



**Partial molar and ultrasonic properties of poly vinyl alcohol (PVA, Mw -125,000) in various solvents at different concentrations and different temperatures**

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**ABSTRACT**

The ultrasonic velocity and density of PVA (Mw-125,000) solutions in solvents distilled water, 1N NaOH, 1N KOH, and 4M Urea have been measured in varying ranges of concentration from 0.004 to 0.080 molm<sup>-3</sup> at 298.15K, 303.15K, 308.15K, 313.15K and at frequency 1MHz. Apparent and partial molar volumes and apparent and partial molar expansionsibilities of these solutions have been determined from density data. The ultrasonic velocity and density data have also been used to evaluate various acoustic parameters such as isentropic compressibility, apparent isentropic molar compressibility, solvation number of the solute and relative association. The results are discussed in the light of solute-solvent interaction and structural effect of the solvents in solution.

**Key words:** PVA solutions, ultrasonic velocity, partial molar properties, acoustic parameters.

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**INTRODUCTION**

The practical importance of the solvation dynamics [1,2] has been the focus of intense research activities during the last two decades. Experimental and theoretical studies have given rise to renewed interest [3,4] in the field in assessing the nature of molecular interactions and investigating the physio-chemical behavior of the solutions [5,6,7]. Measurement of some bulk properties like density and ultrasonic velocity provides insight into the intermolecular arrangement of the components of the solutions, which in turn helps to understand their thermodynamic and acoustic properties. Evaluation of partial molar quantities are of importance as they provide a lot of information regarding the solute-solvent interactions in various solutions. These quantities can not be directly determined from the experiments. However these quantities are related to the corresponding apparent molar quantities, which can be directly determined. The present paper also deals with the study of some acoustic properties of the solutions.

In the present investigation, we have studied the partial molar and ultrasonic properties [8,9] of polymer Poly Vinyl Alcohol in solvents distilled water, strong hydroxides and Urea at four different temperatures.

We have chosen Poly Vinyl Alcohol (PVA) because it is a readily biodegradable water-soluble polymer. It dissolves slowly in cold water, but at higher temperatures, it goes fairly fast into solution, more so around 90°C.

PVA has occupied a separate area of investigation by researchers because of its pharmaceutical, biomedical and industrial applications; which include sizing, binders, fibres, films for agricultural chemicals and hospital laundry bags. It is approved for food contact by the food and drug administration (FDA) in USA.

## EXPERIMENTAL SECTION

The polymer Polyvinyl Alcohol (PVA,  $M_w = 125,000$ ) obtained from E-merk Ltd. (India) was used as such without any further purification. The reagents like NaOH, KOH and Urea were BDH (AR) grade and used as such throughout the experiment. Fresh distilled water was used for preparation of solvents 1N NaOH, 1N KOH & 4M Urea. The PVA solutions in distilled water and in the above mentioned solvents were prepared on the molal basis. Conversion of molality to molarity was done by using the standard expression [10] considering the density differences at the respective temperatures.

**i. Velocity Measurement :**

Ultrasonic velocity measurements of PVA solutions at different concentrations (in the range 0.004 to 0.080 molm<sup>-3</sup>) at four different temperatures and at frequency 1MHz were done using Multifrequency Ultrasonic Interferometer operating at 3 different frequencies (Model MX-3, MITTAL MAKE). The measuring cell of Interferometer is a specially designed double walled vessel with provision for temperature constancy. A constant temperature water bath with pump, thermostat (temperature from ambient to 95°C, SATYAM MAKE) with an accuracy of  $\pm 0.1K$  was used to circulate water through the outer jacket of double-walled measuring cell containing the experimental liquid. The accuracy of the velocity measurement in the interferometer is  $\pm 0.5ms^{-1}$ .

**ii. Density Measurement :**

The densities of PVA solutions of different concentrations were measured using 25ml. specific gravity bottle [11]. The specific gravity bottle with the experimental liquid was immersed in a temperature controlled water bath. The

density was measured using the formula,  $\rho_2 = \left( \frac{W_2}{W_1} \right) \times \rho_1$

where

$W_1$  = Weight of distilled water,  $W_2$  = Weight of experimental liquid .

$\rho_1$  = Density of distilled water,  $\rho_2$  = Density of experimental liquid.

At least five observations were taken and differences in any two readings did not exceed  $\pm = 0.02\%$  .

