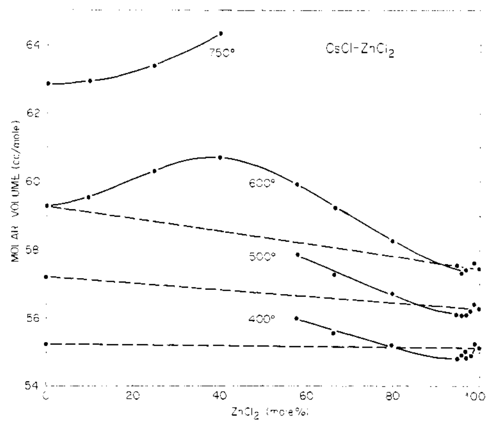


**Figure 1. Molar volumes of molten $CsCl-ZnCl_2$ mixtures as functions of composition**

Each curve is labeled with the temperature in ° C.

taken from the literature (*11*), were extrapolated below the melting point where necessary. The excess molar volume is large and positive near 40 mole % $ZnCl_2$ and small and negative near pure $ZnCl_2$. The general shape of the molar volume curve is similar to that for $KCl-ZnCl_2$ (*10*) and $KCl-MgCl_2$ mixtures (*12*).

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# Temperature Dependence of Conductances and Viscosities for Some Moderately Concentrated Nonaqueous Electrolytic Solutions

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**Conductance, viscosity, and density data at 10° intervals between −50° and 20° C. are reported for 28 nonaqueous electrolytic solutions ranging in concentration from 0.05 to 4.7 molal. Results are summarized also for the fitting of these data as a function of temperature to appropriate polynomial equations by digital computer methods. Conductance-viscosity products and activation energies of conductance and viscous flow are discussed.**

THREE articles originating from this laboratory in 1955 described qualitatively and graphically the conductimetric and viscometric behavior of moderately concentrated solutions for three nonaqueous systems over the temperature range of −50° to 20° C. (*1, 9, 10*). These earlier investigations have yielded corresponding conductance and viscosity data at 10° intervals for eight to 10 solutions each of potassium thiocyanate in methanol, lithium perchlorate in a 50 to 50 weight % mixture of methanol and acetone, and lithium bromide also in the latter medium. Digital computer methods recently have been used to evaluate quantitatively these extensive experimental data in view of more appropriate conductance-temperature and viscosity-temperature relationships. Hence, the objectives of this article are to provide the original publication of the experimental data and to summarize the results of the recent quantitative calculations associated with them.

## EXPERIMENTAL

The experimental equipment and procedures have been described thoroughly in the related previous articles (*1, 9, 10*). An IBM-360 digital computer has been used for the fitting of data by the method of least squares to various polynomial equations. The experimental conductance, viscosity, and density data are compiled in Table I. Densities were used in the calculation of absolute viscosities and in converting concentrations from a weight to volume basis.

## RESULTS AND DISCUSSION

For nonassociated liquids and very dilute solutions of electrolytes in such media, viscous flow and conductance as rate processes can be related to the following equations (*3*):

