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ACOUSTICAL BEHAVIOUR OF DISACCHARIDE IN AQUEOUS SOLUTIONS OF ALKALI METAL HALIDES AT 303, 308 AND 313 K

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ABSTRACT

Density (ρ) and ultrasonic velocity (U) have been measured for maltose in aqueous solutions of alkali metal halides such as NaCl, KCl, KBr and KI for 0.1 $mol\cdot kg^{-1}$ *and 0.5* $mol\cdot kg^{-1}$ *at 303, 308 and 313 K. These measurements have been performed to evaluate some important acoustical parameters, viz., adiabatic compressibility (β), hydration number* (n_H)*, apparent molal compressibility* (φ_K)*, limiting apparent molal compressibility* (φ_K^0)*, constant* (S_K) *and transfer adiabatic compressibility* ($\Delta\varphi_K^0$)*. These parameters have been interpreted in terms of solute–co–solute and solute–solvent interactions present in the given solutions.*

Keywords: *Disaccharide, alkali metal halide,ultrasonic velocity.*

INTRODUCTION

Studies on interactions of non ionic solutes with ionic ones in different solvents are significant for investigating their physico–chemical behaviour. The study of carbohydrates and saccharides has become a subject of increasing interest because of the multidimensional, physical, biomedical, and industrially useful properties of these compounds [1,2]. In addition to their importance in the food, pharmaceuticals and chemical industries, simple saccharides have received considerable attention for their ability to protect biological macromolecules[3]. Most of the biochemical processes occur in aqueous solutions. So, studies on the thermodynamic properties of biological molecules in aqueous solutions are important. Studies involving density and ultrasonic velocity measurements are important for elucidation of ion–solvent, ion–ion and solute–solvent interactions in the mixed solvent systems. Polyhydroxy compounds are popular stabilizing agents[4] for the native state of proteins and enzymes. Stabilizing of polyols and saccharides are related to the number of configuration of the hydroxyl groups[5]. In fact, there are extensive volumetric and thermodynamic property studies of saccharides in aqueous solutions[6], but very few have been conducted in aqueous halide solutions[7,8]. Multi–component liquid mixtures are of great practical importance in many industrial processes. They provide a wide choice of solutions with appropriate compositions and properties, adiabatic compressibility (β),hydration number (n_H), apparent molal compressibility (φ_K), limiting apparent molal compressibility (φ_K^0), constant (S_K) and transfer adiabatic compressibility ($\Delta\varphi_K^0$)provide a better insight into the intermolecular interactions, hence environment in liquid mixtures. The aim of the present investigation is to study the molecular interactions of maltose in aqueous NaCl, KCl, KBr and KI ternary mixtures at 303, 308 and 313 K.

EXPERIMENTAL

Fresh conductivity water has been used for preparing maltose in aqueous alkali metal halides of 0.1 $mol \cdot kg^{-1}$ and 0.5 $mol \cdot kg^{-1}$ mixtures with an accuracy of $\pm 1.10^{-4}$ g. All the chemicals used in this present study are analytical reagent (AR) grade and spectroscopic reagent (SR) grade of minimum assay of 99.9% obtained from E–Merck, Germany and Sdfines Chemicals, India. These chemicals were used as such without further purification. The density and ultrasonic velocity at different molality of maltose in aqueous solutions of alkali metal halides were measured at 303, 308 and 313 K. The density was determined using a specific gravity bottle by relative measurement method with a reproducibility of ± 0.01 $kg \cdot m^{-3}$. The weight of the sample was measured using an electronic digital balance with a precision of ±0.0001 g (Model: SHIMADZU AX200). An ultrasonic interferometer having the frequency 3MHz (MITTAL ENTERPRISES, NEW DELHI, MODEL F–81) with an overall accuracy of ± 0.1% has been used for velocity measurement. An electronic digital constant temperature 'bath' (RAAGA Industries) has been used to circulate water through the double walled measuring cell made up of steel containing the experimental solution at the desired temperature. The temperature stability was maintained within ± 0.1 K.

Theory and Calculations

Using the measured data, some acoustical parameters have been calculated using the standard relations.