**THEORETICAL ASPECT**

The apparent molar volume  $V_\phi = 1000(c\rho_0)^{-1}(\rho_0 - \rho) + M\rho_0^{-1}$  .....(1)

Where  $c$  is the molar concentration (mol dm<sup>-3</sup>),  $\rho_0$  is the density of solvent,  $\rho$  is the density of the solution and  $M$  is the molecular mass of the solute. The  $V_\phi$  data were fitted to the Mason equation by least squares method [12] and the limiting apparent molar volume,  $V_\phi^0$  was determined from the equation :

$$V_\phi = V_\phi^0 + S_v c^{1/2} \dots\dots\dots (2)$$

Where  $S_v$  is the slope in the  $V_\phi$  versus  $c^{1/2}$  plot.

The apparent molar expansibility  $E_\phi$  was calculated by using the equation [12] :

$$E_\phi = \alpha_0 V_\phi + (\alpha - \alpha_0) 1000 c^{-1} \dots\dots\dots (3)$$

Where  $\alpha$  and  $\alpha_0$  are the co-efficient of thermal expansion of the solution and solvent respectively and were determined from the usual relation [12.13].

The  $E_\phi$  data were fitted to the Masson equation to get the limiting apparent expansibility  $E_\phi^0$  and the slope  $S_E$  as follows :

$$E_\phi = E_\phi^0 + S_E c^{1/2} \dots\dots\dots (4)$$

The partial molar volume  $\bar{V}_2$  and the partial molar expansibility  $\bar{E}_2$  were calculated from the following equations :

$$\bar{V}_2 = V_\phi + (1000 - cV_\phi)(2000 + S_v c^{3/2})^{-1} S_v c^{1/2} \dots\dots\dots(5)$$

$$\bar{E}_2 = E_\phi + (1000 - cE_\phi)(2000 + S_E c^{3/2})^{-1} S_E c^{1/2} \dots\dots\dots(6)$$

From the ultrasonic velocity and density data, the values of relative association ( $R_A$ ), isentropic compressibility ( $K_s$ ), apparent isentropic compressibility ( $K_{s,\phi}$ ) and the solvation number ( $S_n$ ) of the solute were calculated by using the following equations [14,15,16] :

$$R_A = \left(\frac{\rho}{\rho_0}\right)\left(\frac{u_0}{u}\right)^{1/3} \dots\dots\dots(7)$$

$$K_s = \left(\frac{1}{u^2 \rho}\right) \dots\dots\dots(8)$$

Where

$u$  = ultrasonic velocity of the solution

$\rho$  = density of solution

$$K_{s,\phi} = 1000K_s c^{-1} - K_s^0 \rho_0^{-1} (1000c^{-1} \rho - M) \dots\dots\dots(9)$$

$$S_n = n_1 n_2^{-1} [1 - V K_s (n_1 V_1^0 K_s^0)^{-1}] \dots\dots\dots(10)$$

Where

$K_s^0$  = Isentropic compressibility at infinite dilution.

$V$  = Volume of the solution containing  $n_2$  moles of the solute of molecular mass  $M$ .

$V_1^0$  = Molar volume of the solvent.

$n_1$  = number of moles of the solvent .

The variation of solvation number with the molar concentration of the solute leads to a limiting solvation number  $S_n^0$ , which is evaluated through the relationship,

$$\lim_{c \rightarrow 0} K_{s\phi}^0 = -S_n^0 V_1^0 K_s^0 \dots\dots\dots(11)$$

## RESULTS AND DISCUSSION

The measured values of ultrasonic velocity and density of PVA solutions at temperatures 298.15K, 303.15K, 308.15K, 313.15K and at frequency 1MHz are given in Table -1 from which  $K_s^0, V_\phi, E_\phi$  can be calculated.

**Table-1** Ultrasonic velocity  $u$  ( $\text{ms}^{-1}$ ) and density  $\rho$  ( $\text{kg m}^{-3}$ ) of PVA solutions in solvents distilled water, 1N NaOH, 1N KOH and 4M Urea at 298.15K, 303.15K, 308.15K and 313.15K.

