



ELECTRICAL CONDUCTIVITY AND ION PAIR FORMATION OF S-ACETYLTHIOCHOLINE HALIDES AND PERCHLORATE IN ETHANOL - WATER AT 25 °C.

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ABSTRACT

The conductance of s-acetylthiocholine halides and perchlorate has been measured in ethanol – water mixtures ($28.6 < D < 72.0$). The conductance parameters derived from Fuoss – Onsager conductance theory indicate that the solvation of halides and perchlorate decreases with the decrease of the dielectric constants until a certain minimum and then increases again. The plot of $\log k_A$ vs. $1/D$ is found to be non linear indicating that the equation of association cannot be applied. The association constant is analyzed using the solvent separated – ion pair model.

KEYWORDS

conductivity, s-acetylthiocholine, ion pair.

INTRODUCTION

Ion pair formation of s-acetylthiocholine halides and perchlorate in ethanol solution was studied¹. the conductometric measurements of these salts in ethanol – water mixtures at 25 °C are recorded, and then analyzed in an attempt to illustrate the electrolyte – solvent interactions, using the Fuoss – Onsager equation². The relation between K_A and size of anions in the above mentioned medium is discussed.

EXPERIMENTAL

Ethanol, s-acetylthiocholine bromide, iodide and perchlorate was purified as reported elsewhere^{1,22}. The specific conductance for purified ethanol was found to be $(1.0-1.4 \times 10^{-8}) \text{ ohm}^{-1} \text{ cm}^{-1}$. The conductivity water was obtained by passing ordinary distilled water from a tin still over a 50 cm long Elgastat deionizer, and guarded against contamination with atmospheric CO_2 by soda lime. Its specific conductance was $(2-4 \times 10^{-6}) \text{ ohm}^{-1} \text{ cm}^{-1}$. The density (d) of pure ethanol was determined using a 25 ml Pyknometer recalibrated at $25 \pm .02$ °C and was found to be 0.78744 g/cm^3 . Its viscosity η was measured using viscometer with flow time at 25 °C of 250 s for conductivity water, it was found to be 1.1018 cp. The dielectric constant value was used as reported in the literature⁷.

Properties of solvent mixtures

Densities (d) of mixtures were determined using a 25 ml Pyknometer at $25 \pm .02$ °C. viscosities η were measured using viscometer at $25 \pm .02$ °C. The dielectric constants (D) of mixtures (ethanol – water) were obtained by interpolation from large scale plot data⁷. In the same way viscosities and densities of experimental solvents



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mixtures used were interpolated from large scale plots of their data. All solutions were prepared by weight reduced to vacuo. Salts weighted by difference on microbalance which read to ± 0.1 mg.

Dilution was carried out successively into the cell by siphoning the solvent by means of dispenser. An Erlenmeyer cell with bright platinum electrodes was used. The cell constant was calculated (0.05443 ± 0.43 % cm^{-1}) using the Lind – Zwolenik – Fuoss²³ equation.

A "Pye" 1700 conductance bridge was used for measuring the resistance of solutions at 5 Kc/s. the density of conductivity water was used as 0.99814 gm/cm^3 and viscosity of conductivity water was used as 0.8903 cp.

RESULT AND DISCUSSION

Conductance of s-acetylthiocholine halides and perchlorate in ethanol – water mixtures at 25 °C are measured, where the equivalent conductance Λ ($\Omega^{-1}\text{equiv}^{-1}\text{cm}^2$) is obtained at several concentrations C in equiv / l.

The data were analyzed on an IBM – Pc computer using the Fuoss – Onsager equation.

In all computations the accuracies required for the absolute values deviation are ± 0.02 for Λ_0 , ± 2 for $J < 200$, ± 5 for J (200 – 1000), and ± 10 for $J > 1000$. The results are depicted in table 1.



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Table 1 :

The characteristic parameters for s-acetylthiocholine Halides and Perchlorate in Ethanol – Water mixture at 25 °C:

a)

