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# To investigate the thermodynamic parameters of Li, Na and K salt of L leucinate at various temperature and concentration by conductometric measurement

M. B. Dhande, D. A. Pund *, M. S. Lunge and D. T. Tayade

[1] *Department of Chemistry, HPT Arts and RYK Science College, Nashik-422005, Maharashtra, India.*
[2] *Department of Chemistry, Shri.R.R.Lahoti Science College, Morshi-444905, M.S., India.*
[3] *Department of Chemistry, JagadambaMahavidyalaya, Achalpur (City), M.S., India.*
[4] *Department of Chemistry, Government Vidarbha Institute of Science and Humanities, Amravati-444 604, Maharashtra, India.*

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## Abstract

Recently in this laboratory the conductometric measurement of aqueous solutions of Li, Na and K salt of L-leucine were studied at different temperature and molar concentration to investigate the solute-solvent, ion-solvent interactions (solute means drug) and also the effect of dilution was investigated. During this work the thermodynamic parameters (change in free energy, change in entropy and change in enthalpy) were investigated at concentrations range (0.01 to 0.15) M and at various temperature 298.15, 303.15, 308.15, and 313.15 K. The thermodynamic parameters helps to understand a solute-solute, solute-solvent and solvent-solvent interaction and this information will also be helpful to understand pharmacokinetics and pharmacodynamics of these drug salts.

**Keywords:** LSL; SSL; PSL; Conductometric thermodynamic parameters.

## 1. Introduction

Metal salts of amino acids received more attention of researchers at global level. These salts have various applications in various field of sciences. These salts are effectively used as $CO_2$ absorbents. Climatic change is a result of excessively changes atmospheric background. Day by day carbon dioxide ($CO_2$) emissions is increasing which is most concerning environmental issue, a global warming. The salt solution of the amino acids is developing into an absorbent for $CO_2$ capture[1-2] for evaluation and thorough characterization of the solvent for $CO_2$ collection and other industrial applications, the physicochemical properties of absorbents are required [3-6]. Solubility, ionisation and mobilization of metal salt closely related to their conductivity. Ionisation and solubility strongly influence by molecular interaction like solute-solute interaction, solute-solvent and solvent-solvent interactions, intra and intermolecular interaction effect on the conductivity. Conductometric measurements are one of the unique non-destructive, environmentally friendly and simple to handle research techniques.

The thermodynamic parameters obtained in conductometric measurements will become a useful tool to predict drug activity and drug effect in medicinal and drug chemistry. Leucine has its own importance in medicinal sciences and pharmaceutical sciences due to their significant application. Metal salt of this amino acid affects the solubility and conductivity. Conductometric investigation received more attention of researchers for molecular interactions investigation at various concentration and different temperatures by using different types of molecules [7-13].

*Corresponding author: Dinesh A. Pund

Navarro *et al*. [14]reported the densities, refractive indices, electrical conductivity and viscosities of aqueous potassium and sodium salt solutions containing serine at normal air pressure and at various temperatures. Tirona*et al.* [15] used experimental validation to correlate the density, refractive index, and electrical conductivity of the amino acid salt solutions with temperature and amino acid salt concentration. In the study of densities, viscosities, refractive indexes, and electrical conductivities of aqueous alkali (potassium or sodium) salts of the amino acid α-alanine at various temperatures and concentrations gave average absolute deviation values of 0.03%. In the studied densities, viscosity, refractive index and electrical conductivity of aqueous alkali (potassium or sodium) salts of the amino acid α-alanine at various temperatures and concentrations for that an empirical equation was applied to correlate the density, refractive index and electrical conductivity of the amino acid salt solutions with temperature gave average absolute deviation values of 0.03%, 0.01% and 0.6% respectively.

Ionic behavior of lithium salt of L-leucine (LSL), sodium salt of L-leucine (SSL) and potassium salt of L-leucine (PSL) were not yet been discussed in the literature at a lower concentration by conductometrically. Therefore, the present investigation designed in the direction to understand effect of low concentrations on thermodynamic parameters of LSL, SSL and PSL at concentration range (0.01 to 0.15) mol $L^{-1}$ and at different temperatures 298.15, 303.15, 308.15 and 313.15 K appraise ionic behavior of lithium sodium and potassium salt of leucinate. The thermodynamic parameters like $\Delta H^0$; $\Delta S^0$ and $\Delta G^0$ for the formation have been studied from the values of ion association constant at various temperatures. The computed values have been used to discuss qualitatively the nature of different interactions.

