

Study of Compressibility, Internal Pressure and Free Volume for Carbohydrates using Ultrasonic Measurements

V.Hariharakrishnan*, R.Ramasamy*, S.Sekar**

* Department of Physics, National College Trichy.

** Professor & Head Dept. of Science & Humanities Oxford Engineering College, Trichy

Abstract- The compressibility of the solution decreases with increase of solute concentration. The decrease in the compressibility is explained by assuming that the solvated molecules are fully compressed by the electrical forces of the ions. Hence a fraction namely those within the primary solvated shell of the ions is rendered incompressible. The compressibility of the solution is mainly due to the free solvent molecules. Internal pressure of liquids provides a wealth of information about the state of liquid. It explains many of the properties of liquids and solutions. The concept of free volume is a generalized aspect of the idea that its neighbors in a cell enclose each molecule. Let us consider some of the sugar alcohols like Maltose, Galactose, Mannonose

Index Terms- Velocity, Adiabatic compressibility, Internal Pressure, Free volume.

I. INTRODUCTION

The number of water molecules that interact with the solute at one time is the measure of the hydration number. Internal pressure though a single factor appears to vary due to all the internal interactions such as hydration of solute solvent interactions. Even microscopic changes occurring in the medium like in molecular orientations or in temperature will change the value of internal pressure. The free volume is broadly defined as the average volume in which the center of the molecule can move inside the hypothetical cell due to the repulsion on the surrounding molecules.

II. EXPERIMENTAL STUDY

Computation of the acoustical parameters require measurement of ultrasonic velocity (U), viscosity (η) and density (ρ). Aqueous solutions of amides of different concentrations were prepared with AR grade salts with double

distilled water. Ultrasonic velocity through the solutions were measured with a Mittal type ultrasonic interferometer with an accuracy of ± 2 m/s. The cell temperature was maintained with a circulating ultrathermostat accurate to within 0.1° C. The viscosity of the solutions were measured using a Cannon Fensky viscometer. The density of the solutions were measured with 10 ml specific gravity bottle.

III. COMPUTATION

Compressibility measurements yield interesting information. They are also highly accurate. Here we assume that the bound water molecules are highly compressed by the intense field of the ion and that further compression affects only the unbound water. The adiabatic compressibility is the fractional decrease of volume per unit increase of pressure, when no heat flows in or out. If there is no heat flow, the entropy is unchanged in a reversible process, is one at constant entropy. Then we have,

Adiabatic compressibility can be determined with the measurement of density and ultrasonic velocity U as

$$\beta = (1/u^2 p) \text{ cm}^2/\text{dyne}$$

$$\pi_i = bRT \left[\frac{K\eta}{U} \right]^{1/2} \cdot \frac{\rho^{2/3}}{M_{eff}^{7/6}}$$

Thermodynamic importance of internal pressure is shown by bringing out its quantitative relationship with entropy and the partition function of the system. Internal pressure is shown to be related to the transport properties in liquids and solutions.

The free volume plays an important role in ultrasonic propagation in liquids, and $V_f^{1/3}$ is very small in the case of solids. The relation between free volume and viscosity has been derived by Bingham and McLeod

(1.15)Tables

Maltose

MOLALITY	Velocity					Adiabatic Compressibility				
	308K	313K	318K	323K	328K	308K	313K	318K	323K	328K
0.1	1509	1534	1560	1579	1616	44.11	43.08	41.26	41.72	38.33
0.4	1517	1547	1567	1580	1632	43.58	40.52	39.39	38.86	36.48
0.6	1527	1556	1607	1613	1656	41.51	38.96	36.72	36.46	34.28
1	1546	1610	1617	1620	1680	40.1	36.63	36.24	35.25	32.85
1.2	1578	1618	1661	1657	1696	37.41	35.59	32.63	33.03	31.25
1.6	1612	1637	1702	1698	1705	34.97	33.27	30.46	32.33	30.33
2	1640	1652	1702	1760	1740	32.61	31.94	29.77	27.92	28.39