Ω

Wt %	D	10 ³ /D	Λ ^a	J	a ^b	K _A	Log K _A	σΛ
a-s-acetylthiocholine bromide								
10.94	72.0	13.8889	71.48±0.0736	253.12	6.5223	72.74	1.8618	0.01762
21.99	65.5	15.2672	52.21±0.0753	221.07	6.5329	59.47	1.7743	0.01430
29.70	61.05	16.3800	44.73±0.0833	219.55	6.5268	32.90	1.5172	0.01372
40.43	54.85	18.2315	38.75±0.0913	240.00	6.5157	17.93	1.2536	0.00793
50.03	49.3	20.2840	37.07±0.1043	291.47	6.5103	20.51	1.3120	0.00517
60.22	43.4	23.0415	35.88±0.1508	382.97	6.5086	19.02	1.2792	0.00782
68.15	39.05	25.6082	34.97±0.1528	484.87	6.5060	19.09	1.2808	0.00564
77.94	33.8	29.5858	36.42±0.2735	722.65	6.5108	31.57	1.4993	0.00599
88.64	28.6	34.9650	37.13±0.3883	1138.2	6.5124	63.19	1.8006	0.00754
b-s-acetylthiocholine iodide								
10.94	72.0	13.8889	70.54±0.0671	233.81	6.0490	68.90	1.8382	0.02902
21.99	65.5	15.2672	50.48±0.0677	200.11	6.0233	27.67	1.4420	0.01333
29.70	61.05	16.3800	43.90±0.0573	201.05	6.0174	34.33	1.5357	0.01053
40.43	54.85	18.2315	38.00±0.0639	220.11	6.0183	15.03	1.1770	0.00852
50.03	49.3	20.2840	36.45±0.0700	268.48	6.0179	13.42	1.1278	0.00853
60.22	43.4	23.0415	36.85±0.1072	366.77	6.0120	15.22	1.1824	0.00700
68.15	39.05	25.6082	37.41±0.1359	482.90	6.0157	23.35	1.3683	0.00880
77.94	33.8	29.5858	39.35±0.2222	730.00	6.0150	22.39	1.3501	0.00731
88.64	28.6	34.9650	40.64±0.3489	1168.8	6.0007	42.76	1.6310	0.01385
c-s-acetylthiocholine perchlorate								
10.94	72.0	13.8889	64.97±0.0659	203.95	5.5561	45.53	1.6583	0.03592
21.99	65.5	15.2672	48.02±0.0525	177.37	5.5039	20.70	1.3160	0.00993
29.70	61.05	16.3800	42.12±0.0543	179.73	5.5134	19.80	1.2967	0.00819
40.43	54.85	18.2315	39.39±0.0570	209.64	5.5171	35.97	1.5559	0.00823
50.03	49.3	20.2840	35.46±0.0746	243.06	5.5131	9.60	0.9823	0.00865
60.22	43.4	23.0415	37.56±0.1100	346.40	5.5084	7.66	0.8842	0.00467
68.15	39.05	25.6082	37.81±0.1481	454.13	5.5114	16.11	1.2071	0.00584
77.94	33.8	29.5858	41.34±0.2216	715.24	5.5212	46.38	1.6663	0.01095
88.64	28.6	34.9650	43.19±0.3416	1164.2	5.5026	106.29	2.0265	0.01225

¹equiv⁻¹cm², b) A⁰



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Table 2
Calculated values of K_2 and U for S-acetylthiocholine Halides and Perchlorate in Ethanol at 25 °C:

Ethanol wt %	K_A	K_1	K_2	U
a-s-acetylthiocholine bromide				
10.94	72.74	2.307722	30.73933	3.450631
21.99	59.47	2.604770	21.83119	3.128128
29.70	32.90	2.861216	10.49861	2.442226
40.43	17.93	3.345667	4.35917	1.678809
50.03	20.51	3.98694	4.144296	1.637889
60.22	19.02	5.052845	2.764216	1.32554
68.15	19.09	6.299523	2.030388	1.108691
77.94	31.57	8.874473	2.557394	1.269028
88.64	63.19	14.09543	3.483015	1.500296
b-s-acetylthiocholine iodide				
10.94	68.90	2.020943	33.09300	3.529092
21.99	27.67	2.280557	11.133	2.495929
29.70	34.33	2.525493	12.59339	2.609583
40.43	15.03	3.000985	4.008356	1.611108
50.03	13.42	3.632222	2.694708	1.306901
60.22	15.22	4.690819	2.244636	1.177003
68.15	23.35	5.959987	2.917794	1.365529
77.94	22.39	8.630598	1.594258	0.953301
88.64	42.76	14.24977	2.000751	1.098862
c-s-acetylthiocholine perchlorate				
10.94	45.53	1.755303	24.93853	3.25573
21.99	20.70	1.989404	9.405127	2.342299
29.70	19.80	2.233041	7.866834	2.182318
40.43	35.97	2.697150	12.3363	2.59049
50.03	9.60	3.319589	1.891924	1.061922
60.22	7.66	4.390204	0.744794	0.556636
68.15	16.11	5.700377	1.826129	1.038908
77.94	46.38	8.539315	4.431349	1.692187
88.64	106.29	14.76332	6.199599	1.974025



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Table 3
Calculation of radii of the ions for s-acetylthiocholine Halides and Perchlorate in Ethanol - Water Mixture at 25 °C:

Ethanol wt %	$\Lambda^{\circ} \eta_0^a$	$\lambda_0^- \eta_0^a$	$\lambda_0^+ \eta_0^a$	${}^bR^-$	${}^bR^+$	${}^bR^+ + R^-$	${}^b a^{\circ}$
a-s-acetylthiocholine bromide							
10.94	0.92281	0.51496	0.40785	1.59119	2.00909	3.60028	6.5223
21.99	0.95962	0.53550	0.42412	1.53015	1.93202	3.46217	6.5329
29.70	0.94201	0.52568	0.41634	1.55875	1.96813	3.52687	6.5268
40.43	0.91063	0.50816	0.40246	1.61247	2.03597	3.64844	6.5157
50.03	0.88301	0.49275	0.39026	1.66291	2.09965	3.76256	6.5103
60.22	0.78793	0.43969	0.34823	1.86358	2.35302	4.21660	6.5086
68.15	0.70535	0.39361	0.31174	2.08176	2.62851	4.71027	6.5060
77.94	0.64864	0.36197	0.28667	2.26375	2.85829	5.12205	6.5108
88.64	0.54358	0.30334	0.24024	2.70126	3.41071	6.11197	6.5124
b-s-acetylthiocholine iodide							
10.94	0.91067	0.52958	0.38110	1.54728	2.15011	3.69739	6.0490
21.99	0.92782	0.53955	0.38827	1.51868	2.11037	3.62904	6.0233
29.70	0.92453	0.53764	0.38690	1.52408	2.11787	3.64195	6.0174
40.43	0.89300	0.51930	0.37370	1.57790	2.19266	3.77056	6.0183
50.03	0.86824	0.50490	0.36334	1.62290	2.25519	3.87809	6.0179
60.22	0.80923	0.47058	0.33864	1.74125	2.41965	4.16090	6.0120
68.15	0.75456	0.43879	0.31577	1.86740	2.59495	4.46235	6.0157
77.94	0.70082	0.40754	0.29328	2.01058	2.79392	4.80450	6.0150
88.64	0.59497	0.34599	0.24898	2.36829	3.29100	5.65930	6.0007
c-s-acetylthiocholine perchlorate							
10.94	0.83876	0.51091	0.32785	1.60381	2.49929	4.10309	5.5561
21.99	0.88261	0.53762	0.34499	1.52414	2.37513	3.89927	5.5039
29.70	0.88705	0.54032	0.34673	1.51651	2.36324	3.87975	5.5134
40.43	0.92567	0.56384	0.36182	1.45324	2.26465	3.71789	5.5171
50.03	0.84466	0.51450	0.33016	1.59262	2.48185	4.07446	5.5131
60.22	0.82482	0.50242	0.32240	1.63092	2.54154	4.17247	5.5084
68.15	0.76263	0.46453	0.29809	1.76392	2.74880	4.51272	5.5114
77.94	0.73627	0.44848	0.28779	1.82708	2.84722	4.67430	5.5212
88.64	0.63230	0.38515	0.24715	2.12749	3.31536	5.44285	5.5026

a) $\Omega^{-1} \text{equiv}^{-1} \text{cm}^2$, b) Å°

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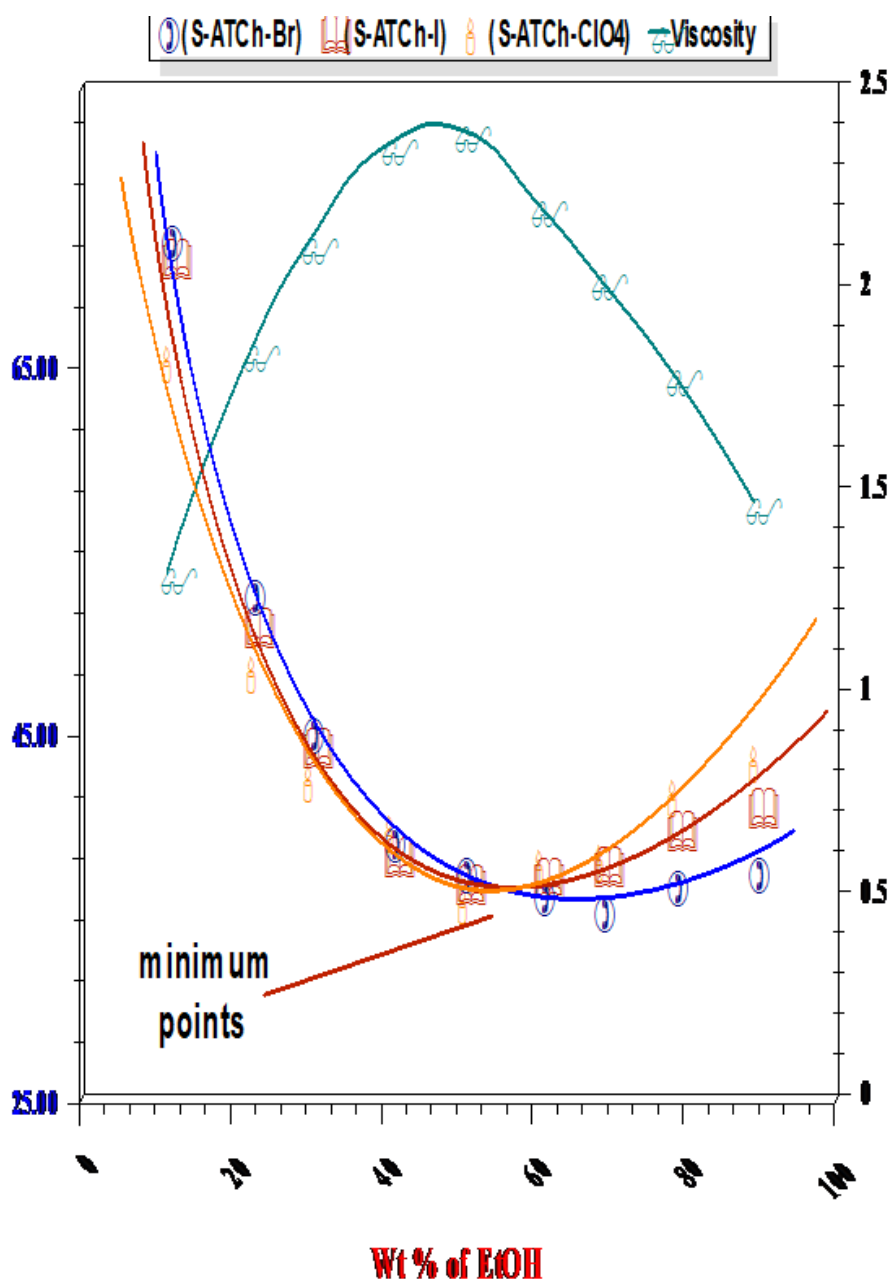