Temperature in K	Concentration $c$ ( $\text{molm}^{-3}$ )	PVA in distilled water		PVA in 1N NaOH		PVA in 1N KOH		PVA in 4M Urea	
		$u$	$\rho$	$u$	$\rho$	$u$	$\rho$	$u$	$\rho$
298.15K	0	1498.00	997.40	1585.33	1036.17	1573.71	1039.57	1601.46	1063.39
	0.004	1499.48	998.74	1587.03	1037.51	1575.35	1040.89	1603.22	1064.64
	0.006	1500.11	999.25	1587.84	1038.10	1576.15	1041.46	1604.03	1065.21
	0.008	1500.80	999.76	1588.42	1038.71	1576.73	1042.04	1604.61	1065.75
	0.010	1501.40	1000.4	1589.18	1039.27	1577.46	1042.56	1605.36	1066.14
	0.040	1505.15	1001.6	1593.31	1041.10	1581.64	1044.21	1609.50	1067.71
	0.060	1507.25	1002.8	1595.25	1043.33	1583.57	1046.19	1611.44	1069.25
	0.080	1509.34	1004.6	1597.34	1045.19	1585.67	1048.06	1613.54	1070.75
303.15K	0	1507.00	995.64	1598.84	1035.83	1587.20	1038.19	1610.87	1062.01
	0.004	1508.46	996.94	1600.52	1037.16	1588.82	1039.49	1612.61	1063.23
	0.006	1509.10	997.39	1601.33	1037.71	1589.61	1040.05	1613.41	1063.78
	0.008	1509.72	997.76	1601.90	1038.18	1590.20	1040.61	1614.00	1064.27
	0.010	1510.35	998.24	1602.64	1038.75	1590.93	1041.11	1614.73	1064.68
	0.040	1514.12	999.74	1606.73	1040.55	1595.09	1042.72	1618.88	1066.58
	0.060	1516.22	1000.9	1608.71	1042.67	1597.02	1044.65	1620.81	1067.78
	0.080	1518.31	1002.5	1610.79	1044.67	1599.12	1046.48	1622.88	1068.83
308.15K	0	1517.00	993.03	1610.63	1034.51	1595.39	1035.87	1617.45	1058.16
	0.004	1518.44	995.20	1612.28	1035.82	1596.99	1037.13	1619.16	1059.33
	0.006	1518.99	995.73	1613.09	1036.37	1597.77	1037.71	1619.96	1059.85
	0.008	1519.65	996.10	1613.65	1036.83	1598.37	1038.21	1620.56	1060.32
	0.010	1520.28	996.55	1614.38	1037.35	1599.09	1038.69	1621.27	1060.71
	0.040	1524.08	998.05	1618.55	1039.02	1603.24	1040.19	1625.33	1062.07
	0.060	1526.19	999.18	1620.46	1041.12	1605.17	1042.09	1627.35	1063.34
	0.080	1528.27	1000.7	1622.53	1043.10	1607.26	1043.88	1629.40	1064.39
313.15K	0	1526.00	992.21	1616.22	1031.67	1604.54	1033.54	1623.01	1055.31
	0.004	1527.42	993.45	1617.84	1032.95	1606.11	1034.76	1624.69	1056.43
	0.006	1524.97	993.85	1618.64	1033.49	1606.89	1035.31	1625.49	1056.93
	0.008	1528.60	994.22	1619.20	1033.94	1607.50	1035.83	1626.10	1057.39
	0.010	1529.21	994.69	1619.93	1034.43	1608.20	1036.31	1626.80	1057.73
	0.040	1533.03	996.13	1624.09	1035.98	1612.36	1037.71	1630.95	1058.99
	0.060	1535.15	997.32	1626.01	1037.91	1614.28	1039.52	1632.81	1060.03
	0.080	1537.21	998.84	1628.08	1039.67	1616.37	1041.16	1634.91	1061.01

Table-1 continued.

The values of  $V_{\phi}^0$  and  $S_v$  obtained from equation (2) at different temperatures are shown in Table 2.

**Table -2** Values of parameters  $V_{\phi}^0$  ( $\text{m}^3 \text{mol}^{-1}$ ),  $S_v$  ( $\text{m}^{\frac{3}{2}} \text{mol}^{-\frac{3}{2}}$ ),  $E_{\phi}^0$  ( $\text{m}^3 \text{mol}^{-1} \text{K}^{-1}$ ),  $S_E$  ( $\text{m}^{\frac{3}{2}} \text{mol}^{-\frac{3}{2}} \text{K}^{-1}$ ) for PVA solutions in distilled water, 1N NaOH, 1N KOH, 4M Urea at four different temperatures and at frequency 1 MHz.

Temperature in K	PVA in distilled water				PVA in 1N NaOH				
	$10^3 V_{\phi}^0$	$10^3 S_v$	$10^3 E_{\phi}^0$	$10^3 S_E$	$10^3 V_{\phi}^0$	$10^3 S_v$	$10^3 E_{\phi}^0$	$10^3 S_E$	
298.15	-283.853	1258.911	-19.494	5.120	-276.739	1133.673	-26.521	6.957	
303.15	-251.828	1151.025	-19.606	5.152	-261.238	1090.577	-26.647	6.993	
308.15	-242.148	1119.818	-19.665	5.169	-256.208	1085.987	-26.593	6.981	
313.15	-232.423	1086.659	-19.720	5.184	-249.952	1085.939	-26.666	7.004	
		PVA in 1N KOH				PVA in 4M Urea			
298.15	-268.489	1130.731	-20.211	5.295	-245.758	1085.202	-33.626	8.831	
303.15	-262.023	1115.468	-20.250	5.307	-236.383	1068.455	-33.688	8.853	
308.15	-252.737	1094.689	-20.312	5.326	-223.045	1041.562	-33.839	8.899	
315.15	-243.427	1073.443	-20.376	5.346	-210.480	1017.447	-33.956	8.936	