## 2. Material and methods

All the chemicals used are of AR grade. L-leucine (Leu CAS No. 61-90-5, 99% purity) were supplied by S D Fine-Chem Ltd, India. Alkali hydroxides viz., lithium hydroxide (LiOH, CAS No. 1310-65-2, GR, % purity) was purchased from Sigma Aldrich, while sodium hydroxide (NaOH, CAS No. 1310-73-2, GR, 98 % purity) and potassium hydroxide (KOH, CAS No. 1310-58-3, GR, 98 % purity) were purchased from Merck. All the solutions during investigations were used freshly prepared. Concentrations of solutions varied from 0.01 to 0.15 ml.By neutralizing the amino acid with an equimolar quantity of base (KOH, NaOH, and LiOH), LSL, SSL and PSL solutions were prepared.

A digital conductivity meter was used to measure electrical conductivity. To measure the conductivity, a conductivity cell was submerged in a sample solution. A thermostat was used to maintain the thermal stability of the water bath within ±0.01 K. A standard KCl solution from Merck was used to calibrate the conductivity meter. Solution's temperature was regulated by placing the sample tube in a water bath. The conductivities were measured for their concentrations range (0.01 to 0.15) M and at 298.15, 303.15, 308.15 and 313.15 K.

The conductivity cell was cleaned with deionised water and ethanol after each test to get rid of any adhering material, and it was then dried before being used for the next measurement. Three repeats of each measurement were made, and the average reading was used. The calculated overall measurement uncertainty was ±1.0%.

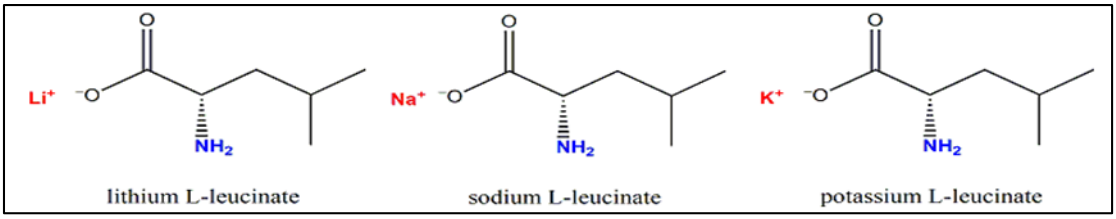


**Figure 1** Structure of LSL, SSL and PSL

## 3. Results and discussion

The observe conductance for each concentration solutions of SSL, LSL and PSL were recorded at temperature 298.15 K, 303.15 K, 308.15 K and 313.15 K. From the data of observed conductance (G), specific conductance (k) and molar conductance (μ) were determined by known literature method and tabulated in Table-1 and Table-2 at 298.15 K, 303.15 K, 308.15 K and 313.15 K respectively.

Table-1, Table-2, Figure 2, Figure 3 and Figure 4 revealed that as concentrations increases the observe conductance and specific conductance also increases while molar conductance decrease for SSL, LSL and PSL solutions. When

temperature increase from 298 K to 313 K observe conductance, specific conductance and molar conductance increases for SSL, LSL and PSL solutions.

Specific conductance and molar conductance were calculated from observe conductance by following equations,

$$K= k*G$$

$$\mu=(K*1000)/M$$

Where k is cell constant and M is molarity.

Observed conductance (G), specific conductance (k) and molar conductance (μ) values of PSL are greater than SSL and LSL solution.

During this investigation it was observed that the molar conductance of PSL is more than SSL and LSL which is clearly indicates that as ionic size of metal ion increases the conductivity increases. This would be due to formation of hydration sphere around metal ions depending on the size, smaller the size higher is the hydration hence restricts the mobility of ions in solution. Thus PSL has good conductivity and mobility in solution among all three salts which is helpful for diffusion of ions or good drug effect of PSL is comparatively good than SSL and LSL. The absorption, transformation and metabolism of PSL are better than SSL and LSL will show good drugs activity than SSL and LSL. In molar conductance of PSL solutions the values are greater than SSL and LSL.

