Ultrasonic Study and Allied Physical Parameters of Uni-Univalent Mixed Electrolytes in Formamide

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Abstract— **Ultrasonic velocities (u) and densities(ρ) of mixed electrolytes : NaBr + NaCl, KBr + KCl, NaBr + NaNO3, KBr + KNO3, CH3COONa + NaNO3 and CH3COOK + KNO3 in Formamide (non – aqueous solvent) have been measured at a constant frequency of 10 M Hz at 298.15 K.. Acoustical parameters, such as, apparent molar compressibility (Φk), inter molecular free length (Lf), specific acoustic impedance (Z), solvation number (Sn) and relative association constant (RA) have been obtained are computed to assess the ion-solvent and ion – ion interaction in these solutions. It is found that the interactions depend on concentration, ionic size and nature of metal ion. Ions behave as structure breaker for the associated clusters of solvent molecules, especially in dilute solution, as evidenced from the trend in the solvation number with molarity. It is also found that the strength of ion-dipole interaction in non aqueous solution of the metal ion is also dependent on concentration of the solution.**

Keywords -- ultrasonic velocities, inter-molecular free length, adiabatic compressibility, apparent molar compressibility, specific acoustic impedance and solvation number.

I. INTRODUCTION

Mixed electrolytes are very important as they are found in numerous processes in chemical industry. They occur in enormous quantities in the water of ocean and play an important role in the physiological process of body fluids and cell equilibria.

From the survey of literature, it appears that no ultrasonic studies on the mixed electrolyte systems vis-à-vis ion-solvent and ion-ion interactions in purely non-aqueous media have been reported so far.

It has been known that the di-electric constant of the medium plays a very important role concerning the behaviour of electrolytes in the solutions1. The solvent formamide is unusual in its properties, in that it is strongly self-associated through extensive network of hydrogen-bonds2,3 and it's di-electric constant and dipole moment (□ =109.5 and D= 3.68 at 298.15K)1 are very high. With this aim in view comprehensive studies on the determination of densities and ultrasonic velocities of some uni-univalent mixed electrolytes viz: : NaBr + NaCl, KBr + KCl, NaBr + NaNO3, KBr + KNO3, CH3COONa + NaNO3 and CH3COOK + KNO3, in Formamide, an aprotic solvent, have been undertaken. The main thrust of this study is to examine the acoustic behaviour and other parameters of the above uni-univalent mixed electrolytes systems.

Application of acoustic methods have showed extensive possibility in the fields of solution chemistry, physical chemistry, biochemistry, chemical engineering and process control for a fundamental understanding of many phenomena in solutions and liquid systems 11,12.

It is also possible to estimate the solvation numbers of the electrolyte solutions from the molar compressibility value at infinite dilution. Metal ions play an important role in chemical and biological systems so the solvation of ions in these systems is a key issue to understand the chemical and dynamical processes 13,14.

Propagation of the sound wave perturbs the equilibrium between solute and solvent molecules and relaxation process are setup leading to excess absorption of the sound wave. Endo et al. 15 studied the ultrasonic velocity of electrolytes of high solubility and showed a decrease in the absorption with increase in concentration. Ultrasonic velocity parameters were used to study interactions in Binary 16- 17 and ternary 18 systems, as well as the ion-solvent and inter ionic interaction in aqueous 19 , mixed aqueous 20 and non aqueous 21 systems.

Bhat and Shiva Kumar 14 studied on acoustic behaviour of potassium thiocyanate in aqueous and various non-aqueous solvents and determined the values of apparent molar compressibility (Φk), apparent molar volume (Φv) and limiting apparent molar compressibility (Φ0k), limiting apparent molar volume (Φ0v) . The ion – ion and ion-solvent interactions have been discussed in terms of these parameters.