MOLALITY

Internal pressure

Free Volume

MOLALITY	Internal pressure					Free Volume				
	308K	313K	318K	323K	328K	308K	313K	318K	323K	328K
0.1	24997	21555	22168	20589	20161	0.02364	0.03794	0.03731	0.0455	0.0548
0.4	23121	20682	22003	20955	19202	0.02486	0.03897	0.03409	0.0412	0.0558
0.6	24100	22530	21492	21326	19928	0.02098	0.02841	0.03397	0.0364	0.0476
1	26156	20185	24150	21227	18360	0.01675	0.03167	0.02394	0.0315	0.0507
1.2	24072	22719	21755	21940	19470	0.01677	0.02095	0.02667	0.0269	0.0411
1.6	25018	23522	22006	20496	18782	0.01315	0.01726	0.0225	0.0262	0.0341
2	28938	25189	24053	23071	20560	0.00764	0.0125	0.0154	0.0182	0.0272

Galactose

MOLALITY

Velocity

Adiabatic Compressibility

MOLALITY	Velocity					Adiabatic Compressibility				
	308K	313K	318K	323K	328K	308K	313K	318K	323K	328K
0.2	1518	1530	1554	1560	1566	43	42.47	41.25	41.03	40.83
0.4	1542	1548	1560	1566	1578	41.21	40.91	40.4	40.18	39.71
0.6	1548	1554	1566	1572	1578	40.38	40.64	39.64	39.44	39.29
0.8	1560	1566	1572	1578	1584	39.74	39.5	39.29	39.1	38.89
1	1578	1590	1602	1614	1620	37.04	37.47	37.01	36.66	36.47
1.2	1590	1602	1608	1614	1626	37.04	36.57	36.34	36.21	36.8
1.4	1602	1608	1614	1626	1632	36.12	35.98	35.81	35.38	35.22
1.525	1614	1620	1632	1650	1656	35.43	34.82	34.82	34.19	34.04

Internal Pressure

Free Volume

	308K	313K	318K	323K	328K	308K	313K	318K	323K	328K
0.2	24585	23590	22959	22090	21283	0.02584	0.03058	0.03456	0.04045	0.0471
0.4	24538	23650	22760	22585	21104	0.020507	0.02928	0.03336	0.0389	0.0466
0.6	24229	23438	22759	21936	21128	0.0251	0.020903	0.03301	0.03844	0.04571
0.8	23970	22897	22474	21563	20488	0.02452	0.02943	0.03247	0.03854	0.04664
1	23991	23918	22413	21713	20585	0.02421	0.02616	0.02756	0.03712	0.04407
1.2	24549	23448	22550	21459	20542	0.02185	0.02616	0.02756	0.03712	0.04407
1.4	24548	23484	22781	21840	20389	0.02118	0.02521	0.0289	0.03407	0.04359

**Mannose
Velocity**

Adiabatic compressibility

	308K	313K	318K	323K	328K	308K	313K	318K	323K	328K
0.2	1520	1532	1552	1560	1565	42.89	42.4	41.38	41.04	40.89
0.4	1538	1544	1558	1567	1576	41.42	41.13	40.51	40.14	39.82
0.6	1546	1553	1564	1573	1580	40.46	40.18	39.77	39.4	39.2
0.8	1560	1567	1570	1580	1586	39.72	39.42	39.4	39.01	38.77
1	1574	1582	1606	1616	1622	38.48	38.23	37.22	36.87	36.74
1.2	1594	1600	1612	1617	1621	37.22	36.65	36.51	36.43	36.74

Internal Pressure

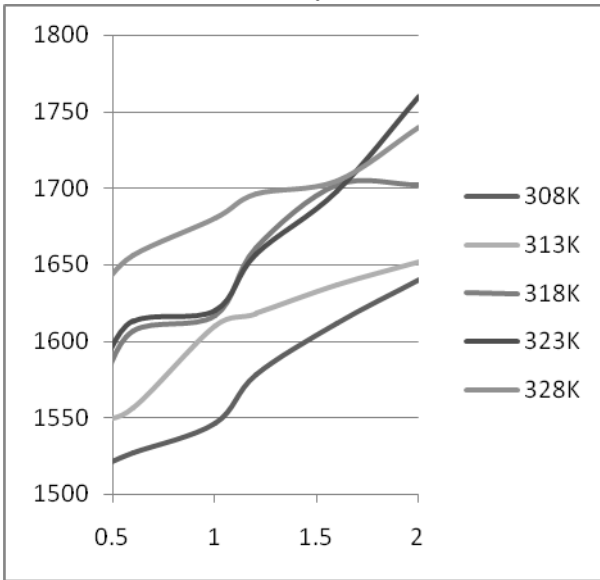
Free Volume

	308K	313K	318K	323K	328K	308K	313K	318K	323K	328K
0.2	24585	23590	22959	22090	21283	0.02584	0.03058	0.03456	0.04045	0.0471
0.4	24538	23650	22760	22585	21104	0.020507	0.02928	0.03336	0.0389	0.0466
0.6	24229	23438	22759	21936	21128	0.0251	0.020903	0.03301	0.03844	0.04571
0.8	23970	22897	22474	21563	20488	0.02452	0.02943	0.03247	0.03854	0.04664
1	23991	23918	22413	21713	20585	0.02421	0.02616	0.02756	0.03712	0.04407
1.2	24549	23448	22550	21459	20542	0.02185	0.02616	0.02756	0.03712	0.04407
1.4	24548	23484	22781	21840	20389	0.02118	0.02521	0.0289	0.03407	0.04359