From Figure 5 it reveals that observed conductance (G) increases in the following increasing order for LSL, SSL and PSL,

$$LSL(G) < SSL(G) < PSL(G).$$

This is because, as the Lewis acidity of alkali cations rises ($Li^+ > Na^+ > K^+$), water molecules clump together more and the sacrificial reduction of counter anions is less effective. Increased $H_2O$ aggregation around $Li^+$ reduces its mobility and hence conductivity. As the alkali cation's Lewis acidity decreases from $Li^+$ to $K^+$, cation-$H_2O$ and cation-anion interactions become weaker[16].

**Table 1** G and K values of LSL, SSL and PSL different temperatures

| **m ($kg.mol^{-1}$)** | **G $10^{-3}$($S.cm^{-1}$)** | | | | **m ($kg.mol^{-1}$)** | **K.$10^{-3}$ ($S.cm^{-1}$)** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **298.15 K** | **303.15 K** | **308.15 K** | **313.15 K** | | **298.15 K** | **303.15 K** | **308.15 K** | **313.15 K** |
| **LSL** | | | | | **LSL** | | | | |
| 0.00999 | 0.74 | 0.84 | 0.92 | 1.01 | 0.00999 | 0.7252 | 0.8232 | 0.9016 | 0.9898 |
| 0.02975 | 1.82 | 2.02 | 2.25 | 2.54 | 0.02975 | 1.7836 | 1.9796 | 2.2060 | 2.4892 |
| 0.04951 | 2.79 | 3.12 | 3.45 | 3.84 | 0.04951 | 2.7342 | 3.0576 | 3.3810 | 3.7632 |
| 0.06957 | 3.64 | 4.04 | 4.49 | 4.97 | 0.06957 | 3.5672 | 3.9592 | 4.4002 | 4.8706 |
| 0.08957 | 4.41 | 4.89 | 5.42 | 5.97 | 0.08957 | 4.3169 | 4.7873 | 5.3067 | 5.8506 |
| 0.10957 | 5.13 | 5.73 | 6.34 | 6.97 | 0.10957 | 5.0274 | 5.6154 | 6.2132 | 6.8306 |
| 0.13147 | 5.89 | 6.56 | 7.28 | 7.99 | 0.13147 | 5.7722 | 6.4239 | 7.1344 | 7.8302 |
| 0.15336 | 6.62 | 7.38 | 8.16 | 9.01 | 0.15336 | 6.4876 | 7.2324 | 7.9968 | 8.8298 |
| **SSL** | | | | | **SSL** | | | | |
| 0.01002 | 0.76 | 0.85 | 0.93 | 1.02 | 0.01002 | 0.7448 | 0.8330 | 0.9114 | 0.9996 |
| 0.03050 | 2.05 | 2.29 | 2.48 | 2.72 | 0.03050 | 2.0090 | 2.2442 | 2.4304 | 2.6656 |
| 0.05098 | 3.25 | 3.63 | 3.98 | 4.34 | 0.05098 | 3.1850 | 3.5574 | 3.9004 | 4.2532 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.06973 | 4.29 | 4.8 | 5.28 | 5.77 | 0.06973 | 4.2042 | 4.704 | 5.1744 | 5.6546 |
| 0.08976 | 5.44 | 6.05 | 6.67 | 7.27 | 0.08976 | 5.3312 | 5.9290 | 6.5366 | 7.1246 |
| 0.10979 | 6.52 | 7.27 | 8.00 | 8.61 | 0.10979 | 6.3896 | 7.1246 | 7.8400 | 8.4378 |
| 0.13074 | 7.55 | 8.42 | 9.25 | 10.01 | 0.13074 | 7.3990 | 8.2516 | 9.0650 | 9.8098 |
| 0.15169 | 8.42 | 9.35 | 10.31 | 11.29 | 0.15169 | 8.2516 | 9.1630 | 10.1040 | 11.0640 |
| **PSL** | | | | | **PSL** | | | | |
| 0.01007 | 0.83 | 0.91 | 0.99 | 1.08 | 0.01007 | 0.8134 | 0.8879 | 0.9712 | 1.0574 |
| 0.03010 | 2.25 | 2.46 | 2.67 | 2.94 | 0.03010 | 2.2050 | 2.4108 | 2.6166 | 2.8812 |
| 0.05014 | 3.51 | 3.86 | 4.27 | 4.72 | 0.05014 | 3.4398 | 3.7828 | 4.1875 | 4.6256 |
| 0.07199 | 4.79 | 5.30 | 5.90 | 6.50 | 0.07199 | 4.6942 | 5.1940 | 5.7820 | 6.3700 |
| 0.09103 | 5.96 | 6.57 | 7.29 | 7.985 | 0.09103 | 5.8457 | 6.4386 | 7.1442 | 7.8253 |
| 0.11007 | 7.13 | 7.87 | 8.60 | 9.35 | 0.11007 | 6.9874 | 7.7126 | 8.4280 | 9.1630 |
| 0.12977 | 8.25 | 9.07 | 9.88 | 10.71 | 0.12977 | 8.0850 | 8.8886 | 9.6824 | 10.496 |
| 0.14947 | 9.32 | 10.22 | 11.15 | 12.07 | 0.14947 | 9.1336 | 10.016 | 10.927 | 11.829 |

