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Electrical Conductivity of $[Co(en)_2Cl_2]$ Cl in Mixed Solvents (Alcohol + Water) at 298K

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ABSTRACT

The electrical conductivity of trans – dichloro bis(ethylenediamine) cobalt (III) chloride $[Co(en)_2Cl_2]$ Cl has been measured in (methanol + water), (ethanol + water) and (isopropanal + water) at different percentages and at 298K. The conductivity parameter, Λ_o (equivalent conductivity at infinite dilution, Ka; (association constant) and R the (distance parameter) between the ions were calculated by using Lee – Wheaton equation for symmetrical electrolytes.

The Walden product $(\Lambda \circ \eta)$ found to be not constant for the three media which describe as to the change of ion-solvation and of the solvent structure.

التوصيلية الكهربائية لمعقد ترانس ثنائي كلوروبس اثيلين ثنائي امين كوبلت (III) كلوريد $[Co(en)_2Cl_2]$ Cl في نسب مختلفة من مزيج (الماء + الكحول) عند درجة حرارة 298 كلفن

الملخص

لقد تم في هذا البحث قياس التوصيلية الكهربائية لمعقد $[Co(en)_2Cl_2]$ Cl في نسب مختلفة من مزيج (ماء + كحول مثيلي)، (ماء + كحول اثيلي) و(ماء + ازو بروبانول) وبدرجة حرارة 298 كلفن ولقد تم حساب ثوابت التوصيلية Λ_o (المواصلة المكافئة عند التخفيف اللانهائي)، Ka (ثابت التجمع الايوني) فضلا عن R (معدل المسافة بين الايونات في المحلول) باستخدام معادلة لي – ويتون في التوصيلية للالكتروليتات المتناظرة، ولقد وجد ان ناتج والدن $(\Lambda \circ \eta)$ ليس ذو قيمة ثابتة في الاوساط الثلاثة والذي يفسر على حصول التغيير في ذوبانية الايونات وعلى تركيب المذيب.

INTRODUCTION

As in other fields of inorganic chemistry some research on coordination compounds has been carried out in non aqueous media in the case in which the coordination compounds reacts with water, the use of non aqueous solvent may be advantageous. A familiar example is the determination of the number of ions in a compound by measuring the conductivity in nitromethane or other highly polar solvent (Geselowitz and Taube, 1982). A conductance measurements of $[Cu(en)_2]So_4$ (2:2) in formamide at 25°C were performed to see whether a high dielectric constant would control ion associated to any extent. The data were analyzed by using the Fuoss – Onsager equation for unassociated electrolytes (Johari and Tewari, 1965).

Copper (II) complexes of secondary and tertiary N – substituted ethylenediamines were prepared by Meek and Ehrhardt (Meek and Ehrhardt, 1965) and there conductivity were measured and found to be increased with time in nitromethane.

Evidences suggested that the substitution of (en) for ammonia in the coordination sphere increase the degree of association. The osmotic and activity coefficients are reported (Masterton, 1967) for the compounds trans – $[Co(en)_2$ NCS. CL]X, where x = $\bar{I}$, $\bar{Br}$, $\bar{Cl}$ or $\bar{NO}_3$. The results are lower than those of most simple 1:1 salts.

The conductances and solubilities of oxalato bis (ethylenediamine) cobalt (III) chloride, bromide, iodide, and perchlorate were determined in water at 25°C by Kubota (Kubota, 1971) and the data were analyzed on the basis of the Fuoss Onsager Skinner theory. Kaneko and Wada (Kaneko and Wada, 1978) studied the conductance behavior of some tris (ethylenediamine) cobalt (III) complexes in dilute aqueous solutions at 25°C to investigate the ion – pair formation.

Solvation and ionic association of bi (β–diketonato) (diamine)cobalt (III) perchlorates in alcohols and ketones have been measured by (Ito et al., 1988).

Their conductances were measured in methanoal, ethanol, 2–propanol, methyl ketone at 25° C.$[Co(acac)_2$ (en)]ClO_4 in alcohols was found to be strongly disassociated and this can be explained as being due to the strong solvation of $[Co(acac)_2$ (en)$]^+$. Tatehata and Asaba (Tatehata and Asaba, 1988), determined by a conductance method at 25° C the diastereometric ion – pair formation constants of C_1–Cis (N)– $[Co(OX)(gly)_2]$ and β– Cis[Co(OX)(edda)] with $[Co(en)]^{3+}$ in solution [where (edda) is ethylenediamine N, N – diacetae dianion, (gly) is glycinate anion].

Yokoyama et al. (Yokoyama et al., 1992), measured the conductivities for aqueous solutions of the chloride, bromide, Iodide, nitrate, and perchlorate of the tris (ethylenediamine) cobalt (III) complex, $[Co(en)_3]^{+3}$ with varying temperatures from 0 to 50° C.

Singh et al. (Singh et al., 1995), have prepared the complex hetereobimetallic salts of the formula [M(L–L) (3)] [$\bar{M}$ (DED)(2)] [M=Zn(II), Ni(II), Co(II), Cd(II); $\bar{M}$ =Ni (II), Zn (II), Cd (II); L – L = $2,\bar{2}$ –bipuridyl (bipy); 1,10 – phenanthroline or ethylenediamine (en). The measured conductivities are inconsistent with those expected for 2:2 electrolytes suggesting that extensive ion pairing is occurring between the highly charged cationic and anionic species in nitrobenzene.

Akrawi (Akrawi et al., 2002) have measured the electrical conductivity of a mixture of both symmetrical and unsymmetrical complexes. $\{[Ni(en)_3](No_3)_2\}+\{[Co(en)_2Cl_2]Cl\}$ in methanol at 298K. The results were analyzed using Lee – Wheaton equation. The equivalent conductivities have been compared with the experimental value at the best – fit values of (R) and they are found to be in a good agreement. Besides it have been calculated the ionic consternation, activities coefficient, transport number for each ion present in the solution.