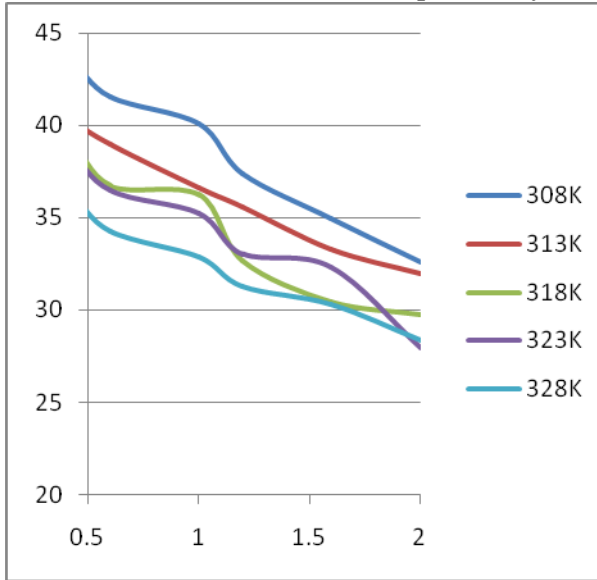
Graphs

Maltose

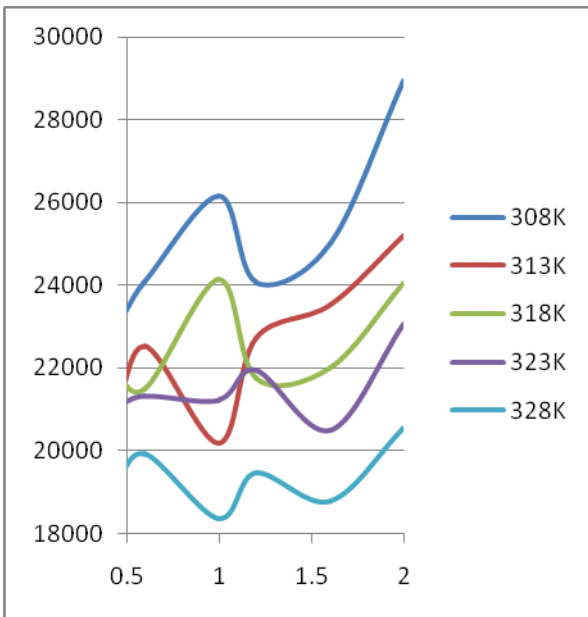
Ultrasonic velocity



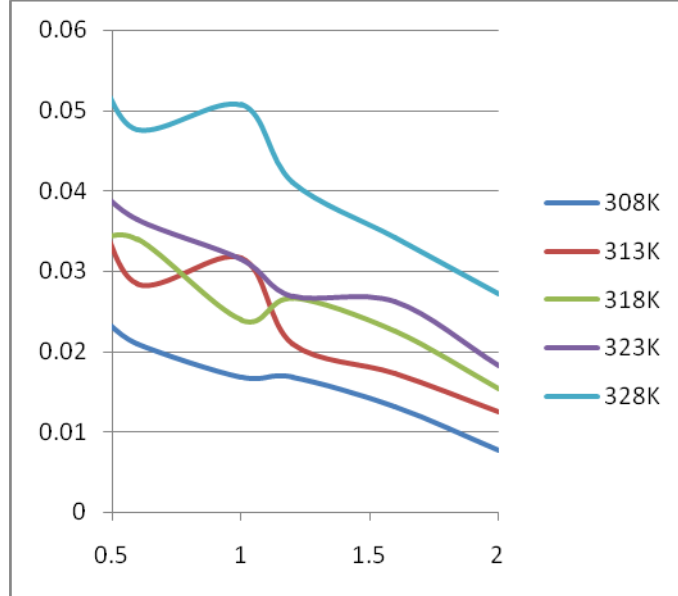
Adiabatic compressibility



Internal Pressure