Table I. Summary of Molar Conductance, Experimental Viscosity, and Density Data

| Molality | Temperature, °C. -50° | -40° | -30° | -20° | -10° | 0° | 10° | 20° |
|---|---|---|---|---|---|---|---|---|
| | | | | Molar Conductances, $Ohm^{-1}$ $Cm^2$ $Mole^{-1}$ | | | | |
| | | | | KSCN in Methanol | | | | |
| 0.0482 | 20.9 | 26.7 | 33.0 | 40.2 | 48.3 | 56.2 | 65.1 | 74.8 |
| 0.111 | 18.7 | 23.9 | 29.6 | 35.9 | 43.2 | 50.1 | 57.9 | 66.3 |
| 0.329 | 15.0 | 19.3 | 24.2 | 29.5 | 35.3 | 41.5 | 48.2 | 55.2 |
| 0.498 | 13.4 | 17.3 | 21.8 | 26.7 | 32.1 | 37.8 | 44.0 | 50.6 |
| 0.777 | 11.4 | 14.9 | 18.9 | 23.4 | 28.3 | 33.3 | 39.3 | 45.4 |
| 1.07 | 9.93 | 13.2 | 16.8 | 21.0 | 25.6 | 30.5 | 35.8 | 41.5 |
| 1.60 | 7.93 | 10.8 | 14.0 | 17.7 | 21.8 | 26.2 | 31.0 | 36.1 |
| 2.18 | 6.38 | 8.91 | 11.8 | 15.1 | 18.8 | 22.8 | 27.1 | 31.8 |
| | | | | $LiClO_4$ in 50-50 Methanol-Acetone | | | | |
| 0.0910 | 22.9 | 27.7 | 32.9 | 38.3 | 43.9 | 49.7 | 56.4 | 63.0 |
| 0.251 | 20.3 | 24.6 | 29.3 | 34.2 | 39.4 | 44.5 | 50.6 | 55.8 |
| 0.512 | 15.3 | 18.8 | 22.6 | 26.7 | 30.9 | 35.1 | 39.9 | 44.4 |
| 0.791 | 12.3 | 15.4 | 18.8 | 22.2 | 25.9 | 29.9 | 33.9 | 38.7 |
| 1.04 | 10.7 | 13.5 | 16.6 | 19.9 | 23.5 | 27.1 | 31.3 | 35.1 |
| 1.64 | 7.21 | 9.44 | 11.9 | 14.6 | 17.6 | 20.7 | 24.0 | 27.5 |
| 2.16 | 5.22 | 7.04 | 9.25 | 11.7 | 14.4 | 17.3 | 20.2 | 23.4 |
| 2.77 | 3.76 | 5.38 | 7.19 | 9.28 | 11.6 | 14.0 | 16.7 | 19.5 |
| 3.68 | 2.41 | 3.60 | 5.12 | 6.83 | 8.79 | 10.9 | 13.2 | 15.8 |
| 4.71 | 1.62 | 2.58 | 3.77 | 5.20 | 6.83 | 8.69 | 10.7 | 12.7 |
| | | | | LiBr in 50-50 Methanol-Acetone | | | | |
| 0.265 | 14.1 | 17.3 | 20.9 | 24.7 | 28.8 | 33.1 | 37.3 | 42.1 |
| 0.388 | 11.4 | 14.2 | 17.2 | 20.5 | 24.1 | 27.8 | 31.7 | 35.9 |
| 0.777 | 7.85 | 9.95 | 12.2 | 14.6 | 17.2 | 20.1 | 23.1 | 26.1 |
| 1.05 | 5.84 | 7.43 | 9.23 | 11.2 | 13.5 | 15.8 | 18.3 | 21.0 |
| 1.53 | 3.87 | 5.02 | 6.33 | 7.86 | 9.54 | 11.3 | 13.3 | 15.5 |
| 2.16 | 2.63 | 3.46 | 4.41 | 5.52 | 6.74 | 8.03 | 9.46 | 11.0 |
| 2.51 | 1.80 | 2.45 | 3.22 | 4.12 | 5.14 | 6.24 | 7.52 | 8.91 |
| 3.10 | 1.19 | 1.68 | 2.25 | 2.94 | 3.74 | 4.65 | 5.67 | 6.81 |
| 3.56 | 0.760 | 1.12 | 1.56 | 2.10 | 2.73 | 3.44 | 4.30 | 5.18 |
| 4.14 | 0.438 | 0.686 | 1.00 | 1.40 | 1.88 | 2.44 | 3.15 | 3.83 |
| | | | | Viscosities, Centipoises | | | | |
| | | | | KSCN in Methanol | | | | |
| 0.0482 | 2.24 | 1.75 | 1.41 | 1.15 | 0.948 | 0.808 | 0.692 | 0.597 |
| 0.111 | 2.32 | 1.81 | 1.45 | 1.18 | 0.978 | 0.833 | 0.711 | 0.614 |
| 0.329 | 2.64 | 2.04 | 1.62 | 1.31 | 1.09 | 0.913 | 0.773 | 0.670 |
| 0.498 | 2.87 | 2.20 | 1.74 | 1.40 | 1.15 | 0.974 | 0.819 | 0.704 |
| 0.777 | 3.29 | 2.48 | 1.94 | 1.55 | 1.26 | 1.05 | 0.890 | 0.764 |
| 1.07 | 3.73 | 2.77 | 2.14 | 1.70 | 1.38 | 1.14 | 0.961 | 0.815 |
| 1.60 | 4.68 | 3.38 | 2.55 | 1.99 | 1.60 | 1.32 | 1.09 | 0.925 |
| 2.18 | [a] | 4.14 | 3.07 | 2.35 | 1.86 | 1.51 | 1.25 | 1.05 |
| | | | | $LiClO_4$ in 50-50 Methanol-Acetone | | | | |
| 0.0910 | 1.26 | 1.03 | 0.852 | 0.721 | 0.620 | 0.540 | 0.475 | 0.421 |
| 0.251 | 1.43 | 1.16 | 0.945 | 0.804 | 0.685 | 0.595 | 0.519 | 0.458 |
| 0.512 | 1.76 | 1.40 | 1.14 | 0.947 | 0.800 | 0.689 | 0.599 | 0.523 |
| 0.791 | 2.15 | 1.70 | 1.36 | 1.12 | 0.939 | 0.800 | 0.686 | 0.597 |
| 1.04 | 2.59 | 2.00 | 1.58 | 1.29 | 1.08 | 0.909 | 0.778 | 0.669 |
| 1.64 | 3.94 | 2.93 | 2.24 | 1.78 | 1.44 | 1.20 | 1.00 | 0.853 |
| 2.16 | 5.88 | 4.20 | 3.09 | 2.36 | 1.88 | 1.52 | 1.25 | 1.06 |
| 2.77 | 8.43 | 5.76 | 4.15 | 3.14 | 2.42 | 1.95 | 1.61 | 1.32 |
| 3.68 | 14.1 | 9.05 | 6.19 | 4.50 | 3.39 | 2.64 | 2.09 | 1.72 |
| 4.71 | 22.8 | 13.9 | 9.07 | 6.37 | 4.69 | 3.55 | 2.75 | 2.24 |
| | | | | LiBr in 50-50 Methanol-Acetone | | | | |
| 0.265 | 1.53 | 1.23 | 1.02 | 0.849 | 0.722 | 0.630 | 0.549 | 0.487 |
| 0.388 | 1.82 | 1.44 | 1.18 | 0.981 | 0.830 | 0.712 | 0.616 | 0.539 |
| 0.777 | 2.23 | 1.76 | 1.43 | 1.18 | 0.992 | 0.842 | 0.726 | 0.629 |
| 1.05 | 2.90 | 2.26 | 1.81 | 1.47 | 1.22 | 1.03 | 0.884 | 0.763 |