The present paper describes the electrical conductivity of Trans-dichloro bis (ethylenediamine) cobalt chloride in methanol+H_2O, ethanol+H_2O and isopropanol+H_2O at different percentages and at 298K.

EXPERIMENTAL

Materials:

Methanol, ethanol and isopropanol (Fluka) were of high purity and used directly. Conductivity water was prepared and used for conductivity measurements.

Trans dichloro bis ethylenediamine cobalt(III) chloride $[Co(en)_2Cl_2]Cl$ (Fernelius, 1946) was prepared by adding 12g. of 10% solution of ethylenediamine (BDH, $\geq$99.5%), with stirring, to a solution of (3.5g. 0.020 mole) cobalt chloride hexa hydrate (Fluka, $\geq$99%) in 10cm^3 of water in a 100cm^3 beaker. A vigorous stream of air is passed through the solution for (2 hrs). Then 7 cm^3 of concentrated hydrochloric acid is added, and the solution is evaporated on steam bath until a crust forms over the surface (15cm^3). This solution is allowed to cool and stand overnight before the bright – green square plates of the hydrochloride of the trans form are filtered. These crystal then washed with alcohol and ether, then dride at 110^{o}C. At this temperature the hydrogen chloride is lost and the crystals crumble to a dull – green poder. This yield is 1.5g. (60% based on the ethylenediamine). The physical properties and C.H.N analysis of $[Co(en)_2Cl_2]Cl$ are: Colour green, M.P/C^o 241, M. wt 285.43

Found			**Calculated**		
C%	H%	N%	C%	H%	N%
16.52	5.45	19.92	16.81	5.60	19.61

Apparatus:

Conductivity measurements were made using Digital Conductivity Meter (Jenway) with a frequency range of 50H$_Z$ – 3 kH$_Z$ and sensitivity between 10^{-1} and 10^{-9} Siemens. The temperature of the cell and its consents was kept constant at 25 ± 0.1^{o}C using water – circulating thermostate type VHS β radiometer. The design of the conductance cell and the nitrogen was the same as that previously used (Akrawi, 1981), the cell constant was checked regularly and found to be 0.94cm^{-1}.

General conductivity measurements:

The following method has been used for measuring the conductivity of each electrolyte: In a clean, dry and weighted empty conductivity cell kept at constant temperature (25 ± 0.1^{o}C), 100 ml of conductivity water was added and the conductance of the solvent was measured, and the cell was reweigted again.

Into the cell, a certain amount of the concentrated $[Co(en)_2Cl_2]Cl$ (10^{-3}m) aqueous solution was injected into the cell from a plastic syringe which was weighted before and after each addition, and the conductivity of the solution was measured. This process was repeated generally for about 12 additions and after all the additions have been made, the cell was re weighted to find the change over the whole run which was found to be not more than 0.025%.

The above procedure was repeated for measuring the conductivity in different percentages of: (methanol + water), (ethanol + water) and (isopropanol + water) each at 298K.

The input data to the computer program (SYM_4) are: solvent data (Temperature T, Dielectric constant D and Viscosity η); association constant K_A and limiting equivalent conductivity Λ_0; and R in the form Rmin., Rmax., ΔR, together with the solution moralities and the corresponding equivalent conductances.

Tables (1-3), shows the solution moralities (mole L^{-1}) and the equivalent conductivities (S mol^{-1} cm^2) of $[Co(en)_2Cl_2]Cl$ in different percentages of (methanol + water), (ethanol+water) and (isopropanol+water) respectively.

Figures (1-3), illustrate the relation between the molar concentration and the equivalent conductance of the $[Co(en)_2Cl_2]Cl$ at different ratios of each (alcohol+water).

RESULTS AND DISCUSSION

It is well known that oppositely charged ions tend to form ion pairs in a medium of low dielectric constant. At constant temperature, free ions and ion pairs are at their equilibrium concentration αC and $C(1- \alpha)$ respectively, (where C = concentration, α = degree of dissociation).

This state described by the thermodynamic equilibrium constant for the ion – association reaction (K) since ion pair is a non – conducting entity, where α is the ratio of the molar conductivity of electrolyte (Λ) to that of free ions (Λ_o). The distance parameter R must be the least distance that two free ions can approach before they merge into an ion pair. Or, in other words, R is the further distance of separation of two paired ions.

For the specific case of solutions containing only a single symmetrical electrolyte this equation has the following general form:-

$$\Lambda_{equiv.} = f(\Lambda_0, R, K_A)$$

Where Λ_0 is equivalent conductance at infinite dilution, K_A the pairwise ion association constant. And R the distance parameter which is defined as the distance between anion and cation at which short-range forces become strong enough to impede further approach of the ions, allowing the formation of CIP or SSIP (Akrawi, 1981).

Lee and Wheaton (Lee and Wheaton, 1979) consider a symmetrical electrolyte MX; and they assumed the solute to be completely dissociated into the species M^{n+} and X^{n-}.

The association eqilibrium :

$$M^{n+} + X^{n-} \overset{K_A}{\rightleftharpoons} MX$$

Will exist between the two species, and if K_A is the pairwise association constant, then :

$$K_A = \frac{[MX]}{[M^{n+}][X^{n-}]f_{\pm}^{2}}$$

Where $f\pm$ is the activity coefficient.