Similar trend is observed for (k) and (μ) values as;LSL < SSL < PSL

The (Ksp), log (Ksp) and thermodynamics parameter viz. change in free energy (ΔG), change in entropy (ΔS) and change in enthalpy (ΔH) of LSL, SSL and PSL were determined by known literature method at various molar concentration and temperatures. The values of Ksp, ΔG, ΔH and ΔS are presented in **Table 2, Table-3 and Table-4, respectively.**

The values of Ksp, (Δ*G*), (Δ*H*) and (Δ*S*) were calculated using following equations,

$$\Delta G = -2.303 * 8.314 * T * \log ksp$$

$$\Delta H = (2.303 * R * T_1 * T_2 * \log ksp_1) / [\log ksp_2 * (T_1 - T_2)]$$

$$\Delta S = (\Delta H - \Delta G) / T_1$$

These tables shows that along with increasing concentration, Ksp, ΔH and ΔS values increases continuously while ΔG decreases for PSL solutions. While temperature increases from 298 K to 313K Ksp, ΔH and ΔS decreases continuously while ΔG increases for LSL, SSL and PSL solutions. PSL shows greater values of thermodynamic parameter as well as Ksp than SSL and LSL.Both the systems have positive ΔG values suggest that in the solvent, the dissociation process is favoured over the association process. The negative values of ΔH and ΔS suggest the dissociation process is exothermic and decrease in randomness in the solvent, respectively [17].