*(Continued on page 126)*

Table I. Summary of Molar Conductance, Experimental Viscosity, and Density Data (*Continued*)

| Molality | Temperature, ° C. −50° | −40° | −30° | −20° | −10° | 0° | 10° | 20° |
|---|---|---|---|---|---|---|---|---|
| | | | | VISCOSITIES, CENTIPOISES | | | | |
| | | | | LiBr in 50-50 Methanol-Acetone | | | | |
| 1.53 | 4.26 | 3.23 | 2.54 | 2.03 | 1.66 | 1.39 | 1.18 | 1.00 |
| 2.16 | 6.30 | 4.73 | 3.61 | 2.85 | 2.30 | 1.89 | 1.58 | 1.32 |
| 2.51 | 10.1 | 7.15 | 5.28 | 4.05 | 3.21 | 2.59 | 2.14 | 1.78 |
| 3.10 | 17.8 | 12.1 | 8.59 | 6.43 | 4.95 | 3.90 | 3.13 | 2.57 |
| 3.56 | 31.7 | 20.5 | 13.9 | 9.95 | 7.47 | 5.79 | 4.48 | 3.69 |
| 4.14 | 67.6 | 40.6 | 25.5 | 17.2 | 12.3 | 9.23 | 7.04 | 5.45 |
| | | | | DENSITIES, GRAMS $CM.^{-3} \times 10^4$ | | | | |
| | | | | KSCN in Methanol | | | | |
| 0.0482 | 8604 | 8509 | 8419 | 8321 | 8217 | 8123 | 8031 | 7938 |
| 0.111 | 8628 | 8535 | 8441 | 8346 | 8252 | 8161 | 8068 | 7979 |
| 0.329 | 8742 | 8643 | 8549 | 8457 | 8367 | 8276 | 8183 | 8091 |
| 0.498 | 8823 | 8730 | 8637 | 8545 | 8458 | 8367 | 8287 | 8196 |
| 0.777 | 8966 | 8872 | 8780 | 8690 | 8596 | 8507 | 8417 | 8325 |
| 1.07 | 9098 | 9006 | 8914 | 8826 | 8738 | 8647 | 8557 | 8468 |
| 1.60 | 9342 | 9251 | 9160 | 9070 | 8979 | 8890 | 8801 | 8712 |
| 2.18 | [a] | 9484 | 9394 | 9306 | 9237 | 9149 | 9060 | 8973 |
| | | | | $LiClO_4$ in 50-50 Methanol-Acetone | | | | |
| 0.0910 | 8710 | 8612 | 8509 | 8409 | 8311 | 8210 | 8112 | 8006 |
| 0.251 | 8804 | 8703 | 8606 | 8506 | 8405 | 8306 | 8208 | 8104 |
| 0.512 | 8943 | 8847 | 8745 | 8647 | 8548 | 8454 | 8353 | 8255 |
| 0.791 | 9114 | 9011 | 8909 | 8815 | 8721 | 8621 | 8523 | 8427 |
| 1.04 | 9216 | 9123 | 9025 | 8927 | 8827 | 8735 | 8639 | 8540 |
| 1.64 | 9492 | 9396 | 9302 | 9206 | 9111 | 9016 | 8920 | 8822 |
| 2.16 | 9735 | 9642 | 9547 | 9456 | 9360 | 9268 | 9176 | 9083 |
| 2.77 | 10040 | 9948 | 9854 | 9764 | 9674 | 9582 | 9491 | 9402 |
| 3.68 | 10341 | 10258 | 10168 | 10072 | 9975 | 9885 | 9794 | 9709 |
| 4.71 | 10707 | 10611 | 10521 | 10422 | 10325 | 10239 | 10148 | 10057 |
| | | | | LiBr in 50-50 Methanol-Acetone | | | | |
| 0.265 | 8844 | 8742 | 8647 | 8543 | 8445 | 8349 | 8248 | 8148 |
| 0.388 | 8931 | 8830 | 8738 | 8641 | 8541 | 8444 | 8343 | 8245 |
| 0.777 | 9111 | 9018 | 8921 | 8821 | 8727 | 8632 | 8532 | 8437 |
| 1.05 | 9322 | 9234 | 9136 | 9039 | 8939 | 8840 | 8748 | 8651 |
| 1.53 | 9620 | 9528 | 9431 | 9333 | 9241 | 9143 | 9048 | 8952 |
| 2.16 | 9927 | 9830 | 9736 | 9642 | 9546 | 9454 | 9360 | 9264 |
| 2.51 | 10183 | 10096 | 9990 | 9906 | 9810 | 9715 | 9617 | 9532 |
| 3.10 | 10516 | 10414 | 10318 | 10227 | 10129 | 10041 | 9952 | 9861 |
| 3.56 | 10785 | 10690 | 10598 | 10509 | 10414 | 10324 | 10229 | 10150 |
| 4.14 | 11102 | 11018 | 10918 | 10826 | 10730 | 10644 | 10548 | 10463 |