Adiabatic compressibility $$\beta = \frac{1}{U^2 \rho} \qquad \ldots(1)$$

The apparent molal compressibility has been calculated using the relation,

$$\varphi_K = \frac{1000}{m\rho_0}\left(\rho_0\beta - \rho\beta_0\right) + \left(\frac{\beta_0 M}{\rho_0}\right) \qquad \ldots(2)$$

where β, ρ and β_0, ρ_0 are the adiabatic compressibility and density of solution and solvent respectively, m is the molal concentration of the solute, and M the molecular mass of the solute. φ_K results can be fitted by the equation:

$$\varphi_K = \varphi_K{}^0 + S_K m^{1/2} \qquad \ldots(3)$$

where φ_K^0 is the limiting apparent molal compressibility at infinite dilution and S_K is a constant. φ_K^0 and S_K of equation (3) have been evaluated by least square method.

Molal hydration number has been computed using the relation.

$$n_H = \left(\frac{n_1}{n_2}\right)\left(1 - \frac{\beta}{\beta_0}\right) \qquad \ldots(4)$$

where n_1 and n_2 are number of moles of solvent and solute respectively.

Transfer adiabatic compressibility ($\Delta\varphi_K^0$) of maltose from water to aqueous alkali metal halide solutions at infinite dilutions have been estimated as below-

$$\Delta\varphi_K^0 = \varphi_K^0 - \varphi_K^0 \text{ (in water)} \qquad \ldots(5)$$

where φ_K^0 is aqueous NaCl / KCl / KBr / KI

RESULTS AND DISCUSSION

The experimental values of density and ultrasonic velocity for different molal concentration of maltose in aqueous alkali metal halides of NaCl, KCl, KBr and KI (0.1 $\mathrm{mol{\cdot}kg^{-1}}$ and 0.5 $\mathrm{mol{\cdot}kg^{-1}}$) are shown in Tables 1 and 2. The values of adiabatic compressibility (β), hydration number (n_H), the apparent molal compressibility (φ_K), limiting apparent molal compressibility (φ_K^0), and their constants (S_K) and transfer adiabatic compressibility ($\Delta\varphi_K^0$) are furnished in Tables 3–6.

In all the four aqueous alkali metal halide systems studied, the values of density increases with increase in concentration of maltose as well as aqueous alkali metal halides (0.1 $\mathrm{mol{\cdot}kg^{-1}}$ and 0.5 $\mathrm{mol{\cdot}kg^{-1}}$) and the same decreases with a rise in temperature. But, however, the ultrasonic velocity values found to be increasing with increase in concentration of maltose, aqueous solutions of alkali metal halides, and also with increase in temperature. Molecular association is thus responsible for the observed increase of ultrasonic velocities in these mixtures. The increase in ultrasonic velocity in these solutions may be attributed to the cohesion brought about by the ionic hydration. Further, the decrease in density and increase in velocity with rise in temperature indicate decrease in intermolecular forces due to increase in thermal energy of the system.

From Table–3, it is found that the values of adiabatic compressibility seem decreases with increasing of the solute content as well as metal halides and rise in temperatures. Such a decrease in adiabatic compressibility observed in this aqueous metal halide with maltose in the present system, generally, confirms the conclusions drawn from the velocity data. The increasing electrostrictive compression of water around the molecules may result in a large decrease in the compressibility of the solutions. The decrease in adiabatic compressibility is attributed to the influence of the electrostatic field of ions (Na^+, Cl^-, K^+, Br^-, I^-, … etc.) on the surrounding solvent molecules. The compressibility appears to be decreasing with decrease in hydrogen bond strength formed by solute and solvent molecules. The behaviour of compressibility depicts the existence of interaction between solute and solvent molecules in which the structural arrangement in the neighbourhood of consistent solutes is considerably affected.

Further, the interaction between the solute and the water molecules present in the solvent can be termed as hydration. From Table–4, it is observed that the values of n_H are positive in all the systems studied and such positive values of n_H indicate an appreciable solvation of solutes[9]. This is an added support not only for the structure promoting tendency of the solutes but also for the presence of appreciable dipole–dipole interactions between solute and water molecules. This also leads further suggestion that the compressibility of the solution will be less than that of the solvent. As a result, solutes will gain mobility and hence there will be more probability of conducting solvent molecules. This may further enhance the interaction between solute and solvent molecules. The values of n_H seem to be decreasing with increase in solute content in an aqueous medium as well as aqueous halide content and the rise of temperature too. Such a decreasing values of n_H which shows the strength of interaction gets weakened in the solute–solvent molecules.

