CHAPTER - III

LITHIUM CHLORIDE IN UREA-WATER SYSTEM

VISCOSITY

RESULTS AND DISCUSSION

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The relative viscosities and densities of Lithium chloride solutions in 0%, 5%, 10%, 15% and 20% by weight of urea in urea-water mixture were determined. The relative viscosity of a solution was determined by determining its density and time of flow very accurately as described in Chapter II. The various temperatures studied were 293°, 298°, 303°, and 308°K.

The concentration range of Lithium chloride was varied from 0.1 M to 2.0 M.

Experiments were designated to include the following studies.

1) The effect of concentration of lithium chloride on viscosity.
2) The effect of urea percentage on viscosity.
3) The effect of temperature on viscosity.
4) The transport properties.

The data on determination of density, time of flow, relative viscosity and viscosity of solutions having different concentrations of LiCl and different percentages of urea by weight at 293°K, 298°K, 303°K and 308°K are given in Table 3.1 to 3.4.

Effect of concentration of Lithium chloride on viscosity :

The results on the effect of variation of lithium chroride concentration (0.1 M to 2 M) in 0% urea water solution at 293°K are given in the Table 3.1. The relative viscosity of 0.1 M LiCl solution was 1.02 and it increased to 1.093 for 0.5 M solution and to 1.3925 for 2 M concentration i.e. the relative viscosity (η_r) increases from 1.02 to 1.392 at 293°K, as the concentration of LiCl is increased from 0.1 M to 2 M. In 5% urea solution, relative viscosity changes from 1.0126 to 1.36 for same range of concentration. In 10% urea solution relative viscosity changes from 1.02 to 1.3438. In 15% urea solution relative viscosity changes from 1.0166 to 1.33 and finally in 20% urea solution it changes from 1.015 to 1.12974.

So it can be seen that as the concentration of LiCl is increased the relative viscosity increases at constant temperature.

In general, it can be said that the relative viscosity of solution increases with increase in concentration of LiCl. However, the relative increase in viscosity seems to be decreasing with increase in the weight percentage of urea in the solution. The relative viscosity (η_r) is plotted against the concentration of LiCl in different concentrations of urea added and it is seen from these plots (Fig.3.2) that relative viscosity varies linearly with the concentration of LiCl It is further seen that the slope of the line is a function of urea concentration, the slope seems to decrease with increase in urea concentration. The plots obtained at other temperatures (298°, 303° and 308°K) are given in Fig. 3.3 to 3.5.

Similar results have been observed at other temperatures as 298°K, 303°K and 308°K.

3.2 Effect of urea on viscosity :

At a given temperature 298°K and for a given concentration of lithium chloride (1.5 M), the observed relative viscosity of lithium chloride solution was :

1.2860 in 0 % urea solution
1.2670 in 5 % urea solution
1.2568 in 10% urea solution
1.220 in 15% urea solution
1.211 in 20% urea solution

At 293°K the relative viscosity is seen to decrease from 1.2975 to 1.2260 while at 303°K the relative viscosity decreases from 1.2770 to 1.20. At 308°K the relative viscosity decreases from 1.2625 to 1.1750. It can be seen, in general, that as the urea concentration increases the relative viscosity (η_r) decreases. Similar results were obtained for other concentrations i.e. 0.1 M to 2 M Lithium chloride. The plots of η_r Vs concentration of urea are given in Fig. 3.21 (for 1.5 M LiCl at different urea %age). The plots are not linear.

3.3 Effect of Temperature on Viscosity :

When 1 M Lithium chloride (definate concentration) in 5% urea + Water mixture (fixed urea concentration) studied at different temperatures results obtained were

At 293 1 M LiCl in 5% urea solution = 1.1851
At 298 ,, ,, = 1.1680
At 303 ,, ,, = 1.1547
At 308 ,, ,, = 1.1488

Here 5% urea solutiion was taken.

The relative viscosity (η_r) decreases from 1.1850 to 1.1488.

for 10% urea solution it decreases from 1.1680 to 1.1358.
for 15% ,, ,, 1.1580 to 1.1280.
for 20% ,, ,, 1.15 to 1.12.
when temperature was changed from 293°K to 308°K.

Similar results were obtained for other concentrations i.e. from 0.1 M to 2 M LiCl solution.

It can be seen that the relative viscosity (η_r) decreases as temperature increases. Plots of relative viscosity η_r Vs temperature are given in Fig. 3.22 and it is seen from figure that the plots are non-linear.

Applications of different equations :

The viscosity data given above have been examined in the light of the following equations.

1) Jones Dole equation
2) Vand equation
3) Moulik equation
4) Thomas equation.

1) Jones Dole Equation :

It has been assumed that the relative viscosity of electrolyte may be represented by Jones Dole equation[15] given below :

$$\eta_r = 1 + A\sqrt{C} + BC$$

where η_r is the relative viscosity of solution and C is the molar concentration.

A is the Falkenhagen coefficient[19] that takes into account ionic interactioins.

B is the Jones Dole coefficient that is related to the size of the ions and to the different ion solvent interactions.

However, at high concentrations ($C \geq 0.1$ M) B overweights the effect of 'A' resulting the equation

$$\eta_r = 1 + BC \qquad \ldots (1)$$

To test the validity of Jones Dole equation, is first to see if a straight line is obtained for the plot of η_r against C and the slope is calculated which gives the value of B. The intercept will be one. The satisfactory agreement between the calculated values of 'B' and that obtained by the graphical method is further test of the Jones Dole equation.

Now, in the present communication we have analysed the data in the light of equation (1). The experimental data recorded in table shows that the plots of η_r Vs C are linear over wide range of concentration of LiCl as shown in Fig. 3.2 indicating thereby that

Jone Dole equation is adequate to describe the concentration effect on viscosity. The slope gave the coefficient 'B'. The values of 'B' thus obtained are given in Table No. 3.5.

The values of B calculated by least square method are also given in Table No. 3.5. As urea concentration increased from 0% to 20%, the B coefficient values at 293°K decreases from 0.1950 to 0.148 l.mol^{-1}

At 298 it decreases from 0.1916 to 0.141 l mol^{-1}

At 303 it decreases from 0.19166 to 0.1375 l mol^{-1}

At 308 it decreases from 0.17916 to 0.10 l mol^{-1}

As temperature was changed from 293 to 308°K, B coefficient values at 5% urea decreases from 0.175 to 0.1541.

at 10% urea solution it decreases from 0.1708 to 0.1416

at 15% urea solution it decreases from 0.166 to 0.133

and 20% urea solution it decreases from 0.1418 to 0.10.

Thus the values of 'B' coefficient are all positive and found to decrease with increase in temperature as well as with urea compositions.

The intercept of all the plots is to be nearly the same and equal to unity.

The Jones Dole equation is satisfactorily applicable for the lithium concentration range from 0.1 M to 2.0 M solution for all urea + water composition.

3.4.2 Vand Equation :

The viscosity data have been examined in the light of Vand equation[51] which may be given as

$$\ln \eta_r = \frac{2.5\Phi}{1-Q\Phi} \qquad \ldots (2)$$

which is applicable for viscosity of aqueous solutions of both electrolytes and ~~noin~~ non electrolytes at higher concentration, Φ is volume fraction and is equal to C V, V being molar volume of electrolyte in solution and Q is the interaction coefficient. The equation of Vand have been rearranged in the linear form as

$$\frac{1}{C} = \frac{(0.921)}{V} \frac{1}{\log \eta_r} + Q\,V \qquad \ldots (3)$$

The plot of $\frac{1}{\log \eta_r}$ Vs $\frac{1}{C}$ is straight line with Q V as intercept and $\frac{0.921}{V}$ as the slope.

The plots are drawn using data given in Tables 3.6to 3.10 . The plots of $\frac{1}{\log \eta_r}$ vs $\frac{1}{C}$ shown in Figs. 3.6-3.10 are linear. The Vand equation is applicable in the concentration range 0.4 M to 2.0 M. At lower concentrations are observed. The viscosity parameters Q and V calculated by graphical method are given in Tables 3.11. When temperature is increased from 293 to 308 V values of 0% urea solution decreases from 0.076 to 0.051 similar pattern is seen in 10%, 15% and 20% urea solution.

When urea concentration was changed from 0% to 20% at constant temperature (293°K), V values decreases from 0.076 to 0.06. Similar observations were seen at other temperatures as 298°K, 303°K and 308°K Thus V values decreases with rise of temperature as well as increase in urea concentration.

3.4.3 Breslau and Miller[56] have suggested a relationship between V and B for uni-unit valent electrolyte.

$$B = 2.90\,V - 0.0\text{[illegible]}9$$

The ratio of B/V for LiCl is 2.56 at 0% urea and 2.46 at 20% urea at 293°K.

3) <u>Moulik Equation</u> :

It has been observed that the relative viscosities of the electrolytic solutions like urea-water may be represented by Moulik equation[54] as

$$\eta_r^2 = M + K'\,C^2$$

Where M and K' are constants.

These parameters cannot be evaluated theoretically therefore, graphical testing has been performed. The same has been performed in the present work.

The applicability of Moulik equation has been tested from the linear plots of η_r^2 Vs C^2. The plots are drawn using the data given in Table No. 3.6. The plots of η_r^2 Vs C^2 are shown in Fig. 3.11. The intercepts and slopes of straight line plots yield M and K' respectively.

At temp. 293°K values decreases from 0.475 to 0.2625 when urea concentration increased from 0% to 20%. (Table 3.13a)

The K value decreases from 0.475 to 0.3583 when temperature increased from 293 to 308.

The M value increases from 1.075 to 1.08 at 293 when urea concentration changes from 0% to 20%.

The M values decreases from 1.075 to 1.06 when temperature changed from 293 to 208°K.

It can be shown that the content M increases with increase in urea concentration and decreases with rise of temperature. The constant K decreases with increase in temperature and concentration of urea It is seen that the change in M or K values is very small.

It can also be seen from the plots that the equation is only applicable in the concentration range of 0.3 M to 0.75 M. After this concentrations deviatioins are seen.

4) Thomas Equation :

For higher concentration of electrolyte Thomas[105] put forwarded the equation as

$$\eta_r = 1 + 2.5\phi + 10.05\phi^2$$

where ϕ is a volume fraction given by $C\bar{V}$ where $\bar{V}$ is the effective rigid molar volume. The above equation may be written as

$$\frac{\eta_r - 1}{C} = 2.5\bar{V} + (10.05\bar{V}^2)\,C$$

Where C is the molar concentration.

The applicability of Thomas equation can be tested from the linear plots of $\frac{\eta_r - 1}{C}$ Vs C. Hence using the data given in Table 3.6.

η_r^{-1} / C Vs C is plotted in Fig. 3.16. It can be seen that the plots are not linear, therefore, Thomas equation is not valid for lithium chloride in the concentration range 0.1 M to 2 M.

From the results to Moulik[54] it also indicates that Thomas equation in its full form, is not valid for few electrolytes and may not be valid for many non-electrolytes.

B) Values from different equations :

B-values were calculated by using different equations, and shown in Table No. 3.5 . It is seen that the B-values are nearly constant.

V - values from different equations :

V values were calculated by using different equation and are shown in Table No. 3.11. It is seen that the values are nearly constant.

DISCUSSION

The concept of structure making and structure breaking effect of solutes[102] :

The water molecules can be considered to be in dynamic equilibrium between the bulky tetrahedrally hydrogen bonded clusters and the denser monomer molecules, and represented by

$$(H_2O)_b \rightleftharpoons (H_2O)_d$$

The statistical degree of ice-likeness (or whatever its structure in water is) is considered to be proportional to the half life of the clusters, which is of the order of 10^{-11}S in pure water[106] when a solute is put into water, it is assumed that the former may shift the equilibrium in either direction. A solute which causes a shift so as to increase the number and the average half-life of the cluster is termed a structure maker, and a solute which has an effect in the opposite directioin is called a structure breaker.[106]

Although the concept of structure making and breaking effects of solutes is not entirely satisfactory, it has proved useful in discussing the effects of solutes on water structure. These effects can be detected experimentally by observing the changes brought about by the solutes in the properties of water, such as fluidity, reorientation time, viscosity, conductance and heat capacity. For instance, structure makers are shown to decrease the fluidity of water (by causing an increase in reorientation time and increase in viscosity) and result in positive excess partial molar heat capacities in water. The reverse is true for structure-breakers.

Frank and Wen[106] in order to explain these phenomena visualized a picture (see Fig. 3.1a and 3.1b) in which an ion is surrounded by concentric regions of water molecules. The intermost region 'A' consists of water molecules polarized, immobilized and electrostricted by the ion. The water molecules in the region C have the normal liquid structure which is polarized in the usual way by the ionic field which at this range will be relatively weak.

The intermediate region B is the region in which water is less ice-like, i.e. more randomly ordered than the normal water. The decreased structure in this region is presumably due to the approximate balance of two competing forces, namely the normal structure-orientating influence of the neighbouring water molecules, and the radially orientating influence of the electric field of the ion, which act simultaneously on any water molecule in this region the latter ionic influence predominates in the region A and the former in region C, and between A and C there should be a region of finite width in which more orientational disorder should exist than in either A or C. Now, it was assumed in the flickering cluster model[106] of water that the lifetime of a cluster is essentially dependent on the fluctuations of energy produced in the liquid water. An ion with its first layer of water molecule will be a disturbing centre which would both interfere with the initiation of clusters and hasten their disruption. Ions with low charge density have relatively weak

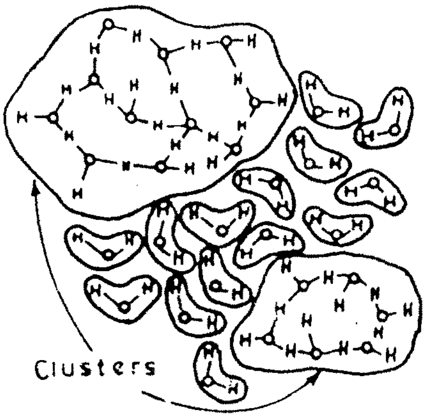

FIG. 3·1 a — FRANK—WEN FLICKERING CLUSTER MODEL OF LIQUID WATER.

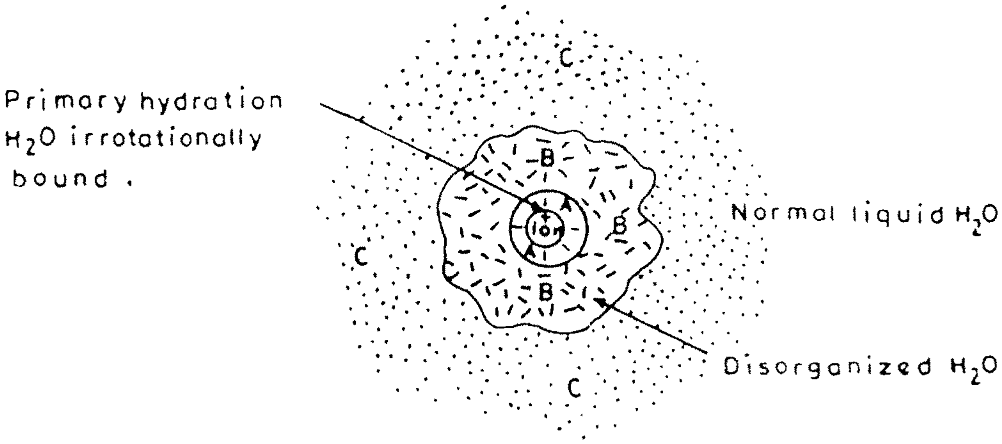

FIG. 3·1 b — FRANK—WEN ZONE MODEL OF WATER IN THE NEIGHBOURHOOD OF A SIMPLE ION.

electrostatic fields which makes the region. A very small thereby causing net decrease in structure. In the case of structure-making ions of high charge density, the region A of immobilization exceeds region B which results in a net structural increase around these ions.

B Values or Coefficient :

To explain the nature of 'B' Cox and Wolfenden[20] have attributed specific additive character of 'B' depending on the constituent ion. Asmus[21] on the other hand suggests 'B' to be dependent on the lyotropic number and the entropy of hydration of the ionic species present in the medium.

Kaminsky[103] and Gurney[106] have suggested that 'B' (in Jones Dole eauation) is a measure of ion dipole interaction between the ion and the solvent molecules and have supported the idea of partitioning the 'B' coefficients to their ionic components assuming that the 'B' components of potassium and chloride ions are equal in potassium chloride. When such interaction is considered, the magnitude of 'B' is dependent on the manner and the extent to which the ions orient the water dipole in their cospheres at a particular temperature.

It is evident from Table 3.5 that B coefficients are all positive but small in magnitude and decrease with increase in temperature as well as with increase in urea content at a particular temperature.

B-coefficient is an adjustable parameter either positive or negative and is said to be measure of effective hydrodynamic volume of solvated ions that accounts for ion-solvent interaction.[107] It is also known as a measure of order or disorder introduced by ions in the solvent structure.