Fig. 1 Variation of viscosity and Λ_0 of S-acetylthiocholine Halides and perchlorate with composition of solvent mixture

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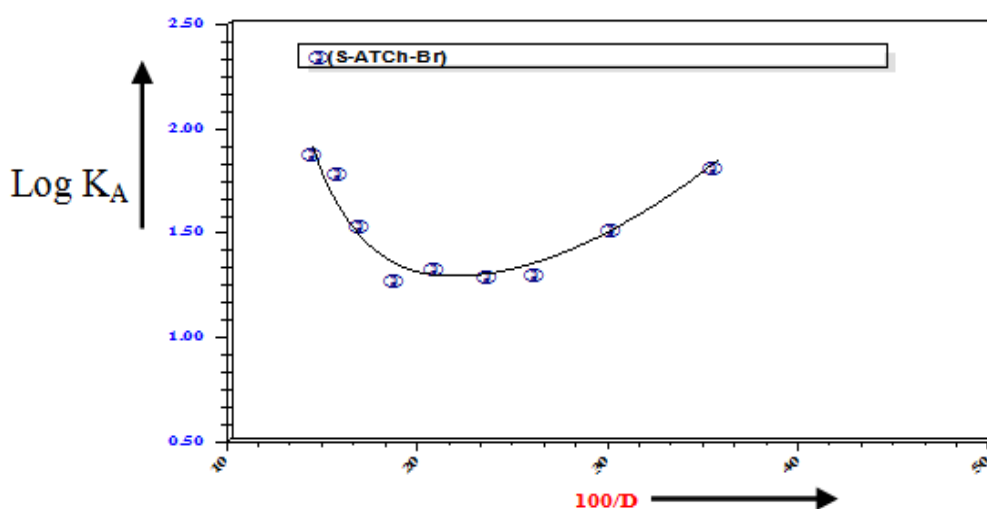
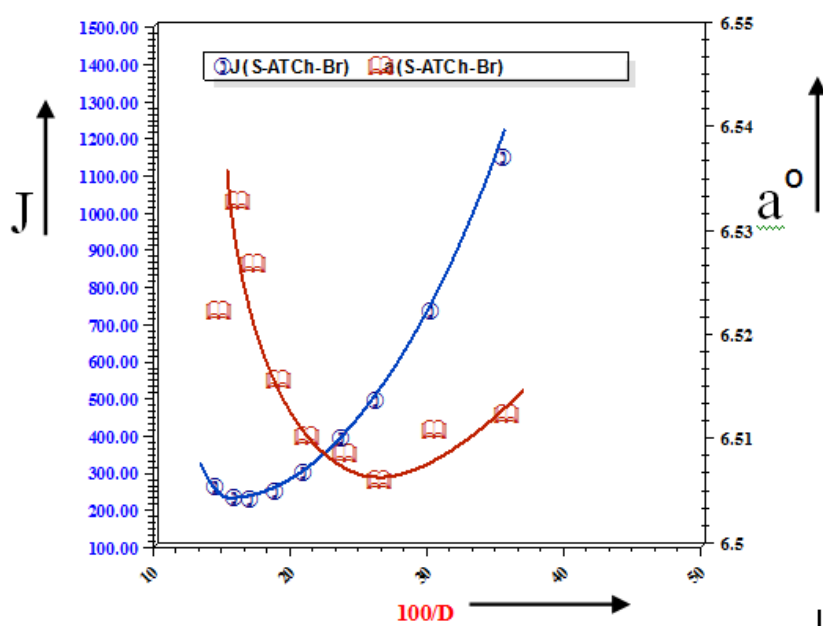


Fig. 2 Variation of J , a° and $\log K_A$ with di electric constant of Ethanol - Water mixture for S-acetylthiocholine Bromide