The model used in this work is that founded by Lee – Wheaton:

$\Lambda = \Lambda_o\left[1 + C_1\,\beta_k + C_2(\beta_k)^2 + C_3(\beta_k)^3\right] - \frac{\rho k}{1+kR}\left[1 + C_4\beta_k + C_5(\beta_k)^2 + \frac{kR}{12}\right]$ where $\mathbf{\Lambda_o}$ is the molar conductivity at infinite dilution, $\mathbf{\beta = 2q, k^2 = 1600\pi N_A q C\alpha}$, $q = \frac{e^2}{8\pi E_o E_1 kT}$, $\mathbf{C_1 \rightarrow C_5}$ and other symbols are either defined in the cited literature (Akrawi, 1981) or have their usual significant.

The model was considered as non – linear function of three parameters $\mathbf{\Lambda = \Lambda(\Lambda_o, k_A, R)}$, and was resolved by an iterative procedures.

A broader range of R was scanned by a series of successive steps of definite size for each step, the parameters $\mathbf{\Lambda_o}$ and $\mathbf{k_A}$ are obtained at the end of a sequence of alternating linearizations and least – square optimizations of the model, when $\mathbf{\Lambda_o}$ satisfied the criterion for convergence. In a row of three parameter sets, the (best) is the one by which the model is best fitted to experimental data, i.e the minimal standard deviation ($\sigma\Lambda$) is attend. The step size is then lowered by an order of magnitude, and the search is continued in the region around the (best) R.

This procedure is repeated until the final (best triplet) of parameters $\mathbf{(\Lambda_o, k_A, R)}$ is established when the step size equals to 0.1 pm.

Values of the limiting molar conductivity $\mathbf{\Lambda_o}$, ion – association constant ($\mathbf{k_A}$), distance parameter (**R**) and standard deviation of experimental Λ from the model $\sigma(\Lambda)$, obtained by using LW equation are shown in Table (4). This analysis has done to understand the solute – solvent interactions characteristics in different mixed solvents.

It is natural that the $\mathbf{\Lambda_o}$ value depends on the medium in each mixture, it decreases with increasing the percentage of any alcohol. Also it is found that the $\mathbf{\Lambda_o}$'s decrease in the order = [methanol +water] > (ethanol + water] > (isopropanol + water)].This is due to the increase of the viscosity of the medium in the same order (Doe et al., 1990).

Table 1: The plot of equivalent conductance Λ (Sienens equiv.$^{-1}$ cm^{2}) against the square root of molar concentration $\sqrt{\mathbf{C}}$ (mole. L^{-1}) for $[Co(en)_2Cl_2]Cl$ in a mixture of (methanol + water) at 298K.

H	**80% MeOh**		**60% MeOH**		**40% MeOH**		**20% MeOH**		**100%**	
	$\sqrt{\mathbf{C}}$	Λ	$\sqrt{\mathbf{C}}$	Λ	$\sqrt{\mathbf{C}}$	Λ	$\sqrt{\mathbf{C}}$	Λ	$\sqrt{\mathbf{C}}$	
3108	0.04644	77.1420	0.04803	80.6552	0.05674	102.7481	0.04285	124.8761	0.04285	1
2415	0.04803	76.9890	0.04952	80.4794	0.05867	102.6665	0.04472	124.5500	0.04472	1
9325	0.05091	76.8678	0.05091	80.4937	0.06123	102.5226	0.04803	124.2416	0.04644	1
1050	0.05345	76.6581	0.05222	80.3094	0.06276	102.3684	0.04952	124.1682	0.04803	1
3000	0.05461	76.5893	0.05345	80.2772	0.06416	102.2731	0.05091	124.0038	0.04952	1
0085	0.05570	76.6320	0.05461	80.0563	0.06607	102.2651	0.05222	124.0833	0.05091	1
6137	0.05674	76.4773	0.05570	79.9639	0.0666	102.1555	0.05345	123.7058	0.05222	1
1382∞	0.05773	76.4227	0.05674	79.9801	0.06723	102.0933	0.05461	123.5515	0.05345	1
2256	0.05956	76.2956	0.05773	79.8067	0.06778	102.0916	0.05570	123.5805	0.05461	1
9515	0.06042	76.2155	0.05867	79.7304			0.05674	123.4729	0.05570	1
5586	0.06123	76.2026	0.05956	79.7395			0.05773	123.2352	0.05674	1
0531	0.06348	76.0434					0.05867	123.1452	0.05773	1
7388	0.06723	75.8968					0.05956	123.1857	0.05867	1
5861							0.06042	123.0777	0.05956	1
2890									0.06042	1
1275										
0855										

Table 2: The plot of equivalent conductance Λ (Sienens equiv.$^{-1}$ cm^2) against the square root of molar concentration $\sqrt{C}$ (mole. L^{-1}) for $[Co(en)_2Cl_2]Cl$ in a mixture of (Ethanol + water) at 298K.

% EtOH	80% EtOH		60% EtOH		40% EtOH		20% EtOH		
Λ	$\sqrt{C}$	Λ	$\sqrt{C}$	Λ	$\sqrt{C}$	Λ	$\sqrt{C}$	Λ	√
23.5348	0.05345	35.5325	0.05091	48.2237	0.05674	56.6282	0.04803	103.0594	0.04
23.2189	0.05461	35.6156	0.05222	47.9099	0.05773	56.6825	0.04952	103.0903	0.04
23.3773	0.05570	35.4385	0.05345	47.7057	0.05956	56.6919	0.05091	102.9739	0.04
22.8428	0.05674	35.3196	0.05461	47.2773	0.06042	56.6466	0.05222	102.7134	0.04
22.2166	0.05773	35.2503	0.05570	46.9485	0.06123	56.6506	0.05345	102.6495	0.04
22.3723	0.05867	35.2233	0.05674	46.7037	0.06276	56.5531	0.05461	102.4342	0.05
22.0627	0.05956	35.2337	0.05773	46.5304	0.06348	56.6827	0.05570	102.3700	0.05
21.8083	0.06042	35.0179	0.05867	46.1453	0.06416	56.6155	0.05674	102.1643	0.05
21.6004	0.06123	35.0933	0.05956	46.0641	0.06482	56.5860	0.05773	102.0850	0.05
21.1502	0.06201	34.9496	0.06042	45.8323	0.06546	56.5881			0.05
21.0248	0.06276	34.8386	0.06123	45.8720	0.06607	56.6226			0.05
20.6634	0.06348	34.7560	0.06201	45.7034	0.06723	56.5601			0.05
20.3413	0.06416	34.6998	0.06276	45.5766	0.06831	56.6022			0.05
20.0533	0.06482	34.6673			0.06882	56.5571			0.05
19.7966	0.06546	34.6547			0.06931	56.5357			0.06
19.5669	0.06607	34.6625							
19.3607	0.0666	34.6863							
19.1762	0.06723	34.5183							
19.0111	0.06778	34.5761							
18.8627									
18.5153									