Recently it has been emphasized by a number of workers that dB/dT is a more important criterion for determining the solute-solvent interactions. Viscosity study of number of such solutions has shown that structure makers will have negative values or dB/dT and structure breakers positive values. Accordingly, in the present case the negative temperature coefficient of B in 5%, 10%, 15% and 20% urea water mixture suggest that Lithium chloride behaves as a structure maker/ promoter.

d) Dependence of 'B' on Temperature :

According to Stokes and Mills,[49] the viscosity of dilute electrolytic solutions incorporates that of the solvent and the contribution from other sources. They are n_E, the positive increase due to the shape and size of the ion, n_A the increase due to the alignment or orientation of the polar molecules by the ionic field n_D, the decrease in viscosity arising out of the distortion of the solvent structure. Therefore, 'B' coefficients can be discussed in terms of these viscosity effects at different temperatures.

Kiminsky[103] has related negative temperature coefficient of 'B' to the fact that oriented water molecules in the secondary layer will be less rigidly held due to increased thermal motion. This will give a significant decrease in n_A. However, inspite of this decrease the sum of $n_E + n_D$ will still be larger than n_D because with increasing temperature n_D will decrease due to less competition between the ionic field and the reduced solvent structure. n_E will remain fairly constant and n_A will decrease fairly slowly so that eventually $n_E + n_A > n_D$ and 'B' will be positive. Nightingale also suggests that hydration may increase as the water structure is broken down but it is arguable that the increased thermal motion would counteract this tendency. It may be added that there is no thermodynamic evidence to support increased hydration.

e) Dependence of B on urea content :

The decrease in 'B' coefficient with increase in urea content in the solvent mixture (Table 3.5) may be attributed to the small size of the solvent molecules and also to the weak association between water and urea through hydrogen bonding[77] and for solvated ions it would lead to smaller values of n_E and n_A. Consequently, the 'B' coefficient becomes smaller and smaller with the increase in urea content in the medium.

Addition of small amounts of urea to water may give rise to two effects. If the urea is accommodated in the solvent structure, it may strengthen the water structure and B value will increase with increase in urea content.

Since urea is basic and water automatically acts as an acid the three dimnsional water structure is broken down and the 'B' coefficient is expected to decrease with the increase in urea content. The latter is in conformity with the experimental results.

The structure-making[57] ions have positive ionic molar volume ($V \neq$) and hydration number (NB) and structure breaking ions have negative ionic molar volumes ($V \neq$) and hydration number in solution. Hydration number (NB) of ion can be obtained from the equation

$$V_{\neq} = V_{o\ \text{ion}} + N_B V_S^o$$

where V_o ion is the free ionic volume calculated from equation V^o ion = 2.52 r^3 (r = ionic radius) and V_S is the molar volume of water equal to 6.62 cm^3 $mole^{-1}$. The hydration numbers of positive and negative ions bear different linear relationship with their ionic B coefficient. This supports the idea that structure making ion have positive ionic molar volumes, positive hydration numbers and positive entropy changes while structure breaking ions have negative ionic molar volumes, hydration numbers and negative entropy changes in aqueous solutions.

The idea of positive and negative hydration and hence the positive and negative hyrdation numbers get support from the work of Angel[100]. The values of ionic parameters at 298°K in 0% urea water solution are given in Table 3.14. From the table it is seen that ionic parameter values of Li^+ ion are all positive. This supports the idea[109,110] that Li^+ ion is electrostictive structure making ion with positive ionic volume ($V_{\neq}$), hydration number (NB) and entropy change(ΔS^*).

3.5 TRANSPORT PROPERTIES :

From the table No.3.14, it is seen that the energy and entropy of activation of the viscous flow of solution are more than those of solvent. When ΔE^* and ΔS^* of viscous flow are less than that of solvent indicates solute-solvent interaction and when ΔE^* and ΔS^* of viscous flow are more than that of solvent indicates little solute solvent interaction.[27,28,30] In our calculations ΔE^* and ΔS^* of viscous flow of solutions are more than that of solvents shows that there is little solute solvent interaction.

According to D.K.Das and P.B.Das[37] when ΔF^*, ΔF^* and ΔS^* values are less than that of solvent. It indicates structure breaking effect and when ΔE^*, ΔF^* and ΔS^* values are more than solvent indicates structure making effect. They have studied thermodynamic properties of cadmium nitrate and strontinum nitrate in different weight proportions of methanol at 308°K. According to them ΔE^*, ΔS^* and ΔF^* values of viscous flow of solutions are less than that of solvents indicating structure breaking effect. In our data ΔE^*, ΔS^* and ΔF^* of viscous flow are more than that of solvent indicates structure making effect of lithium chloride. From above results it clearly indicates that due to presence of Li^+, the solvent structure is stabilised. It not only stabilises the solvent structure but also predominatesd over the structure breaking properties of its partner. The thermodynamic parameters of viscous flow of Lithium chloride in 10% urea-water solution are calculated at 298°K. The values are represented in Table 3.15. These results are in agreement with

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TABLE 3.1

Viscosity data for Lithium chloride in different urea-water compositions at 293°K.

Concentration moles/litre	Density g mol^{-1}	Av.time sec.	η_r $d_c t_c / d_e t_o$	η mN sm^{-2}
Wt % of urea in urea + H_2O = 0 %				
0.1	1.05786	304.0	1.02501	1.21712
0.2	1.06000	308.0	1.04124	1.23562
0.3	1.06178	309.5	1.06001	1.24375
0.4	1.06399	317.0	1.07754	1.27653
0.5	1.06639	321.5	1.09312	1.29764
0.75	1.07157	334.0	1.14522	1.34801
1.0	1.07653	349.0	1.19825	1.42202
1.5	1.08701	374.5	1.29756	1.54071
2.0	1.09673	399.5	1.39254	1.65621
wt % of urea in urea + H_2O = 5 %				
0.1	1.04365	289.0	1.01262	1.14152
0.2	1.04585	293.0	1.03581	1.16765
0.3	1.04831	300.0	1.05592	1.19034
0.4	1.05025	304.0	1.07195	1.20832
0.5	1.05241	308.5	1.08502	1.22881
0.75	1.05802	318.4	1.12963	1.27342
1.0	1.06321	332.0	1.18511	1.33601
1.5	1.07375	356.5	1.27625	1.43871
2.0	1.08361	375.0	1.36501	1.53792

Concentration moles/litre	Density g mol^{-1}	Av.time sec.	η_r $d_c t_c / d_o t_o$	η mN sm^{-2}
Wt % of urea in urea + H_2O = 10 %				
0.1	1.02902	283.5	1.02192	1.10413
0.2	1.03131	286.5	1.03501	1.11831
0.3	1.03365	290.0	1.04991	1.13449
0.4	1.04081	296.5	1.07002	1.16800
0.5	1.04272	297.7	1.08732	1.17487
0.75	1.04731	307.5	1.12803	1.21692
1.0	1.05194	319.0	1.16804	1.37009
1.5	1.06113	340.0	1.26375	1.36549
2.0	1.07021	357.2	1.34581	1.47943
wt % of urea in urea + H_2O = 15 %				
0.1	1.01641	278.0	1.01662	1.06942
0.2	1.02041	282.0	1.03441	1.08871
0.3	1.02131	286.0	1.05041	1.10552
0.4	1.02431	289.0	1.06341	1.11853
0.5	1.02712	292.0	1.07921	1.13512
0.75	1.03291	301.0	1.11864	1.17682
1.0	1.03901	310.0	1.15801	1.21903
1.5	1.05182	332.5	1.25834	1.32378
2.0	1.06421	348.0	1.33241	1.40165

Concentration moles/litre	Density g mol^{-1}	Av.time sec.	ηr d_ct_c/d_ot_o	η mN sm^{-2}
		Wt % of urea in urea + H_2O = 20 %		
0.1	1.00275	269.0	1.01585	1.02093
0.2	1.00523	273.0	1.03351	1.03867
0.3	1.00751	276.0	1.04572	1.05241
0.4	1.00979	279.0	1.06102	1.06632
0.5	1.01231	282.5	1.07510	1.08048
0.75	1.01806	239.0	1.10804	1.11358
1.0	1.02368	298.5	1.15079	1.15654
1.5	1.03514	314.5	1.22605	1.23212
2.0	1.04556	329.5	1.22974	1.30394

TABLE 3.2

Viscosity data for Lithium chloride in different urea-water compositions at 298°K.

Concentration moles/litre	Density g mol^{-1}	Av.time sec.	η_r $d_c t_c / d_e t_o$	η mN sm^{-2}
		Wt % of urea in urea + H_2O = 0 %		
0.1	1.05975	272.5	1.01123	1.07668
0.2	1.06048	276.5	1.03114	1.09746
0.3	1.06[illegible]2	280.0	1.05112	1.12271
0.4	1.06352	282.2	1.06531	1.13352
0.5	1.06572	287.4	1.08701	1.15523
0.75	1.07150	298.5	1.13520	1.21336
1.0	1.07622	311.0	1.18801	1.26412
1.5	1.08677	333.0	1.28601	1.36682
2.0	1.09633	355.0	1.38251	1.46995
		wt % of urea in urea + H_2O = 5 %		
0.1	1.04385	259.5	1.01161	1.02302
0.2	1.04586	263.0	1.02721	1.03881
0.3	1.04799	264.5	1.03542	1.04693
0.4	1.05019	271.0	1.06172	1.07491
0.5	1.05241	275.0	1.08041	1.09301
0.75	1.05807	285.0	1.12505	1.13892
1.0	1.06314	294.0	1.16802	1.18051
1.5	1.07369	315.0	1.26701	1.27731
2.0	1.08356	335.0	1.35105	1.37091

Concentration moles/litre	Density g mol^{-1}	Av.time sec.	ηr $d_c t_c / d_o t_o$	η mN sm^{-2}
Wt % of urea in urea + H_2O = 10 %				
0.1	1.02917	251.0	1.07015	0.97618
0.2	1.02657	256.4	1.03401	0.99817
0.3	1.03112	257.3	1.03971	1.0045
0.4	1.04052	260.8	1.06125	1.02547
0.5	1.04231	264.0	1.07601	1.04076
0.75	1.0468	272.2	1.11432	1.07674
1.0	1.05171	280.4	1.15302	1.11369
1.5	1.06026	303.0	1.25681	1.21401
2.0	1.06981	313.8	1.31251	1.26961
wt % of urea in urea + H_2O = 15 %				
0.1	1.01629	244.0	1.01702	0.93652
0.2	1.01896	246.5	1.02901	0.94861
0.3	1.02132	249.0	1.04012	0.96049
0.4	1.02700	251.5	1.05612	0.97553
0.5	1.02707	254.5	1.07001	0.98721
0.75	1.03282	262.0	1.10702	1.02201
1.0	1.03875	268.5	1.14001	1.05339
1.5	1.05102	285.0	1.22001	1.13139
2.0	1.06312	298.0	1.29251	1.19655

Concentration moles/litre	Density g mol^{-1}	Av.time sec.	η_r $d_c t_c / d_o t_o$	η mN sm^{-2}
		Wt % of urea in urea + H_2O = 20 %		
0.1	1.00051	239.0	1.01101	0.90317
0.2	1.00488	241.0	1.02421	0.91466
0.3	1.00705	243.0	1.03512	0.92421
0.4	1.00961	248.0	1.05317	0.94566
0.5	1.01236	249.0	1.06641	0.95202
0.75	1.01788	255.0	1.09721	0.98032
1.0	1.02379	262.0	1.13501	1.01301
1.5	1.03501	267.5	1.21101	1.08081
2.0	1.04581	295.0	1.27801	1.14032

TABLE 3.3

Viscosity data for Lithium chloride in different urea-water compositions at 303°K.

Concentration moles/litre	Density g mol^{-1}	Av.time sec.	η_r $d_c t_c/d_e t_o$	η mN sm^{-2}
		Wt % of urea in urea + H_2O = 0 %		
0.1	1.05621	246.0	1.01123	0.97185
0.2	1.05837	250.0	1.03125	0.98965
0.3	1.06034	254.5	1.05121	1.00931
0.4	1.06244	255.7	1.05845	1.01615
0.5	1.06499	259.0	1.07321	1.03175
0.75	1.07016	269.8	1.12489	1.07995
1.0	1.07503	281.5	1.17900	1.13195
1.5	1.08565	302.0	1.27702	1.22635
2.0	1.05416	322.0	1.37201	1.31951
		wt % of urea in urea + H_2O = 5 %		
0.1	1.04082	239.0	1.020741	0.930432
0.2	1.04188	240.0	1.02605	0.93521
0.3	1.04298	244.0	1.04425	0.95181
0.4	1.04400	247.7	1.05398	0.96532
0.5	1.04539	250.6	1.07490	0.97988
0.75	1.04693	260.0	1.11692	1.04731
1.0	1.04801	268.5	1.15471	1.05256
1.5	1.05271	288.0	1.24001	1.32749
2.0	1.06070	395.0	1.32749	1.21005

Concentration moles/litre	Density $g\ ml^{-1}$	Av.time sec.	η_r d_ct_c/d_ot_o	η $mN\ sm^{-2}$
		Wt % of urea in urea + H_2O = 10 %		
0.1	1.02781	228.0	1.01512	0.87659
0.2	1.03068	230.2	1.02751	0.88742
0.3	1.03261	232.0	1.03721	0.89607
0.4	1.04021	233.2	1.04991	0.90733
0.5	1.04210	236.7	1.06841	0.92264
0.75	1.04629	242.0	1.10492	0.95490
1.0	1.05145	267.4	1.14861	0.99107
1.5	1.06043	267.4	1.22751	1.06061
2.0	1.06934	281.8	1.30301	1.12592
		wt % of urea in urea + H_2O = 15 %		
0.1	1.01581	219.2	1.01581	0.82954
0.2	1.01898	220.0	1.02270	0.83516
0.3	1.02001	223.0	1.03768	0.84740
0.4	1.02358	224.5	1.04833	0.85609
0.5	1.02656	228.0	1.06771	0.87192
0.75	1.03259	232.5	1.09519	0.89440
1.0	1.03845	240.0	1.13699	0.92851
1.5	1.05115	254.0	1.21803	0.99464
2.0	1.06282	265.5	1.28731	1.05125

Concentration moles/litre	Density g mol^{-1}	Av.time sec.	η_r $d_c t_c/d_o t_o$	η mN sm^{-2}
		Wt % of urea in urea + H_2O = 20 %		
0.1	1.00247	217.0	1.01616	0.81364
0.2	1.00488	217.0	1.01864	0.81562
0.3	1.00712	219.0	1.03039	0.82501
0.4	1.00966	221.5	1.04501	0.83652
0.5	1.01186	223.0	1.05402	0.84401
0.75	1.01774	230.0	1.09347	0.87552
1.0	1.02351	236.5	1.13074	0.90534
1.5	1.03462	250.0	1.02011	0.96742
2.0	1.04546	260.3	1.27122	1.01788

TABLE 3.4

Viscosity data for Lithium chloride in different urea-water compositions at 308°K.