The following observations have been made on apparent molal compressibility φ_K (Table–5) of the maltose in aqueous metal halide solution:

(i) The values of φ_K are all negative over the entire range of molality of maltose and seem to be increasing in the concentration of aqueous metal halides as well as rise in temperature.

(ii) The negative φ_K values are increasing with increasing the solute content in an aqueous medium, but it decreases with the addition of metal halide contents.

(iii) With further rise of temperature, these values seem to increase in aqueous medium but, however, it decreases with the further addition of metal halides.

All the above observation clearly suggests that the solute–solvent interaction takes place in all the four systems. The negative values of φ_K indicates hydrophilic interactions occurring in these systems. Since, more number of water molecules is available at lower concentration of metal halides, the chances for the penetration of solute molecules in the solvent molecules are highly favoured. The increasing values of φ_K with increasing of the solute content in aqueous medium reveal the strengthening of the solute–solvent interaction and the same gets decreased with the addition of alkali halide contents. But, however, with the elevation of the temperature, the solute–solvent interactions get weakened with the addition of halides.

The limiting apparent molal compressibility due to[10], φ_K^0 and the related constant S_K for all the four halides have been studied. The value of φ_K^0 provides information regarding solute–solvent interaction, and the related constant S_K, that of solute–solute interaction in the solution. It is noticed from Table–6 that φ_K^0 values are negative in all the systems studied. These values are found to be in increasing trend with the addition of halide contents as well as temperature. Appreciable negative values of φ_K^0 reinforce our earlier view regarding the existence of solute–solvent interactions in the present system. The values of S_K exhibits positive in aqueous medium whereas it is found to be negative when halide contents are added. The decreasing trend was obtained with the addition of halide contents, and with increase in temperature. This trend predicts the existence of solute–ion/solute–solute interaction with the addition of halides content and suggests structure making/breaking effect of maltose. It is well known that the solutes causing electrostriction lead to decreasing the compressibility of the solution. This can be understood by the negative values of φ_K of the solutions.

The values of $\Delta\varphi_K^0$ (Table–6) are positive for maltose with increase in concentration of the co–solutes (NaCl, KCl, KBr and KI) at all temperatures. Further, these values increase with increasing the concentration of co–solutes such as NaCl and KI but the reverse trend is observed in KCl and KBr. The increasing behaviour of $\Delta\varphi_K^0$ shows stronger and more extensive interactions between maltose and co–solute and vice–versa. The transfer adiabatic compressibility $\Delta\varphi_K^0$ can also be explained on the basis of co–sphere overlap model[11]. The overlap of ions of co–solute and saccharide comes into play because of the interactions between (i) ions of co–solutes (NaCl / KCl / KBr / KI) and hydrophilic, —OH sites of saccharide molecules and (ii) ions of co–solutes and the hydrophobic parts/groups of the saccharide molecules. The first type of interaction contributes positively, whereas the second type contributes negatively to $\Delta\varphi_K^0$ values[12]. Therefore, from Fig.1, the significant positive $\Delta\varphi_K^0$ values obtained for the studied saccharide over the entire concentration range of co–solutes indicate that the hydrophilic–ionic interactions dominate over the hydrophobic – ionic interactions.

CONCLUSION

In the present investigation, density and ultrasonic velocity data have been measured for maltose in aqueous solution of alkali metal halides at 303, 308 and 313 K and their acoustical parameters have been used to study the molecular interaction in the solution. From the behaviour of acoustical parameters, it can be concluded that solute–solvent interaction gets weakened with addition of alkali metal halides as well as rising of temperature. Further, the transfer adiabatic compressibility $\Delta\varphi_K^0$ calculated from φ_K^0 suggests the predominance of hydrophilic–ionic interactions over hydrophobic–ionic interactions. From the co–sphere overlap model it can be concluded that solute and co–solute interactions are dominating over the solute–solvent interactions.