A perusal of Table -2 shows that the values of  $S_v$  are high and positive for PVA solutions in all the four solvents, which indicate the presence of strong ion-ion interactions varying with change of temperature and the solvents [17]. The lowering of  $S_v$  values with increase in temperature points to the fact that, the ionization increases with increase in temperature i.e., temperature effect promotes structure breaking. The  $V_{\phi}^0$  values are negative for all solutions at the experimental temperatures, which indicate a weak solute-solvent interaction and also provides the evidence of electrostriction. With increase in temperature, the interactions are strengthened resulting increase in  $V_{\phi}^0$  values. The values of  $E_{\phi}^0$  and  $S_E$  as obtained from equation (4) are also given in Table -2. Since  $E_{\phi}^0$  gives an indication of caging or packing effect [18], the negative values of  $E_{\phi}^0$  suggest that, the structure making effect

of the solute is not favoured in all the solvents. Unlike  $S_v$ , the  $S_E$  values increase with increase in temperature and its value is more for solvents strong hydroxides and Urea in comparison with the solvent distilled water.

Table .3 shows an increase in  $\bar{V}_2$  with concentration and temperature in all the solvents. Increase of  $\bar{V}_2$  with concentration is owing to the structure breaking of the solvent molecules. As expected, values decrease with concentration and increase with temperature.

As observed, the relative association ( $R_A$ ) is a function of ultrasonic velocity (Table-3). It is influenced by two factors; (i) the breaking up of the solvent structures on addition of solute to it and (ii) solvation of solute. The former results in decrease and the latter results in increase in  $R_A$ . The increase in  $R_A$  with concentration suggests that the solvation of polymer PVA predominates over the breaking up of the solvent structure  $R_A$  values increase linearly with concentration for the PVA solutions in various solvents. But with increase in temperature the former predominates over the latter resulting decrease in the value of  $R_A$ . The variation of  $R_A$  with concentration for PVA solutions is shown in Fig.1

**Table -3 : Values of parameters for PVA solutions in distilled water, 1N NaOH, 1N KOH, 4M Urea at four different temperatures and at frequency 1MHz.**