Concentration moles/litre	Density g mol^{-1}	Av.time sec.	ηr $d_c t_c/d_e t_o$	η mN sm^{-2}
Wt % of urea in urea + H_2O = 0 %				
0.1	1.05706	223.8	1.01021	0.88616
0.2	1.05912	227.2	1.03012	0.90061
0.3	1.06117	230.0	1.04512	0.91425
0.4	1.06323	233.4	1.06251	0.92952
0.5	1.06529	237.4	1.08015	0.94572
0.75	1.07093	245.0	1.12345	0.98281
1.0	1.07591	253.9	1.16805	1.02121
1.5	1.08617	271.5	1.26254	1.10464
2.0	1.09596	288.0	1.35215	1.18254
wt % of urea in urea + H_2O = 5 %				
0.1	1.03482	216.0	1.00751	0.83742
0.2	1.03506	219.5	1.02475	0.84537
0.3	1.04136	220.3	1.03474	0.85944
0.4	1.04401	223.0	1.04861	0.87101
0.5	1.04558	226.0	1.06582	0.88521
0.75	1.04784	234.0	1.10592	0.91862
1.0	1.05250	242.0	1.14881	0.95466
1.5	1.05365	262.0	1.24512	1.03423
2.0	1.06324	273.0	1.30441	1.08342

Concentration moles/litre	Density g mol^{-1}	Av.time sec.	η_r $d_c t_c/d_o t_o$	η mN sm^{-2}
Wt % of urea in urea + H_2O = 10 %				
0.1	1.02807	208.5	1.01890	0.80599
0.2	1.03085	210.0	1.02900	0.81103
0.3	1.03287	214.0	1.05065	0.83112
0.4	1.04071	217.5	1.07514	0.85116
0.5	1.04241	223.5	1.10741	0.87281
0.75	1.04676	228.5	1.13692	0.89935
1.0	1.05162	237.5	1.18721	0.93572
1.5	1.06071	254.5	1.28312	1.01504
2.0	1.06955	270.0	1.37334	1.08784
wt % of urea in urea + H_2O = 15 %				
0.1	1.01530	199.5	1.01250	0.75560
0.2	1.01772	200.0	1.01741	0.75928
0.3	1.02057	202.0	1.03021	0.76904
0.4	1.02505	203.5	1.04212	0.77816
0.5	1.02629	205.5	1.05424	0.78675
0.75	1.03217	211.0	1.08866	0.81243
1.0	1.03789	217.5	1.12841	0.84214
1.5	1.05083	227.0	1.19292	0.88985
2.0	1.06252	236.0	1.25341	0.93541

Concentration moles/litre	Density g mol^{-1}	Av.time sec.	η_r $d_c t_c/d_o t_o$	η mN sm^{-2}
Wt % of urea in urea + H_2O = 20 %				
0.1	1.00240	194.7	1.01815	0.73102
0.2	1.00475	195.0	1.01534	0.73394
0.3	1.00706	196.5	1.02514	0.74138
0.4	1.00939	198.0	1.03521	0.74861
0.5	1.01176	201.0	1.05234	0.76192
0.75	1.01749	205.0	1.08341	0.78131
1.0	1.02337	211.5	1.12341	0.81071
1.5	1.03439	219.0	1.17521	0.84852
2.0	1.04504	229.0	1.24511	0.89677

TABLE 3.5

B-values of lithium chloride in different urea-water compositions at different temperatures

Mass fraction of urea	Temp. °K	B^a	B^b	$B^c/l\ mol^{-1}$
0 %	293	0.1950	0.1900	0.1750
	298	0.1916	0.1625	0.1541
	303	0.1996	0.1375	0.1421
	308	0.1791	0.1275	0.1422
5 %	293	0.1752	0.1725	0.1608
	298	0.1791	0.1550	0.1395
	303	0.1660	0.1325	0.1302
	308	0.1541	0.1225	0.1285
10 %	293	0.1708	0.1625	0.1574
	298	0.1625	0.1500	0.1477
	303	0.1583	0.1225	0.1264
	308	0.1416	0.1175	0.1217
15 %	293	0.1660	0.1550	0.1501
	298	0.1510	0.1425	0.1291
	303	0.1458	0.1151	0.1048
	308	0.1330	0.0975	0.1002
20 %	293	0.1418	0.1521	0.1404
	298	0.1412	0.1475	0.1160
	303	0.1375	0.1025	0.0955
	308	0.1001	0.0925	0.0900

a = B values obtained from the plot of η/η_0 versus C

b = B values obtained from Einstein'sequation $B = 2.5\ V$

c = B values obtained from Breslau & Miller's equation $B = 2.90\ V_e - 0.018$

TABLE 3.6

Viscosity data for Lithium chloride in 0% urea-water solution at different temperatures.

Temperature (°K)	Concentration (C) moles/lit	$\frac{1}{C}$	C^2	$\frac{1}{\log\eta_r}$	η_r^2	$\eta_r -1$ /C
	0.1	10.0	0.01	116.27	1.0404	0.2500
	0.2	5.0	0.04	58.70	1.0816	0.2062
	0.3	3.3	0.09	39.51	1.1236	0.2000
	0.4	2.5	0.16	31.83	1.1551	0.1937
293	0.5	2.0	0.25	25.89	1.1942	0.1860
	0.75	1.3	0.56	16.98	1.3112	0.1936
	1.0	1.0	1.00	12.73	1.4117	0.1982
	1.5	0.6	2.25	8.84	1.6801	0.2650
	2.0	0.5	4.0	6.95	1.9321	0.1962
	0.1	10.0	0.1	210.47	1.0221	0.1100
	0.2	5.0	0.04	75.42	1.7161	0.1550
	0.3	3.3	0.09	47.19	1.1025	0.1666
	0.4	2.5	0.16	36.56	1.1342	0.1625
298	0.5	2.0	0.25	29.21	1.1815	0.1740
	0.75	1.3	0.56	18.15	1.2881	0.1808
	1.0	1.0	1.0	13.36	1.3812	0.1880
	1.5	0.6	2.25	9.15	1.6531	0.1906
	2.0	0.5	4.0	7.10	1.9112	0.1912

Temperature (°K)	Concentration (C) moles/lit	$\frac{1}{C}$	C^2	$\frac{1}{\log \eta_r}$	η_r^2	$\eta_r - 1$ /C
	0.1	10.0	0.01	231.41	1.0201	0.1000
	0.2	5.0	0.04	77.89	1.0609	0.1500
	0.3	3.3	0.09	47.19	1.1025	0.1660
	0.4	2.5	0.16	40.84	1.1257	0.1450
303	0.5	2.0	0.25	32.59	1.1820	0.1464
	0.75	1.3	0.56	19.52	1.2651	0.1664
	1.0	1.0	1.00	13.98	1.3600	0.1790
	1.5	0.6	2.25	9.41	1.6307	0.1846
	2.0	0.5	4.00	7.28	1.8823	0.1860
	0.1	10.0	0.01	231.41	1.0201	0.1000
	0.2	5.0	0.04	77.89	1.1025	0.1500
	0.3	3.3	0.09	52.31	1.0921	0.1500
	0.4	2.5	0.16	44.00	1.1289	0.1562
308	0.5	2.0	0.25	35.00	1.1664	0.1600
	0.75	1.3	0.56	22.51	1.2544	0.1645
	1.0	1.0	1.00	15.00	1.3351	0.1680
	1.5	0.6	2.25	9.87	1.5939	0.1750
	2.0	0.5	4.00	5.45	1.8225	0.1750

TABLE 3.7

Viscosity data for Lithium chloride in 5% urea-water solution at different temperatures.

Temperature (°K)	Concentration (C) moles/lit	$\frac{1}{C}$	C^2	$\frac{1}{\log\eta_r}$	η_r^2	$\eta_r -1 /C$
	0.1	10.0	0.01	183.89	1.0253	0.1269
	0.2	5.0	0.04	81.09	1.0584	0.1792
	0.3	3.3	0.09	75.42	1.0629	0.1869
	0.4	2.5	0.16	33.14	1.1490	0.1797
293	0.5	2.0	0.25	28.22	1.1772	0.1700
	0.75	1.3	0.56	18.89	1.2759	0.1729
	1.0	1.0	1.00	14.05	1.3776	0.1851
	1.5	0.6	2.25	9.44	1.6281	0.1841
	2.0	0.5	4.00	7.44	1.8564	0.1825
	0.1	10.0	0.01	199.64	1.0233	0.1160
	0.2	5.0	0.04	86.42	1.0547	0.1350
	0.3	3.3	0.09	66.93	1.0712	0.1166
	0.4	2.5	0.16	38.45	1.1272	0.1542
298	0.5	2.0	0.25	29.91	1.1664	0.1600
	0.75	1.3	0.56	22.06	1.2650	0.1666
	1.0	1.0	1.00	14.82	1.3642	0.1680
	1.5	0.6	2.25	9.72	1.6052	0.1780
	2.0	0.5	4.00	7.65	1.8252	0.1755

Temperature (°K)	Concentration (C) moles/lit	$\frac{1}{C}$	C^2	$\frac{1}{\log \eta_r}$	η_r^2	$\frac{\eta_r - 1}{C}$
	0.1	10.0	0.01	231.40	1.0201	0.2074
	0.2	5.0	0.04	89.70	1.0526	0.1302
	0.3	3.3	0.09	58.70	1.0816	0.1106
	0.4	2.5	0.16	40.16	1.1214	0.1349
303	0.5	2.0	0.25	32.83	1.1556	0.1498
	0.75	1.3	0.56	22.37	1.2508	0.1558
	1.0	1.0	1.00	15.88	1.3360	0.1547
	1.5	0.6	2.25	10.70	1.5801	0.1600
	2.0	0.5	4.00	8.23	1.7490	0.1637
	0.1	10.0	0.01	288.97	1.0161	0.0750
	0.2	5.0	0.04	93.24	1.0502	0.1237
	0.3	3.3	0.09	62.59	1.0764	0.1158
	0.4	2.5	0.16	47.65	1.1014	0.1215
308	0.5	2.0	0.25	37.50	1.1341	0.1316
	0.75	1.3	0.56	23.59	1.2155	0.1412
	1.0	1.0	1.00	17.02	1.3112	0.1488
	1.5	0.6	2.25	10.43	1.5551	0.1634
	2.0	0.5	4.00	8.77	1.6900	0.1522

TABLE 3.8

Viscosity data for Lithium chloride in 10% urea-water solution at different temperatures.

Temperature (°K)	Concentration (C) moles/lit	$\frac{1}{C}$	C^2	$\frac{1}{\log\eta_r}$	η_r^2	$\eta_r -1$ /C
	0.1	10.0	0.01	105.81	1.0441	0.2190
	0.2	5.0	0.04	66.93	1.0712	0.1750
	0.3	3.3	0.09	47.19	1.1025	0.1663
	0.4	2.5	0.16	34.03	1.1449	0.1750
293	0.5	2.0	0.25	27.45	1.1826	0.1746
	0.75	1.3	0.56	19.54	1.2656	0.1707
	1.0	1.0	1.00	14.82	1.3500	0.1680
	1.5	0.6	2.25	9.71	1.6065	0.1758
	2.0	0.5	4.00	7.76	1.8090	0.1729
	0.1	10.0	0.01	110.79	1.0424	0.1000
	0.2	5.0	0.04	68.86	1.0691	0.1700
	0.3	3.3	0.09	58.85	1.0813	0.1323
	0.4	2.5	0.16	38.88	1.1257	0.1525
298	0.5	2.0	0.25	32.68	1.1513	0.1520
	0.75	1.3	0.56	21.27	1.2416	0.1524
	1.0	1.0	1.00	16.17	1.3294	0.1530
	1.5	0.6	2.25	10.80	1.5310	0.1712
	2.0	0.5	4.00	8.76	1.7226	0.1562

Temperature (°K)	Concentration (C) moles/lit	$\frac{1}{C}$	C^2	$\frac{1}{\log\eta_r}$	η_r^2	$\eta_r - 1/C$
	0.1	10.0	0.01	117.23	1.0399	0.1500
	0.2	5.0	0.04	80.82	1.0586	0.1373
	0.3	3.3	0.09	63.37	1.0753	0.1233
	0.4	2.5	0.16	44.00	1.1022	0.1247
303	0.5	2.0	0.25	35.00	1.1406	0.1360
	0.75	1.3	0.56	23.00	1.2208	0.1398
	1.0	1.0	1.00	16.61	1.3192	0.1486
	1.5	0.6	2.25	10.56	1.5400	0.1516
	2.0	0.5	4.00	8.64	1.7030	0.1525
	0.1	10.0	0.01	122.33	1.0381	0.1890
	0.2	5.0	0.04	73.10	1.0652	0.1450
	0.3	3.3	0.09	80.82	1.0586	0.1688
	0.4	2.5	0.16	47.50	1.0880	0.1875
308	0.5	2.0	0.25	38.27	1.1178	0.2149
	0.75	1.3	0.56	24.72	1.2047	0.1825
	1.0	1.0	1.00	18.10	1.2895	0.1872
	1.5	0.6	2.25	12.07	1.5284	0.1887
	2.0	0.5	4.00	9.63	1.6129	0.1866

TABLE 3.9

Viscosity data for Lithium chloride in 15% urea-water solution at different temperatures.

Temperature (°K)	Concentration (C) moles/lit	$\frac{1}{C}$	C^2	$\frac{1}{\log\eta_r}$	η_r^2	$\eta_r - 1$ /C
	0.1	10.0	0.01	139.85	1.0334	0.1662
	0.2	5.0	0.04	67.12	1.0710	0.1745
	0.3	3.3	0.09	47.19	1.1025	0.1698
	0.4	2.5	0.16	37.11	1.1320	0.1580
293	0.5	2.0	0.25	30.24	1.1642	0.1582
	0.75	1.3	0.56	20.54	1.2512	0.1582
	1.0	1.0	1.00	15.62	1.3428	0.1588
	1.5	0.6	2.25	10.31	1.5625	0.1722
	2.0	0.5	4.00	8.07	1.7689	0.1662
	0.1	10.0	0.01	145.05	1.0322	0.1700
	0.2	5.0	0.04	83.38	1.0567	0.1450
	0.3	3.3	0.09	52.33	1.0920	0.1333
	0.4	2.5	0.16	42.25	1.1151	0.1400
298	0.5	2.0	0.25	34.03	1.1449	0.1400
	0.75	1.3	0.56	92.65	1.2254	0.1426
	1.0	1.0	1.00	17.57	1.2996	0.1400
	1.5	0.6	2.25	11.50	1.4884	0.1466
	2.0	0.5	4.00	8.97	1.6701	0.1462

Temperature (°K)	Concentration (C) moles/lit	$\frac{1}{C}$	C^2	$\frac{1}{\log \eta_r}$	η_r^2	$\eta_r - 1 / C$
	0.1	10.0	0.01	154.65	1.0301	0.1581
	0.2	5.0	0.04	116.27	1.0402	0.1135
	0.3	3.3	0.09	63.37	1.0751	0.1256
	0.4	2.5	0.16	49.11	1.0986	0.1208
303	0.5	2.0	0.25	39.50	1.1236	0.1354
	0.75	1.3	0.56	25.37	1.1990	0.1269
	1.0	1.0	1.00	17.93	1.2927	0.1369
	1.5	0.6	2.25	12.07	1.4641	0.1453
	2.0	0.5	4.00	9.11	1.6572	0.1436
	0.1	10.0	0.01	231.40	1.0221	0.1250
	0.2	5.0	0.04	132.71	1.0351	0.0870
	0.3	3.3	0.09	77.89	1.0692	0.1000
	0.4	2.5	0.16	55.32	1.0861	0.1050
308	0.5	2.0	0.25	43.02	1.1130	0.1084
	0.75	1.3	0.56	27.91	1.1793	0.1182
	1.0	1.0	1.00	19.11	1.2723	0.1284
	1.5	0.6	2.25	13.23	1.4161	0.1286
	2.0	0.5	4.00	10.13	1.5750	0.1263

TABLE 3.10

Viscosity data for Lithium chloride in 20% urea-water solution at different temperatures.

Temperature (°K)	Concentration (C) moles/lit	$\frac{1}{C}$	C^2	$\frac{1}{\log\eta_r}$	η_r^2	$\eta_r -1$ /C
293	0.1	10.0	0.01	154.60	1.0301	0.1585
	0.2	5.0	0.04	70.92	1.0672	0.1675
	0.3	3.3	0.09	52.31	1.0921	0.1524
	0.4	2.5	0.16	38.88	1.1257	0.1525
	0.5	2.0	0.25	31.83	1.5556	0.1502
	0.75	1.3	0.56	22.45	1.2276	0.1440
	1.0	1.0	1.00	16.47	1.3010	0.1507
	1.5	0.6	2.25	11.30	1.5030	0.1506
	2.0	0.5	4.00	8.84	1.6832	0.1483
298	0.1	10.0	0.01	231.40	1.0201	0.1000
	0.2	5.0	0.04	97.08	1.0482	0.1200
	0.3	3.3	0.09	61.73	1.07771	0.1166
	0.4	2.5	0.16	42.50	1.1088	0.1325
	0.5	2.0	0.25	36.02	1.1363	0.1320
	0.75	1.3	0.56	24.87	1.2034	0.1293
	1.0	1.0	1.00	18.18	1.2881	0.1350
	1.5	0.6	2.25	12.07	1.4771	0.1400
	2.0	0.5	4.00	9.38	1.6332	0.1390

Temperature (°K)	Concentration (C) moles/lit	$\frac{1}{C}$	C^2	$\frac{1}{\log\eta_r}$	η_r^2	$\eta_r -1$ /C
	0.1	10.0	0.01	210.00	1.0322	0.1616
	0.2	5.0	0.04	129.06	1.0363	0.0932
	0.3	3.3	0.09	80.54	1.0588	0.1013
	0.4	2.5	0.16	52.31	1.0920	0.1125
303	0.5	2.0	0.25	43.78	1.1109	0.1080
	0.75	1.3	0.56	27.30	1.1837	0.1246
	1.0	1.0	1.00	18.81	1.2851	0.1307
	1.5	0.6	2.25	12.61	1.4421	0.1333
	2.0	0.5	4.00	9.63	1.6129	0.1356
	0.1	10.0	0.01	248.73	1.0141	0.1800
	0.2	5.0	0.04	154.65	1.0302	0.0750
	0.3	3.3	0.09	93.24	1.0501	0.0833
	0.4	2.5	0.16	57.30	1.0832	0.0875
308	0.5	2.0	0.25	45.42	1.1067	0.1040
	0.75	1.3	0.56	29.91	1.1612	0.1060
	1.0	1.0	1.00	20.31	1.2314	0.1200
	1.5	0.6	2.25	14.27	1.4347	0.1166
	2.0	0.5	4.00	10.71	1.5376	0.1200

TABLE 3.11 A

V-values of lithium chloride in different urea-water compositions at different temperatures