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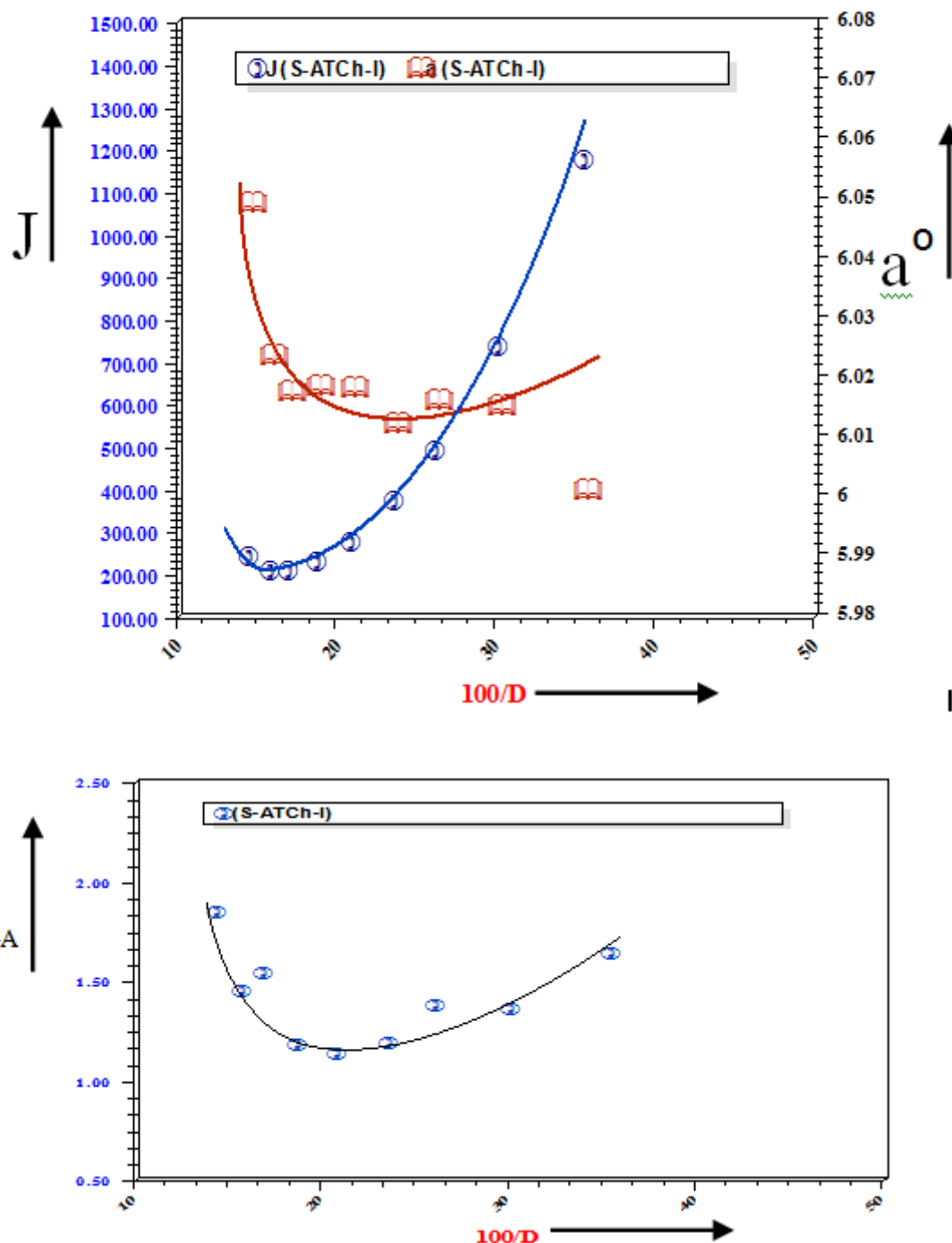


Fig. 3 Variation of J, a° and log K_A with di electric constant of Ethanol - Water mixture for S-acetylthiocholine Iodide

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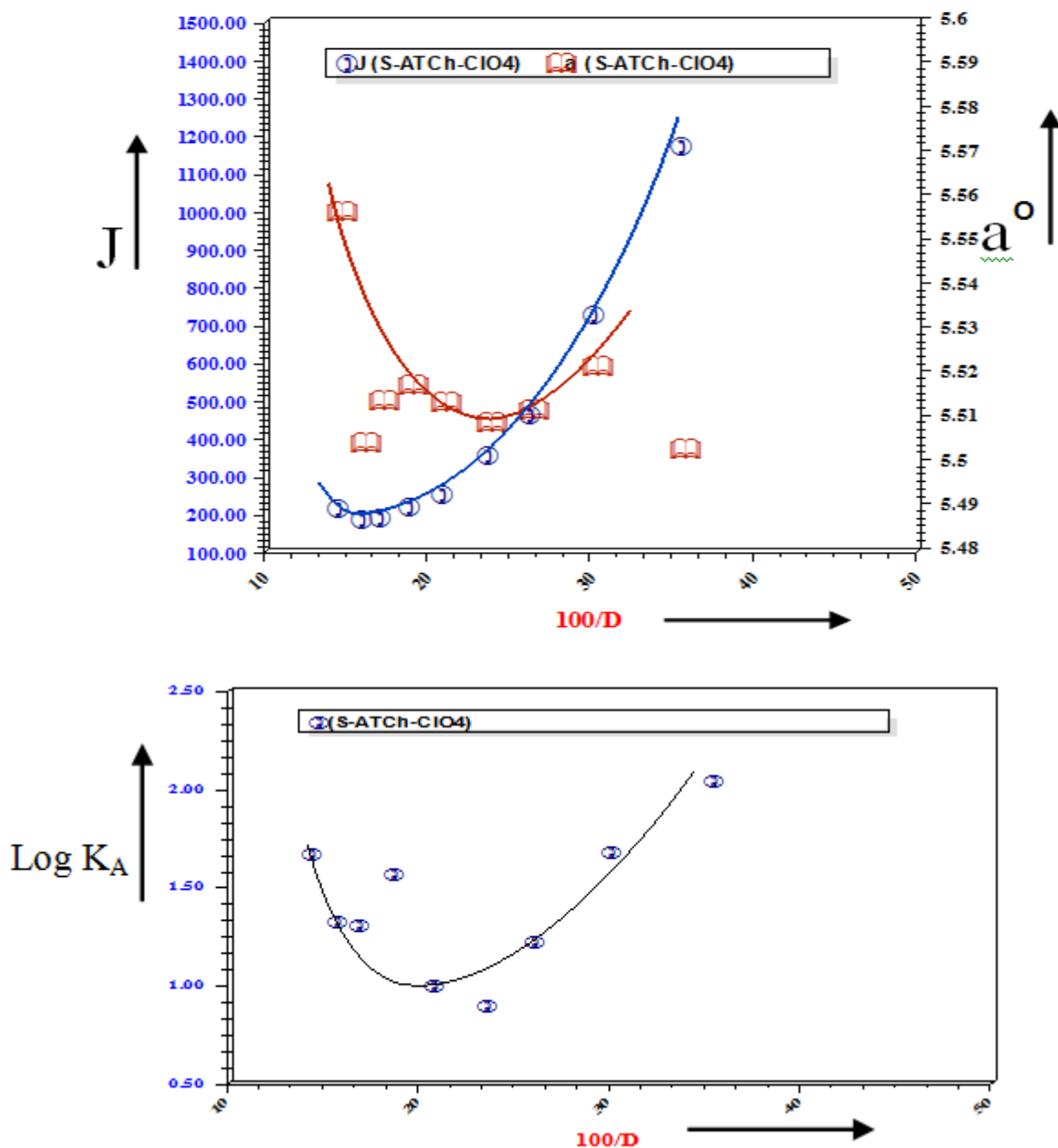