Table: 1. Values of density (ρ) of maltose in aqueous solutions of alkali metal halides at 303, 308 and 313K

molality m / (mol·kg^{-1})	ρ/(kg.m^{-3})								
	0 m / (mol·kg^{-1})			0.1 m / (mol·kg^{-1})			0.5 m / (mol·kg^{-1})		
	303 K	308 K	313 K	303 K	308 K	313 K	303 K	308 K	313 K
System 1: Maltose + Aqueous NaCl									
0.00	995.7	994.0	992.2	1003.6	1003.1	1001.2	1019.7	1017.7	1014.2
0.02	1002.0	1001.1	999.8	1005.2	1004.5	1003.1	1020.3	1019.0	1016.2
0.04	1003.1	1002.3	1001.7	1006.2	1005.8	1005.3	1027.1	1019.9	1019.8
0.06	1006.6	1004.9	1002.4	1009.7	1009.1	1007.9	1028.1	1024.1	1022.8
0.08	1008.3	1006.9	1005.1	1012.9	1011.7	1009.3	1029.6	1026.5	1024.5
0.10	1010.7	1008.4	1007.0	1015.9	1014.5	1011.6	1031.7	1028.0	1026.2
System II: Maltose + Aqueous KCl									
0.00	995.7	994.0	992.2	1004.4	1003.1	1002.3	1021.8	1022.2	1018.4
0.02	1002.0	1001.1	999.8	1008.6	1005.5	1004.5	1024.4	1024.1	1018.8
0.04	1003.1	1002.3	1001.7	1010.1	1007.6	1006.1	1029.4	1026.9	1022.4
0.06	1006.6	1004.9	1002.4	1011.7	1009.9	1008.4	1032.7	1031.7	1025.2
0.08	1008.3	1006.9	1005.1	1013.2	1012.3	1010.1	1034.0	1032.2	1026.7
0.10	1010.7	1008.4	1007.0	1016.9	1015.1	1012.5	1035.8	1034.6	1028.7
System III: Maltose + Aqueous KBr									
0.00	995.7	994.0	992.2	1006.3	1004.6	1003.9	1036.6	1034.2	1032.4
0.02	1002.0	1001.1	999.8	1009.2	1006.5	1005.6	1039.7	1037.7	1035.3
0.04	1003.1	1002.3	1001.7	1011.1	1009.1	1007.6	1042.2	1041.1	1038.2
0.06	1006.6	1004.9	1002.4	1013.5	1010.5	1009.1	1045.8	1043.9	1040.9
0.08	1008.3	1006.9	1005.1	1016.6	1014.1	1012.4	1047.8	1045.8	1042.8
0.10	1010.7	1008.4	1007.0	1019.6	1017.7	1014.2	1049.3	1048.3	1044.6
System IV: Maltose + Aqueous KI									
0.00	995.7	994.0	992.2	1011.7	1009.7	1006.3	1055.1	1051.8	1050.2
0.02	1002.0	1001.1	999.8	1012.3	1011.4	1006.5	1055.7	1054.3	1053.1
0.04	1003.1	1002.3	1001.7	1013.8	1013.6	1009.3	1058.1	1055.9	1054.6
0.06	1006.6	1004.9	1002.4	1016.3	1015.6	1011.1	1059.6	1057.1	1056.1
0.08	1008.3	1006.9	1005.1	1018.7	1016.3	1016.3	1061.1	1061.2	1058.5
0.10	1010.7	1008.4	1007.0	1023.3	1022.9	1022.4	1064.1	1062.9	1060.6

Table: 2. Values of ultrasonic velocity (U) of maltose in aqueous solutions of alkali metal halides at 303, 308 and 313K