Mass fraction of urea	Temp. °K	V^a	V^b_c	V^c
0 %	293	0.0761	0.0665	0.0781
	298	0.0650	0.0592	0.0762
	303	0.0550	0.0552	0.0760
	308	0.0512	0.0551	0.0710
5 %	293	0.0691	0.0612	0.0701
	298	0.0620	0.0541	0.0712
	303	0.0531	0.0511	0.0661
	308	0.0491	0.0505	0.0612
10 %	293	0.0651	0.0601	0.0684
	298	0.0602	0.5712	0.0651
	303	0.0491	0.0491	0.0632
	308	0.0471	0.0481	0.0561
15 %	293	0.0621	0.0571	0.0661
	298	0.0572	0.0501	0.0602
	303	0.0461	0.0421	0.0581
	308	0.0391	0.0402	0.0531
20 %	293	0.0601	0.0542	0.0592
	298	0.0591	0.0461	0.0561
	303	0.0412	0.0391	0.0552
	308	0.0371	0.0372	0.0400

V^a V values calculated by using Vand equation

$$\frac{1}{C} = \frac{0.0921}{V} \frac{1}{\log_r} + QV$$

V^b_e = V values calculated by Breslau & Miller equation

$$V_e = \frac{-2.5C + [(2.5C)^2 - 40.20\, C^2\, (1- n_{rel})]^{\frac{1}{2}}}{20.10\, C^2}$$

V = V values calculated by Einstein's equation : E = 2.5 V

TABLE 3.11 b

Q values of lithium chloride in urea-water solution at different temperatures

Temperature °K	Mass fraction of urea				
	0 %	5 %	10 %	15 %	20 %
293	12.92	21.42	22.05	22.72	25.42
298	-19.58	7.04	15.38	16.66	17.85
303	-39.16	-30.30	-23.50	-20.48	18.18
308	-55.86	-49.18	-35.71	-34.60	75.00

TABLE 3.12

B/V values of lithium chloride in urea-water solution at different temperatures

Temperature °K	Mass fraction of urea				
	0 %	5 %	10 %	15 %	20 %
293	2.56	2.53	2.59	2.64	2.46
298	2.94	2.85	2.70	2.60	2.35
303	3.97	3.37	3.21	3.16	3.28
308	3.50	3.12	2.97	3.37	2.68

TABLE 3.13.a

K-values of lithium chloride in urea-water solution at different temperatures

Temperature °K	Mass fraction of urea				
	0 %	5 %	10 %	15 %	20 %
293	0.4750	0.3463	0.3016	0.2916	0.2625
298	0.4416	0.3000	0.2833	0.2660	0.2437
303	0.4083	0.2833	0.2750	0.2500	0.2375
308	0.3583	0.2666	0.2583	0.2166	0.2125

TABLE 3.13.b

M-values of lithium chloride in urea-water solution at different temperatures

Temperature °K	Mass fraction of urea				
	0 %	5 %	10 %	15 %	20 %
293	1.0750	1.1000	1.1000	1.0801	1.0800
298	1.0650	1.0902	1.0801	1.0751	1.0701
303	1.0601	1.0871	1.0652	1.0652	1.0601
308	1.0601	1.0701	1.0501	1.0520	1.0572

Table 3.14

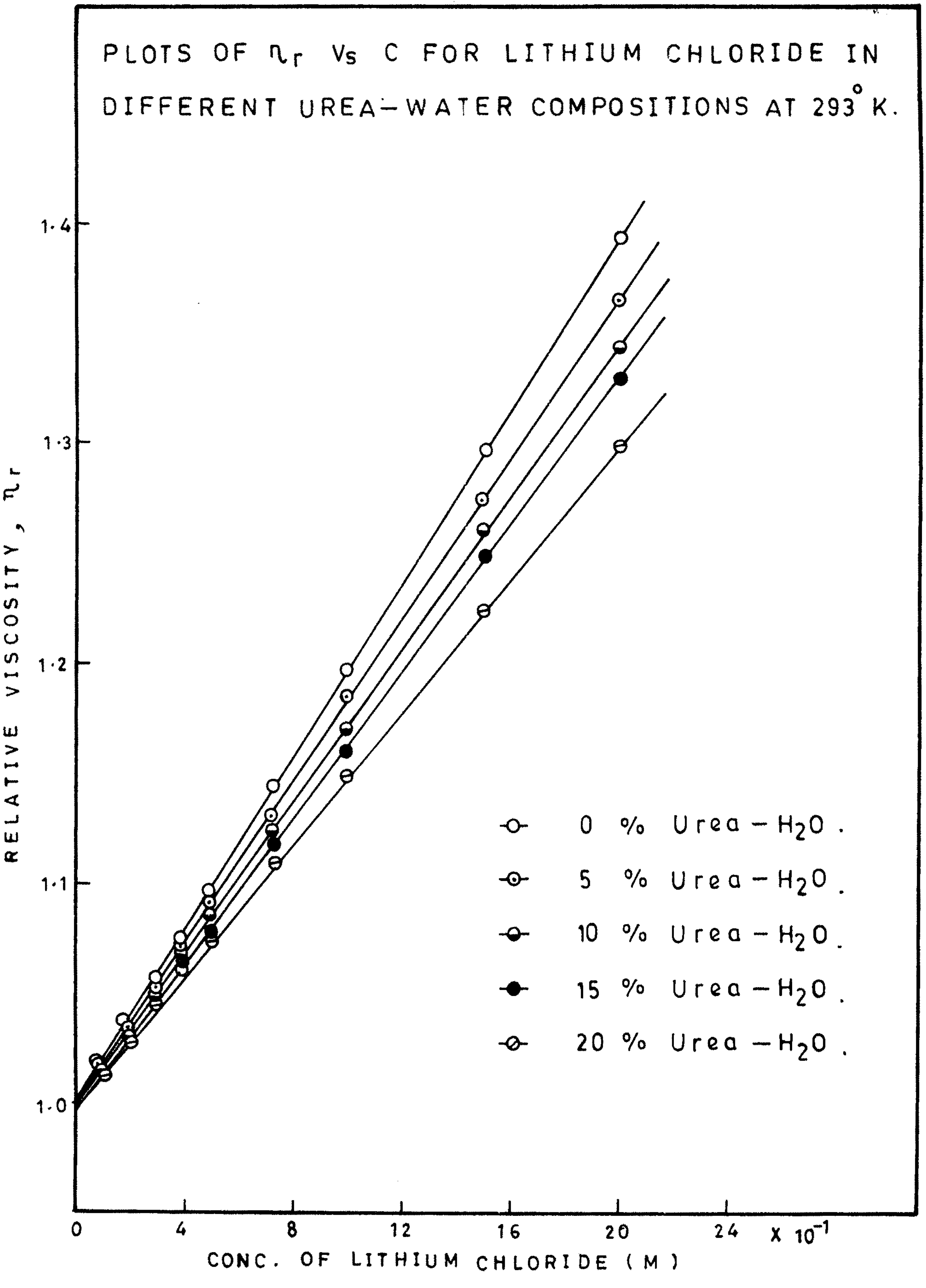
Free energy, energy and entropy of activation for viscous flow of Lithium chloride solution at 298°K (C = 1 mol/lit)

Wt. % urea in urea-H_2O		ΔE^* K.cal	ΔF^* K.cal	ΔS^* K.cal
0 %	Solvent (water)	3.884	2.187	5.690
	LiCl	4.222	2.453	5.936
5%	Solvent	4.212	2.421	6.010
	LiCl	4.470	2.540	6.476
10 %	Solvent	4.422	2.507	6.920
	LiCl	4.714	2.560	7.224
15 %	Solvent	4.612	2.521	7.016
	LiCl	4.829	2.670	7.244
20 %	Solvent	4.821	2.060	7.419
	LiCl	5.012	2.720	7.691

Table 3.15

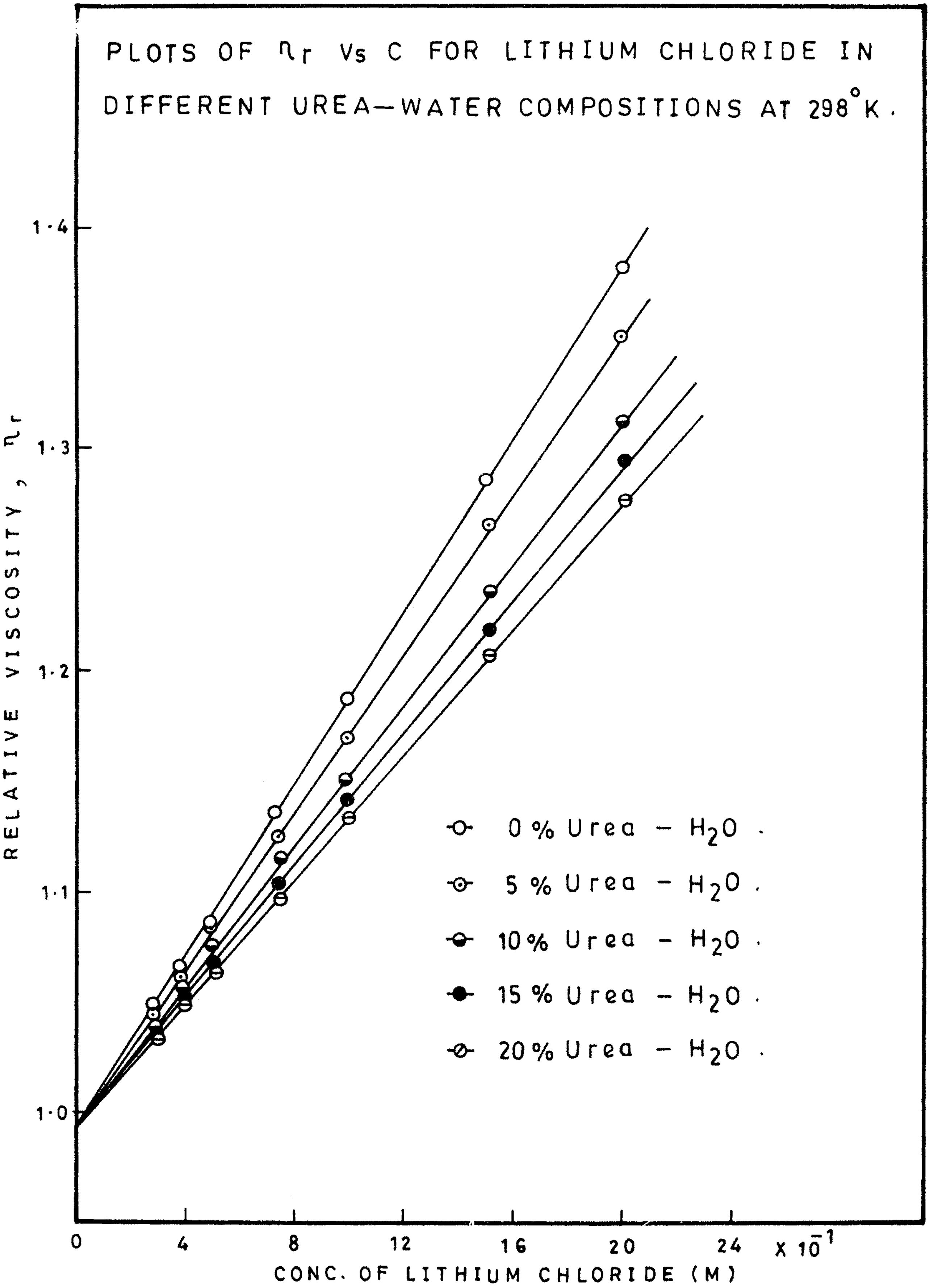
Transport properties of viscous flow of Lithium Chloride in 10% urea-water solution at 298°K

Concentration moles/litre	ΔE^* K.cal	ΔF^* K.cal	ΔS^* e.u.
0.10	4.712	2.550	7.2550
0.20	4.710	2.552	7.2416
0.30	4.710	2.554	7.2348
0.40	4.711	2.556	7.2315
0.50	4.710	2.558	7.2284
0.75	4.711	2.559	7.2264
1.00	4.714	2.560	7.2240
1.50	4.714	2.562	7.2210
2.00	4.698	2.564	7.1610



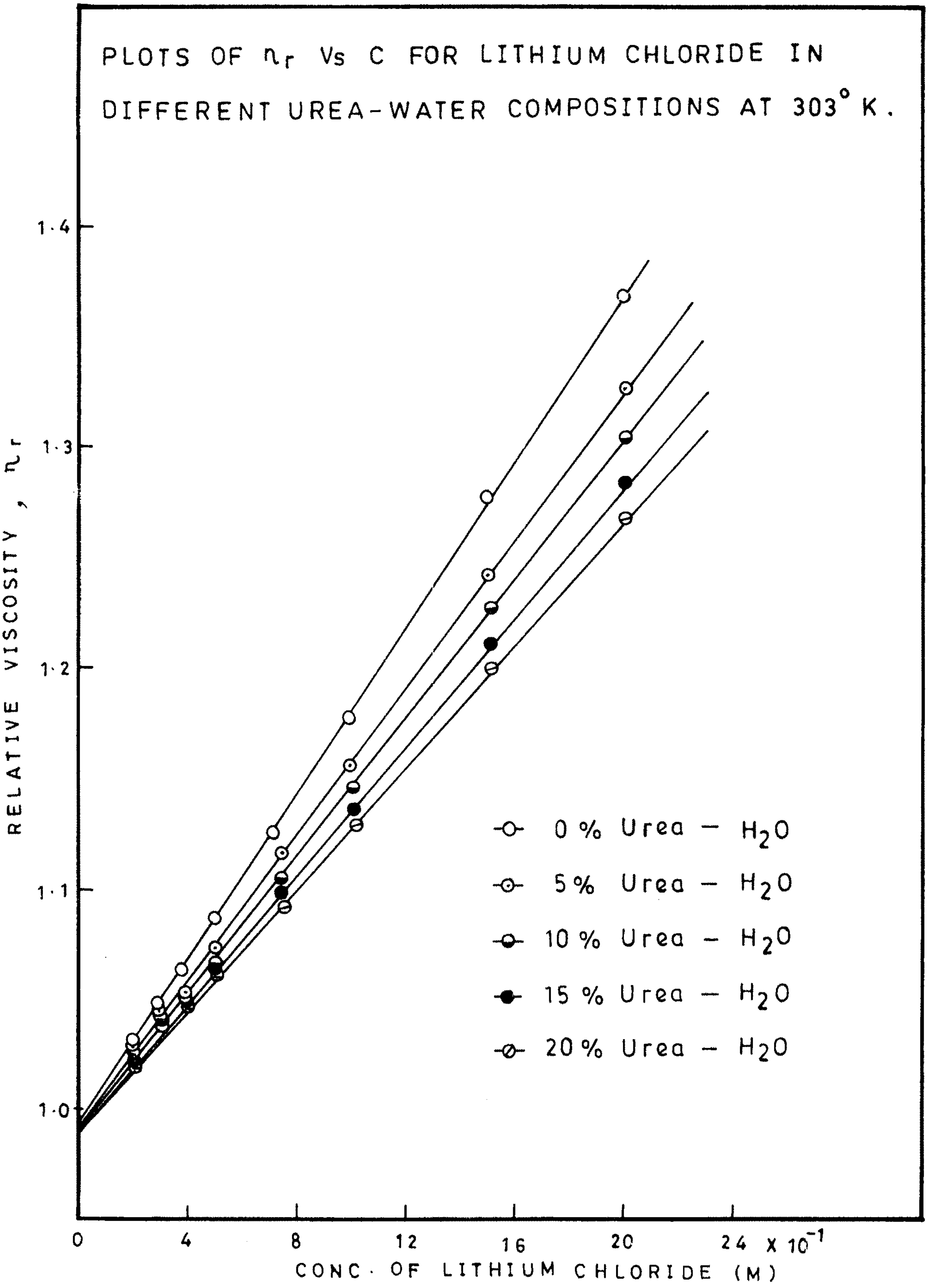
PLOTS OF η_r Vs C FOR LITHIUM CHLORIDE IN DIFFERENT UREA-WATER COMPOSITIONS AT 293° K.

FIG. NO. 3·2



PLOTS OF η_r Vs C FOR LITHIUM CHLORIDE IN DIFFERENT UREA—WATER COMPOSITIONS AT 298°K.

FIG. NO. 3·3



PLOTS OF η_r Vs C FOR LITHIUM CHLORIDE IN DIFFERENT UREA-WATER COMPOSITIONS AT 303° K.