Fig. 4 Variation of J, a° and $\log K_A$ with dielectric constant of Ethanol - Water mixture for S-acetylthiocholine Perchlorate

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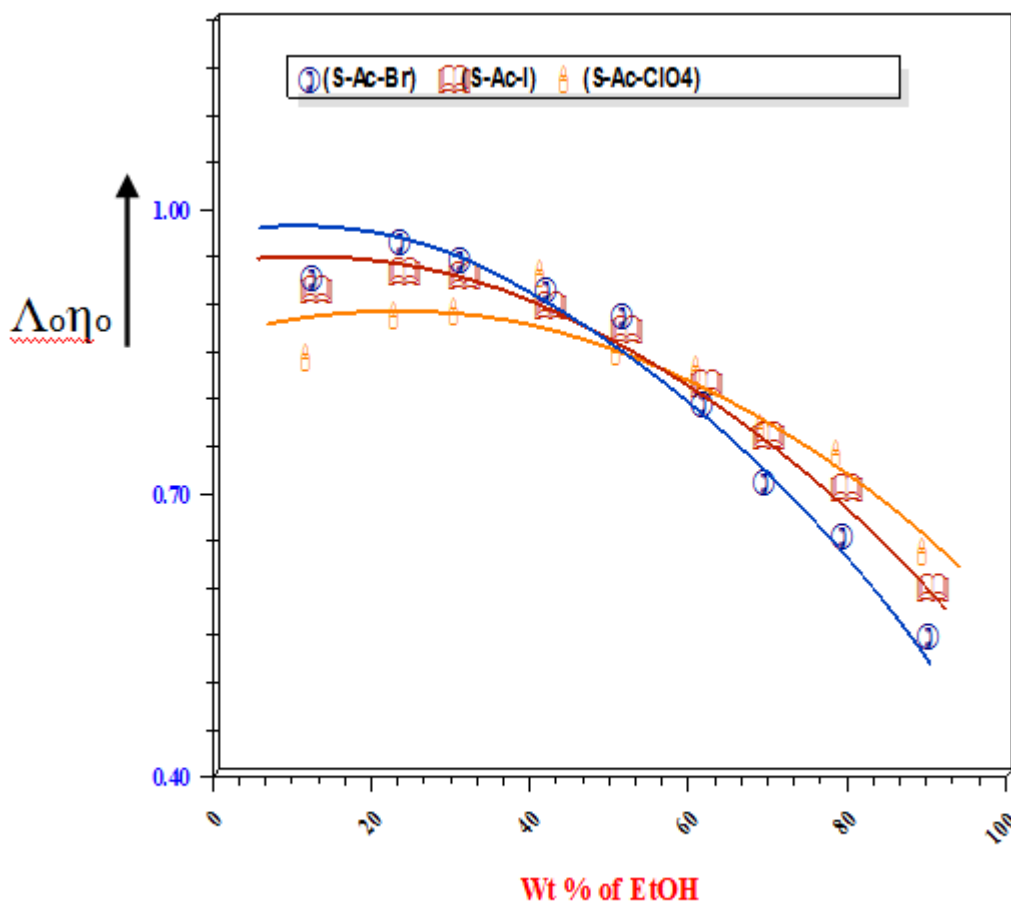


Fig. (5) Variation of Walden Product ($\Lambda_0\eta_0$) with composition of solvent mixture

It can be readily seen from table 1 and fig. 1 that Λ_0 for s-acetylthiocholine halides and perchlorate exhibits minima at 50.5 wt% ethanol. One can observe that the composition at which the minima occur, do not coincide with the the maximum in the viscosity ethanol wt% (maximum at 42 wt% ethanol) this deviation due to the interaction between ions and solvent.

The occurrence of a minimum in the value of Λ_0 , is an unexpected behavior. Since on decreasing the dielectric constant, the ionic mobilities are hindered and the chance for ion pair formation is more prevailed. So Λ_0 should decrease with decrease of the dielectric constants.