molality m / (mol·kg^{-1})	U/(m.s^{-1})								
	0 m / (mol·kg^{-1})			0.1 m / (mol·kg^{-1})			0.5 m / (mol·kg^{-1})		
	303 K	308 K	313 K	303 K	308 K	313 K	303 K	308 K	313 K
System 1: Maltose + Aqueous NaCl									
0.00	1510.2	1522.6	1531.4	1527.0	1532.4	1535.4	1548.3	1551.3	1554.5
0.02	1517.1	1525.8	1528.0	1529.0	1535.6	1539.8	1549.9	1556.5	1563.2
0.04	1521.9	1528.8	1531.8	1533.0	1537.8	1542.0	1554.1	1558.8	1565.9
0.06	1529.2	1533.9	1538.9	1539.0	1543.8	1545.1	1557.3	1563.9	1568.9
0.08	1532.7	1539.6	1543.3	1542.3	1548.9	1549.2	1560.6	1566.3	1571.3
0.10	1534.3	1540.2	1544.1	1545.3	1551.2	1554.9	1565.4	1571.4	1576.8
System II: Maltose + Aqueous KCl									
0.00	1510.2	1522.6	1531.4	1514.4	1527.0	1532.4	1536.8	1541.9	1545.9
0.02	1517.1	1525.8	1528.0	1526.8	1529.2	1537.8	1545.0	1549.5	1550.8
0.04	1521.9	1528.8	1531.8	1528.6	1534.8	1539.6	1546.0	1551.4	1556.4
0.06	1529.2	1533.9	1538.9	1531.9	1535.8	1541.4	1548.6	1553.2	1559.6
0.08	1532.7	1539.6	1543.3	1535.6	1538.4	1545.2	1551.9	1557.5	1562.3
0.10	1534.3	1540.2	1544.1	1537.1	1541.4	1548.6	1553.9	1561.4	1566.4
System III: Maltose + Aqueous KBr									
0.00	1510.2	1522.6	1531.4	1521.6	1524.3	1527.2	1525.2	1529.7	1537.5
0.02	1517.1	1525.8	1528.0	1523.5	1525.9	1529.7	1527.9	1530.6	1540.6
0.04	1521.9	1528.8	1531.8	1525.7	1528.2	1530.9	1530.8	1534.8	1543.9
0.06	1529.2	1533.9	1538.9	1528.3	1531.0	1536.6	1535.0	1537.6	1549.8
0.08	1532.7	1539.6	1543.3	1531.8	1536.6	1540.9	1537.8	1548.7	1552.9
0.10	1534.3	1540.2	1544.1	1534.9	1537.0	1542.7	1540.2	1552.8	1559.6
System IV: Maltose + Aqueous KI									
0.00	1510.2	1522.6	1531.4	1515.0	1518.2	1524.0	1507.0	1515.0	1519.0
0.02	1517.1	1525.8	1528.0	1517.1	1520.9	1527.6	1512.0	1520.4	1523.8
0.04	1521.9	1528.8	1531.8	1519.0	1523.4	1530.9	1515.2	1522.4	1525.8
0.06	1529.2	1533.9	1538.9	1524.1	1531.6	1534.8	1520.5	1524.8	1528.8
0.08	1532.7	1539.6	1543.3	1527.3	1533.2	1537.5	1525.8	1526.2	1530.0
0.10	1534.3	1540.2	1544.1	1530.1	1536.4	1539.0	1529.6	1528.1	1534.8

Table: 3. Values of adiabatic compressibility (β) of maltose in aqueous solutions of alkali metal halides at 303, 308 and 313K

molality m / (mol·kg^{-1})	β/(×10^{-10} m^2 N^{-1})								
	0 m / (mol·kg^{-1})			0.1 m / (mol·kg^{-1})			0.5 m / (mol·kg^{-1})		
	303 K	308 K	313 K	303 K	308 K	313 K	303 K	308 K	313 K
System 1: Maltose + Aqueous NaCl									
0.00	4.4036	4.3395	4.2976	4.2733	4.2453	4.2368	4.0909	4.0831	4.0803
0.02	4.3362	4.2907	4.2839	4.2553	4.2218	4.2046	4.0840	4.0507	4.0271
0.04	4.3041	4.2688	4.2546	4.2289	4.2043	4.1835	4.0315	4.0352	3.9991
0.06	4.2483	4.2294	4.2125	4.1815	4.1580	4.1559	4.0107	3.9925	3.9721
0.08	4.2218	4.1898	4.1773	4.1505	4.1200	4.1282	3.9879	3.9709	3.9534
0.10	4.1997	4.1804	4.1650	4.1227	4.0965	4.0887	3.9555	3.9394	3.9194
System II: Maltose + Aqueous KCl									
0.00	4.4036	4.3395	4.2976	4.2845	4.2754	4.2487	4.1438	4.1148	4.1088
0.02	4.3362	4.2907	4.2839	4.2532	4.2529	4.2097	4.0895	4.0670	4.0813
0.04	4.3041	4.2688	4.2546	4.2369	4.2132	4.1932	4.0644	4.0460	4.0377
0.06	4.2483	4.2294	4.2125	4.2120	4.1981	4.1739	4.0378	4.0178	4.0102
0.08	4.2218	4.1898	4.1773	4.1855	4.1740	4.1464	4.0156	3.9937	3.9905
0.10	4.1997	4.1804	4.1560	4.1622	4.1463	4.1184	3.9983	3.9646	3.9623