Table 3: The plot of equivalent conductance Λ (Sienens equiv.$^{-1}$ cm^{2}) against the square root of molar concentration $\sqrt{C}$ (mole. L^{-1}) for $[Co(en)_2Cl_2]Cl$ in a mixture of (Isoproponal + water) at 298K.

100% Isoproponal		**80% Isoproponal**		**60% Isoproponal**		**100% (H_2O)**	
$\sqrt{C}$	Λ	$\sqrt{C}$	Λ	$\sqrt{C}$	Λ	$\sqrt{C}$	Λ
0.02641	4.0424	0.04285	25.5893	0.05091	42.0597	0.04285	194.9910
0.03859	3.7870	0.04472	25.3800	0.09345	41.7836	0.04472	194.5800
0.04285	3.5825	0.04644	25.2781	0.05461	41.9192	0.04644	193.9447
0.04644	3.4866	0.04803	25.2556	0.05570	41.7993	0.04803	193.4910
0.04952	3.4491	0.05091	25.0183	0.05674	41.7414	0.04952	193.1506
0.05091	3.2632	0.05222	24.8166	0.05773	41.7364	0.05091	192.1697
0.05345	3.2900	0.05345	24.6753	0.05956	41.5917	0.05222	191.9844
0.05461	3.1518	0.05674	24.5194	0.06123	41.6106	0.05345	191.4808
0.05570	3.3318	0.05773	24.5342	0.06201	41.5485	0.05461	191.3157
0.05674	3.2108	0.05956	24.3722	0.06276	41.5200	0.05570	190.8229
0.05773	3.1020	0.06042	24.4610	0.06348	41.5206	0.05674	190.6095
0.05956	3.1789	0.06123	24.3146	0.06416	41.5484	0.05773	190.0699
0.06042	3.0898	0.06201	24.1959	0.06546	41.4541	0.05867	189.7693
0.06123	3.0080	0.06276	24.1007	0.06607	41.3366	0.05956	189.1497
0.06348	3.0324	0.06546	23.9074	0.06666	41.4544	0.06042	188.9938
0.06416	2.9677	0.06607	23.8977	0.06778	41.3276		
0.0666	2.9610	0.06666	23.8997	0.06831	41.2934		
		0.06723	23.9132	0.06882	41.2768		
				0.06931	41.2769		
				0.07026	41.3190		
				0.07114	41.2272		