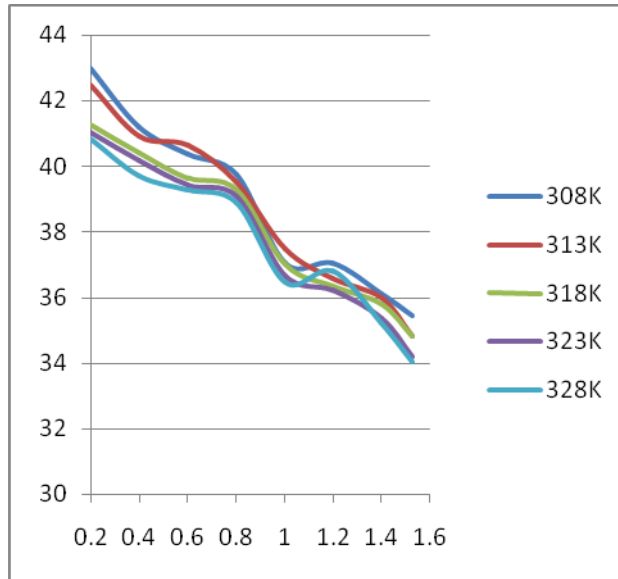
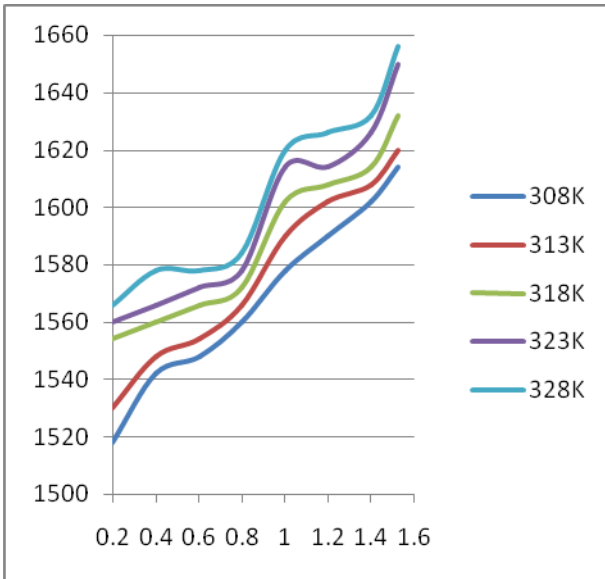
Free volume



Galactose

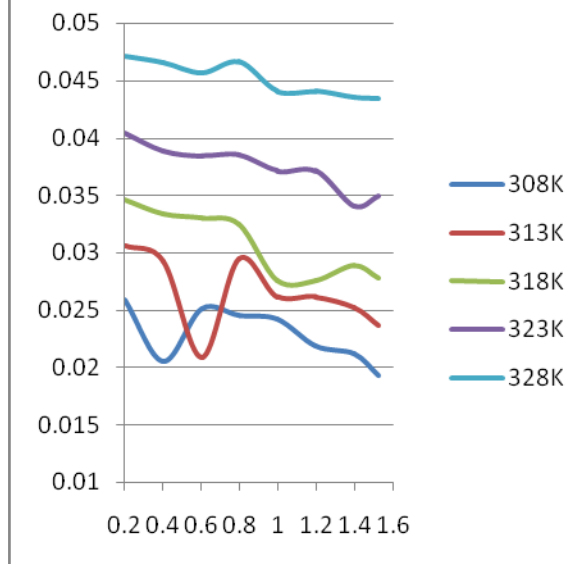
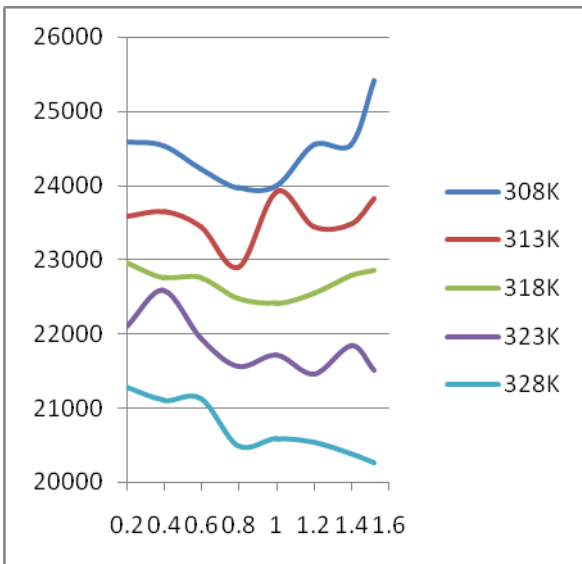
Ultrasonic velocity