Concentration C (mol m-3)	PVA in distilled water			PVA in 1N NaOH			PVA in 1N KOH			PVA in 4M Urea		
	$10^3 \bar{V}_2$	$10^3 \bar{E}_2$	$R_A$	$10^3 \bar{V}_2$	$10^3 \bar{E}_2$	$R_A$	$10^3 \bar{V}_2$	$10^3 \bar{E}_2$	$R_A$	$10^3 \bar{V}_2$	$10^3 \bar{E}_2$	$R_A$
	298.15K											
0.004	-170.7	5.722	1.0010	-166.8	7.730	1.0009	-161.4	5.918	1.0009	-142.0	9.839	1.0008
0.006	-135.0	3.858	1.0014	-145.9	5.230	1.0014	-138.9	3.975	1.0013	-125.6	6.642	1.0012
0.008	-114.1	2.939	1.0017	-135.0	4.001	1.0018	-126.1	3.027	1.0017	-111.3	5.065	1.0016
0.010	-116.4	2.386	1.0023	-121.8	3.268	1.0022	-110.8	2.465	1.0021	-86.8	4.151	1.0018
0.040	144.5	1.052	1.0027	114.5	1.426	1.0031	121.2	1.080	1.0028	124.0	1.813	1.0024
0.060	187.2	0.987	1.0034	143.1	1.332	1.0048	151.3	1.009	1.0043	157.4	1.701	1.0034
0.080	210.1	0.994	1.0047	170.0	1.334	1.0062	175.8	1.010	1.0056	182.3	1.708	1.0044
	303.15K											
0.004	-164.5	5.733	1.0009	-165.8	7.761	1.0009	-157.3	5.928	1.0009	-135.7	9.860	1.0008
0.006	-122.8	3.880	1.0013	-139.4	5.261	1.0013	-135.0	3.986	1.0013	-118.7	6.653	1.0011
0.008	-89.1	2.960	1.0015	-114.1	4.023	1.0016	-121.0	3.037	1.0017	-100.5	5.086	1.0015
0.010	-78.0	2.418	1.0019	-106.6	3.289	1.0020	-105.0	2.475	1.0020	-80.0	4.162	1.0017
0.040	137.1	1.065	1.0025	115.3	1.439	1.0029	122.3	1.091	1.0027	125.8	1.825	1.0023
0.060	177.5	1.001	1.0032	143.0	1.336	1.0045	152.1	1.020	1.0042	159.9	1.704	1.0032
0.080	199.0	0.999	1.0044	166.2	1.348	1.0060	176.1	1.010	1.0055	186.3	1.721	1.0039
	Table-3 continued.											
	308.15K											
0.004	-158.2	5.753	1.0009	-161.4	7.763	1.0009	-148.8	5.949	1.0008	-125.3	9.901	1.0007
0.006	-115.9	3.890	1.0013	-136.7	5.271	1.0013	-132.9	3.996	1.0012	-107.7	6.695	1.0011
0.008	84.4	2.971	1.0015	-110.9	4.023	1.0016	-112.7	3.048	1.0016	-90.4	5.118	1.0014
0.010	-71.7	2.438	1.0018	-99.3	3.292	1.0019	-96.8	2.486	1.0019	-70.7	4.195	1.0016
0.040	136.0	1.067	1.0024	119.9	1.440	1.0028	125.3	1.093	1.0025	129.4	1.840	1.0021
0.060	175.1	1.003	1.0032	146.2	1.337	1.0043	153.4	1.124	1.0040	162.9	1.720	1.0029
0.080	196.7	1.001	1.0043	168.6	1.350	1.0058	176.6	1.023	1.0053	189.6	1.738	1.0035
	313.15K											
0.004	-152.1	5.764	1.0009	-154.6	7.772	1.0009	-140.2	5.969	1.0008	-114.7	9.943	1.0007
0.006	-107.4	3.901	1.0012	-130.8	5.261	1.0012	-122.9	4.017	1.0012	-98.0	6.726	1.0010
0.008	-78.6	2.982	1.0014	-105.3	4.033	1.0015	-108.0	3.059	1.0016	-82.4	5.140	1.0013
0.010	-69.6	2.439	1.0018	-92.0	3.300	1.0019	-93.3	2.497	1.0018	-60.0	4.217	1.0014
0.040	135.3	1.068	1.0024	12.8	1.441	1.0026	126.9	1.105	1.0024	132.5	1.850	1.0019
0.060	171.9	1.005	1.0031	152.1	1.348	1.0040	154.8	1.025	1.0038	167.3	1.735	1.0025
0.080	193.8	1.003	1.0042	175.6	1.351	1.0053	178.4	1.027	1.0049	192.6	1.744	1.0030

The ultrasonic velocity  $u$  of PVA solutions at different concentrations were fitted to an equation of the form [19, 20, 21].

$$u = u_0 + Ac + Bc^{3/2} + Cc^2 \dots \dots \dots (11)$$

over the concentration range studied, where  $u_0$  is the sound velocity of pure solvent and A,B,C are the characteristic constants given in Table -4 Fig.2 shows variation of  $\frac{u - u_0}{c}$  versus  $c^{1/2}$  which is parabolic in nature and fairly agrees with equation (11). The values of isentropic compressibility  $K_s$  as calculated by equation (8) were fitted to an equation of the form :

$$K_s = K_s^0 + A'c + B'c^{3/2} + C'c^2 \dots\dots\dots (12)$$

Where  $A', B', C'$  are constants and  $K_s^0$  is isentropic compressibility of the solvent concerned. The value of constants  $A', B', C'$  are given in Table -4. As observed, the  $K_s$  value decreases as the concentration of the solution increase. The values of  $K_{s,\phi}$  computed by means of equation(9) were fitted into equation :

$$K_{s,\phi} = K_{s,\phi}^0 + A''c^{1/2} + B''c \dots\dots\dots (13)$$

to obtain  $K_{s,\phi}^0$  the limiting apparent isentropic molar compressibility. The values of  $K_{s,\phi}^0$ ,  $A''$ ,  $B''$  are given in Table -4. As observed the isentropic molar compressibility  $K_{s,\phi}$  of the solution increases with increase in concentration as well as increase in temperature. The values of  $K_{s,\phi}$  and  $K_{s,\phi}^0$  are negative. The negative  $K_{s,\phi}^0$  values can be explained in terms of loss of compressibility of surrounding solvent molecules due to strong electrostrictive forces causing electrostrictive solvation of ions. The  $K_{s,\phi}^0$  values of PVA solution for various solvents follow the order, 4M Urea > 1N KOH > 1N NaOH > distilled water. Typical plots are shown in Fig.3