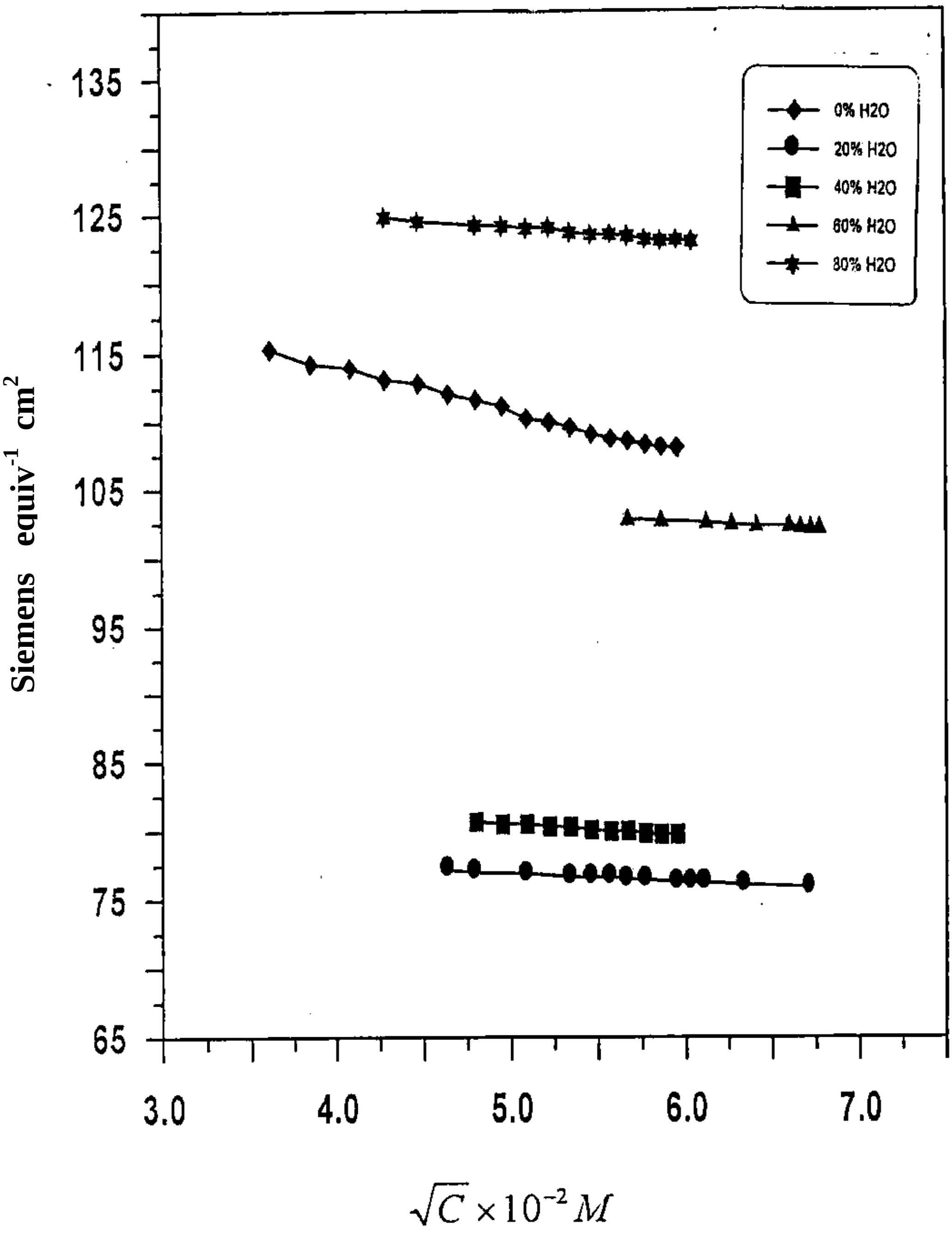

Figure 1:The plot of equivalent conductivity against the square root of molar concentration of $[Co(en)_2Cl_2]Cl$ in (Methanol + Water) at 298K°

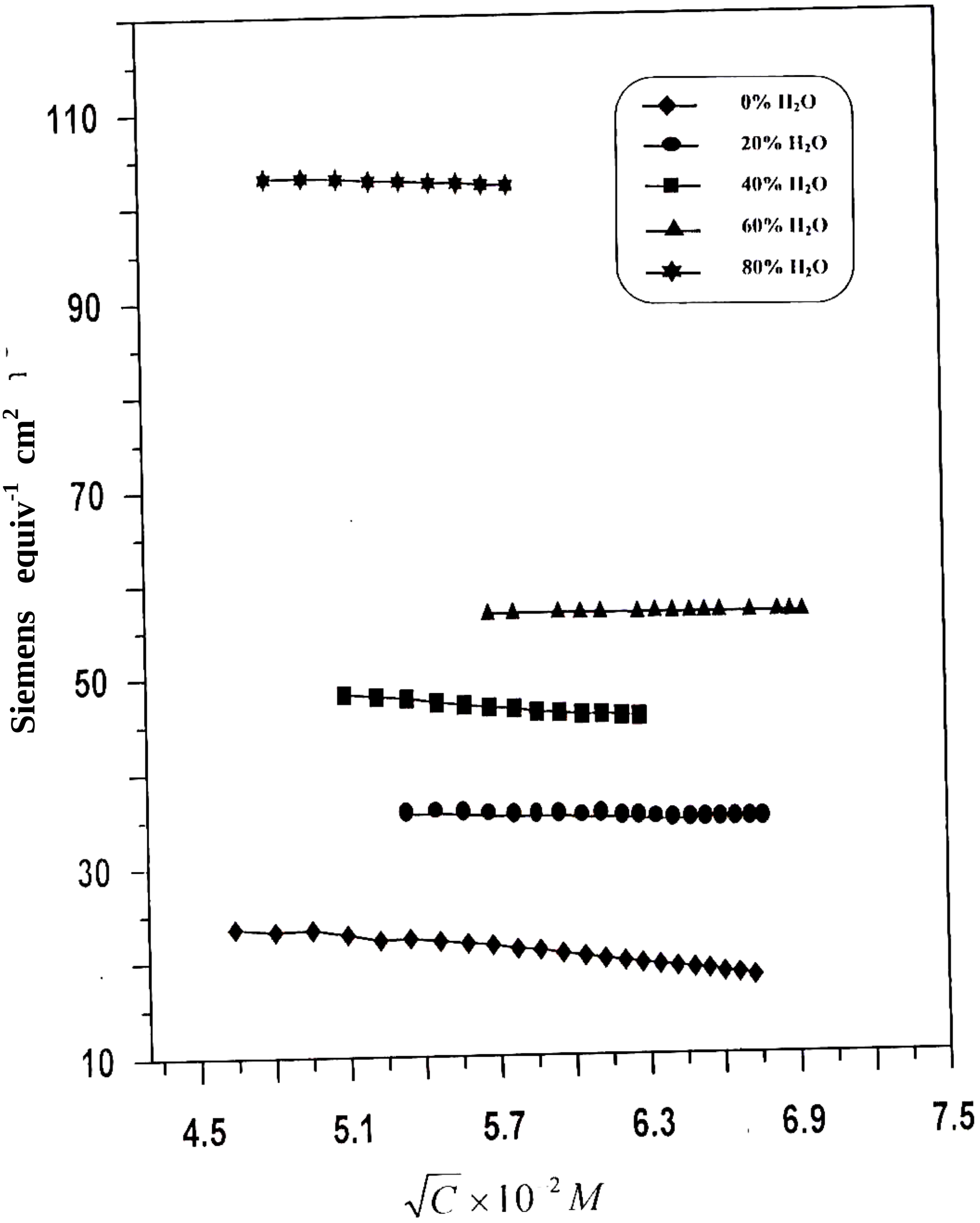

Figure 2:The plot of equivalent conductivity against the square root of molar concentration of $[Co(en)_2Cl_2]Cl$ in (Eethanol + Water) at 298K°