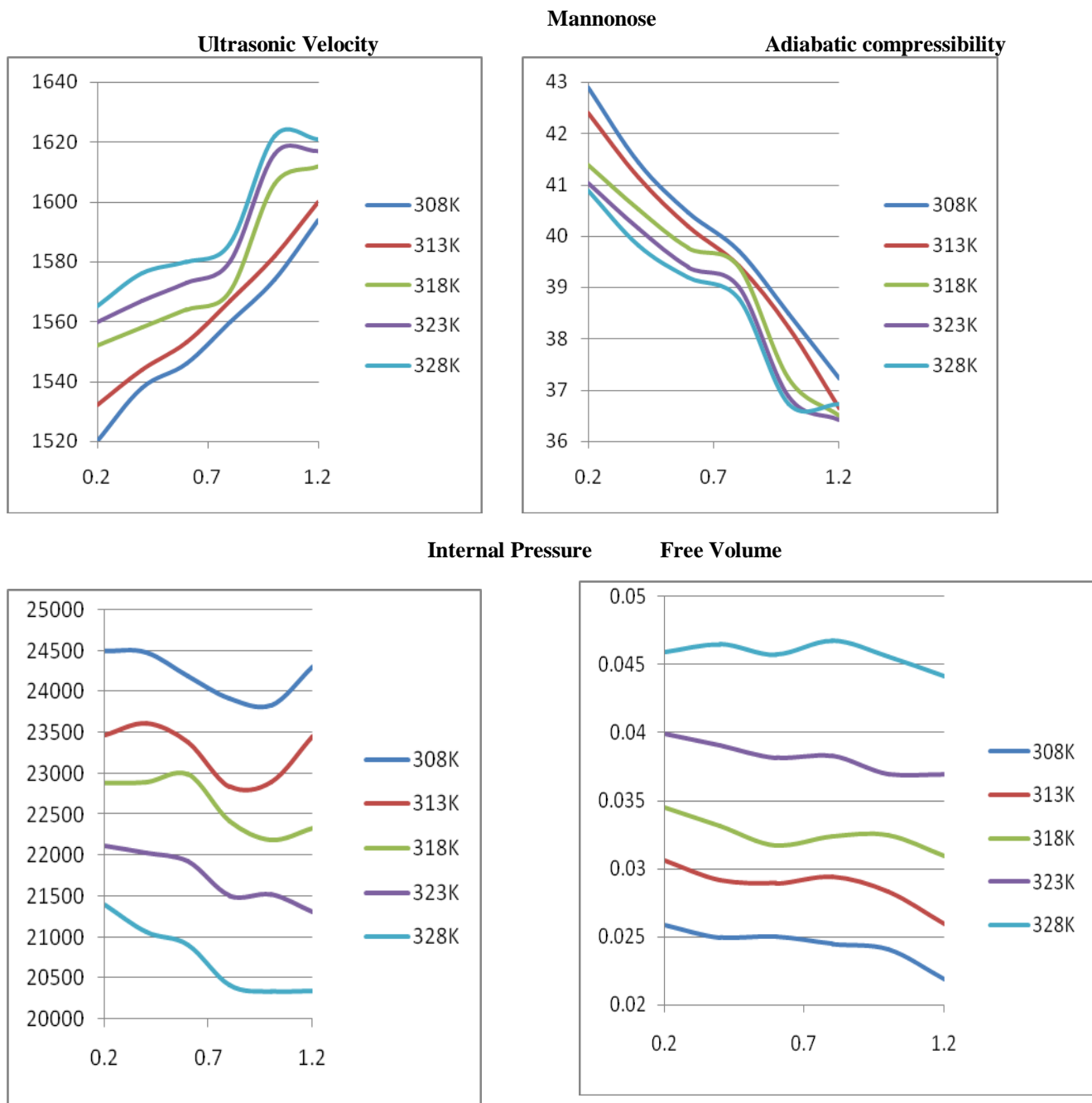
Adiabatic compressibility



Internal Pressure

Free Volume





IV. RESULTS AND DISCUSSION

The experimentally determined values of ultrasonic velocity for Maltose, Galactose, Mannonose at temperatures at, 308K, 313K, 318K and 323K, 328K are summarized in the table.