**Table 2** μ and Ksp of LSL, SSL and PSL at different temperatures

| **M (mol.L$^{-1}$)** | **μ (S.cm$^2$.mol$^{-1}$)** | | | | **M (mol.L$^{-1}$)** | **Ksp.10-3** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **298.15 K** | **303.15 K** | **308.15 K** | **313.15 K** | | **298.15 K** | **303.15 K** | **308.15 K** | **313.15 K** |
| **LSL** | | | | | **LSL** | | | | |
| 0.00996 | 72.808 | 82.647 | 90.518 | 99.373 | 0.00996 | 0.1033 | 0.1030 | 0.1027 | 0.1023 |
| 0.02966 | 60.131 | 66.739 | 74.371 | 83.919 | 0.02966 | 0.9161 | 0.9135 | 0.9106 | 0.9072 |
| 0.04936 | 55.389 | 61.941 | 68.492 | 76.235 | 0.04936 | 2.5372 | 2.5301 | 2.5219 | 2.5127 |
| 0.06936 | 51.427 | 57.079 | 63.437 | 70.218 | 0.06936 | 5.0097 | 4.9957 | 4.9795 | 4.9613 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.08930 | 48.339 | 53.607 | 59.423 | 65.513 | 0.08930 | 8.3041 | 8.2808 | 8.2540 | 8.2238 |
| 0.10924 | 46.020 | 51.402 | 56.874 | 62.526 | 0.10924 | 12.4264 | 12.3916 | 12.3515 | 12.3063 |
| 0.13108 | 44.036 | 49.008 | 54.428 | 59.736 | 0.13108 | 17.8902 | 17.8400 | 17.7822 | 17.7171 |
| 0.15290 | 42.429 | 47.300 | 52.300 | 57.748 | 0.15290 | 24.3435 | 24.2752 | 24.1966 | 24.1080 |
| **SSL** | | | | | **SSL** | | | | |
| 0.00999 | 74.552 | 83.380 | 91.228 | 100.056 | 0.00999 | 0.1039 | 0.1036 | 0.1033 | 0.1029 |
| 0.03041 | 66.064 | 73.799 | 79.922 | 87.656 | 0.03041 | 0.9629 | 0.9602 | 0.9571 | 0.9536 |
| 0.05083 | 62.661 | 69.988 | 76.736 | 83.677 | 0.05083 | 2.6901 | 2.6826 | 2.6739 | 2.6641 |
| 0.06952 | 60.472 | 67.661 | 74.427 | 81.334 | 0.06952 | 5.0328 | 5.0187 | 5.0024 | 4.9841 |
| 0.08949 | 59.571 | 66.251 | 73.040 | 79.610 | 0.08949 | 8.3393 | 8.3159 | 8.2890 | 8.2587 |
| 0.10946 | 58.372 | 65.086 | 71.622 | 77.083 | 0.10946 | 12.4763 | 12.4414 | 12.4011 | 12.3557 |
| 0.13035 | 56.762 | 63.303 | 69.543 | 75.257 | 0.13035 | 17.6920 | 17.6424 | 17.5852 | 17.5209 |
| 0.15124 | 54.560 | 60.587 | 66.807 | 73.157 | 0.15124 | 23.8161 | 23.7493 | 23.6724 | 23.5857 |
| **PSL** | | | | | **PSL** | | | | |
| 0.01004 | 81.053 | 88.474 | 96.775 | 105.368 | 0.01004 | 0.1049 | 0.1046 | 0.1042 | 0.1038 |
| 0.03001 | 73.471 | 80.328 | 87.186 | 96.002 | 0.03001 | 0.9378 | 0.9352 | 0.9322 | 0.9288 |
| 0.04999 | 68.812 | 75.674 | 83.771 | 92.534 | 0.04999 | 2.6018 | 2.5945 | 2.5861 | 2.5767 |
| 0.07177 | 65.402 | 72.366 | 80.558 | 88.750 | 0.07177 | 5.3640 | 5.3489 | 5.3316 | 5.3121 |
| 0.09076 | 64.411 | 70.943 | 78.718 | 86.223 | 0.09076 | 8.5764 | 8.5524 | 8.5247 | 8.4935 |
| 0.10974 | 63.673 | 70.281 | 76.800 | 83.498 | 0.10974 | 12.5393 | 12.5041 | 12.4636 | 12.4180 |
| 0.12938 | 62.490 | 68.701 | 74.836 | 81.123 | 0.12938 | 17.4298 | 17.3810 | 17.3247 | 17.2613 |
| 0.14902 | 61.289 | 67.208 | 73.324 | 79.374 | 0.14902 | 23.1238 | 23.0590 | 22.9843 | 22.9002 |