Sadek et al³, obtained similar behavior for Λ_0 in case of s-alkylisothiouranium iodide in methanol – water mixtures. **El – Hammamy et al.**, obtained the same behavior for Λ_0 in case of the following: N-N¹-diphenyl –s- alkylisothiouranium bromides⁴ in methanol – water mixtures, Co (II) complexes of acetone thiosemicarbazone halides⁵ in methanol – water mixtures, acetylcholine halides and perchlorate in methanol – water⁶ mixtures and ethanol – water⁷ mixtures. But in case of n-propanol – water⁸ mixtures,



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Λ° exhibits smooth curves and decreases with increasing the n-propanol concentration i.e., Λ° decreases with decreasing of dielectric constant of medium.

El – Hammamy⁹ et al., obtained similar behavior for Λ° of s-acetylthiocholine iodide in methanol – water mixtures. Kawana and El – Hammamy¹⁰, obtained similar behavior for Λ° in case of S-acetylthiocholine bromide in n-propanol – water mixtures exhibits smooth curve and decreases with increasing of n-propanol concentration i.e., with decreasing of dielectric constant of medium.

On the other hand figs (2-4) show that a° , J and K_A pass through minimum values at certain dielectric constants.

The initial decreasing in a° for s-acetylthiocholine halides and perchlorate can be explained on the basis that the strength of hydrogen bonds between ions and water are so high to be affected by adding small amounts of ethanol. On increasing ethanol content, depolymerization occurs and increase of a° values is observed.

The minimum in $\log K_A$ vs. $1/D$ plot may be explained on the basis that water is a highly associated solvent due to hydrogen bonds forming plomeric aggregates. It is possible that pure water can stabilize the ion – pairs formed as results of the molecular chains which created hydrogen bonding. On addition of ethanol, depolymerization occurs and less associated forms are produced, since it was seen from density and viscosity studies¹¹ that ethanol –water is a strong hydrogen bonded system. On further increasing the ethanol content the K_A values tend to increase regularly. In this region, it is assumed that over a certain ethanol concentration, the water structure which could affect. The association process of the ions would undergo less marked variation. Also the trend to a° show that, on addition of ethanol to water a° decrease (solvation decrease) till a minimum value and the increases for ethanol – rich solution as discussed before.

From above picture of variation of both a° and K_A with dielectric constant, one can conclude that the sphere in continuum model can not be applied to these systems. Further evidence in supported this conclusion can be obtained by using the expression¹²

$$\ln K_A = \ln (4 \Pi N a^{\circ 3} / 3000) + e^2 / a^\circ DKT + U \dots\dots\dots(1)$$

where

$$U = \Delta S / k - E_s / kT$$

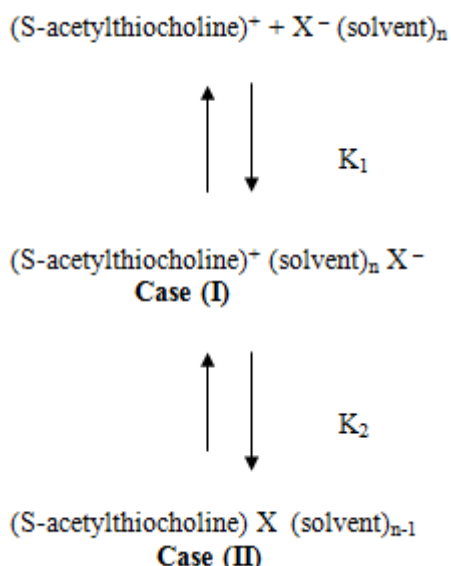
The factor E_s / kT was introduced by Gilkerson¹³ to account for the energy of ion – dipole interaction, which should be different from that when ion – pairs are considered. The entropy term $\Delta S / k$ was included¹² to account for the change of entropy due to different arrangements of solvent molecules around free ions and ion – pairs.

The last column in table 3 shows that U term for s-acetylthiocholine halides and perchlorate decreases as ethanol wt% increases at the preliminary stages. This may be due to the fact that the $\Delta S / k$ decreases (entropy / Boltzmann ratio) as the dielectric constant of medium decreases. This reflects that the ion – dipole interaction term increases as a result of modification of the structure of the mixed solvents and interaction between solute and solvent. On further addition of ethanol, the U term slightly increases as the dielectric constant of medium decreases. This indicates that entropy change due to solvent molecules arrangement around ions and ion – pairs becomes greater than the ion – dipole interaction term, which may be attributed to the disturbance due to the fact that orientation of solvent molecules around the ions increases as the dielectric constant decreases.

Finally¹⁴, the solvent separated – ion pairs model is applied as follows:



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The association constant has thus given by expression:

$$\mathbf{K_A} = \mathbf{K \Sigma} = (\mathbf{C_{(ion\ pairs)}}) / (\mathbf{C_{(s-acetylthiocholine)^+}})(\mathbf{C_{X^- (solvent)_n}}) = \mathbf{K_1(1 + K_2)} \dots \dots \dots (2)$$

where $\mathbf{K_A} = \mathbf{K \Sigma}$ is obtained from the conductance measurements,

$$\mathbf{K_1} = \mathbf{4 \Pi N a^{o3} e^b / 3000} \dots \dots \dots (3)$$

From **table 2** it is evident that $\mathbf{K_1}$ for s-acetylthiocholine bromide, iodide and perchlorate in ethanol – water mixtures increases as wt% of ethanol increases. This behavior may be explained on the basis that the formed ion – pairs prefers the more solvated form case (I) to the desolvated form case (II).