The measurement of ultrasonic velocity is an important tool to study the physical & chemical properties of the liquid. Ultrasonic velocity and allied parameters of Maltose, Galactose, Mannonose for various concentrations, at different temperatures are presented in tables and represented graphically in figures.

Ultrasonic velocity, adiabatic compressibility, Internal Pressure and Free volume for Maltose, Galactose, Mannonose were determined at different temperatures.

The plots between the ultrasonic velocity and concentration potential shows that the ultrasonic velocity is found to linearly increase with temperatures. This linear increase suggests that there are strong solute-solvent interactions in the liquid solution. These interactions are both concentration and temperature dependent. The effects of temperature on the interactions are more than that of concentration. At low concentrations, the number of hydrogen bonds formed may be less and at higher concentrations, it may be more due to solute-solute interactions. Ultrasonic velocity is found to linearly increase with

both molality as well as temperature as reported in literature for other carbohydrates[Graph1].

The compressibility is a macroscopic observable, which is sensitive to solute-solvent interactions. Any modifications induced by the solute on the local structure of the solvent generate changes in the adiabatic compressibility of the solutions and therefore compressibility can be used to characterize solvated properties of solute in dilute solutions.

The decrease in the values of adiabatic compressibility with increase in ultrasonic velocity indicates that there is a significant interaction between solute and solvent molecules due to which the structural arrangement in the neighbourhood of constituent ions is considerably affected[Graph2]. The variation in compressibility values of the carbohydrates is found to be in good agreement with the reported values for electrolytes.[11]. The solute solvent interaction becomes weak with increase in concentration and temperature. The changes in Internal pressure and Free volume was noted for Maltose,Galactose,Mannonose .

REFERENCES

- [1] D.T. Warner, Nature 196, 1055 (1962)
- [2] D.T. Warner, Ann.N.Y.Acad. Science 125, 605 (1965)
- [3] D.T. Warner, Ann.Rep.Med.Chem 256 (1970)
- [4] A.Passynski, Acta physicochem. 8 385 (1930).
- [5] S. Barnartt, J.Chem.Phys. 20 278 (1952)
- [6] J.F. Hinton and H.S. Amis, Chem.Rev. 71 627 (1971)
- [7] Tunetaka Sasaki and Yasunaga, Bull.Chem.Soc. JPN 28 269 (1955)
- [8] S.Kalyanasundaram and R.Bhawanth, Trans.SAEST 25 99 (1990)

- [9] R.Varadarajan, Pia Thomas and S.Kalyanasundaram 6th National Symposium 1994.
- [10] R.Varadarajan, Pia Thomas and S.Kalyanasundaram, Fifth International Symposium on Advances in Electrochem.Science and Technology, 1994. Article 2.53
- [11] D.S. Gill and M.S.Chauhan Z.Phys.Chem.(N.F) 140 139-144,149-156 .
- [12] S.Sekar : Ultrasonic velocity, Freevolume, Hydration number and Acoustical parameters as functions of internal pressure in carbohydrates and sugar alcohols' – PhD Thesis BharadhidasanUniversity, India 1996.
- [13] Ragamathunnisa M., Jasmine Vasantha Rani E., Padmavathy R., Radha N.. IJCRR 2012; 4(23): 30-41
- [14] T Sumathi, M Varalakshmi - Rasayan J. Chem, 2010
- [15] KN Mehrotra, SK Upadhyaya, (1988) J. Industrial Research. 1988..
- [16] .Palani, A. Geetha, SVSL Poornima, (2011) International Journal of Research in Pure and Applied Physics
- [17] M Gowrisankar, P Venkateswarlu... - Journal of Industrial and ..., 2013 - Elsevier
- [18] MG Sankar, V Ponneri, KS Kumar... - Journal of Thermal ..., 2013 – Springer
- [19] J. D. Pandey,a Ranjan Dey*a and J. Chhabraa PhysChemComm, 2003,6, 55-58
- [20] S. Cabini, G. Conti, E. Matteoli and M.R.Tine, J. Chem. Soc. Faraday Trans., 77, 2385 (1981)

AUTHORS

First Author – V.Hariharakrishnan, Department of Physics, National College Trichy., Email: hariharan_mphil@yahoo.co.in
Second Author – R.Ramasamy, Department of Physics, National College Trichy.
Third Author – S.Sekar, Professor & Head Dept. of Science & Humanities Oxford Engineering College, Trichy