FIG. NO. 3·4

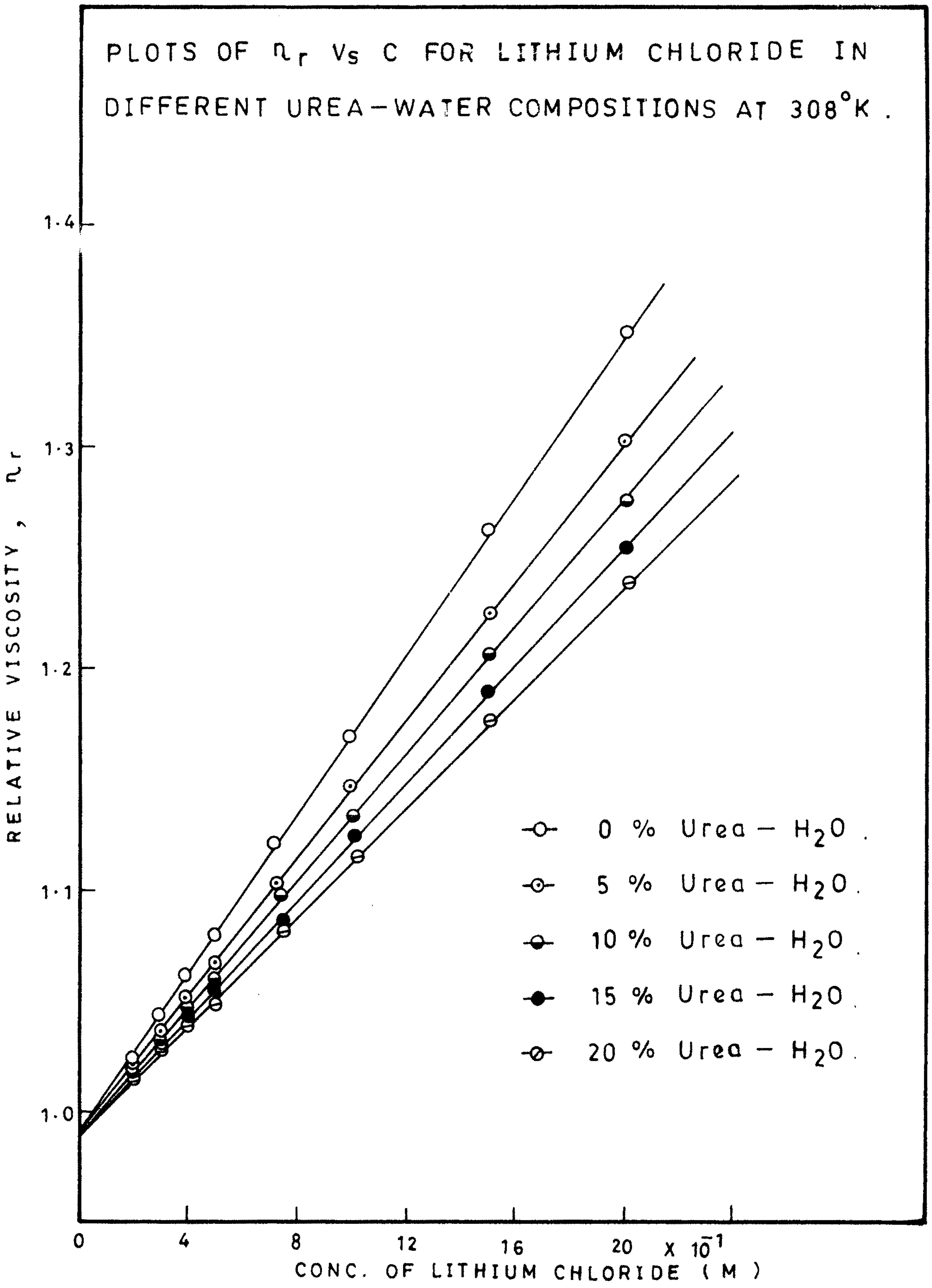
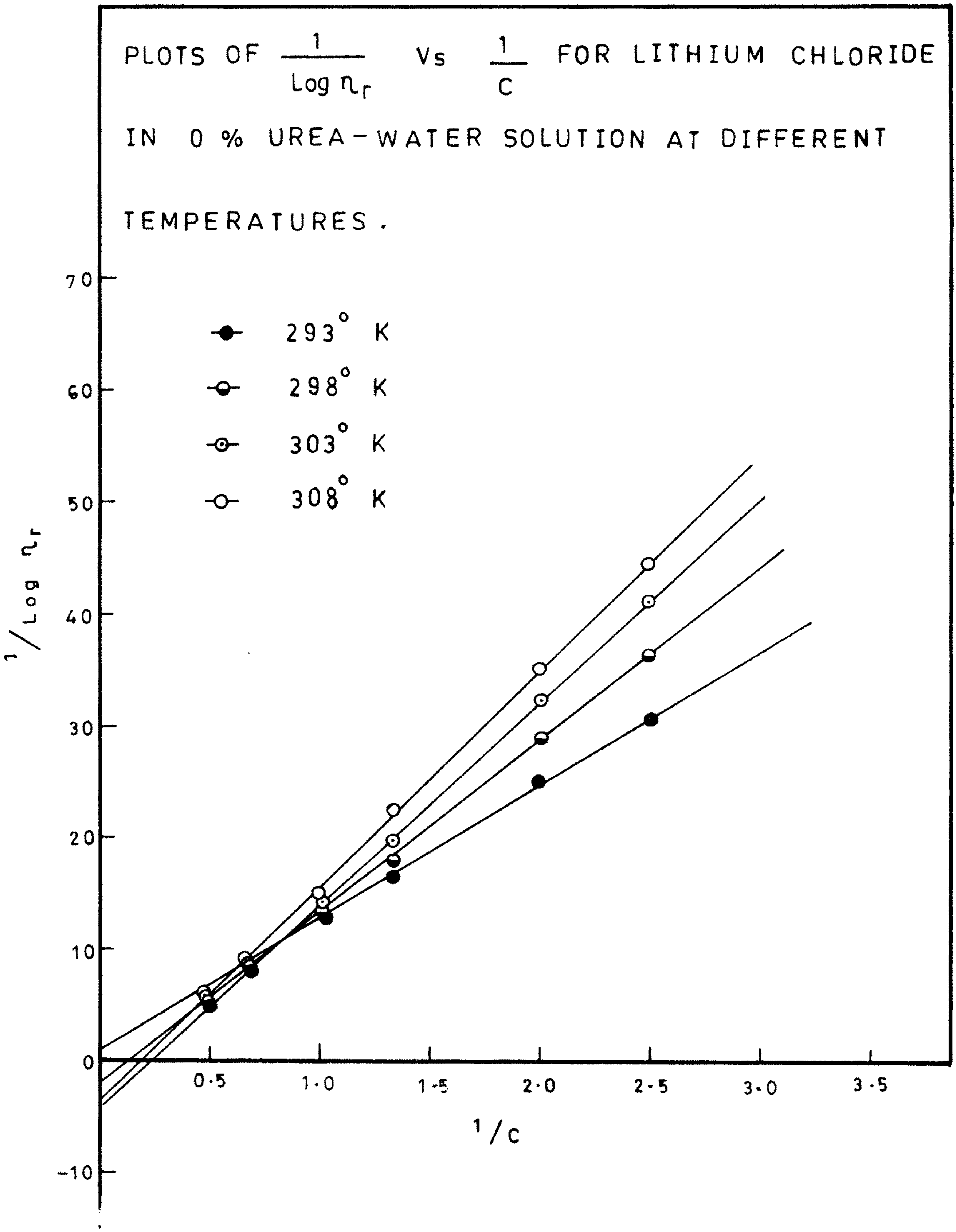

PLOTS OF η_r Vs C FOR LITHIUM CHLORIDE IN DIFFERENT UREA-WATER COMPOSITIONS AT 308°K.
RELATIVE VISCOSITY, η_r
1·4
1·3
1·2
1·1
1·0
0
4
8
12
16
20
X 10^{-1}
CONC. OF LITHIUM CHLORIDE (M)
0 % Urea − H_2O.
5 % Urea − H_2O.
10 % Urea − H_2O.
15 % Urea − H_2O.
20 % Urea − H_2O.

FIG. NO. 3·5



PLOTS OF $\frac{1}{\mathrm{Log}\ \eta_r}$ Vs $\frac{1}{C}$ FOR LITHIUM CHLORIDE IN 0 % UREA-WATER SOLUTION AT DIFFERENT TEMPERATURES.

FIG. NO. 3·6

PLOTS OF $\frac{1}{\text{Log}\ \eta_r}$ Vs $\frac{1}{C}$ FOR LITHIUM CHLORIDE IN 5% UREA–WATER SOLUTION AT DIFFERENT TEMPERATURES.

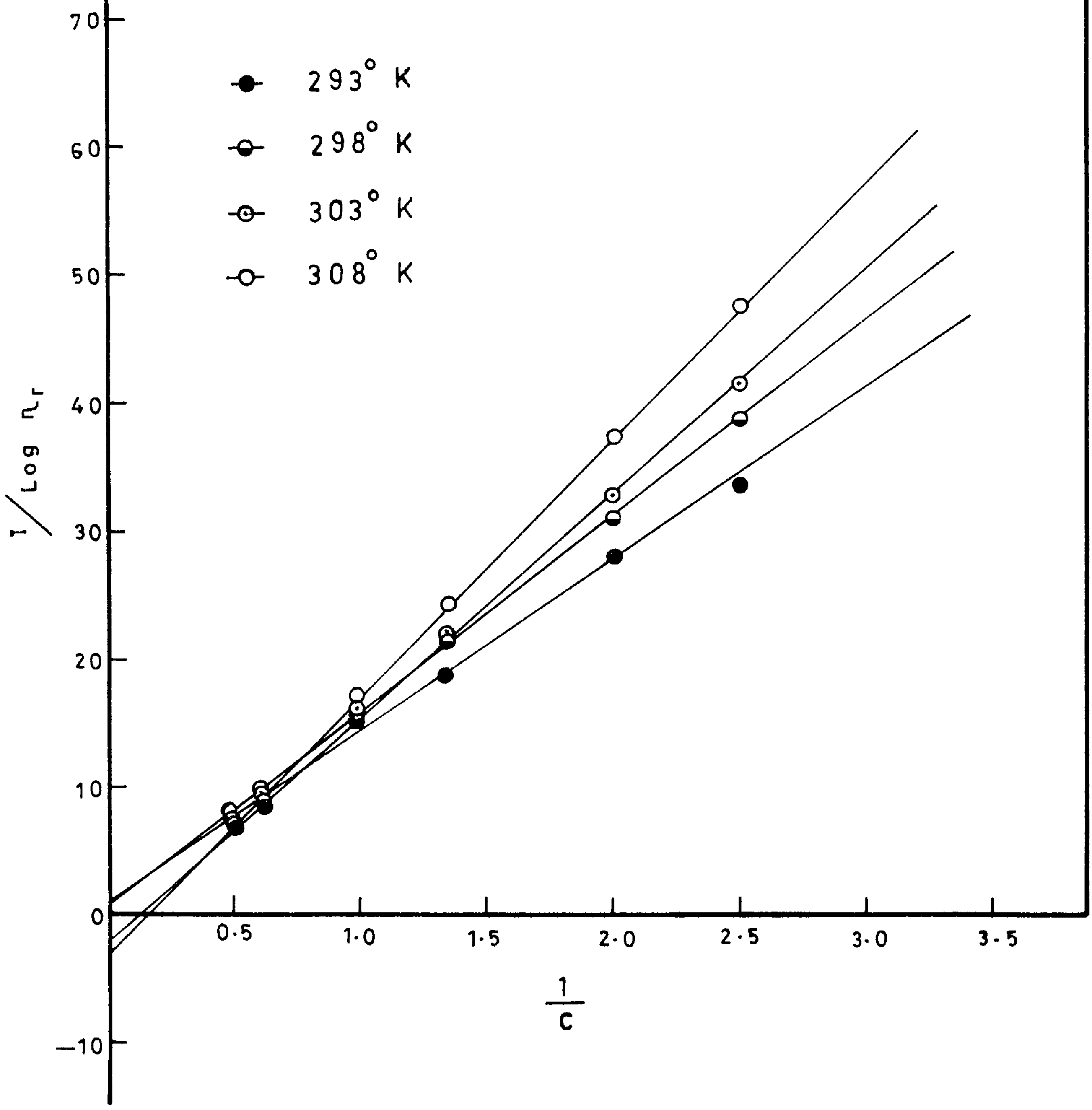


FIG. NO. 3·7

PLOTS OF $\frac{1}{\text{Log } \eta_r}$ Vs $\frac{1}{C}$ FOR LITHIUM CHLORIDE IN 10% UREA-WATER SOLUTION AT DIFFERENT TEMPERATURES.

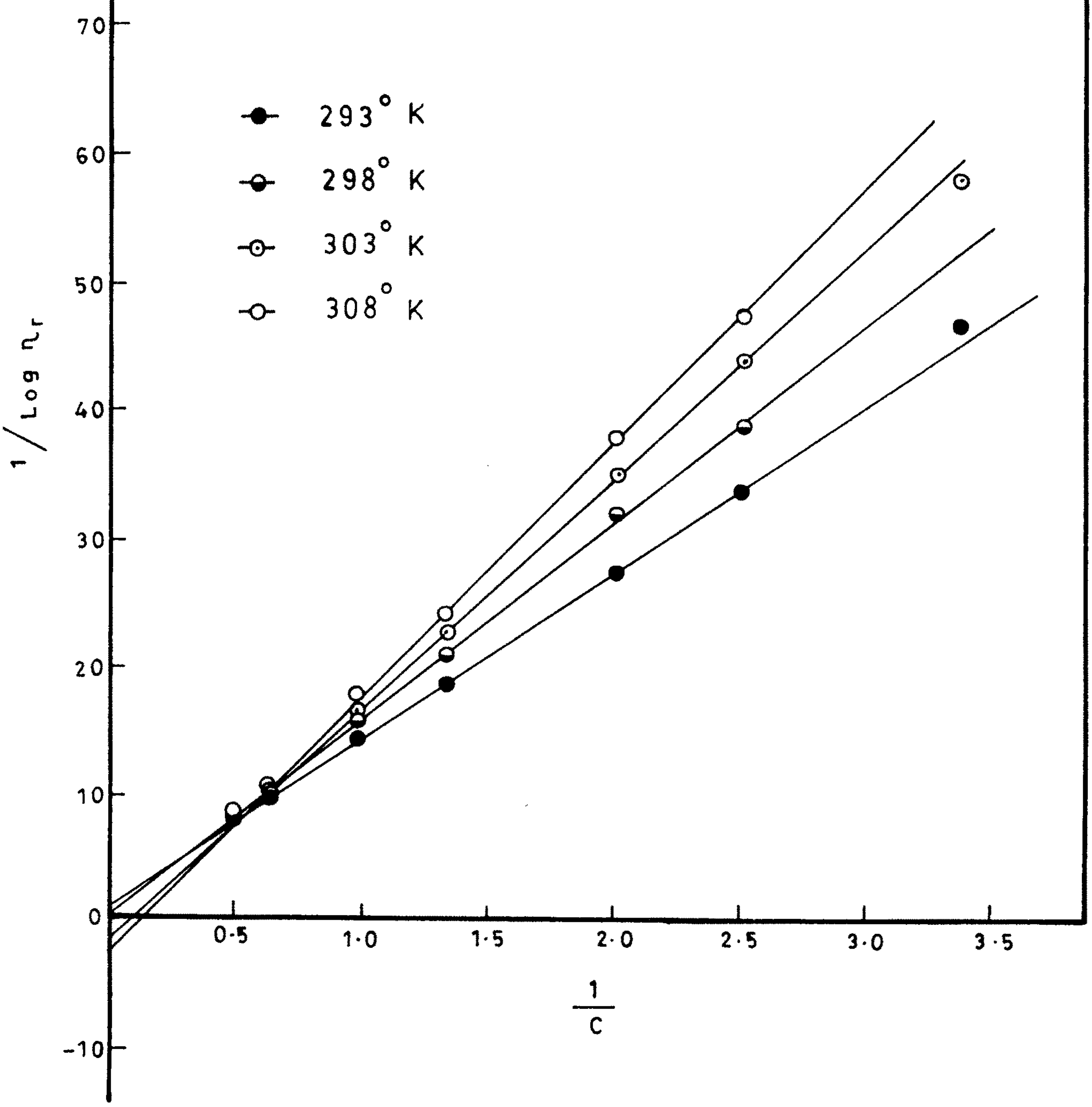


FIG. NO. 3·8

PLOTS OF $\frac{1}{\mathrm{Log}\ \eta_r}$ Vs $\frac{1}{C}$ FOR LITHIUM CHLORIDE IN 15 % UREA-WATER SOLUTION AT DIFFERENT TEMPERATURES.