The review of literature on acoustical studies of solutions reveal that the ultrasonic velocity data as such do not provide significant information about the native and relative strength of various types of inter molecular and inter- ionic interactions between components. Hence in present study, their derived parameters of non aqueous solutions of mixed electrolytes such as adiabatic compressibility (βad), apparent molar compressibility (Φk), inter molecular free length (Lf), specific acoustic impedance (Z), solvation number (Sn) and relative association constant (RA) have been calculated to give more emphasis on such interactions.

With this aim in view, ultrasonic studies of aqueous solutions of mixed electrolytes have been undertaken in the light of the following aspects:

1. Determination of ultrasonic velocities at a constant frequency of 10 M Hz and a constant temperature 298.15 K, of the following uni-uni valent mixed electrolytes in non aqueous (formamide) mixture : NaBr + NaCl, KBr + KCl, NaBr + NaNO3, KBr + KNO3, CH3COONa + NaNO3 and CH3COOK + KNO3 Determination of the values of various acoustic parameters, viz; Adiabatic Compressibility (βad),

Apparent Molar Compressibility (Φk), Inter Molecular Free Length (Lf), Specific Acoustic Impedance (Z), solvation Number (Sn) and Relative Association Constant (RA).

2. Ascertaining the nature of ion-solvent and ion- ion interactions in terms of acoustic parameters.

II.EXPERIMENTAL

All the chemicals used were of AR grade and were used as such without further purification. The digital electronic balance (Metteler) with accuracy ± 0.1 mg, was used for the mass determination. The ultrasonic velocity measurements were recorded on a multi-frequency ultrasonic interferometer (M-83; Mittal Enterprises, New Delhi) at 298.15 K by using a cell of 10 MHz frequency. . The solutions of electrolytes were prepared in formamide (A. R. Grade)

The various acoustic parameters were determined as below:

$\beta_{ad} = 1 / u^2 \rho$ ------- (1)

$Z = u \cdot \rho$ ------- (2)

$L_f = K (\beta_{ad})^{1/2}$ ------- (3)

$\Phi_k = 1000/ C \cdot \rho_0 (\beta_{ad} \rho_0 - \beta_{0\,ad} \rho) + M \cdot \beta_{0\,ad} / \rho_0$ ------- (4)

$R_A = \rho / \rho_0 \cdot (u_0 / u)^{1/3}$ ------- (5)

$Sn = n_1 / n_2 [1 - \beta_{ad} / \beta_{0\,ad}]$ ------- (6)

In the above relationships, u and ρ are the ultrasonic velocity and density of the solution respectively. ρ, ρ_0 and β_{ad} , $\beta_{0\,ad}$ are the density and adiabatic compressibility of the solution and solvent respectively. M is the molecular weight of the solute and C is the molar concentration of the solution. K is the Jacobson constant (temperature dependent constant), Z is the acoustic impedance, S_n is solvation number , n_1 and n_2 are the no. of moles of solvent and solute respectively.

III. RESULTS AND DISCUSSION

The densities (ρ), ultrasonic velocities (u) and other acoustic parameters of non aqueous solutions of the mixed uni-univalent electrolyte systems (in all the three mixed electrolyte sets : (NaBr + $NaNO_3$, KBr + KNO_3) (CH_3COONa + $NaNO_3$, CH_3COOK + KNO_3) and (KBr + KCl and NaBr + NaCl) anion is common only cation gets changed, have been determined as a function of fraction of ionic strength (y) due to the first electrolyte in the mixture of two electrolytes of constant ionic strength, μ = 1.0 Table 1& 2 shows that the ultrasonic velocity (u) increases with y in the following mixed electrolyte systems: NaBr + $NaNO_3$, KBr + KNO_3 , KBr + KCl and NaBr + NaCl. The increase in ultrasonic velocity (u) with y may be due[17] the structure making properties of the first electrolyte in these mixed systems. CH_3COONa + $NaNO_3$, CH_3COOK + KNO_3, it decreases with y. The increase or decrease in ultrasonic velocity (u) with y may be due[12] the structure making or braking properties of the first electrolyte in these mixed systems.