**Table -4. Values of constants A,B,C of equation (11),  $A', B', C'$  of equation (12);  $K_{s,\phi}^0$  ( $m^3 mol^{-1} Pa^{-1}$ );  $A'', B''$  of equation (13) and  $S_n^0$  for PVA solutions in distilled water, 1N NaOH, 1N KOH and 4M Urea at four different temperatures and at frequency 1 MHz.**

Constants	PVA in distilled water				PVA in 1N NaOH				
	298.15K	303.15K	308.15K	313.15K	298.15K	303.15K	308.15K	313.15K	
$10^{-2}A$	5.145	5.072	4.898	4.829	6.008	5.953	5.810	5.684	
$-10^{-3}B$	2.260	2.239	2.131	2.110	2.757	2.743	2.613	2.514	
$10^{-3}C$	3.254	3.278	3.112	3.126	4.042	4.054	3.762	3.560	
$-10^{10}A'$	5.401	5.212	4.979	4.815	4.819	4.683	4.537	4.416	
$10^9B'$	2.724	2.732	2.595	2.507	2.390	2.399	2.324	2.246	
$-10^9C'$	4.333	4.594	4.371	4.240	3.772	3.944	3.826	3.658	
$-10^{10}K_{s,\phi}^0$	7.182	6.903	6.591	6.353	6.270	6.108	5.939	5.777	
$10^9A''$	4.091	4.148	3.957	3.815	3.436	3.500	3.432	3.331	
$-10^9B''$	6.704	7.266	6.944	6.708	5.571	5.974	5.896	5.668	
$10^{-2}S_n^0$	636.337	598.759	577.373	560.452	667.156	646.856	634.191	618.272	
		PVA in 1N KOH				PVA in 4M Urea			
$10^{-2}A$	5.757	5.670	5.585	5.467	6.255	6.167	6.046	5.927	
$-10^{-3}B$	2.556	2.483	2.415	2.311	2.984	2.913	2.805	2.697	
$10^{-3}C$	3.633	3.473	3.330	3.097	4.558	4.408	4.161	3.913	
$-10^{10}A'$	4.759	4.599	4.480	4.306	4.550	4.398	4.256	4.122	
$10^9B'$	2.358	2.274	2.219	2.090	2.335	2.244	2.150	2.063	
$-10^9C'$	3.721	3.584	3.506	3.223	3.762	3.584	3.386	3.205	
$-10^{10}K_{s,\phi}^0$	6.214	6.025	5.848	5.597	5.809	5.596	5.385	5.191	
$10^9A''$	3.446	3.358	3.279	3.088	3.298	3.168	3.037	2.921	
$-10^9B''$	5.635	5.511	5.408	4.974	5.429	5.165	4.894	4.655	
$10^{-2}S_n^0$	642.678	629.473	614.465	596.628	562.753	546.811	527.292	509.370	

A perusal of Table 4 shows that the values of limiting solvation number are very high in PVA solutions for all type of solvents and are in the order.

1N NaOH > 1N KOH > distilled water > 4M Urea.

The high value of  $S_n^0$  is due to the formation of solvation layer around the ions of the solvents. The decrease in  $S_n^0$  with increase in temperature may be attributed to the fact that the thickness and/or hardness of the solvation layer becomes thin/or loose as the temperature increases. Fig.4. shows the variation of  $S_n$  with concentration.