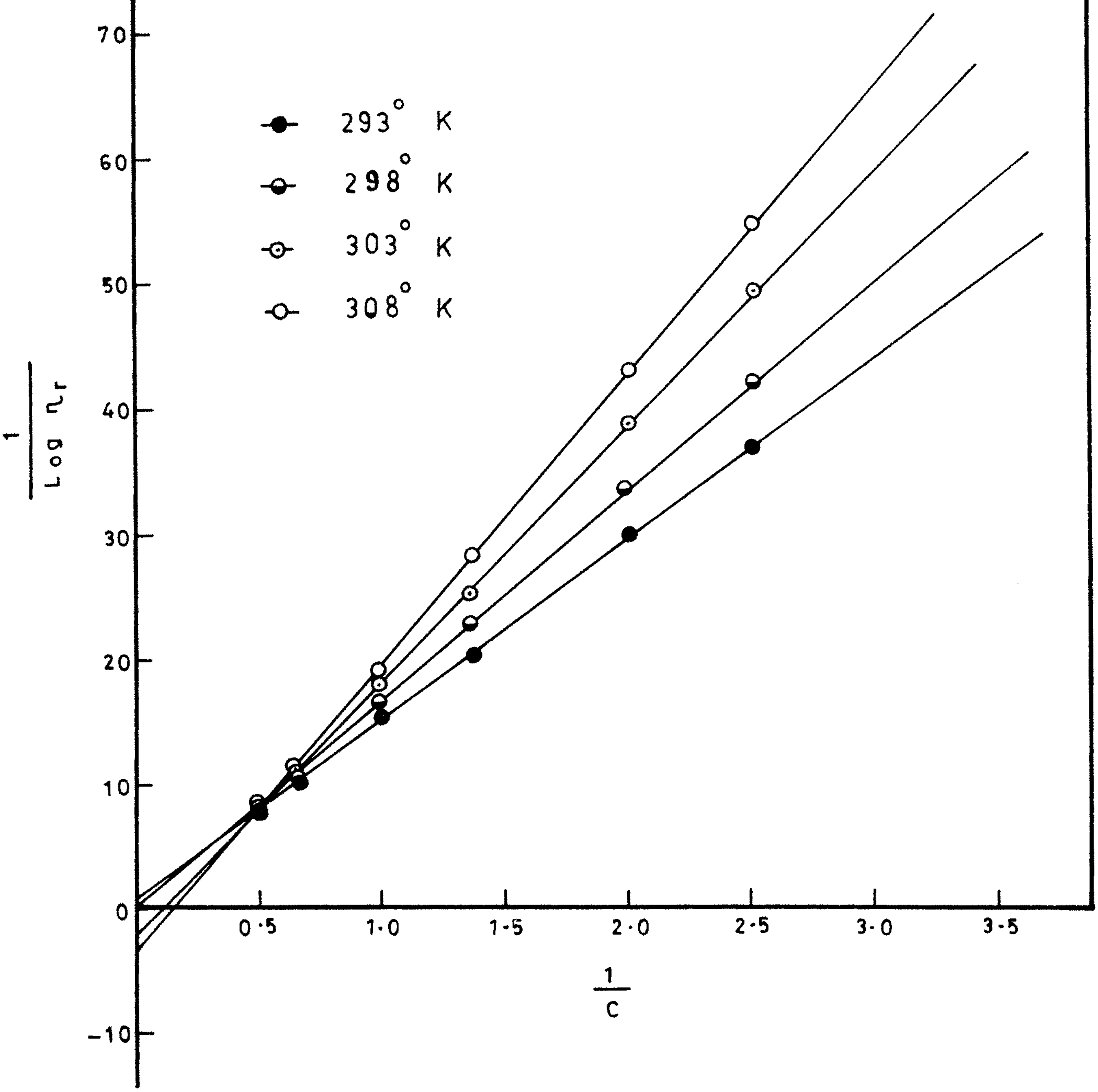
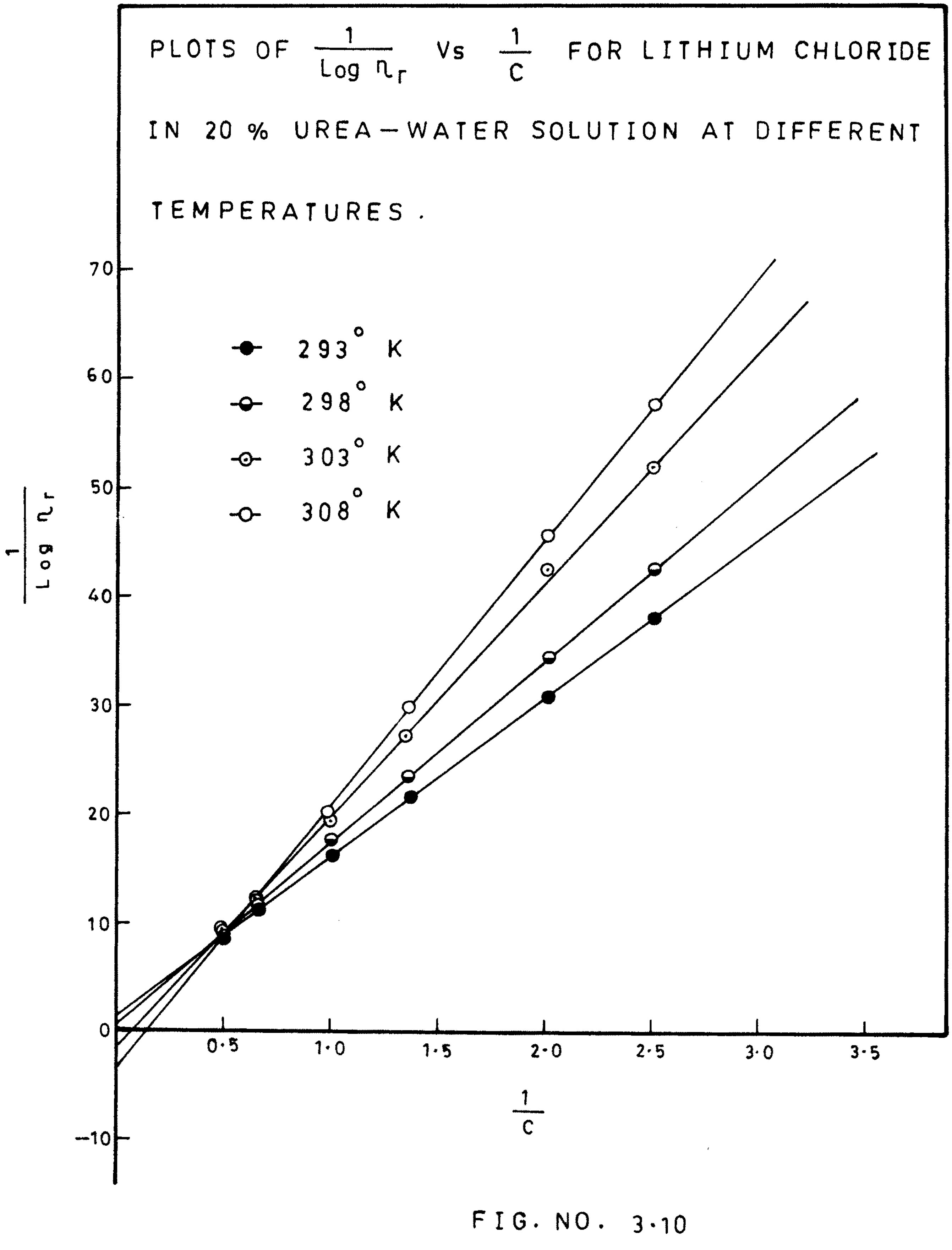
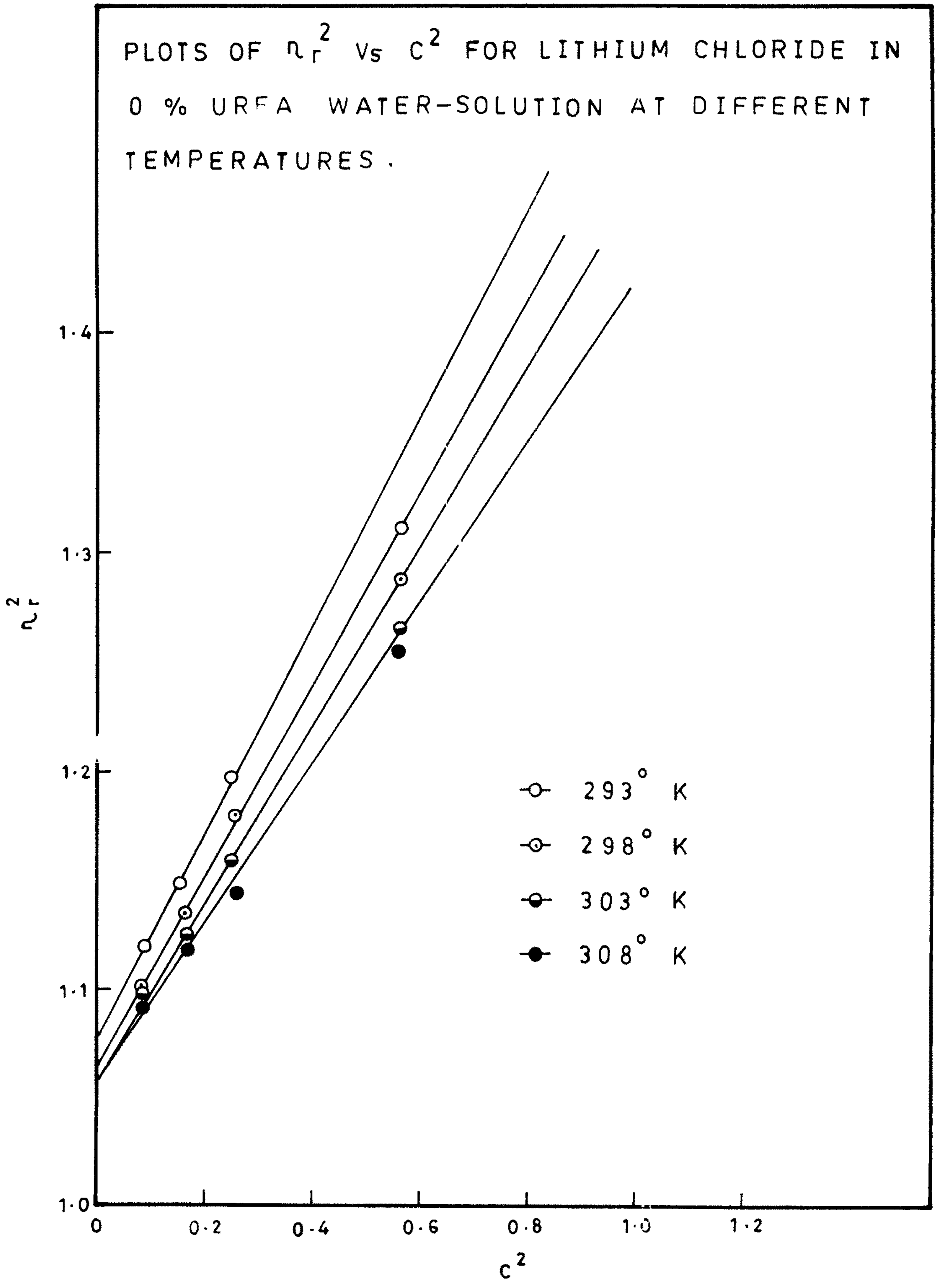


FIG. NO. 3·9



PLOTS OF $\frac{1}{\text{Log } \eta_r}$ Vs $\frac{1}{C}$ FOR LITHIUM CHLORIDE IN 20 % UREA – WATER SOLUTION AT DIFFERENT TEMPERATURES.

FIG. NO. 3·10



PLOTS OF η_r^2 Vs C^2 FOR LITHIUM CHLORIDE IN 0 % UREA WATER-SOLUTION AT DIFFERENT TEMPERATURES.

FIG. NO. 3·11

PLOTS OF η_r^2 Vs C^2 FOR LITHIUM CHLORIDE IN 5 % UREA-WATER SOLUTIONS AT DIFFERENT TEMPERATURES .

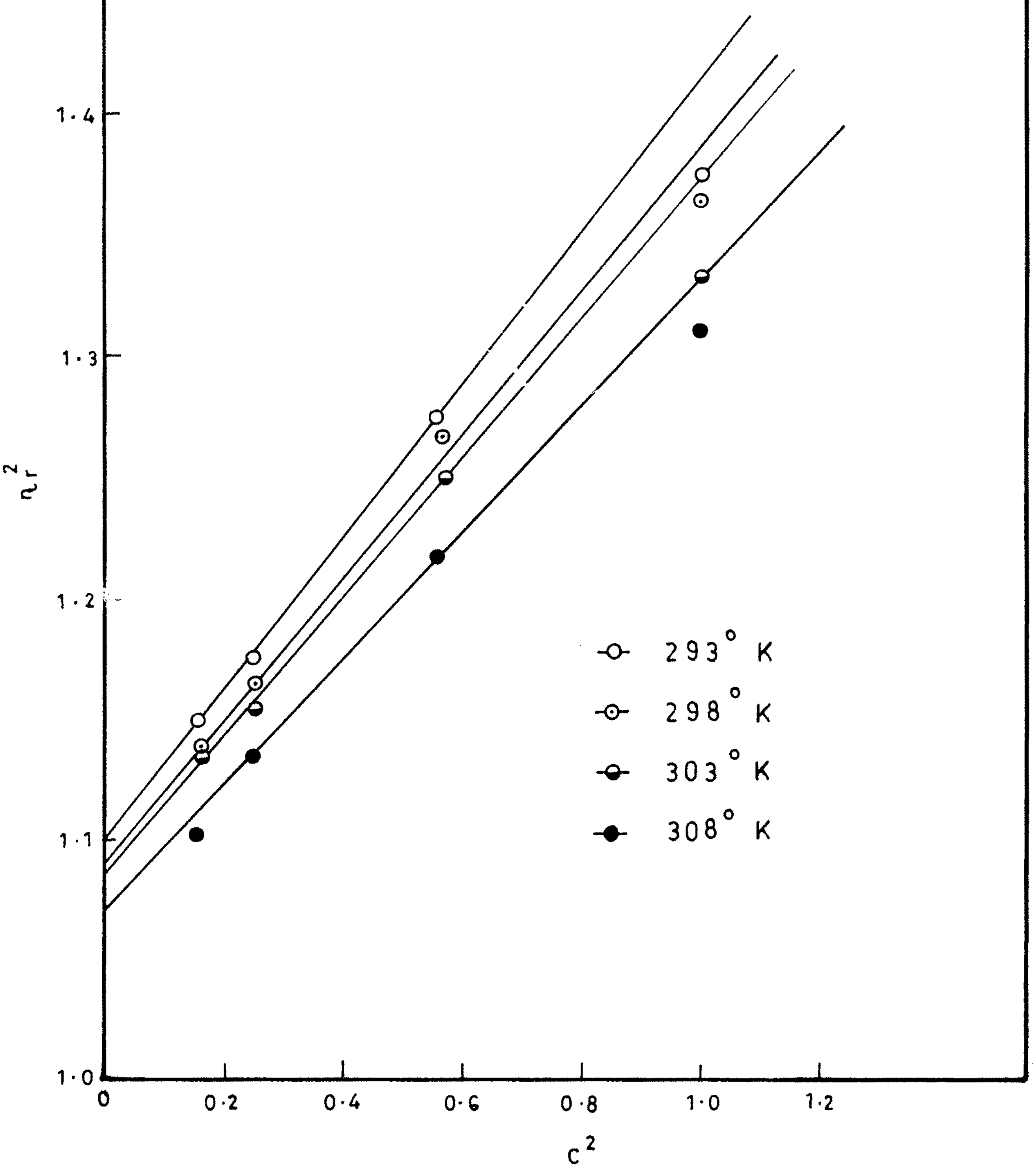
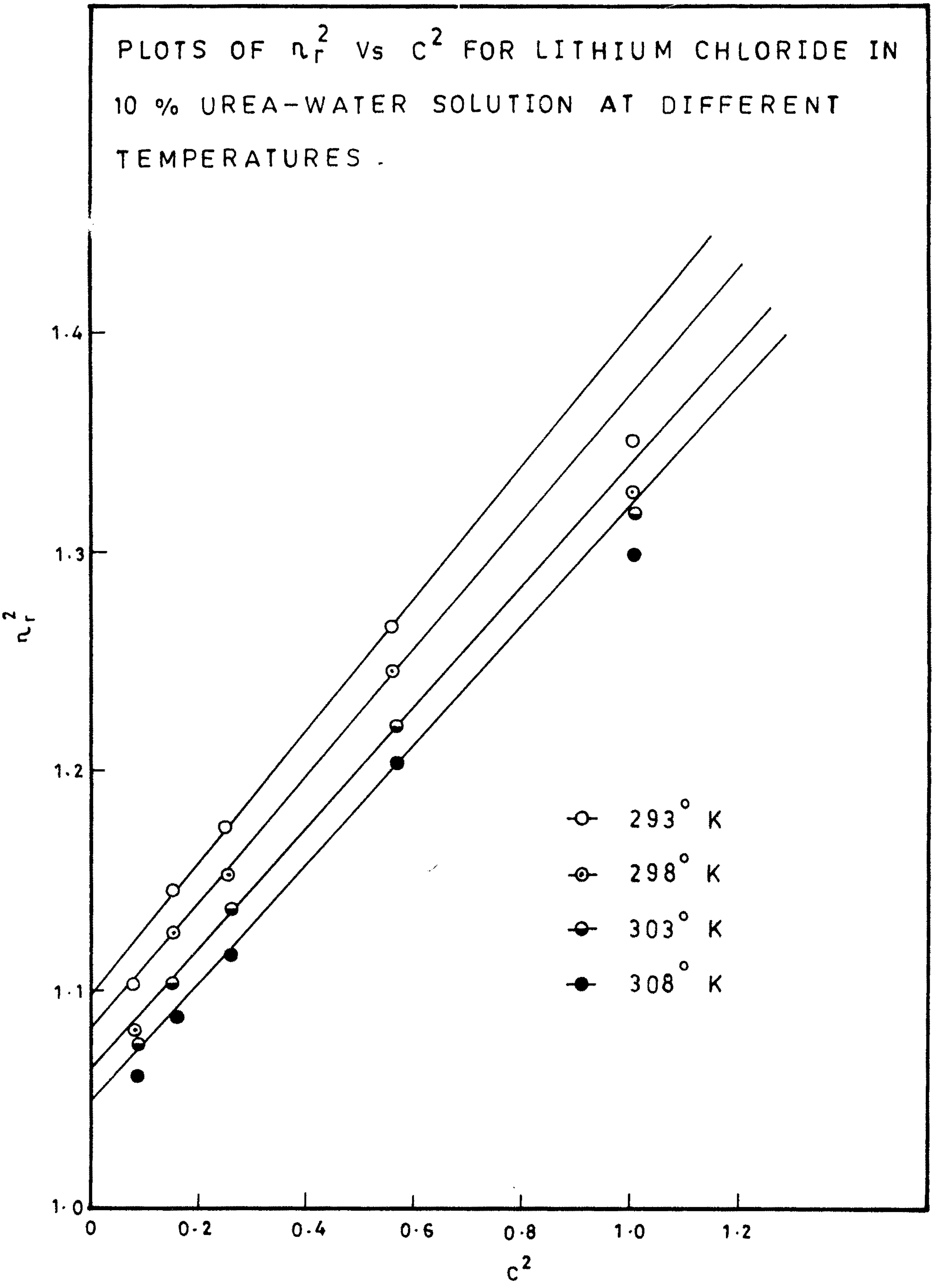
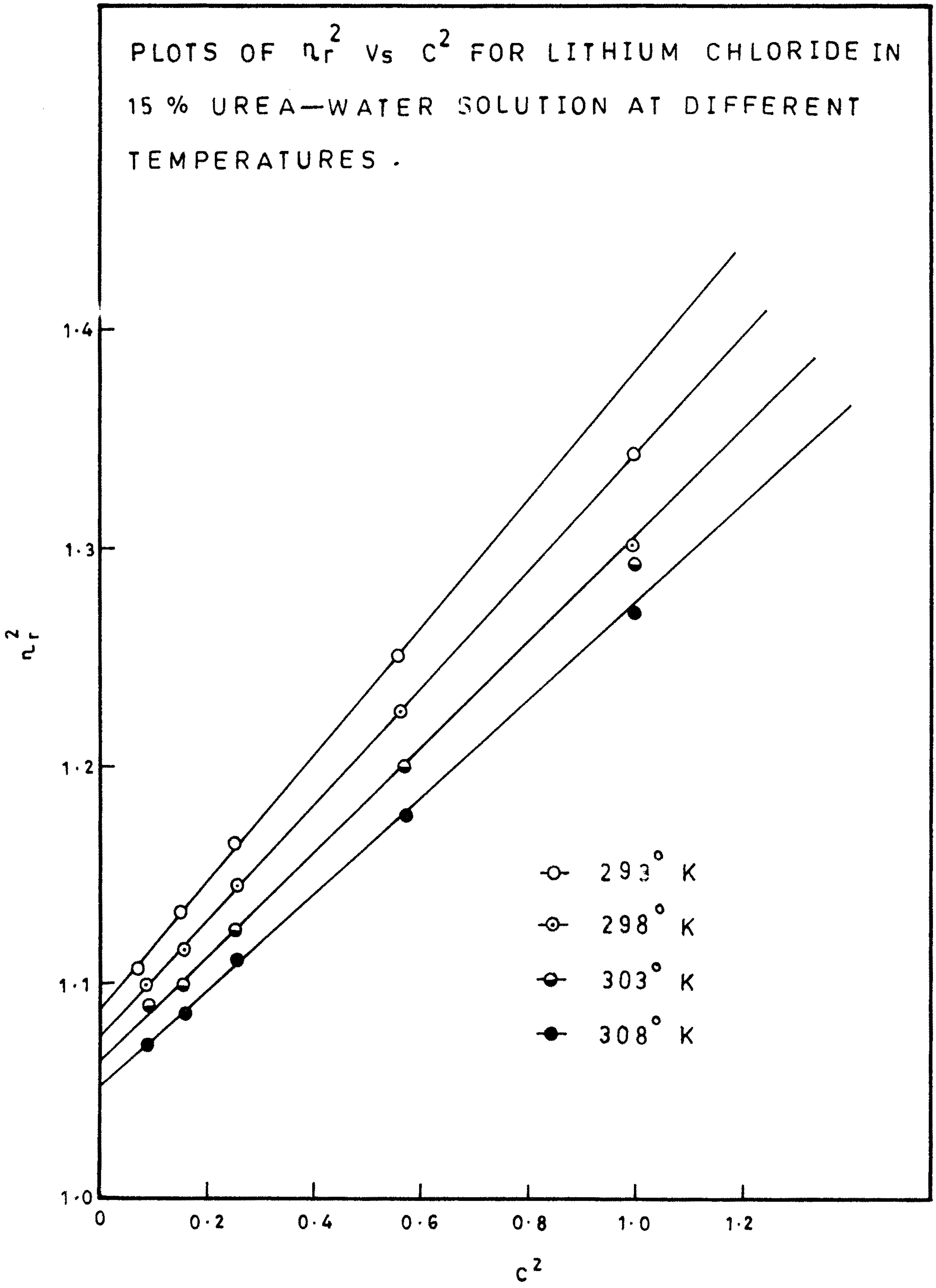