**Table 3** ΔG and ΔH of LSL, SSL and PSL at different temperatures

| **M ($mol.L^{-1}$)** | **ΔG($J.mol^{-1}$)** | | | | **M ($mol.L^{-1}$)** | **ΔH($J.mol^{-1}$)** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **298.15 K** | **303.15 K** | **308.15 K** | **313.15 K** | | **298.15 K** | **303.15 K** | **308.15 K** | **313.15 K** |
| **LSL** | | | | | **LSL** | | | | |
| 0.00996 | 22754.35 | 23143.02 | 23533.04 | 23924.44 | 0.00996 | -346013.92 | -357602.24 | -369381.52 | - |
| 0.02966 | 17343.40 | 17641.32 | 17940.60 | 18241.25 | 0.02966 | -345980.92 | -357562.84 | -369335.56 | - |
| 0.04936 | 14817.80 | 15073.37 | 15330.30 | 15588.60 | 0.04936 | -345957.28 | -357534.61 | -369302.64 | - |
| 0.06936 | 13131.13 | 13358.41 | 13587.05 | 13817.07 | 0.06936 | -345936.42 | -357509.72 | -369273.62 | - |
| 0.08930 | 11878.19 | 12084.46 | 12292.09 | 12501.09 | 0.08930 | -345917.10 | -357486.66 | -369246.73 | - |
| 0.10924 | 10878.84 | 11068.35 | 11259.22 | 11451.46 | 0.10924 | -345898.50 | -357464.46 | -369220.86 | - |
| 0.13108 | 9975.34 | 10149.70 | 10325.42 | 10502.51 | 0.13108 | -345878.48 | -357440.57 | -369193.02 | - |
| 0.15290 | 9211.69 | 9373.25 | 9536.16 | 9700.44 | 0.15290 | -345858.50 | -357416.73 | -369165.24 | - |
| **SSL** | | | | | **SSL** | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.00999 | 22739.49 | 23127.90 | 23517.68 | 23908.82 | 0.00999 | -346013.85 | -357602.16 | -369381.42 | - |
| 0.03041 | 17219.94 | 17515.80 | 17813.01 | 18111.59 | 0.03041 | -345979.93 | -357561.66 | -369334.18 | - |
| 0.05083 | 14672.73 | 14925.86 | 15180.36 | 15436.22 | 0.05083 | -345955.67 | -357532.70 | -369300.41 | - |
| 0.06952 | 13119.74 | 13346.84 | 13575.29 | 13805.11 | 0.06952 | -345936.27 | -357509.53 | -369273.40 | - |
| 0.08949 | 11867.69 | 12073.78 | 12281.24 | 12490.06 | 0.08949 | -345916.92 | -357486.45 | -369246.48 | - |
| 0.10946 | 10868.90 | 11058.25 | 11248.95 | 11441.03 | 0.10946 | -345898.30 | -357464.22 | -369220.58 | - |
| 0.13035 | 10002.96 | 10177.78 | 10353.96 | 10531.51 | 0.13035 | -345879.14 | -357441.37 | -369193.94 | - |
| 0.15124 | 9265.99 | 9428.46 | 9592.28 | 9757.47 | 0.15124 | -345860.02 | -357418.56 | -369167.36 | - |
| **PSL** | | | | | **PSL** | | | | |
| 0.01004 | 22717.15 | 23105.20 | 23494.60 | 23885.36 | 0.01004 | -346013.75 | -357602.03 | -369381.27 | - |
| 0.03001 | 17285.25 | 17582.20 | 17880.51 | 18180.18 | 0.03001 | -345980.46 | -357562.29 | -369334.91 | - |
| 0.04999 | 14755.45 | 15009.97 | 15265.85 | 15523.10 | 0.04999 | -345956.59 | -357533.80 | -369301.69 | - |
| 0.07177 | 12961.72 | 13186.17 | 13411.97 | 13639.14 | 0.07177 | -345934.03 | -357506.86 | -369270.29 | - |
| 0.09076 | 11798.17 | 12003.10 | 12209.39 | 12417.05 | 0.09076 | -345915.73 | -357485.02 | -369244.82 | - |
| 0.10974 | 10856.43 | 11045.57 | 11236.06 | 11427.93 | 0.10974 | -345898.04 | -357463.92 | -369220.23 | - |
| 0.12938 | 10039.96 | 10215.41 | 10392.21 | 10570.38 | 0.12938 | -345880.03 | -357442.42 | -369195.17 | - |
| 0.14902 | 9339.12 | 9502.82 | 9667.87 | 9834.28 | 0.14902 | -345862.06 | -357420.98 | -369170.19 | - |

**Table 4** ΔS values of LSL, SSL and PSL different temperatures

| **M(mol.L$^{-1}$)** | **ΔS(J.mol$^{-1}$ K$^{-1}$)** | | | |
|---|---|---|---|---|
| | **298.15 K** | **303.15 K** | **308.15 K** | **313.15 K** |
| **LSL** | | | | |
| 0.00996 | -1236.85 | -1255.96 | -1275.08 | - |
| 0.02966 | -1218.60 | -1237.68 | -1256.78 | - |
| 0.04936 | -1210.05 | -1229.12 | -1248.20 | - |
| 0.06936 | -1204.32 | -1223.38 | -1242.45 | - |
| 0.08930 | -1200.05 | -1219.10 | -1238.16 | - |
| 0.10924 | -1196.64 | -1215.68 | -1234.72 | - |
| 0.13108 | -1193.54 | -1212.57 | -1231.60 | - |
| 0.15290 | -1190.91 | -1209.93 | -1228.95 | - |
| **SSL** | | | | |
| 0.00999 | -1236.80 | -1255.91 | -1275.03 | - |
| 0.03041 | -1218.18 | -1237.27 | -1256.36 | - |
| 0.05083 | -1209.55 | -1228.63 | -1247.71 | - |
| 0.06952 | -1204.28 | -1223.34 | -1242.41 | - |
| 0.08949 | -1200.02 | -1219.07 | -1238.12 | - |
| 0.10946 | -1196.60 | -1215.64 | -1234.69 | - |

| | | | | |
|---|---|---|---|---|
| 0.13035 | -1193.63 | -1212.66 | -1231.70 | - |
| 0.15124 | -1191.10 | -1210.12 | -1229.14 | - |
| **PSL** | | | | |
| 0.01004 | -1236.73 | -1255.84 | -1274.95 | - |
| 0.03001 | -1218.40 | -1237.49 | -1256.58 | - |
| 0.04999 | -1209.83 | -1228.91 | -1247.99 | - |
| 0.07177 | -1203.74 | -1222.80 | -1241.87 | - |
| 0.09076 | -1199.78 | -1218.83 | -1237.88 | - |
| 0.10974 | -1196.56 | -1215.60 | -1234.65 | - |
| 0.12938 | -1193.76 | -1212.79 | -1231.83 | - |
| 0.14902 | -1191.35 | -1210.37 | -1229.39 | - |