β_{ad} is a measure of intermolecular association or dissociation. It also determines the orientation of the solvent molecules around the solute molecules. A perusal of Tables 33-50 shows that the adiabatic compressibility β_{ad} of all the uni-univalent electrolyte solutions are found to be less than that of pure formamide which is in agreement with the previous workers[5.] Further, it is seen that the β_{ad} of the mixed systems: KBr + KCl, KBr + KNO_3, decreases with y. However, in case of mixed electrolyte systems: CH_3COONa + $NaNO_3$, NaBr + NaCl, CH_3COOK + KNO_3, and NaBr + $NaNO_3$, β_{ad} increases with y. The decrease or increase in β_{ad} with y may be attributed[4,6]
to the structure making or breaking properties of the first electrolyte in these mixed systems.

Ultrasonic waves are high frequency mechanical waves. Their velocities in medium depend inversely on compressibility of the medium reported by Hykes et al [23] . The rapid decrease of adiabatic compressibility, with increase of first electrolyte concentration, clearly indicates the formation of a large number of tightly bound systems. Since the velocity increases with concentration and the density does so, the compressibility must decrease with increase in concentration. Such reduction in compressibility has been found in the solution due to solute molecules. The decreased compressibility brings the molecules to a closer packing resulting in a decrease of intermolecular free length which is evident from the L_f value.

A perusal of Tables, shows that, at lower concentration of KBr in the mixture of KBr + KCl, KBr + KNO_3 the molecules are not closer and thus inter molecular free length, L_f is high. But as the concentration of KBr in mixed non-aqueous solution increases, the molecules come closer and solvent- solvent interaction will exist, thereby decreasing the L_f and hence internal pressure decreases.

A continuous decrease in βad or L_f is a clear evidence for the existence of strong interactions. Such strong interaction may be due to dipole- dipole, ion - dipole, H-bonding, etc. In other mixed electrolyte system the value of L_f increases with increase in concentration of first electrolyte, which reflect the poor interaction.

A perusal of Tables , shows that the acoustic impedance (Z) increases with y in the mixed electrolyte systems: KBr + KCl, KBr + KNO_3, however in mixed electrolyte systems: CH_3COONa + $NaNO_3$, NaBr + NaCl and CH_3COOK + KNO_3 and NaBr + $NaNO_3$, mixed electrolyte systems the acoustic impedance decreases with y. The increase in the value of acoustic impedance (Z) with y supports [25] the structure making property of the first electrolyte in these mixed electrolyte systems, while decrease in Z with y supports[6] the structure breaking property of the first electrolyte in these mixed systems. which indicates that there is a significant interaction between ion- ion and ion- solvent molecules which considerably affect the structural arrangement. The increase in the values of specific acoustic impedance, Z with increasing KBr concentration, can be explained on the basis of lyophilic interaction between the solute – solute and solute- solvent molecules, which increases the intermolecular distance, making relatively wider gaps between the molecules and becoming the main cause of impedance in the propagation of ultrasonic waves. Mehrotra [26,27],

A perusal of Tables shows that in the mixed electrolyte systems: CH_3COONa + $NaNO_3$, CH_3COOK + KNO_3 the relative association constant (R_A) decreases with y (at ionic strength μ = 1.0), signifies[6] a decrease in the solvation of the first electrolyte in these mixed systems. However, in the mixed systems: NaBr + $NaNO_3$, KBr + KCl, KBr + KNO_3, NaBr + NaCl, it is seen that relative association constant (R_A) increases with y which signifies[6] an increase in solvation of the first electrolyte in these mixed systems.