FIG. NO. 3·12



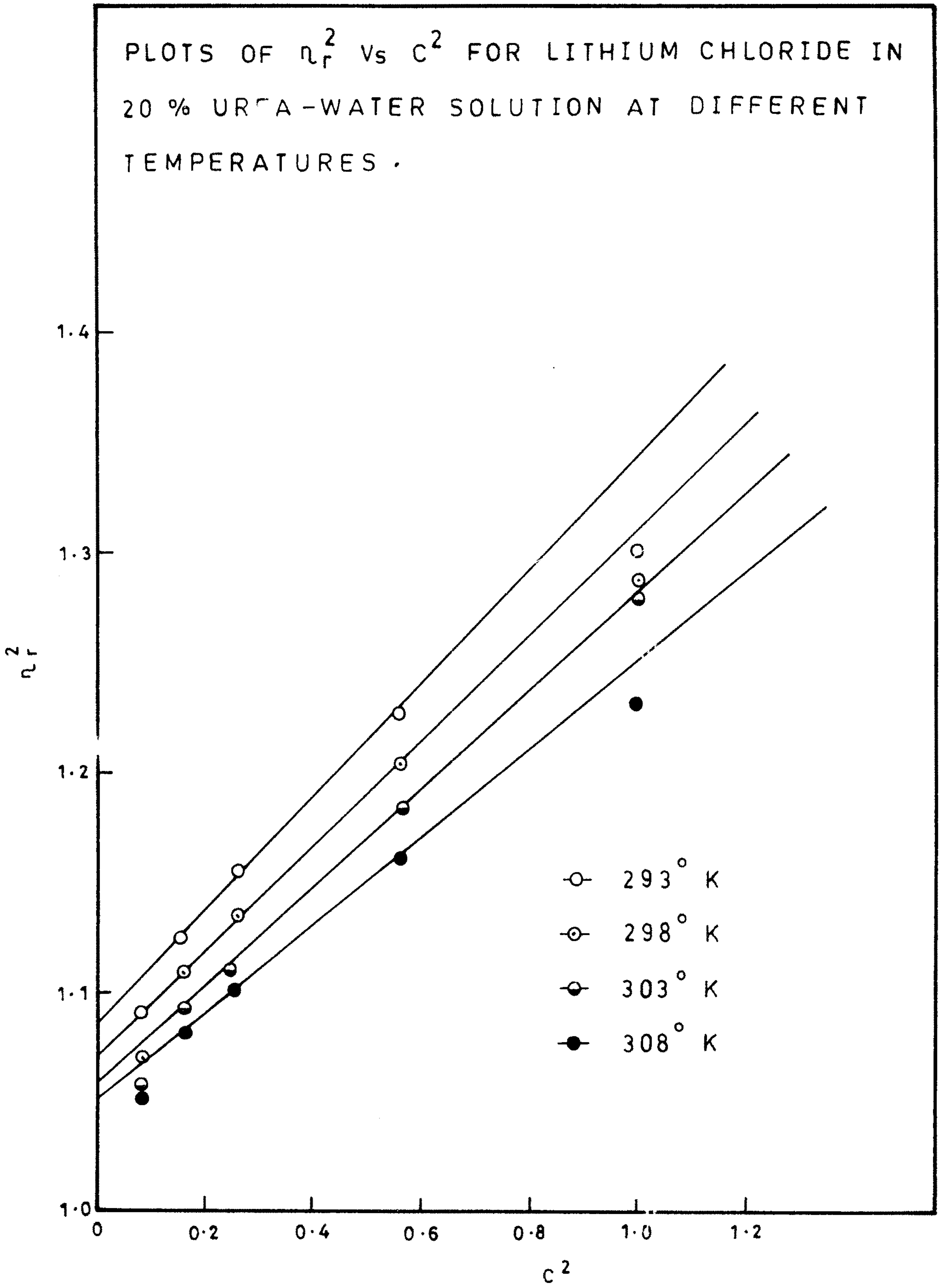
PLOTS OF η_r^2 Vs c^2 FOR LITHIUM CHLORIDE IN 10 % UREA-WATER SOLUTION AT DIFFERENT TEMPERATURES.

FIG. NO. 3·13



PLOTS OF η_r^2 Vs C^2 FOR LITHIUM CHLORIDE IN 15 % UREA—WATER SOLUTION AT DIFFERENT TEMPERATURES.

FIG. NO. 3·14



PLOTS OF η_r^2 Vs C^2 FOR LITHIUM CHLORIDE IN 20 % UREA-WATER SOLUTION AT DIFFERENT TEMPERATURES.

FIG. NO. 3·15

PLOTS OF $\frac{\eta_r - 1}{C}$ Vs C FOR LITHIUM CHLORIDE IN 0 % UREA-WATER SOLUTION AT DIFFERENT TEMPERATURES.

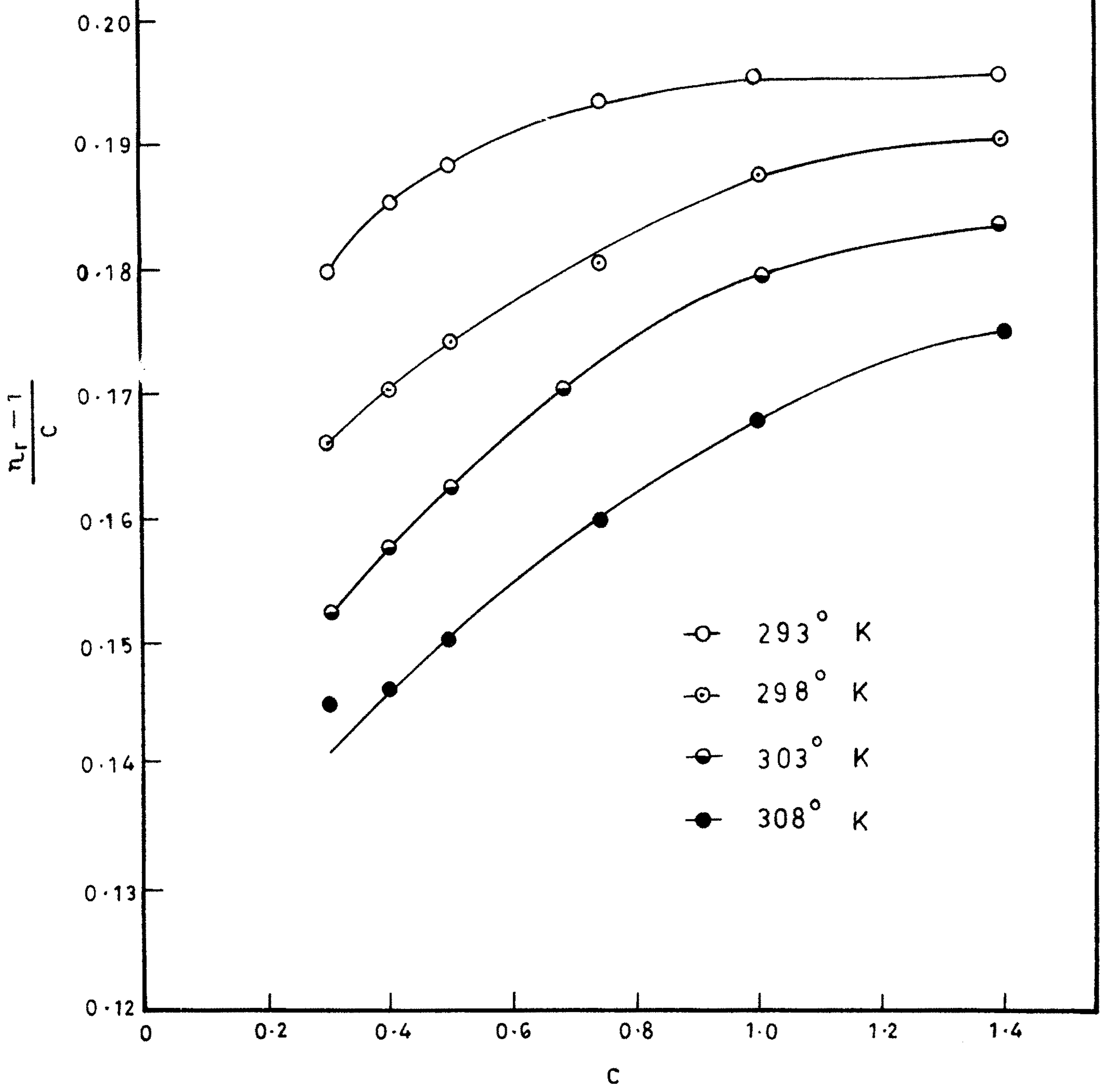
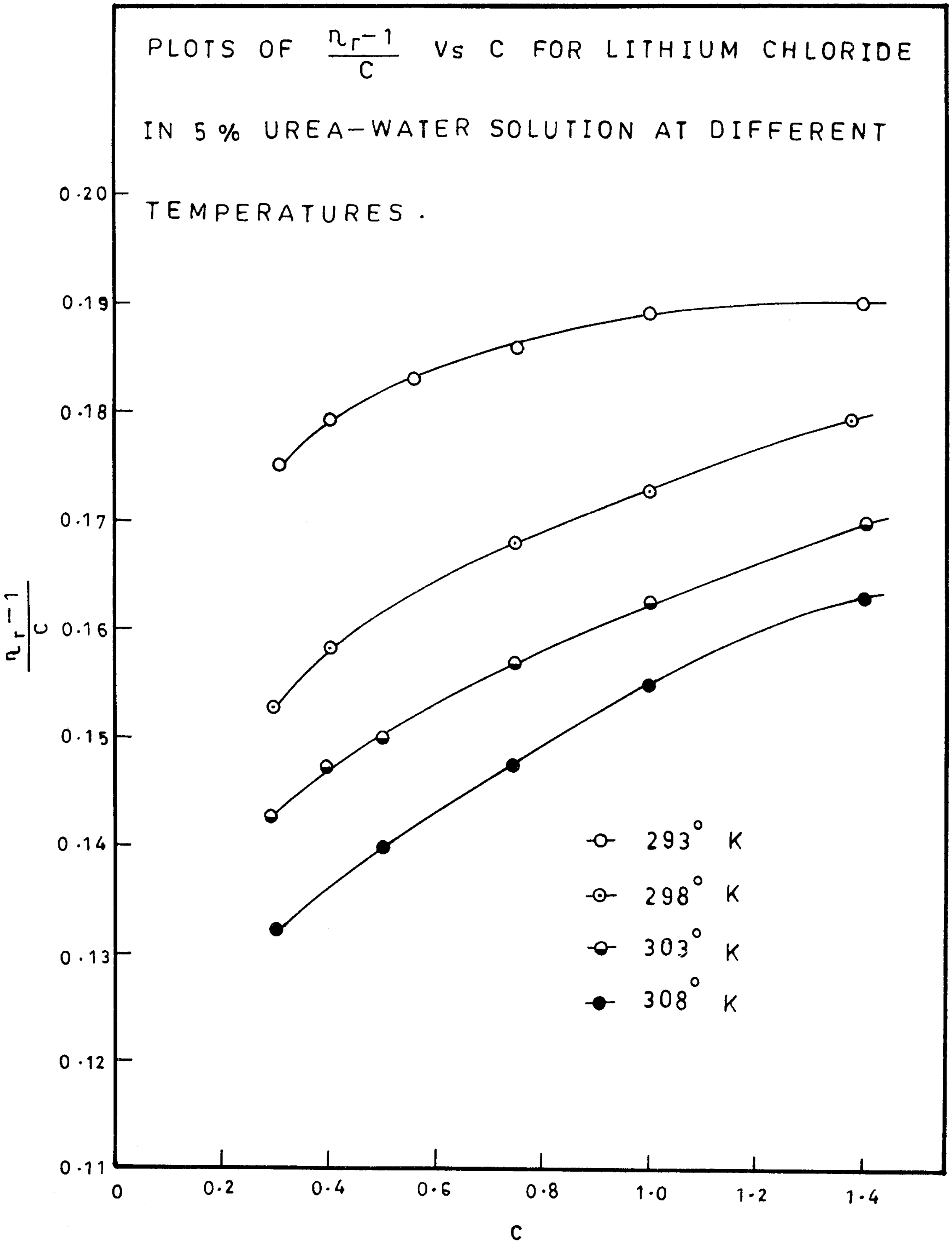


FIG. NO. 3·16



PLOTS OF $\frac{\eta_r - 1}{C}$ Vs C FOR LITHIUM CHLORIDE IN 5 % UREA-WATER SOLUTION AT DIFFERENT TEMPERATURES.