[a] Some solid phase also present.

$$\eta = A \exp (B/RT) \quad (1)$$

$$\Lambda = A' \exp (-B'/RT) \quad (2)$$

Equations 1 and 2 may be expressed also in a familiar logarithmic form:

$$\log \eta = \log A + \frac{B}{2.303R}\frac{1}{T} \quad (3)$$

$$\log \Lambda = \log A' - \frac{B'}{2.303R}\frac{1}{T} \quad (4)$$

In the application of Equations 3 and 4, where log $\eta$ or log $\Lambda$ is a linear function of $1/T$, $B$ or $B'$ is constant and considered as the activation energy of viscous flow, $E_{vis}$, or the activation energy of conductance or ion mobility, $E_{con}$.

$$E_{vis} = B = 2.303R \frac{d(\log \eta)}{d(1/T)} \quad (5)$$

$$E_{con} = B' = 2.303R \frac{d(\log \Lambda)}{d(1/T)} \quad (6)$$

For associated liquids or for nondilute electrolytic solutions, however, plots of log $\eta$ or log $\Lambda$ *vs.* $1/T$ are nonlinear. In these types of systems, $B$ or $B'$ is not constant but a function of temperature. Equations 1 and 2 consequently may be modified appropriately to account for this:

$$\eta = D \exp\left(\frac{F + G/T}{RT}\right) \quad (7)$$

$$\Lambda = D' \exp\left(\frac{-F' - G'/T}{RT}\right) \quad (8)$$

Equations 7 and 8 in logarithmic form may be written:

$$\log \eta = \alpha + \frac{\beta}{T} + \frac{\gamma}{T^2} \quad (9)$$

$$\log \Lambda = \alpha' + \frac{\beta'}{T} + \frac{\gamma'}{T^2} \quad (10)$$

Equation 9 is known as the Girifalco equation (*2, 7*) which upon differentiation with respect to $1/T$ provides a means for calculating the activation energy of viscous flow as a function of temperature (*8*):

$$E_{vis} = 2.303R \frac{d(\log \eta)}{d(1/T)} = 2.303R[\beta + (2\gamma/T)] \quad (11)$$

An expression for $E_{con}$ can be obtained in a logical parallel manner.

$$E_{con} = 2.303R \frac{d(\log \Lambda)}{d(1/T)} = 2.303R[\beta' + (2\gamma'/T)] \quad (12)$$

For the moderately concentrated solutions under consideration, plots of log $\eta$ or log $\Lambda$ *vs.* $1/T$ were nonlinear with the deviation from linearity becoming more pronounced with increasing concentration of solute. Consequently, analysis of the experimental data in Table I in terms of Equations 9 and 10, respectively, appeared both appropriate and desirable. The results are summarized in Tables II and III. The percentages of deviation between calculated and observed values for both viscosities and conductances are uniformly low reflecting the excellent representation of the data by Equations 9 and 10.

Values of $E_{vis}$ and $E_{con}$ at 20° C. calculated using Equations 11 and 12 also are presented in Tables II and III. Evidently, the values of $E_{vis}$ or $E_{con}$ continuously increase with increasing solute concentration for each system. $E_{vis}$ is always greater than the corresponding $E_{con}$. For each solution the difference decreases with decreasing temperature; also, for each system at a fixed temperature the difference increases with increasing concentration of electrolyte.