The apparent molar compressibility (Φk) has been calculated from ultrasonic velocity (u) and density (ρ) data (at ionic strength Φ=1.0 and 2.0). For a single electrolyte system the concentration-dependence of the apparent molar compressibility (Φk) is given by the following relation[28]

$$\Phi_k = \Phi^0{}_k + S_{k\,.}\, y$$

A perusal of this Table shows that the values of ϕ□ are negative in mixed systems: NaBr + $NaNO_3$, CH_3COONa + $NaNO_3$, NaBr + NaCl, KBr + KNO_3, CH_3COOK + KNO_3, and which signify 7, 29 the loss of compressibility of the surrounding formamide molecules due to strong electrostrictive forces in the vicinity of ions of mixed electrolyte systems causing electrostrictive solvation of the electrolytes. However in the mixed systems: KBr + KCl, the values of ϕ_k are found to be positive. (NaBr + $NaNO_3$, KBr + KNO_3) (CH_3COONa + $NaNO_3$, CH_3COOK + KNO_3) and (KBr + KCl and NaBr + NaCl)

The solvation number, S_n has been calculated as a function of y (at the ionic strength μ=1.0) and the values of S_n have been presented in Tables 33-50. It is seen that in the mixed systems: KBr + KCl and KBr + KNO_3 the values of S_n increases with y which indicate[8] the decrease in ion-ion interactions. However in the mixed systems: CH_3COONa + $NaNO_3$, NaBr + NaCl, CH_3COOK + KNO_3 and NaBr + $NaNO_3$ decrease in the values of S_n with y signify[8] the increase in ion-ion interactions. A perusal of Table shows that for all the mixed electrolyte systems containing K^+ & Na^+ the values of Sn, lies between 0-3. These results are supported by the values of S_n reported in literature[21]. Further the values of Sn increases with increase in the concentration of KBr in KBr + KCl, KBr + KNO_3.

CONCLUSION

A survey of authors` scientific investigations in the field ultrasound velocity measurements in electrolyte solutions and various liquid systems is presented.

Out of all electrolytic combinations KBr + KNO_3 and KBr +KCl is showing different behaviour. Hence KBr is playing key role in changing the physical properties of mixture solution, Various acoustic parameters; viz. specific acoustic impedance, Z, apparent molal compressibility, Φ_k and solvation number, Sn increase, while adiabatic compressibility, β_{ad} inter-molecular free-length, L_f and relative association number , R_A decreases with increase in concentration of KBr, irrespective of the total concentration of the solution and the second electrolyte taken in the mixed electrolyte system.

At any given concentration, the different acoustic parameters increases or decreases, this indicates the structure promoting nature of K^+ and Na^+ is balanced and subdued by the presence of different anions consistent with the behavior of anion disrupting the hydrogen bonded structure of formamide.

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Table: Densities(ρ), ultrasonic velocities (u) and other acoustic parameters of mixed electrolyte systems in formamide solution as a function of the fraction of ionic strength(y) due to the first electrolyte in the mixture of two electrolytes at constant ionic strength, μ= 1.0 at temperature 298.15 K

NaBr + NaNO3 MIXED ELECTROLYTE SYSTEM

S.NO.	Mixed	ρ	u 10^{-5}	$\beta_{ad}10^{12}$	Z 10^{-4}	L_f	$\phi_k\ 10^{11}$	R_A	S_n
	Electrolyte	gm c.c^{-1}	cm sec^{-1}	cm^2 dyne^{-1}	gm.cm^{-2}sec^{-1}	Å	cm^{2}mol^{-1}		
1	0 .0 + 1.0	1.1849	1.6460	31.15	19.50	0.3488	-184.73	1.04	2.06
2	0.05 + 0.95	1.1854	1.6440	31.21	19.49	0.3492	-177.56	1.04	2.02
3	0.1 + 0.9	1.1860	1.6420	31.27	19.47	0.3495	-170.66	1.04	1.97
4	0.2 + 0.8	1.1870	1.6360	31.48	19.42	0.3506	-147.29	1.04	1.82
5	0.25 + 0.75	1.1875	1.6336	31.56	19.40	0.3511	-138.09	1.04	1.76
6	0.3 + 0.7	1.1903	1.6244	31.84	19.34	0.3527	-105.08	1.05	1.56
7	0.5 + 0.5	1.1924	1.6180	32.03	19.29	0.3537	-81.64	1.05	1.42
8	0.75 + 0.25	1.1929	1.6120	32.26	19.23	0.3550	-57.44	1.05	1.26
9	0.8 + 0.2	1.1935	1.6108	32.29	19.22	0.3552	-53.57	1.05	1.24
10	0.9 + 0.1	1.1945	1.6088	32.35	19.22	0.3555	-45.2	1.05	1.19
11	0.95 + 0.05	1.1950	1.6080	32.36	19.22	0.3556	-43	1.05	1.19
12	1.0 + 0.0	1.1956	1.6064	32.41	19.21	0.3558	-37.13	1.06	1.15
13	Pure Solvent	1.134	1.6100	34.02	-------	-------	-------	-------	-------