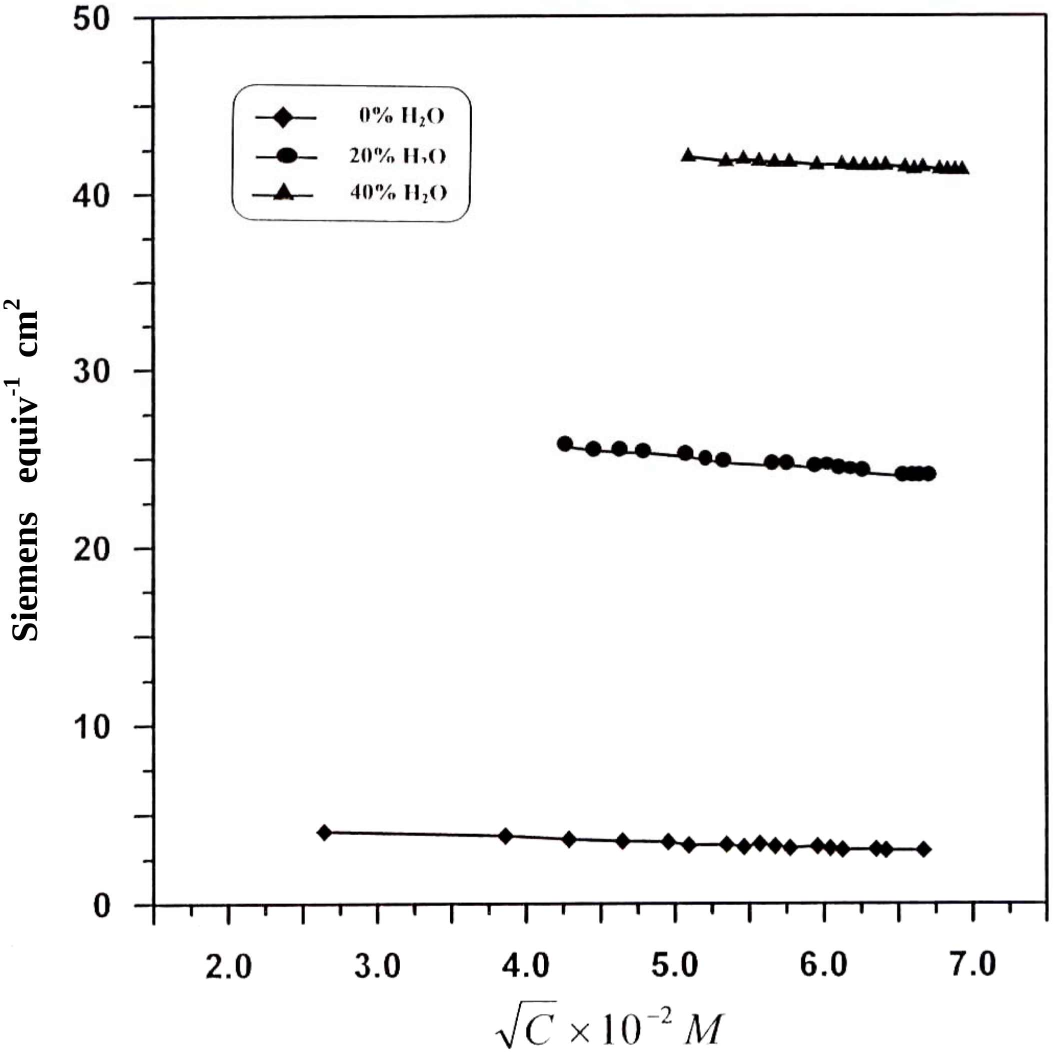

Figure 3:The plot of equivalent conductivity against the square root of molar concentration of [Co(en)$_2$Cl$_2$]Cl in (Isopropanol + Water) at 298K^0

Table 4: Λ_o, k_A, R and $\sigma(\Lambda)$ for $[Co(en)_2Cl_2]Cl$ in different mixed (alcohol + water) at 298K.

Methanol + Water				
Percentage of alcohol	Λ_o/S mole^{-1} cm^2	**K_A**	**R/A^o**	$\sigma(\Lambda)$
-	204.797 (207.0)*	19.232	28	0.140
20	129.183 (129.0)*	4.898	28	0.079
40	107.353 (106.5)*	1.179	28	0.033
60	85.688 (85.0)*	4.028	28	0.049
80	82.461 (81.5)*	2.966	20	0.036
100	127.241 (127.0)*	32.235	10	0.191
Ethanol + Water				
Percentage of alcohol	Λ_o/S mole^{-1} cm^2	**K_A**	**R/A^o**	$\sigma(\Lambda)$
-	204.797 (207.0)*	19.232	28	0.140
20	108.258 (108.2)*	7.567	28	0.067
40	59.626 (59.6)*	6.199	28	0.035
60	59.146 (59.1)*	64.819	12	0.112
80	42.138 (42.1)*	4.438	8	0.062
100	44.695 (44.6)*	817.471	22	0.032
Isopropanol + Water				
Percentage of alcohol	Λ_o/S mole^{-1} cm^2	**K_A**	**R/A^o**	$\sigma(\Lambda)$
-	204.797(207.0)*	19.232	28	0.140
20	-	-	-	-
40	-	-	-	-
60	44.882 (44.8)*	1.178	20	0.048
80	29.092 (29.09)*	23.485	10	0.062
100	6.916 (5.0)*	1040.705	2	0.0113

* The values of Λ_o between two brackets are obtained by extrapolation of the straight line.