The conductance-viscosity products are summarized in Table IV. For each of the 28 solutions, the $\Lambda\eta$-product decreases continuously with increasing temperature. Also, quite simply, the logarithm of the $\Lambda\eta$-product is a linear function of $1/T$.

$$\log \Lambda\eta = H + (J/T) \quad (13)$$

The results for fitting the data in Table IV to Equation 13 are summarized in Table V. In general, agreement between calculated and observed products is very good. Equation 13 appears to be a versatile, general relationship which applies also to molten salt systems (*5*). For infinitely dilute solutions of electrolytes the $\Lambda\eta$-product is approximately constant and therefore practically independent of temperature (*4*).

The data in Table IV show that the $\Lambda\eta$-product for each system at each temperature tends to approach or pass through a minimum value as the concentration of

**Table II. Summary of Results for Conductance Data in Table I Fitted to Equations 10 and 12**

| | | | | (% Dev.)[a] 10 | | $E_{con}$, at 293° K., | Std. Dev. in $E_{con}$, |
|---|---|---|---|---|---|---|---|
| Molality | $\alpha'$ | $-\beta'$ | $-\gamma'$ | Mean | Max. | Cal./Mole | Cal./Mole |
| | | | KSCN in Methanol | | | | |
| 0.0482 | 3.1036 | 242.28 | 34736 | 3 | 6 | 2193 | 30 |
| 0.111 | 2.9286 | 181.68 | 41953 | 3 | 7 | 2141 | 32 |
| 0.329 | 2.8488 | 169.77 | 45399 | 1 | 2 | 2194 | 12 |
| 0.498 | 2.8352 | 174.34 | 46157 | 1 | 2 | 2239 | 13 |
| 0.777 | 2.8096 | 168.82 | 49606 | 1 | 1 | 2321 | 7 |
| 1.07 | 2.6954 | 115.63 | 58746 | 2 | 4 | 2363 | 19 |
| 1.60 | 2.4756 | 7.59 | 76749 | 2 | 5 | 2431 | 23 |
| 2.18 | 2.2057 | −130.22 | 98747 | 3 | 5 | 2487 | 29 |
| | | | $LiClO_4$ in 50-50 Methanol-Acetone | | | | |
| 0.0910 | 2.9540 | 285.67 | 15592 | 3 | 7 | 1793 | 33 |
| 0.251 | 2.7183 | 187.99 | 28314 | 2 | 7 | 1744 | 32 |
| 0.512 | 2.5237 | 123.23 | 39183 | 2 | 5 | 1787 | 22 |
| 0.791 | 2.6050 | 176.42 | 35991 | 5 | 8 | 1931 | 51 |
| 1.04 | 2.4801 | 114.84 | 46609 | 2 | 5 | 1980 | 27 |
| 1.64 | 2.2948 | 29.47 | 64943 | 2 | 3 | 2162 | 16 |
| 2.16 | 1.9741 | −152.22 | 96607 | 2 | 5 | 2319 | 28 |
| 2.77 | 1.5492 | −370.67 | 131110 | 4 | 8 | 2397 | 45 |
| 3.68 | 1.2393 | −555.50 | 166616 | 4 | 8 | 2659 | 49 |
| 4.71 | 0.6210 | −883.63 | 217577 | 4 | 7 | 2749 | 41 |
| | | | LiBr in 50-50 Methanol-Acetone | | | | |
| 0.265 | 2.6877 | 211.55 | 29432 | 2 | 4 | 1887 | 21 |
| 0.388 | 2.7090 | 242.31 | 28180 | 1 | 2 | 1988 | 13 |
| 0.777 | 2.5042 | 190.98 | 37461 | 3 | 5 | 2043 | 29 |
| 1.05 | 2.6345 | 281.89 | 30138 | 2 | 5 | 2231 | 23 |
| 1.53 | 2.6742 | 338.71 | 28320 | 2 | 4 | 2434 | 24 |
| 2.16 | 2.3197 | 218.09 | 45949 | 1 | 3 | 2432 | 17 |
| 2.51 | 2.3832 | 247.59 | 50695 | 2 | 5 | 2715 | 22 |
| 3.10 | 2.3414 | 241.90 | 58781 | 2 | 6 | 2942 | 27 |
| 3.56 | 1.9360 | 38.65 | 93666 | 3 | 6 | 3101 | 34 |
| 4.14 | 1.6750 | −107.09 | 125082 | 5 | 12 | 3415 | 60 |

[a] $\% \text{ Dev.} = \frac{(\Lambda_{calcd.} - \Lambda_{obsd})}{\Lambda_{obsd}} 100.$

