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070561.002211.04958430.999331.031631.070061.002801.04910440.998921.031191.069601.002381.04864	1.11190
251.005531.038371.077441.009021.05616261.005251.038041.077081.008741.05584271.004991.037741.076731.008741.05551281.004701.037441.076381.008181.05517291.004351.037081.075951.007861.05477301.004051.036711.075581.007561.05442311.003731.036361.075191.007241.05405321.003411.036011.074811.006921.05367331.003091.035661.074421.006591.05295351.002431.034941.073621.005891.05255361.002041.034511.072771.005161.05173381.001311.033731.072331.004791.05130391.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070561.002111.04958430.999331.031631.070661.002801.04910440.998921.031191.069601.002381.04864	1.11152
261.005251.038041.077081.008741.05584271.004991.037741.076731.008471.05551281.004701.037441.076381.008181.05517291.004351.037081.075951.007861.05477301.004051.036711.075581.007561.05442311.003731.036361.075191.007241.05405321.003411.036011.074811.006921.05367331.003091.035661.074421.006591.05231341.002781.035321.074021.006591.05295351.002041.034511.073181.005531.05211371.001701.034151.072771.005161.05173381.001311.033731.072331.004791.05130391.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070561.002211.04958430.999331.031631.070661.002801.04910440.998921.031191.069601.002381.04864	1.11114
271.004991.037741.076731.008471.05551281.004701.037441.076381.008181.05517291.004351.037081.075951.007861.05477301.004051.036711.075581.007561.05442311.003731.036361.075191.007241.05405321.003411.036011.074811.006921.05367331.003091.035661.074421.006591.05231341.002781.035321.074021.006591.05295351.002041.034941.073621.005891.05255361.002041.034511.072771.005161.05173381.001311.033731.072331.004791.05130391.000921.033111.071891.004411.05086401.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070661.002801.04910440.998921.031191.069601.002381.04864	1.11078 1.11038
281.004701.037441.076381.008181.05517291.004351.037081.075951.007861.05477301.004051.036711.075581.007561.05442311.003731.036361.075191.007241.05405321.003411.036011.074811.006921.05367331.003091.035661.074421.006591.05331341.002781.035321.074021.006251.05295351.002041.034941.073621.005891.05255361.002041.034511.072771.005161.05173381.001311.033731.072331.004791.05130391.000921.033111.071891.004411.05086401.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070561.002111.04958430.999331.031631.070661.002801.04910440.998921.031191.069601.002381.04864	1.11058
291.004351.037081.075951.007861.05477301.004051.036711.075581.007561.05442311.003731.036361.075191.007241.05405321.003411.036011.074811.006921.05367331.003091.035661.074421.006591.05331341.002781.035321.074021.006591.05295351.002041.034941.073621.005891.05255361.002041.034511.072771.005161.05173381.001311.033731.072331.004791.05130391.000921.033111.071891.004411.05086401.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070561.002211.04958430.999331.031631.070661.002801.04910440.998921.031191.069601.002381.04864	1.10952
301.004051.036711.075581.007561.05442311.003731.036361.075191.007241.05405321.003411.036011.074811.006921.05367331.003091.035661.074421.006591.05331341.002781.035321.074021.006591.05295351.002041.034941.073621.005891.05255361.002041.034511.072771.005161.05173381.001701.034151.072771.005161.05173381.000921.033311.071891.004411.05086401.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070561.002211.04958430.999331.031631.070661.002801.04910440.998921.031191.069601.002381.04864	1.10932
311.003731.036361.075191.007241.05405321.003411.036011.074811.006921.05367331.003091.035661.074421.006591.05331341.002781.035321.074021.006251.05295351.002431.034941.073621.005891.05255361.002041.034511.073181.005531.05211371.001701.034151.072771.005161.05173381.001311.033731.072331.004791.05130391.000921.033111.071891.004411.05086401.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070561.002111.04958430.999331.031631.070661.002801.04910440.998921.031191.069601.002381.04864	1.10867
331.003091.035661.074421.006591.05331341.002781.035321.074021.006251.05295351.002431.034941.073621.005891.05255361.002041.034511.073181.005531.05211371.001701.034151.072771.005161.05173381.001311.033731.072331.004791.05130391.000921.033111.071891.004411.05086401.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070561.002111.04958430.999331.031631.070661.002801.04910440.998921.031191.069601.002381.04864	1.10824
341.002781.035321.074021.006251.05295351.002431.034941.073621.005891.05255361.002041.034511.073181.005531.05211371.001701.034151.072771.005161.05173381.001311.033731.072331.004791.05130391.000921.033111.071891.004411.05086401.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070561.002111.04958430.999331.031631.070061.002801.04910440.998921.031191.069601.002381.04864	1.10779
351.002431.034941.073621.005891.05255361.002041.034511.073181.005531.05211371.001701.034151.072771.005161.05173381.001311.033731.072331.004791.05130391.000921.033311.071891.004411.05086401.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070561.002111.04958430.999331.031631.070061.002801.04910440.998921.031191.069601.002381.04864	1.10736
361.002041.034511.073181.005531.05211371.001701.034151.072771.005161.05173381.001311.033731.072331.004791.05130391.000921.033311.071891.004411.05086401.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070561.003211.04958430.999331.031631.070061.002801.04910440.998921.031191.069601.002381.04864	1.10693
371.001701.034151.072771.005161.05173381.001311.033731.072331.004791.05130391.000921.033311.071891.004411.05086401.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070561.003211.04958430.999331.031631.070061.002801.04910440.998921.031191.069601.002381.04864	1.10646
381.001311.033731.072331.004791.05130391.000921.033311.071891.004411.05086401.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070561.003211.04958430.999331.031631.070061.002801.04910440.998921.031191.069601.002381.04864	1.10599
391.000921.033311.071891.004411.05086401.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070561.003211.04958430.999331.031631.070061.002801.04910440.998921.031191.069601.002381.04864	1.10547
401.000541.032911.071441.004031.05043411.000151.032491.070991.003621.05000420.999771.032091.070561.003211.04958430.999331.031631.070061.002801.04910440.998921.031191.069601.002381.04864	1.10497 1.10448
411.000151.032491.070991.003621.05000420.999771.032091.070561.003211.04958430.999331.031631.070061.002801.04910440.998921.031191.069601.002381.04864	1.10448
420.999771.032091.070561.003211.04958430.999331.031631.070061.002801.04910440.998921.031191.069601.002381.04864	1.10398
430.999331.031631.070061.002801.04910440.998921.031191.069601.002381.04864	1.10301
44 0.99892 1.03119 1.06960 1.00238 1.04864	1.10247
	1.10194
45 0.99849 1.03073 1.06912 1.00197 1.04816	1.10141
46 0.99807 1.03028 1.06865 1.00153 1.04771	1.10089
47 0.99763 1.02983 1.06818 1.00110 1.04723	1.10037
48 0.99720 1.02938 1.06769 1.00065 1.04676	1.09984
49 0.99674 1.02889 1.06717 1.00021 1.04626	1.09926
50 0.99630 1.02843 1.06670 0.99975 1.04579	1.09874
51 0.99584 1.02795 1.06619 0.99929 1.04527	1.09817
52 0.99538 1.02746 1.06569 0.99882 1.04478 52 0.00488 1.02765 1.06515 0.09882 1.04478	1.09762
53 0.99488 1.02695 1.06515 0.99835 1.04425   54 0.99442 1.02646 1.06466 0.99786 1.04375	1.09705 1.09649
54 0.99442 1.02646 1.06466 0.99786 1.04375   55 0.99391 1.02594 1.06409 0.99737 1.04320	1.09649
56 0.99341 1.02542 1.06356 0.99687 1.04268	1.09533
57 0.99293 1.02494 1.06307 0.99637 1.04217	1.09333
57 0.99293 1.02494 1.00507 0.99057 1.04162   58 0.99243 1.02440 1.06250 0.99587 1.04162	1.09419
59 0.99193 1.02388 1.06196 0.99537 1.04109	1.09363
60 0.99142 1.02336 1.06142 0.99483 1.04054	1.09307
610.990901.022821.060860.994311.03998	1.09248
620.990371.022271.060300.993791.03942	1.09190