KBr + KNO_3 MIXED ELECTROLYTE SYSTEM

S.NO.	Mixed	ρ	u 10^{-5}	$\beta_{ad}10^{12}$	Z 10^{-4}	L_f	$\phi_k\,10^{11}$	R_A	S_n
	Electrolyte	gm $c.c^{-1}$	cm sec^{-1}	$cm^2\,dyne^{-1}$	$gm.cm^{-2}sec^{-1}$	Å	cm^2mol^{-1}		
1	0 .0 + 1.0	1.1871	1.6296	31.72	19.35	0.3520	-86.00	1.04	1.63
2	0.05 + 0.95	1.1882	1.6288	31.72	19.35	0.3520	-86.60	1.04	1.63
3	0.1 + 0.9	1.1893	1.6285	31.71	19.37	0.3519	-88.23	1.04	1.64
4	0.2 + 0.8	1.1916	1.6270	31.70	19.39	0.3519	-90.76	1.05	1.65
5	0.25 + 0.75	1.1928	1.6263	31.70	19.40	0.3519	-91.66	1.05	1.65
6	0.3 + 0.7	1.1939	1.6255	31.70	19.41	0.3519	-92.29	1.05	1.65
7	0.5 + 0.5	1.1985	1.6225	31.70	19.45	0.3519	-95.35	1.05	1.65
8	0.75 + 0.25	1.2048	1.6195	31.65	19.51	0.3516	-105.81	1.06	1.69
9	0.8 + 0.2	1.2054	1.6188	31.66	19.51	0.3517	-103.94	1.06	1.68
10	0.9 + 0.1	1.2077	1.6173	31.66	19.53	0.3516	-105.47	1.06	1.68
11	0.95 + 0.05	1.2086	1.6165	31.66	19.54	0.3517	-105.47	1.06	1.68
12	1.0 + 0.0	1.2097	1.6176	31.59	19.57	0.3513	-113.10	1.07	1.73
13	Pure Solvent	1.134	1.6100	34.02	----------	-----	---------	---------	------

NaBr + NaCl MIXED ELECTROLYTE SYSTEM

S.NO.	Mixed	ρ	u 10^{-5}	$\beta_{ad}10^{12}$	Z 10^{-4}	L_f	$\phi_k\,10^{11}$	R_A	S_n
	Electrolyte	gm $c.c^{-1}$	cm sec^{-1}	$cm^2\,dyne^{-1}$	$gm.cm^{-2}sec^{-1}$	Å	cm^2mol^{-1}		
1	0 .0 + 1.0	1.1657	1.6776	30.48	19.56	0.3451	-273.60	1.01	2.56
2	0.05 + 0.95	1.1672	1.6712	30.68	19.51	0.3462	-251.44	1.02	2.41
3	0.1 + 0.9	1.1687	1.6708	30.65	19.53	0.3460	-252.28	1.02	2.43
4	0.2 + 0.8	1.1717	1.6637	30.83	19.49	0.3471	-229.96	1.02	2.30
5	0.25 + 0.75	1.1732	1.6566	31.06	19.44	0.3483	-204.80	1.02	2.13
6	0.3 + 0.7	1.1747	1.6564	31.03	19.46	0.3481	-205.64	1.03	2.15
7	0.5 + 0.5	1.1807	1.6424	31.40	19.39	0.3502	-160.00	1.03	1.88
8	0.75 + 0.25	1.1881	1.6208	32.04	19.26	0.3538	-84.93	1.05	1.42
9	0.8 + 0.2	1.1896	1.6136	32.29	19.20	0.3551	-57.77	1.05	1.24
10	0.9 + 0.1	1.1926	1.6132	32.22	19.24	0.3548	-60.45	1.05	1.29
11	0.95 + 0.05	1.1941	1.6065	32.45	19.18	0.3560	-35.20	1.05	1.12
12	1.0 + 0.0	1.1956	1.6064	32.41	19.21	0.3558	-37.13	1.06	1.15
13	Pure Solvent	1.134	1.6100	34.02	----------	----- ----	---------	-------	---- ---