Table III. Summary of Results for Viscosity Data in Table I Fitted to Equations 9 and 11

| Molality | $-\alpha$ | $\beta$ | $\gamma$ | (% Dev.)[a] 10 Mean | Max. | $E_{vis}$, at 293° K., Cal./Mole | Std. Dev. in $E_{vis}$, Cal./Mole |
|---|---|---|---|---|---|---|---|
| | | | KSCN in Methanol | | | | |
| 0.0482 | 1.7551 | 382.72 | 19439 | 3 | 7 | 2358 | 33 |
| 0.111 | 1.6790 | 347.97 | 24161 | 2 | 5 | 2347 | 25 |
| 0.329 | 1.6951 | 361.52 | 24717 | 2 | 4 | 2426 | 25 |
| 0.498 | 1.6575 | 344.49 | 28441 | 2 | 9 | 2464 | 36 |
| 0.777 | 1.4479 | 236.02 | 45181 | 2 | 3 | 2490 | 17 |
| 1.07 | 1.4490 | 235.29 | 48059 | 3 | 4 | 2577 | 27 |
| 1.60 | 1.1521 | 79.64 | 72898 | 4 | 10 | 2640 | 46 |
| 2.18 | 1.0752 | 38.60 | 82981 | 1 | 2 | 2767 | 21 |
| | | | $LiClO_4$ in 50-50 Methanol-Acetone | | | | |
| 0.0910 | 1.5723 | 279.74 | 20886 | 2 | 3 | 1932 | 16 |
| 0.251 | 1.5754 | 288.12 | 21880 | 3 | 10 | 2001 | 42 |
| 0.512 | 1.5438 | 278.81 | 26868 | 2 | 3 | 2115 | 21 |
| 0.791 | 1.6380 | 334.62 | 23469 | 2 | 4 | 2264 | 24 |
| 1.04 | 1.4932 | 266.49 | 35414 | 4 | 7 | 2325 | 45 |
| 1.64 | 1.3538 | 192.50 | 54080 | 3 | 8 | 2569 | 36 |
| 2.16 | 1.0121 | 5.12 | 87610 | 3 | 5 | 2758 | 33 |
| 2.77 | 0.7241 | −130.67 | 111249 | 4 | 11 | 2875 | 62 |
| 3.68 | 0.3930 | −322.87 | 148755 | 5 | 8 | 3166 | 50 |
| 4.71 | 0.0340 | −516.78 | 184546 | 5 | 10 | 3396 | 63 |
| | | | LiBr in 50-50 Methanol-Acetone | | | | |
| 0.265 | 1.4643 | 240.68 | 28418 | 3 | 6 | 1988 | 32 |
| 0.388 | 1.6331 | 330.94 | 20354 | 2 | 5 | 2150 | 27 |
| 0.777 | 1.7648 | 418.28 | 11845 | 2 | 3 | 2284 | 20 |
| 1.05 | 1.5880 | 347.11 | 24660 | 1 | 3 | 2358 | 16 |
| 1.53 | 1.4876 | 323.82 | 33123 | 3 | 6 | 2516 | 36 |
| 2.16 | 1.6235 | 420.47 | 26829 | 3 | 6 | 2762 | 38 |
| 2.51 | 0.9494 | 87.10 | 77794 | 4 | 6 | 2827 | 38 |
| 3.10 | 0.9076 | 85.43 | 88326 | 4 | 8 | 3148 | 43 |
| 3.56 | 0.4315 | −149.90 | 129674 | 5 | 12 | 3362 | 67 |
| 4.14 | 0.0555 | −363.37 | 174997 | 8 | 13 | 3800 | 86 |

[a] % Dev. = $\frac{(\eta_{calcd} - \eta_{obsd})}{\eta_{obsd}}$ 100.