FIG. NO. 3-17

PLOTS OF $\frac{\eta_r - 1}{C}$ Vs C FOR LITHIUM CHLORIDE IN 10 % UREA-WATER SOLUTION AT DIFFERENT TEMPERATURES.

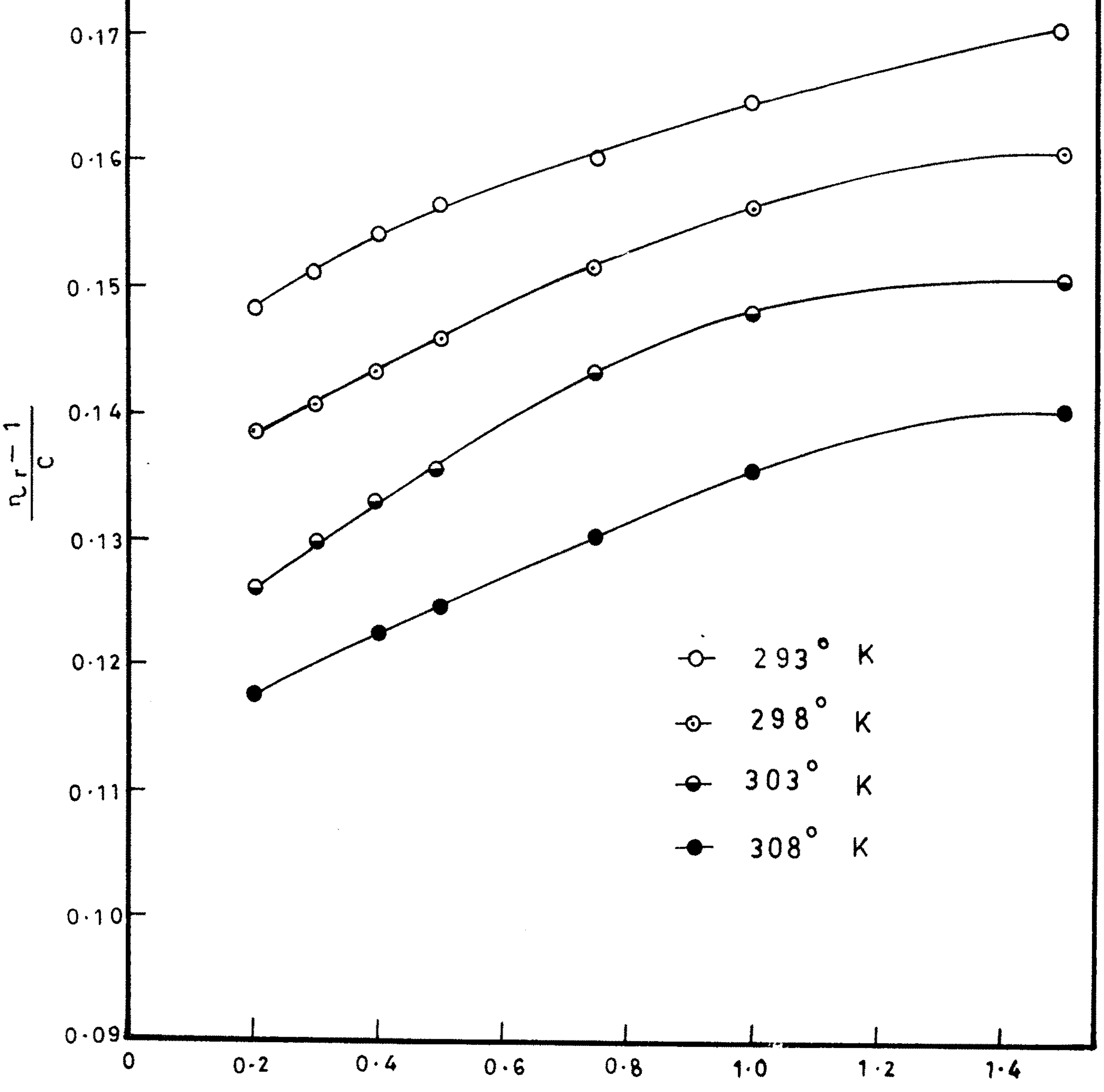
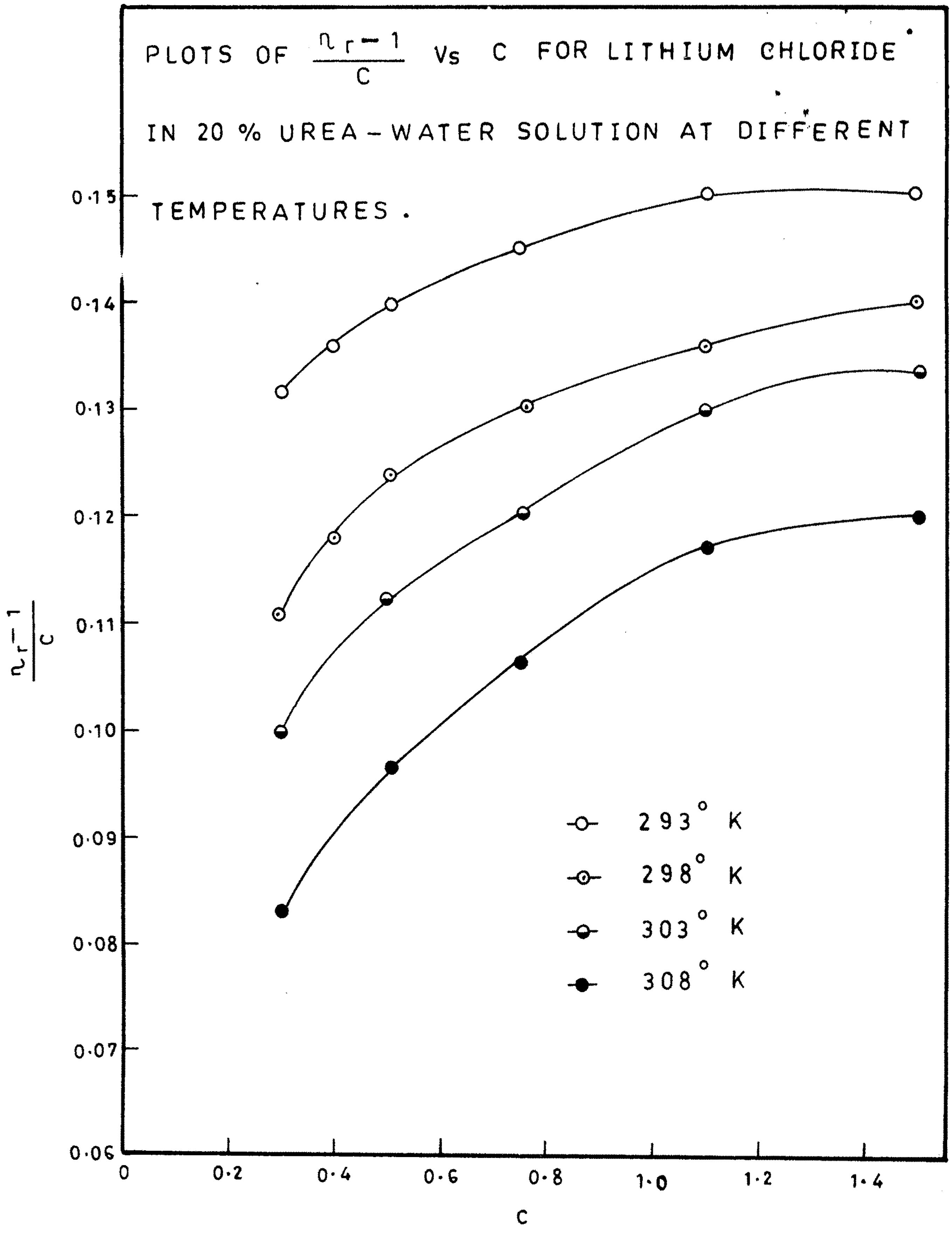
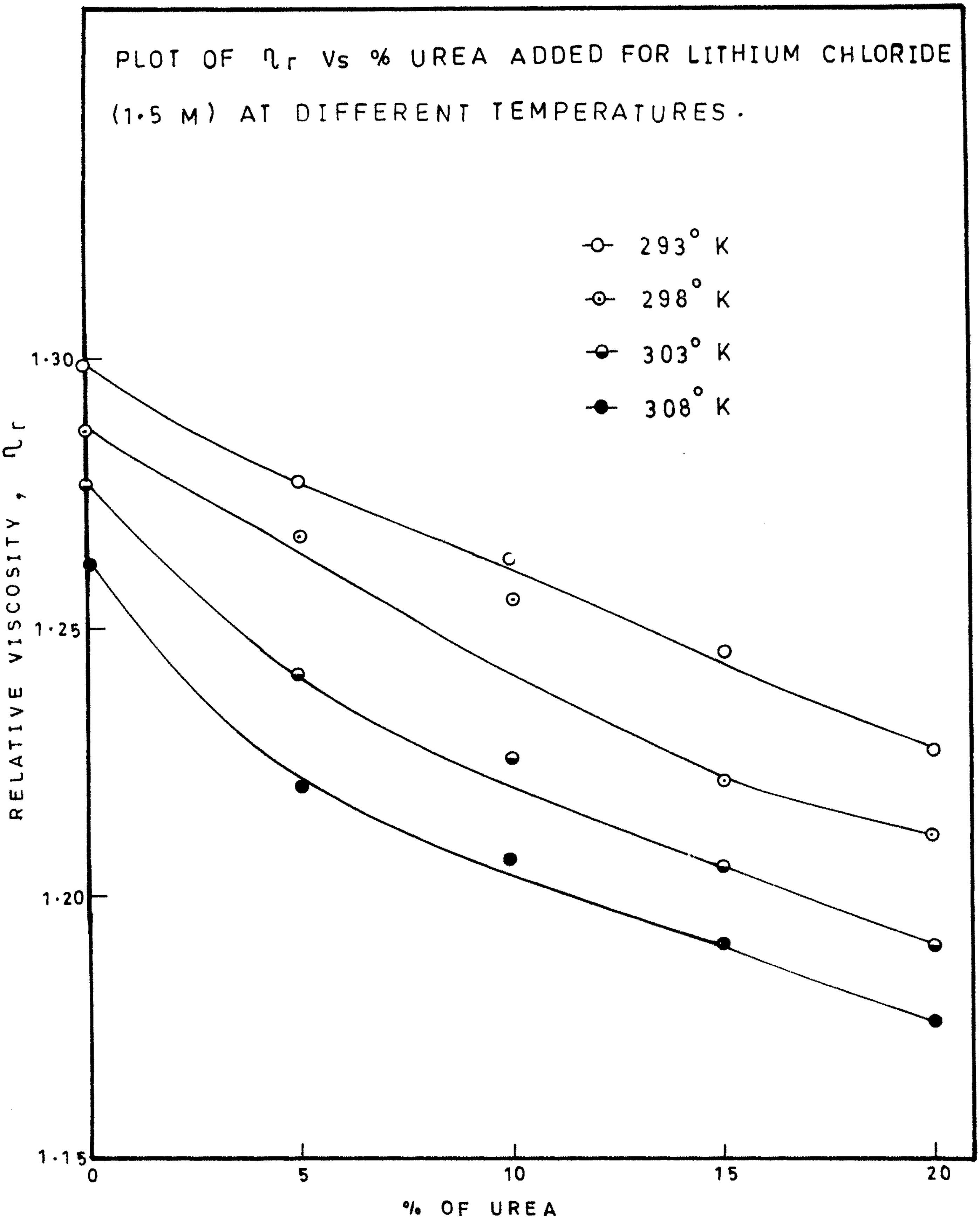


FIG. NO. 3·18



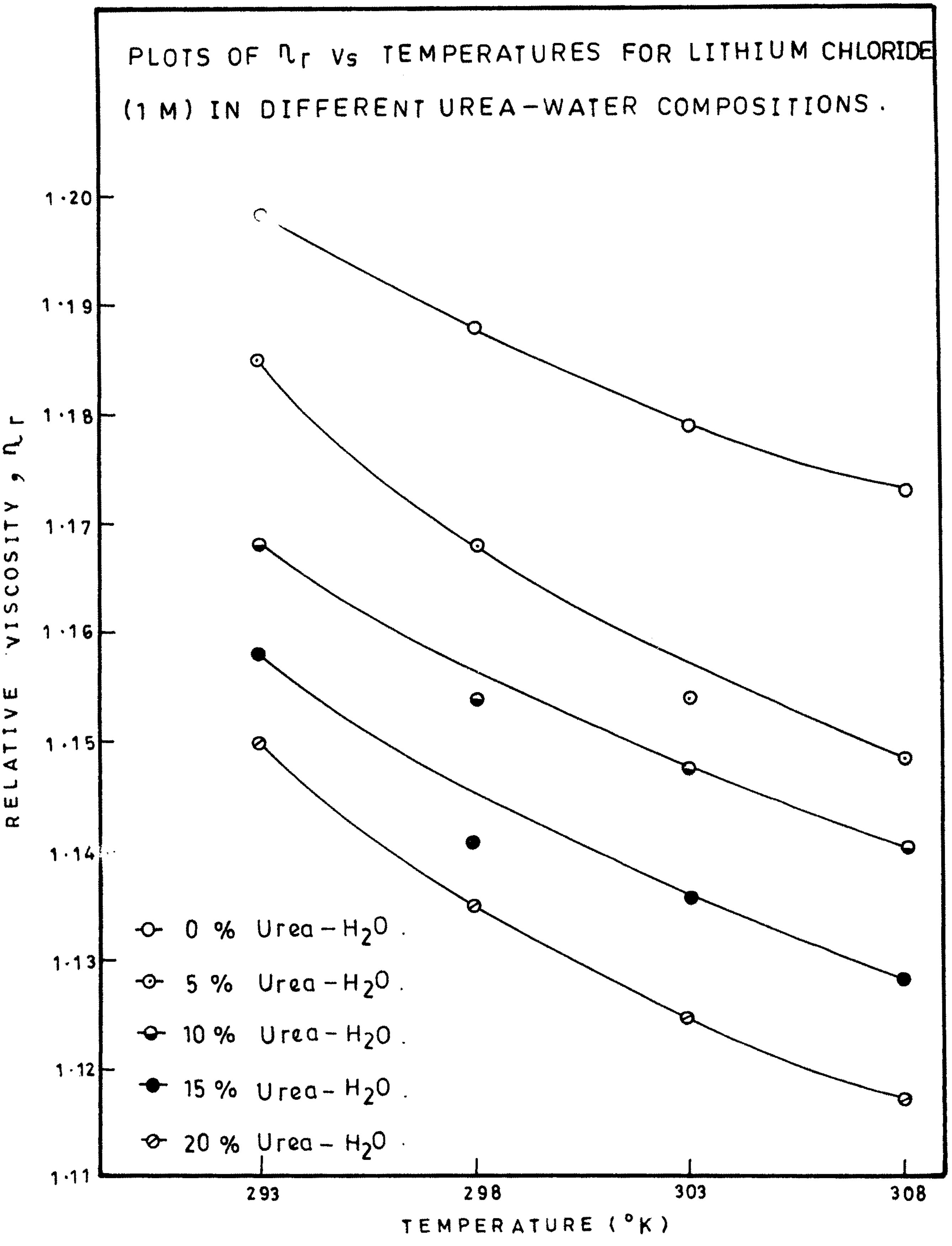
PLOTS OF $\frac{\eta_r - 1}{C}$ Vs C FOR LITHIUM CHLORIDE IN 20 % UREA-WATER SOLUTION AT DIFFERENT TEMPERATURES.

FIG. NO. 3·19



PLOT OF η_r Vs % UREA ADDED FOR LITHIUM CHLORIDE (1·5 M) AT DIFFERENT TEMPERATURES.

FIG. NO. 3·21



PLOTS OF η_r Vs TEMPERATURES FOR LITHIUM CHLORIDE (1 M) IN DIFFERENT UREA–WATER COMPOSITIONS.

FIG. NO. 3·22