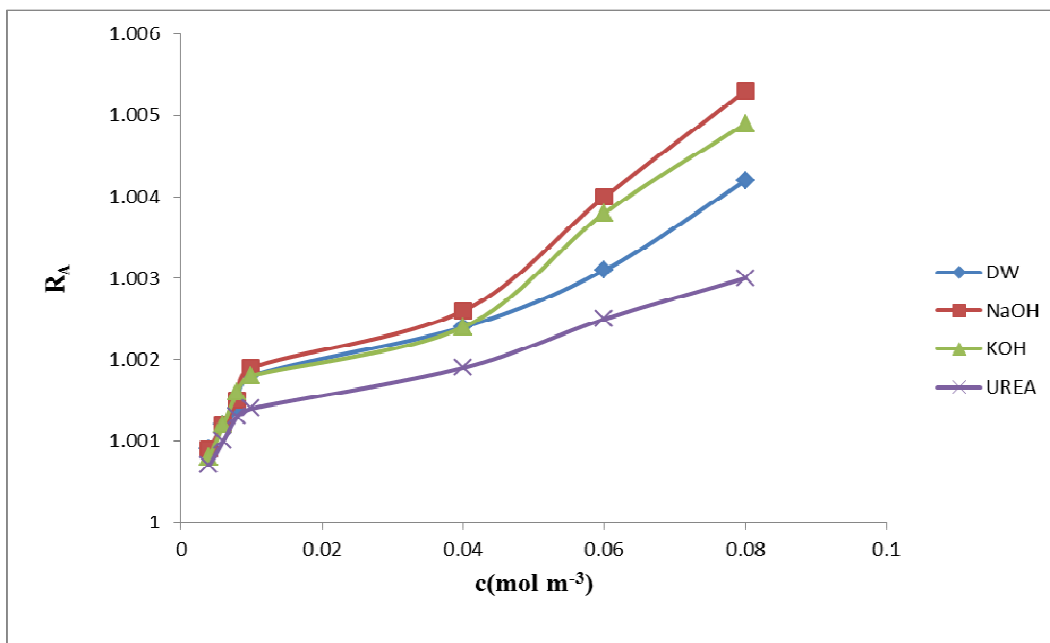


Fig. 1 Plot of  $R_A$  versus  $c$  for PVA solutions in solvent distilled water, 1N NaOH, 1N KOH and 4M Urea at 313.15K

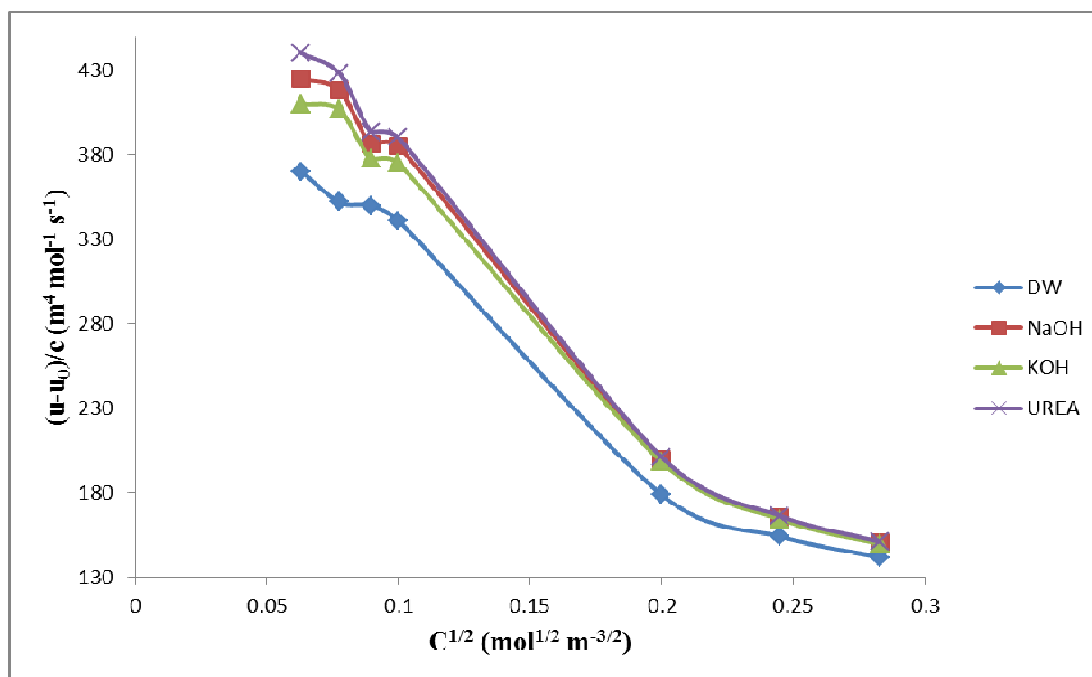


Fig. 2 Plot of  $(u-u_0)/c$  versus  $c^{1/2}$  for PVA solutions in solvent distilled water, 1N NaOH, 1N KOH and 4M Urea at 298.1K