Table IV. Summary of Conductance-Viscosity Product Data

| Molality | Conductance-Viscosity Product (Ohm$^{-1}$ Cm.$^2$ Mole$^{-1}$ Centipoise) −50° | −40° | −30° | −20° | −10° | 0° | 10° | 20° |
|---|---|---|---|---|---|---|---|---|
| | | | KSCN in Methanol | | | | | |
| 0.0482 | 46.8 | 46.7 | 46.5 | 46.2 | 45.8 | 45.4 | 45.1 | 44.7 |
| 0.111 | 43.4 | 43.3 | 42.9 | 42.4 | 42.3 | 41.7 | 41.2 | 40.7 |
| 0.329 | 39.6 | 39.3 | 39.2 | 38.6 | 38.5 | 37.9 | 37.3 | 37.0 |
| 0.498 | 38.5 | 38.1 | 37.9 | 37.4 | 36.9 | 36.8 | 36.0 | 35.6 |
| 0.777 | 37.5 | 37.0 | 36.7 | 36.3 | 35.7 | 35.3 | 35.0 | 34.7 |
| 1.07 | 37.0 | 36.6 | 36.0 | 35.7 | 35.3 | 34.8 | 34.4 | 33.8 |
| 1.60 | 37.1 | 36.5 | 35.7 | 35.2 | 34.9 | 34.6 | 33.8 | 33.4 |
| 2.18 | ... | 36.9 | 36.2 | 35.5 | 35.0 | 34.4 | 33.9 | 33.4 |
| | | | $LiClO_4$ in 50-50 Methanol-Acetone | | | | | |
| 0.0910 | 28.9 | 28.5 | 28.0 | 27.6 | 27.2 | 26.8 | 26.8 | 26.5 |
| 0.251 | 29.0 | 28.5 | 27.7 | 27.5 | 27.0 | 26.5 | 26.3 | 25.6 |
| 0.512 | 26.9 | 26.3 | 25.8 | 25.3 | 24.7 | 24.2 | 23.9 | 23.2 |
| 0.791 | 26.5 | 26.2 | 25.6 | 24.9 | 24.3 | 23.9 | 23.3 | 23.1 |
| 1.04 | 27.7 | 27.0 | 26.2 | 25.7 | 25.4 | 24.6 | 24.4 | 23.5 |
| 1.64 | 28.4 | 27.7 | 26.7 | 26.0 | 25.3 | 24.8 | 24.0 | 23.5 |
| 2.16 | 30.7 | 29.6 | 28.6 | 27.6 | 27.1 | 26.3 | 25.3 | 24.8 |
| 2.77 | 31.7 | 31.0 | 29.8 | 29.1 | 28.1 | 27.3 | 26.9 | 25.7 |
| 3.68 | 34.0 | 32.6 | 31.7 | 30.7 | 29.8 | 28.8 | 27.6 | 27.2 |
| 4.71 | 36.9 | 35.9 | 34.2 | 33.1 | 32.0 | 30.9 | 29.4 | 28.5 |
| | | | LiBr in 50-50 Methanol-Acetone | | | | | |
| 0.265 | 21.6 | 21.3 | 21.3 | 21.0 | 20.8 | 20.8 | 20.5 | 20.5 |
| 0.388 | 20.8 | 20.5 | 20.3 | 20.1 | 20.0 | 19.8 | 19.5 | 19.3 |
| 0.777 | 17.5 | 17.5 | 17.4 | 17.2 | 17.1 | 16.9 | 16.8 | 16.4 |
| 1.05 | 16.9 | 16.8 | 16.7 | 16.5 | 16.5 | 16.3 | 16.2 | 16.0 |
| 1.53 | 16.5 | 16.2 | 16.1 | 16.0 | 15.8 | 15.7 | 15.7 | 15.5 |
| 2.16 | 16.6 | 16.4 | 15.9 | 15.7 | 15.5 | 15.2 | 15.0 | 14.5 |
| 2.51 | 18.2 | 17.5 | 17.0 | 16.7 | 16.5 | 16.2 | 16.1 | 15.9 |
| 3.10 | 21.2 | 20.3 | 19.3 | 18.9 | 18.5 | 18.1 | 17.8 | 17.5 |
| 3.56 | 24.1 | 23.0 | 21.7 | 20.9 | 20.4 | 19.9 | 19.3 | 19.1 |
| 4.14 | 29.6 | 27.9 | 25.5 | 24.1 | 23.1 | 22.5 | 22.2 | 20.9 |

Table V. Summary of Results for Conductance-Viscosity Data in Table IV Fitted to Equation 13

| Molality | $G$ | $H$ | $\frac{(\Lambda\eta)_{calcd} - (\Lambda\eta)_{obsd}}{(\Lambda\eta)_{obsd}}$ 100 Mean | Max. |
|---|---|---|---|---|
| | | KSCN in Methanol | | |
| 0.0482 | 1.5481 | 19.91 | 0.3 | 0.7 |
| 0.111 | 1.5237 | 26.05 | 0.5 | 0.7 |
| 0.329 | 1.4738 | 28.32 | 0.5 | 0.9 |
| 0.498 | 1.4507 | 30.53 | 0.5 | 0.8 |
| 0.777 | 1.4300 | 32.32 | 0.2 | 0.4 |
| 1.07 | 1.4109 | 35.46 | 0.3 | 0.6 |
| 1.60 | 1.3828 | 41.70 | 0.3 | 0.8 |
| 2.18 | 1.3562 | 49.23 | 0.1 | 0.2 |
| | | $LiClO_4$ in 50–50 Methanol-Acetone | | |
| 0.0910 | 1.3003 | 35.76 | 0.3 | 0.6 |
| 0.251 | 1.2421 | 49.45 | 0.4 | 0.7 |
| 0.512 | 1.1695 | 58.56 | 0.3 | 0.8 |
| 0.791 | 1.1597 | 59.58 | 0.5 | 1.0 |
| 1.04 | 1.1592 | 63.45 | 0.4 | 1.1 |
| 1.64 | 1.1083 | 77.45 | 0.4 | 0.8 |
| 2.16 | 1.1005 | 86.43 | 0.4 | 0.8 |
| 2.77 | 1.1309 | 83.51 | 0.6 | 1.2 |
| 3.68 | 1.1217 | 91.80 | 0.6 | 1.2 |
| 4.71 | 1.0956 | 106.57 | 0.8 | 1.3 |
| | | LiBr in 50–50 Methanol-Acetone | | |
| 0.265 | 1.2389 | 21.15 | 0.4 | 0.7 |
| 0.388 | 1.1962 | 27.02 | 0.2 | 0.5 |
| 0.777 | 1.1336 | 25.50 | 0.6 | 1.2 |
| 1.05 | 1.1304 | 22.14 | 0.2 | 0.5 |
| 1.53 | 1.1125 | 22.99 | 0.2 | 0.4 |
| 2.16 | 0.9906 | 51.71 | 0.6 | 1.2 |
| 2.51 | 1.0162 | 53.12 | 0.6 | 1.2 |
| 3.10 | 0.9789 | 76.33 | 0.7 | 1.5 |
| 3.56 | 0.9498 | 95.26 | 0.9 | 1.5 |
| 4.14 | 0.8505 | 137.09 | 1.5 | 2.6 |