System III: Maltose + Aqueous KBr									
0.00	4.4036	4.3395	4.2976	4.2921	4.2842	4.2709	4.1470	4.1322	4.0975
0.02	4.3362	4.2907	4.2839	4.2691	4.2671	4.2497	4.1201	4.1134	4.0696
0.04	4.3041	4.2688	4.2546	4.2488	4.2433	4.2347	4.0946	4.0776	4.0409
0.06	4.2483	4.2294	4.2125	4.2243	4.2220	4.1971	4.0582	4.0519	3.9998
0.08	4.2218	4.1898	4.1773	4.1922	4.1764	4.1601	4.0357	3.9867	3.9766
0.10	4.1997	4.1804	4.1560	4.1630	4.1616	4.1430	4.0174	3.9563	3.9357
System IV: Maltose + Aqueous KI									
0.00	4.4036	4.3395	4.2976	4.3065	4.2968	4.2786	4.1733	4.1423	4.1268
0.02	4.3362	4.2907	4.2839	4.2920	4.2744	4.2576	4.1434	4.1032	4.0895
0.04	4.3041	4.2688	4.2546	4.2750	4.2512	4.2275	4.1166	4.0862	4.0730
0.06	4.2483	4.2294	4.2125	4.2360	4.1975	4.1986	4.0821	4.0687	4.0513
0.08	4.2218	4.1898	4.1773	4.2083	4.1858	4.1624	4.0487	4.0456	4.0358
0.10	4.1997	4.1804	4.1560	4.1741	4.1415	4.1295	4.0166	4.0291	4.0026

Table: 4. Values of hydration number (n_H) of maltose in aqueous solutions of alkali metal halides at 303, 308 and 313K

molality m / (mol·kg^{-1})	n_H								
	0 m / (mol·kg^{-1})			0.1 m / (mol·kg^{-1})			0.5 m / (mol·kg^{-1})		
	303 K	308 K	313 K	303 K	308 K	313 K	303 K	308 K	313 K
System 1: Maltose + Aqueous NaCl									
0.02	42.4	31.2	17.1	19.5	19.4	20.9	35.4	21.5	18.0
0.04	31.3	22.6	13.9	14.3	13.4	17.4	19.7	15.9	27.1
0.06	32.6	23.5	18.3	19.8	19.5	17.6	17.8	20.1	24.0
0.08	28.6	23.9	19.4	18.9	20.4	17.7	17.1	18.7	21.5
0.10	25.7	20.3	8.8	11.6	15.3	19.3	21.1	16.1	7.2
System II: Maltose + Aqueous KCl									
0.02	42.4	31.2	17.1	25.3	16.7	16.9	35.2	31.2	19.2
0.04	31.3	22.6	13.9	14.4	20.1	18.1	25.8	22.5	23.3
0.06	32.6	23.5	18.3	15.6	16.6	16.2	22.9	21.2	21.6
0.08	28.6	23.9	19.4	15.9	16.4	16.6	20.8	19.8	19.4
0.10	25.7	20.3	8.8	20.1	14.5	15.8	18.9	19.7	18.0
System III: Maltose + Aqueous KBr									
0.02	42.4	31.2	17.1	39.7	19.5	21.5	20.4	21.9	16.7
0.04	31.3	22.6	13.9	32.3	17.5	18.8	16.3	17.0	17.8
0.06	32.6	23.5	18.3	27.6	19.4	16.8	18.4	16.7	20.5
0.08	28.6	23.9	19.4	24.5	20.6	17.3	17.3	22.7	19.1
0.10	25.7	20.3	8.8	23.9	17.8	19.1	17.5	11.7	16.1
System IV: Maltose + Aqueous KI									
0.02	42.4	31.2	17.1	39.8	19.6	21.6	23.1	24.2	19.3
0.04	31.3	22.6	13.9	32.4	17.6	18.9	17.5	17.4	16.7
0.06	32.6	23.5	18.3	27.7	19.5	16.9	18.7	15.2	14.4
0.08	28.6	23.9	19.4	24.6	20.8	17.4	19.1	15.0	14.2
0.10	25.7	20.3	8.8	23.6	17.9	19.4	18.4	14.1	15.5