The ion – association constant **k_a** values are in the order (methanol +water) < (ethanol + water) < (isopropanol + water). This order is expected that such an increase in **k_A** is partly due to a decrease in the dielectric constant (Hawlicka and Grabowski, 1991) and partly can be explained in terms of diminution in dielectric constant in the vicinity of an ion – pair (Evans and Gardam, 1968). Besides the values of **k_A** 's generally increase with increasing the percentage of alcohol in each mixture. This is due to the decreasing of the dielectric constant by increasing the percentage of any alcohol.

The distance parameter R is almost constant, this can be explained that it is more characteristic of the salt (Nilson, 1973) which is the same in the three mixtures, but at higher percentage of alcohol, R usually decreases and the solvent effect becomes more effective. The values of R indicates the formation of solvent – separated ion – pairs in each mixture.

The values of $\sigma(\Lambda)$ are small indicating the good applicability of the conductivity equation used (LW equation).

A plot of Λ_o against the composition of the solvent mixture is shown in figure (4). In the three mixed solvent composition, the limiting equivalent conductance Λ_o decrease by increasing the wt % of any alcohol since the dielectric constant of the medium decreasing. Beside, the curve of the plot is higher for (methanol + water) due to the higher mobility as compared to that in the lower dielectric medium. In case of methanol and ethanol mixture, a minimum is obtained at 80% of alcohol and then Λ_o increase when the solvent is only alcohol, this is because the characteristic of pure alcohol is predominate (Islam and Ansari, 1989).

In order to analyse the structural changes of the solution when varying the solvent composition, figure (5), the Walden product ($\Lambda_o\eta$)for the three media represented as a function of the reciprocal dielectric constant $\frac{1}{D}$. From this figure it is clear that the Walden product is not constant. This can be described as to the change of ion solvation and of the solvent structure (Domench and Miro, 1988). Besides, there is a maxima at this may be due to the various degree of solvation of the cations with increasing amount of alcohol in any mixture (Hikmat, 2002).

The height of these maxima are different and so at different percentage depending on the structure breaking power and dehydration of the ions upon addition of the second solvent (Broadwater and kay, 1970).

Comparing our results with the only available data from the literature:

To compare the conductivity and the association of our results for $[Co(en)_2Cl_2]Cl$ with $[Co(en)_3]Cl_2$ (Al-Tamer,1999) both in water and methanol and at 298K by LW equation, it is found that :

In water:

Compounds	**K_A**	Λ_0	**R/A^0**
$[Co(en)_2Cl_2]Cl$	19.23	204.79	28.0
$[Co(en)_3]Cl_2$	36.0	145.75	10.0

In methanol:

Compounds	**K_A**	Λ_0	**R/A^0**
$[Co(en)_2Cl_2]Cl$	32.2	127.24	10.0
$[Co(en)_3]Cl_2$	872.0	118.35	8.3

It is concluded that:

K_A for (2:1) > K_A for (1:1) both in water and in methanol

$\left.\begin{array}{l} K_A \text{ for (2:1) and} \\ \quad\text{for (1:1)} \end{array}\right\}$ in water < $\left.\begin{array}{l} K_A \text{ for (2:1) and} \\ \quad\text{for (1:1)} \end{array}\right\}$ in methanol

While

Λ_0 for (2:1) < Λ_0(1:1) both in water and in methanol

$\left.\begin{array}{l} \Lambda_0 \text{ for (2:1) and} \\ \quad\text{for (1:1)} \end{array}\right\}$ in water > $\left.\begin{array}{l} \Lambda_0 \text{ for (2:1) and} \\ \quad\text{for (1:1)} \end{array}\right\}$ in methanol