Fig. 5 shows that the Walden product $\mathbf{\Lambda \cdot \eta_o}$, a function of solvent composition, for s-acetylthiocholine halides and perchlorate in ethanol – water mixtures at 25 °C varies in the usual manner, i.e., it decreases with decreasing dielectric constant. This is in agreement with general findings on several small size (uni-univalent)^{15,16} and (bi-bivalent)¹⁷ systems and can be attributed to ion – solvent relaxation drag^{18,19}.

The electrostatic radii $\mathbf{R^+}$ and $\mathbf{R^-}$ can be determined by using the stokes' equation in the following form:

$$\mathbf{R^\pm} = \mathbf{0.8194 \times 10^{-8} / \lambda_o^\pm \eta_o} \dots \dots \dots (4)$$

It is clear that application of stokes' equation needs the determination of the true values of ionic conductance. According to the Fuoss assumption²⁰ that the transport number is independent of the solvent composition, the ionic equivalent conductance for cations and anions are calculated and introduced in the stokes' equation. The results are contained in **table 3**.

It can be readily seen from **table 3** that the values of $\mathbf{R^+}$ and $\mathbf{R^-}$ and summation $\mathbf{(R^+ + R^-)}$ decrease on addition of small portion of ethanol and then increase on decreasing the dielectric constant of the medium i.e., increase with increasing the wt% of ethanol. This can be explained on the basis that, the small portion of ethanol will diminish the aggregation of water around the ions so the radius of ions decreases at first. On



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further addition of ethanol, the solvation shell will trend to ethanol more than water and so the radius of ions increases. It is due to cosolvent structure.

It was observed that the values of a° was found to be greater than that of stokes' radii ($R^{+} + R^{-}$) in mixed solvents. This behavior can be explained on the basis Nightingale's conclusions²¹.

REFERENCES

1. N. H. El – Hammamy, A .M. Ismaeil, M. F. Amira and N. S. El – Sisy, J. Indian Chem. Soc., 86, 878-881, August,2009
2. R. M. Fuoss and L. Onsager, J. Phys. Chem. Soc., 1957, 61, 668; R. M. Fuoss, J. Am. Chem. Soc., 1959, 81, 2659.
3. H. Sadek, A. M. Hafez, and N. H. El Hammamy, Pakistan J. Sci. Pres., 1977, 29, 100.
4. N. H. El – Hammamy, A. A. Hasaniien, H. A. Mahmoud, and F. M. abd El – Halim, J. Chem.. Soc. Pak., 1986, 8, 125.
5. N. H. El – Hammamy, A.A.Zaghloul, A.I.Kwana and F.M.Abd El – Halim, Egypt. J. Chem., 1992, 35(1), 35-45.
6. N. H. El – Hammamy, A.M.Ahmed, F.F.El – Bardisy and F.M.Abd El – Halim, Alex. Eng. J., 1989, 28 (2), 867.
7. N. H. El – Hammamy, A.M.Ahmed, F.F.El – Bardisy and F.M.Abd El – Halim, Bulletin of electroChemistry, 1995,11(5), 253 – 259.
8. N. H. El – Hammamy, Bull. Fac. Sci. Alex. Univ., 1991, 31 (A), 20-39.
9. N. H. El-Hammamy, A. I. Kawana, S. A. El-Shazly and A. A. Zaghloul, Egypt. J. Chem., 1993, 36(5), 351-362.
10. A. I. Kawana and N. H. El-Hammamy, Egypt.J. Chem., 2002, 45 (2), 345 – 357.
11. N. H. El – Hammamy, M. M. El-Kholy, M. F. Amira and N. S. El – Sisy, Alex. J. Pharm. Sci, 23(2), 75-79,sept(2009)
12. F. Accascina, A. D'Aprano, and Triolo, J. Phys. Chem.,1967, 71, 3744.
13. W. R. Gilkerson, J. Chem. Phys., 1956, 25, 1199.
14. D. F. Evans and P. Gardam, J. Phys. Chem., 1969, 73, 158.
15. J.E. Lind and R.M. Fuoss, J. Phys. Chem., 1961, 65, 1001.
16. R.W. Kunze and R.M Fuoss, J. Phys. Chem. Soc., 1963, 67, 911.
17. G.Atkinsen and S. Petrucci, J. Phys. Chem. Soc., 1964, 86, 7.
18. R. M. Fuoss, Proc. Nat. Acad. Soc. U. S., 1959, 45, 807.
19. R. Zwanzing, J. Chem. Phys., 1963, 38, 1603.
20. H. Sadek and R. M. Fuoss, J. Am. Chem. Soci., 1959, 81, 4507.
21. E. R. Nightingale, J. Phys. Chem., 1959, 63, 1381.
22. N. H. El – Hammamy, A.M.Abou Skkina, S.A.Abou – El – Enein and A.A.Zaghloul, Egypt. J. Chem., 1992 35, 75.
23. J.E. Lind, J. J. Zwolenik and R.M. Fuoss, J. Am. Chem. Soc.,1959, 81, 1557.