Table: 5. Values of apparent molal compressibility (φ_K) of maltose in aqueous solutions of alkali metal halides at 303, 308 and 313 K

molality m / (mol·kg^{-1})	$-\varphi_K/(\times10^{-7}\ m^2\ N^{-1})$								
	0 m / (mol·kg^{-1})			0.1 m / (mol·kg^{-1})			0.5 m / (mol·kg^{-1})		
	303 K	308 K	313 K	303 K	308 K	313 K	303 K	308 K	313 K
System 1: Maltose + Aqueous NaCl									
0.02	4.76	3.99	2.33	1.24	1.48	1.90	0.66	1.85	2.09
0.04	3.30	2.67	2.11	1.39	1.31	1.77	2.24	1.42	2.59
0.06	3.39	2.63	2.15	1.96	1.88	1.82	1.89	1.94	2.38
0.08	2.97	2.57	2.20	2.03	2.02	1.79	1.78	1.84	2.10
0.10	2.70	2.22	1.96	2.01	1.97	2.03	1.84	1.88	3.06
System II: Maltose + Aqueous KCl									
0.02	4.76	3.99	2.33	1.74	1.64	1.76	2.02	2.00	2.05
0.04	3.30	2.67	2.11	1.79	1.58	1.78	2.76	2.19	2.61
0.06	3.39	2.63	2.15	1.73	1.77	1.68	2.50	2.25	2.39
0.08	2.97	2.57	2.20	1.71	1.76	1.69	2.22	2.02	2.11
0.10	2.70	2.22	1.96	2.42	1.80	2.46	3.11	2.77	3.24
System III: Maltose + Aqueous KBr									
0.02	4.76	3.99	2.33	1.42	1.26	1.77	1.80	1.64	1.97
0.04	3.30	2.67	2.11	1.59	1.50	1.29	1.87	2.05	1.99
0.06	3.39	2.63	2.15	1.64	1.46	1.59	2.09	1.99	2.19
0.08	2.97	2.57	2.20	1.79	1.85	1.84	1.95	2.39	2.03
0.10	2.70	2.22	1.96	1.72	1.80	1.85	1.97	2.32	2.10
System IV: Maltose + Aqueous KI									
0.02	4.76	3.99	2.33	0.85	1.48	1.09	1.59	1.57	1.65
0.04	3.30	2.67	2.11	1.01	1.56	1.59	1.71	1.80	1.77
0.06	3.39	2.63	2.15	1.50	2.07	1.67	1.81	1.59	1.64
0.08	2.97	2.57	2.20	1.60	1.74	1.98	1.86	1.67	1.54
0.10	2.70	2.22	1.96	1.82	2.11	2.18	1.92	2.45	2.43

Table –6: Values of limiting apparent molal compressibility (ϕ_K^0), constant (S_K) and transfer adiabatic compressibility ($\Delta\phi_K^0$) of maltose in aqueous solutions of alkali metal halides at 303, 308 and 313 K

Alkali metal halides	m/(mol·kg^{-1})	$-(\phi_K^0)$ / $(\times10^{-7}\ m^2\ N^{-1})$			S_K / $(\times10^{-7}\ m^3 \cdot L^{1/2} \cdot mol^{-3/2})$			$(\Delta\phi_K^0)$ / $(\times10^{-7}\ m^2\ N^{-1})$		
		T = 303 K	T = 308 K	T = 313 K	T = 303 K	T = 308 K	T = 313 K	T = 303 K	T = 308 K	T = 313 K
Aqueous Nacl	0.0	5.95	4.91	2.49	10.64	8.83	1.43	…	…	…
	0.1	1.64	0.82	1.74	–6.20	–3.85	–0.52	4.31	4.09	0.75
	0.5	0.48	1.55	1.68	–5.06	–1.10	–3.24	5.47	3.36	0.81
Aqueous Kcl	0.0	5.95	4.91	2.49	10.64	8.83	1.43	…	…	…
	0.1	1.24	0.73	1.25	–2.68	–2.34	–2.67	4.71	4.18	1.24
	0.5	1.63	1.53	1.49	–3.78	–3.02	–4.16	4.32	3.38	1.00
Aqueous KBr	0.0	5.95	4.91	2.49	10.64	8.83	1.43	…	…	…
	0.1	1.18	0.79	1.34	–1.92	–3.29	–1.36	4.77	4.12	1.15
	0.5	1.69	1.13	1.88	–1.06	–4.01	–0.74	4.26	3.78	0.61
Aqueous KI	0.0	5.95	4.91	2.49	10.64	8.83	1.43	…	…	…
	0.1	5.06	1.01	0.29	–15.63	–3.35	–5.96	0.89	3.90	2.20
	0.5	1.33	0.99	1.15	–1.89	–3.48	–2.76	4.62	3.92	1.34