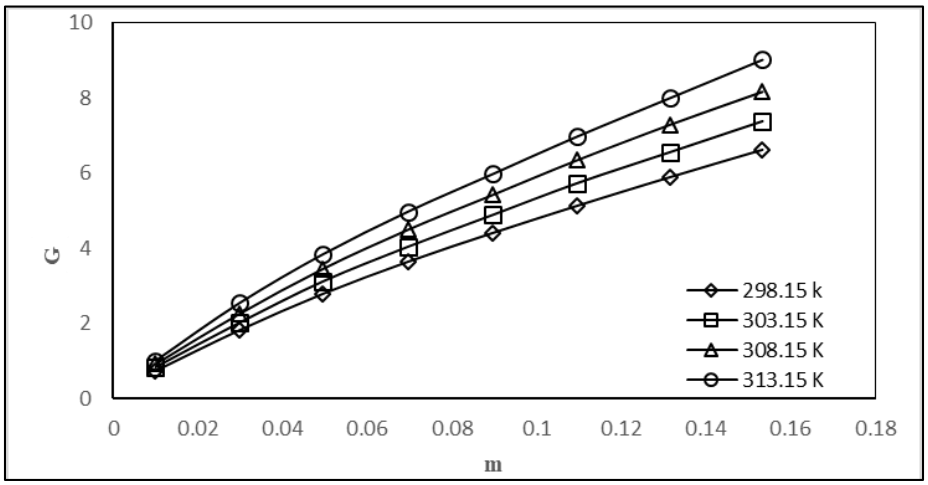


**Figure 2** Graph of ($G$) vs concentration of LSL in water at different temperatures ($T$).

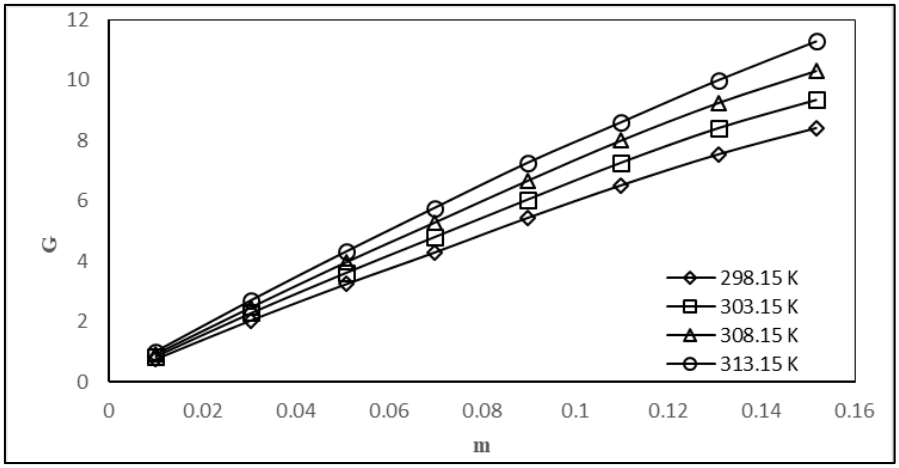


**Figure 3** Graph of ($G$) vs concentration of SSL in water at different temperatures ($T$).

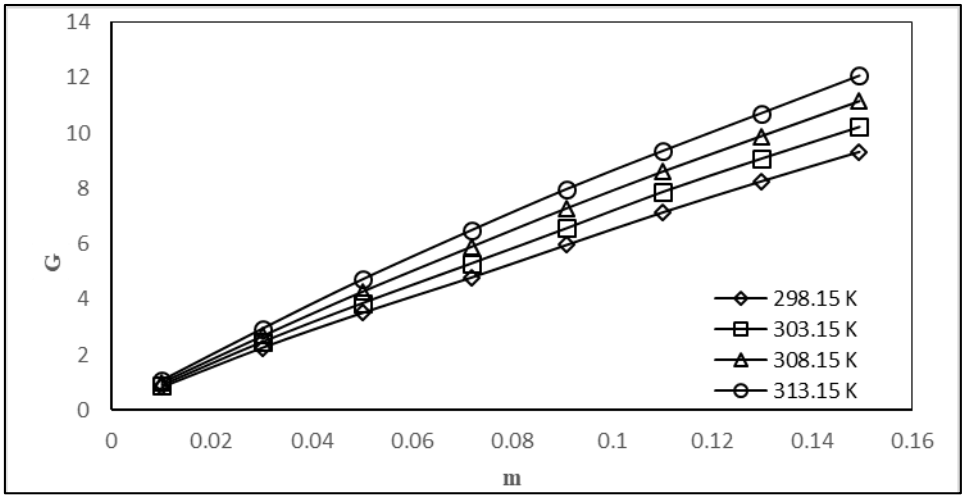


**Figure 4** Graph of ($G$) vs concentration of PSL in water at different temperatures ($T$).

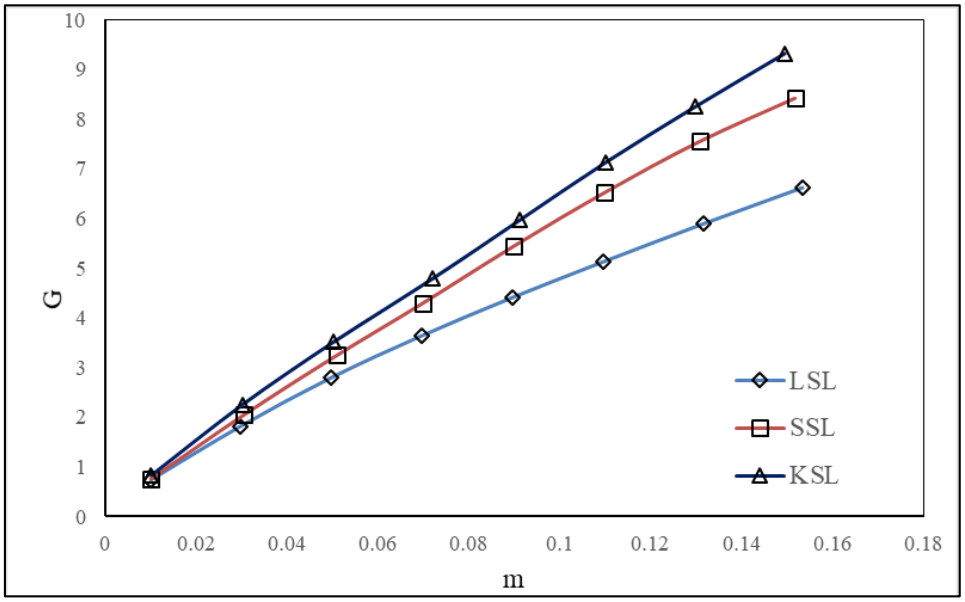


**Figure 5** Graph of comparison of (G)vs concentration of LSL, SSL and KSL in water at 298.15 K ($T$).

## 4. Conclusion

The conductivity was measured for LSL, SSL and PSL solutions at concentrations range (0.01 to 0.15) M and at various temperature 298.15, 303.15, 308.15 and 313.15 K. All studied salt solution showed good conductivity at all temperatures, the conductivity of the PSL was found to be greater than SSL and LSL. Li+ have shorter ionic size than other cations ($K^+$and $Na^+$), which results in more water molecules surrounding them and forming larger hydrated spheres in solution, which reduces their mobility in aqueous solutions. This hydration affects the mobility and conductivity of solution. While the potassium was slowly crystallizing with water. Metal hydration and crystallization affects the ionisation and mobilisation of metal salts. Lithium ion react with water molecules and this fact affect LSL's ionisation and conductivity.

The temperature, molar concentrations and percentage compositions are also responsible for change in the values of these parameters. The solute-solvent interactions, solvent-solvent interactions and solute-solute interactions are another factor which directly hampers these parameters. The internal geometry as well as internal and intra hydrogen bonding affect these parameters. The molar conductance of PSL is higher than SSL and LSL this fact support to good ionisation and mobility of PSL. Thus PSL would also show good pharmacodynamics than SSL and LSL.

## Compliance with ethical standards

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*Disclosure of conflict of interest*

The authors declare that they have no known financial or personal conflicts that would have appeared to have an impact on the research presented in this study.

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