Table	1	(continued)
-------	---	-------------

т Ө	KBr			KI		
0	0.1 <sup>a</sup>	0.5 <sup>b</sup>	$1.0^{\rm c}$ $\rho(T;m)/$ g cm <sup>-3</sup>	0.1 <sup>d</sup>	0.5 <sup>e</sup>	1.0 <sup>f</sup>
63	0.98982	1.02169	1.05971	0.99323	1.03883	1.09135
64	0.98931	1.02115	1.05916	0.99270	1.03828	1.09076
65	0.98876	1.02057	1.05859	0.99216	1.03771	1.09019
t c	m = 0.1999 m = 0.99962 m = 0.1000 m = 0.5055	7 mol kg <sup><math>-1</math></sup> . 2 mol kg <sup><math>-1</math></sup> . 8 mol kg <sup><math>-1</math></sup> .				

capacity with pressure,  $[(\partial C_p)/(\partial P)]_{T,m}$ . Hepler [10] was the first to correlate, at least qualitatively, these derivatives at an infinite dilution of solute with the structure of water (the transformation of a strongly hydrogen-bonded structure of water into a "normal" liquid as temperature or pressure increases) and to distinguish between the structure-making and structure-breaking solutes. Similar considerations for aqueous solutions of polar and nonpolar nonelectrolytes were given by Neal and Goring [11] and Sakurai et al. [12,13].

In this work, which continues our previous investigations on the volume-temperature relations in aqueous electrolyte solutions, two more salts, potassium bromide, and potassium iodide are considered. KBr and KI solutions were extensively studied in the literature (for the complete list of references see Refs. [1-4]; however, the quality of reported data is highly uneven. Critical analysis of the apparent molar volumes at T=298.15 K performed by Krumgalz et al. [14] showed that in the calculation of the Pitzer coefficients from 15 available sets of data for potassium bromide, 8 sets should be partially or completely rejected. In the case of potassium iodide, from 11 sets of data, 4 sets were discarded. With regard to the temperature dependence of densities at considered concentrations, the measurements at 5-, 10-, and 20-K temperature intervals were performed with KBr or KI solutions by Prakash et al. [15], Suhrmann and Wiedersich [16], Lengyel et al. [17], Ellis [18], Out and Los [19], Isono [20] and Maksimova et al. [21]. Millero and Drost-Hansen [22] measured densities of m=0.10457 mol kg<sup>-1</sup> potassium bromide and m=0.10154 mol kg<sup>-1</sup> potassium iodide solutions at 1-K temperature intervals, but only in the T=293.15 to 313.15 K temperature range. At one temperature, usually at T=298.15 K, densities or  $V_{2,\phi}(T;m)$  were reported for the studied concentrations in the investigations of Scott [23], Jones and Talley [24], Jones and Bickford [25], Scott et al. [26], Wirth [27], Halasey [28], McInnes and Dayhoff [29], Dunn [30], Fortier et al. [31], Vorobiev et al. [32], and Millero et al. [33]. Recently, using a pycnometer, Rohman et al. [41] measured densities of KBr solutions (from m=0.0085 to Download English Version:

https://daneshyari.com/en/article/9588625

Download Persian Version:

https://daneshyari.com/article/9588625

Daneshyari.com