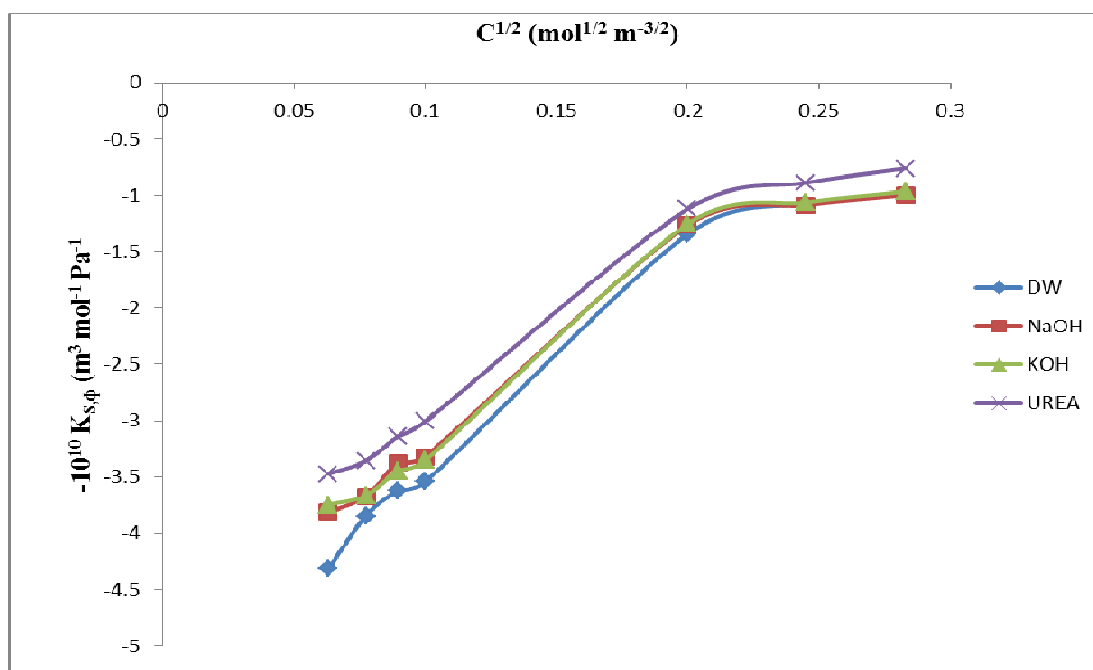


Fig. 3 Plot of  $K_{s,\phi}$  versus  $c^{1/2}$  for PVA solutions in solvent distilled water, 1N NaOH, 1N KOH and 4M Urea at 308.1K

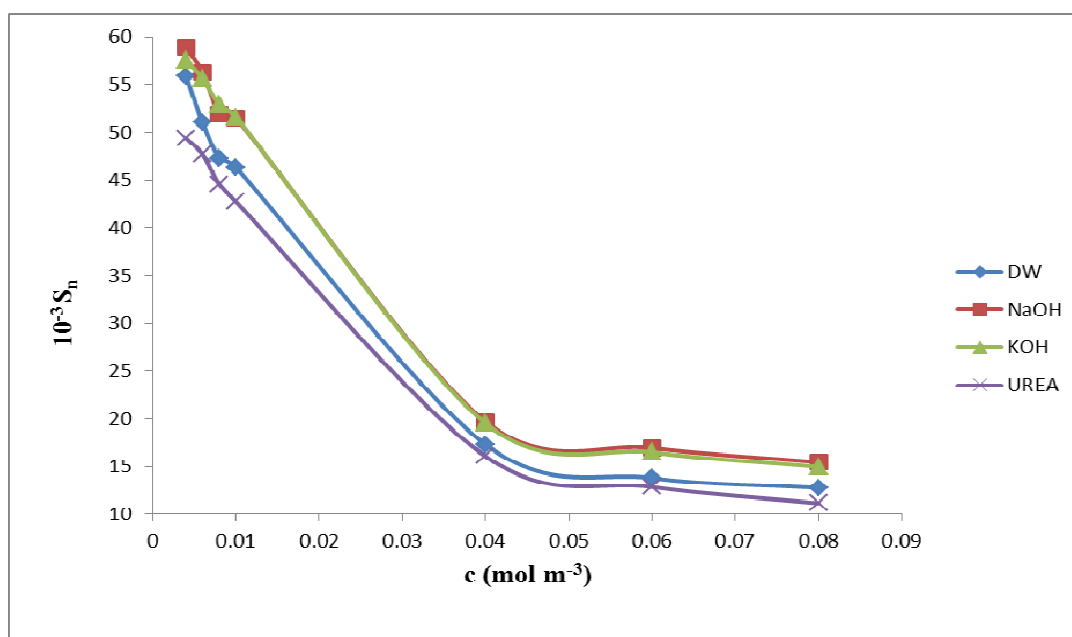


Fig. 4 Plot of  $S_h$  versus  $c$  for PVA solutions in solvent distilled water, 1N NaOH, 1N KOH and 4M Urea at 303.15K

### CONCLUSION

Ultrasonic method is a powerful probe for characterizing the physio-chemical properties of liquids. The results of the present investigation of PVA solutions in various solvents reveal that, the solvents which show high ion-ion interaction, show minimum solute-solvent interaction and vice versa. The results also describe the structural effects of the solute on the solvent in solution. However, any deviation from the usual behavior is probably due to characteristic structural changes in the respective system.

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