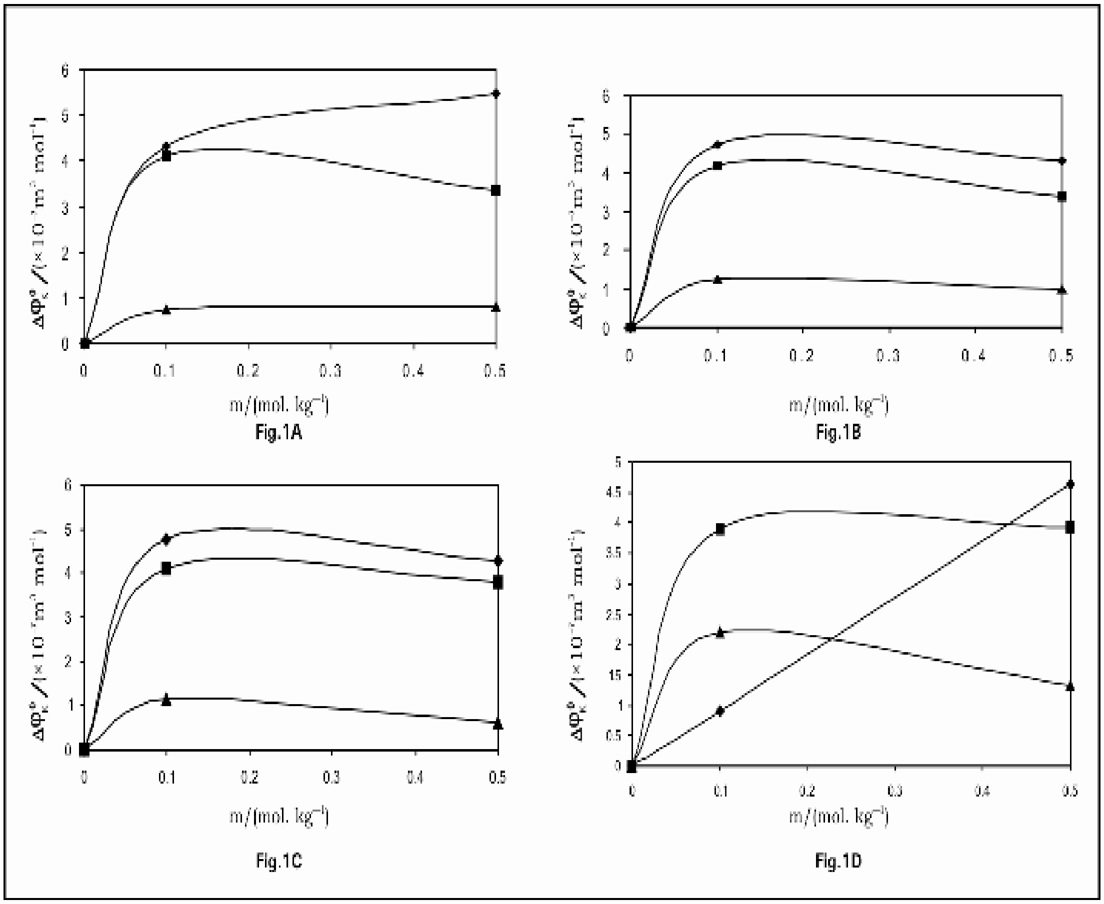

Fig.1 Transfer adiabatic compressibility ($\Delta\Phi_K^0$) with molality of aqueous alkali metal halides at 303, 308 and 313 K
Fig.1A. Maltose + aqueous NaCl; **Fig.1B.** Maltose + aqueous KCl;**Fig.1C.** Maltose + aqueous KBr;
Fig.1D. Maltose + aqueous KI.
υ – T = 303 K ν – T = 308 K σ – T = 313 K

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