Table VI. Summary of Results for Density Data Fitted to Equation 14

| Molality | $a \times 10^4$ | $b \times 10^7$ | (% Deviation) 100 Mean | Max. |
|---|---|---|---|---|
| | | KSCN in Methanol | | |
| 0.0482 | 10742 | 9576 | 3 | 7 |
| 0.111 | 10702 | 9300 | 2 | 4 |
| 0.329 | 10800 | 9245 | 2 | 6 |
| 0.498 | 10811 | 8930 | 4 | 6 |
| 0.777 | 11003 | 9137 | 1 | 3 |
| 1.07 | 11100 | 8981 | 1 | 3 |
| 1.60 | 11349 | 9001 | 1 | 2 |
| 2.18 | 11445 | 8421 | 4 | 9 |
| | | $LiClO_4$ in 50–50 Methanol-Acetone | | |
| 0.0910 | 10949 | 10027 | 2 | 4 |
| 0.251 | 11029 | 9971 | 1 | 3 |
| 0.512 | 11137 | 9831 | 1 | 3 |
| 0.791 | 11290 | 9770 | 2 | 6 |
| 1.04 | 11375 | 9669 | 2 | 4 |
| 1.64 | 11624 | 9551 | 1 | 2 |
| 2.16 | 11814 | 9318 | 1 | 2 |
| 2.77 | 12073 | 9115 | 1 | 2 |
| 3.69 | 12389 | 9155 | 3 | 5 |
| 4.71 | 12778 | 9295 | 3 | 7 |
| | | LiBr in 50–50 Methanol-Acetone | | |
| 0.265 | 11057 | 9921 | 2 | 3 |
| 0.388 | 11115 | 9785 | 2 | 4 |
| 0.777 | 11267 | 9654 | 1 | 3 |
| 1.05 | 11483 | 9661 | 3 | 5 |
| 1.53 | 11756 | 9562 | 1 | 2 |
| 2.16 | 12033 | 9444 | 1 | 2 |
| 2.51 | 12276 | 9373 | 3 | 7 |
| 3.10 | 12587 | 9314 | 4 | 8 |
| 3.56 | 12819 | 9127 | 3 | 7 |
| 4.14 | 13160 | 9215 | 3 | 7 |

electrolyte increases. This type of behavior has been observed in other related investigations (*6, 11*) although the minima are observed to occur at somewhat higher concentrations in this study.

The density data for each solution as a function of temperature may be described by the usual type of linear equation:

$$d = a - bT \quad (14)$$

The results for fitting the data in Table I to Equation 14 are summarized in Table VI. The agreement between calculated and observed values is exceptionally good.

## NOMENCLATURE

- $\Lambda$ = molar conductance in $ohm^{-1}$ $cm^2$ $mole^{-1}$
- $\eta$ = viscosity in centipoises
- $d$ = density in g. $cm.^{-3}$
- $T$ = temperature in ° K.
- $E_{vis}$ = activation energy of viscous flow in cal. $mole^{-1}$
- $E_{con}$ = activation energy of conductance in cal. $mole^{-1}$
- log = logarithm to base 10
- exp = notation that following term in parentheses is exponential power of base $e$
- $R$ = molar gas constant, 1.987 cal. $mole^{-1}$ $deg.^{-1}$
- $a, b$ = constants in Equation 14
- $A, B$ = constants in Equations 1 and 3
- $A', B'$ = constants in Equations 2 and 4
- $F, G$ = constants in Equation 7
- $F', G'$ = constants in Equation 8
- $H, J$ = constants in Equation 13
- $\alpha, \beta, \gamma$ = constants in Equation 9
- $\alpha', \beta', \gamma'$ = constants in Equation 10

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