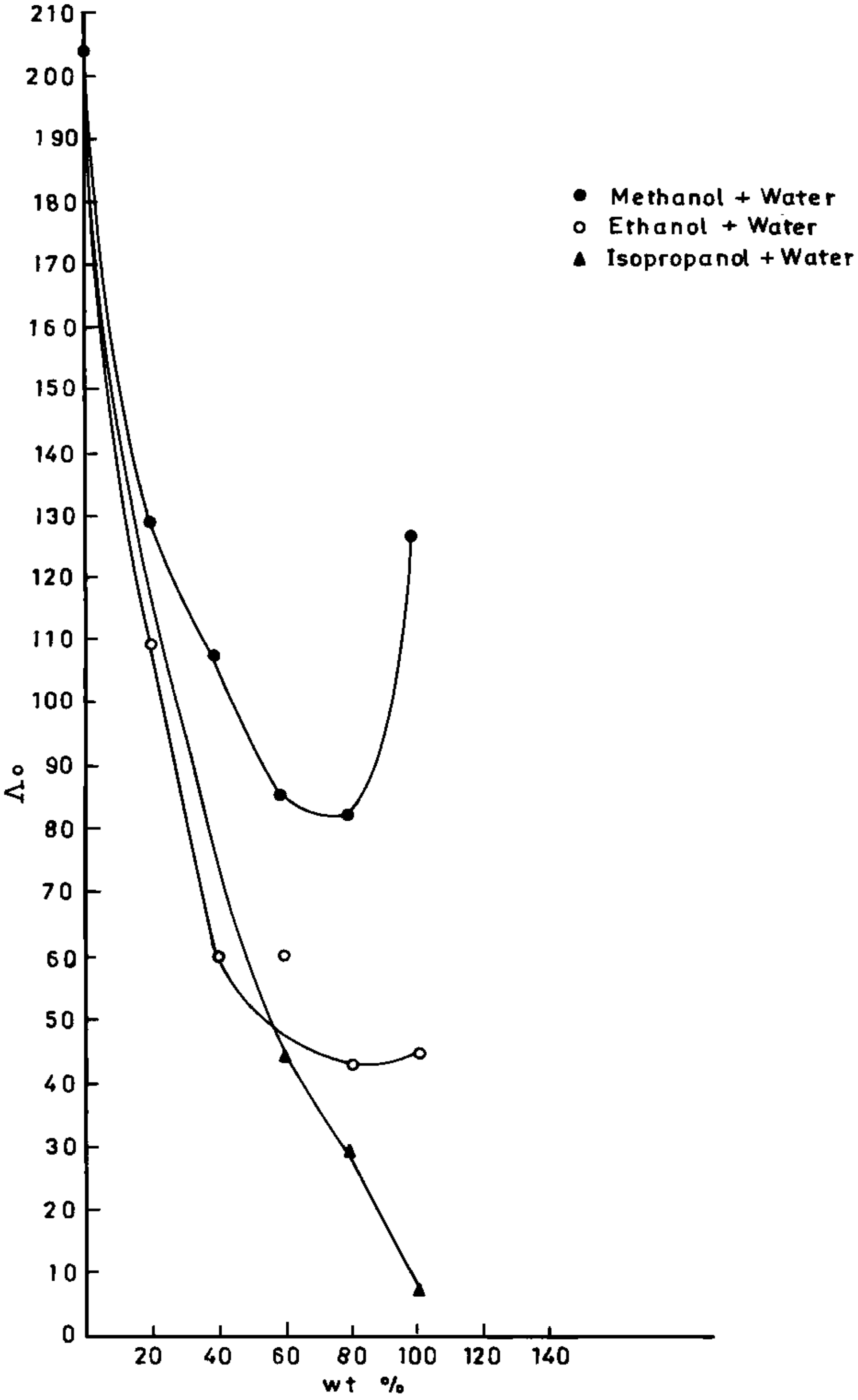

Figure (4) : The plot of limiting equivalent conductance against the wt% of $[CO(en)_2Cl_2]Cl$ in a mixture of (alkohol + water) at 298K.

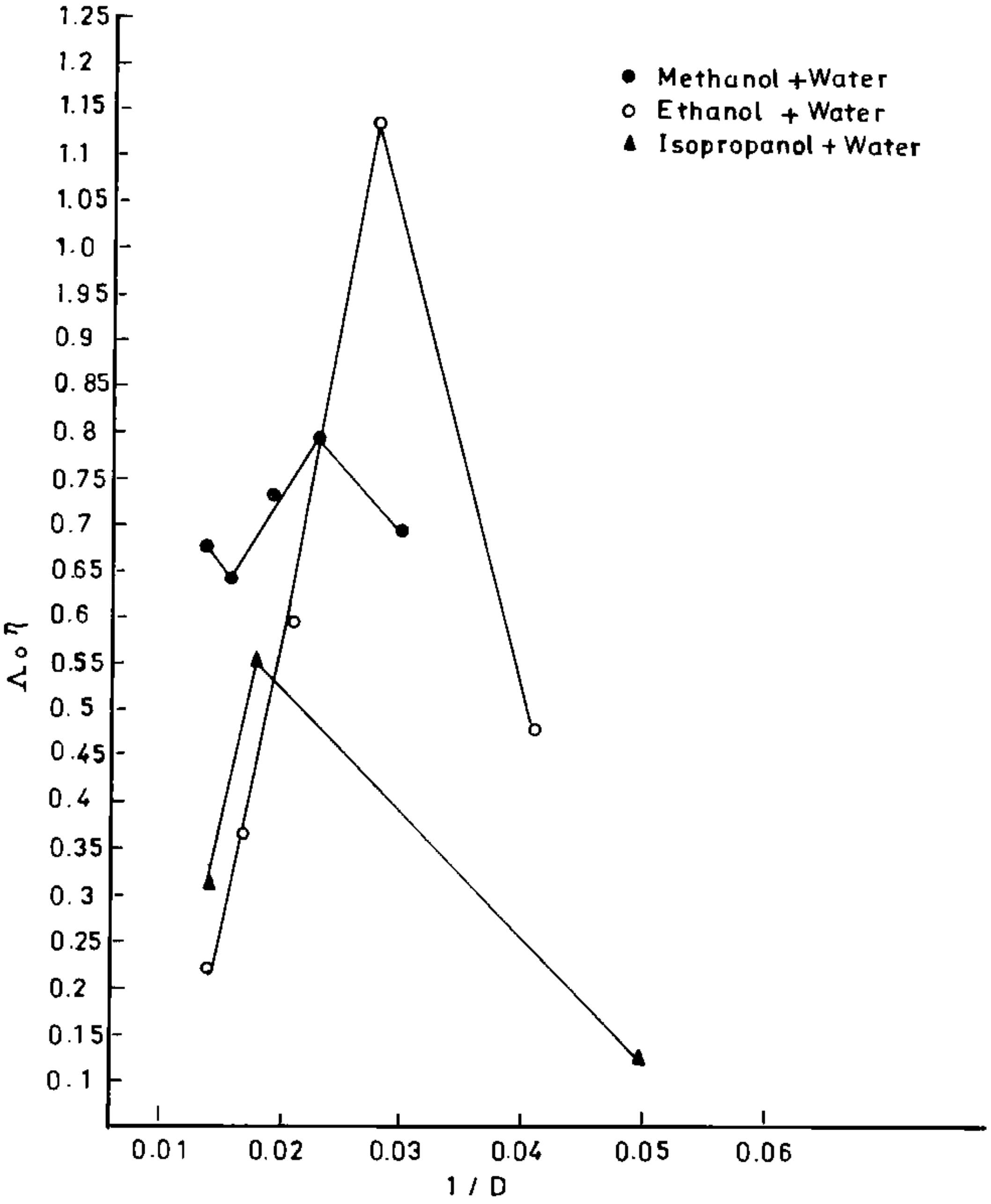

Figure (5) : The plot of the walden product against 1/D for [CO(en)$_2$Cl$_2$]Cl in a mixture of (alkohol + water) at 298K.

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