KBr + KCl MIXED ELECTROLYTE SYSTEM

S.NO.	Mixed	ρ	u 10^{-5}	$\beta_{ad}10^{12}$	Z 10^{-4}	L_f	$\phi_k\,10^{11}$	R_A	S_n
	Electrolyte	gm $c.c^{-1}$	cm sec^{-1}	$cm^2\,dyne^{-1}$	$gm.cm^{-2}sec^{-1}$	Å	cm^2mol^{-1}		
1	0 .0 + 1.0	1.1741	1.5920	33.61	18.69	0.3623	62.38	1.04	0.29
2	0.05 + 0.95	1.1758	1.5930	33.51	18.73	0.3618	53.94	1.04	0.37
3	0.1 + 0.9	1.1776	1.5945	33.40	18.78	0.3612	44.20	1.04	0.44
4	0.2 + 0.8	1.1812	1.5972	33.19	18.87	0.3600	25.75	1.04	0.60
5	0.25 + 0.75	1.1830	1.5990	33.06	18.92	0.3594	14.01	1.05	0.69
6	0.3 + 0.7	1.1848	1.5999	32.97	18.96	0.3589	6.27	1.05	0.75
7	0.5 + 0.5	1.1920	1.6050	32.57	19.13	0.3567	-28.66	1.05	1.04
8	0.75 + 0.25	1.2010	1.6110	32.08	19.35	0.3540	-71.33	1.06	1.39
9	0.8 + 0.2	1.2028	1.6125	31.97	19.40	0.3534	-81.07	1.06	1.46
10	0.9 + 0.1	1.2064	1.6155	31.76	19.49	0.3522	-99.52	1.06	1.61
11	0.95 + 0.05	1.2082	1.6172	31.65	19.54	0.3516	-109.26	1.06	1.69
12	1.0 + 0.0	1.2097	1.6176	31.59	19.57	0.3513	-113.10	1.07	1.73
13	Pure Solvent	1.134	1.6100	34.02	------ ----	----- ---	-------- -	----- ---	--- ---

$CH_3COONa + NaNO_3$ MIXED ELECTROLYTE SYSTEM

S.NO.	Mixed	ρ	u 10^{-5}	$\beta_{ad} 10^{12}$	Z 10^{-4}	L_f	$\phi_k 10^{11}$	R_A	S_n
	Electrolyte	gm $c.c^{-1}$	cm sec^{-1}	cm^2 $dyne^{-1}$	$gm.cm^{-2} sec^{-1}$	Å	$cm^2 mol^{-1}$		
1	0 .0 + 1.0	1.1849	1.6460	31.15	19.50	0.3488	-184.73	1.04	2.06
2	0.05 + 0.95	1.1834	1.6440	31.27	19.46	0.3495	-160.58	1.04	1.97
3	0.1 + 0.9	1.1818	1.6428	31.35	19.41	0.3500	-140.10	1.04	1.90
4	0.2 + 0.8	1.1788	1.6400	31.54	19.33	0.3510	-96.77	1.03	1.76
5	0.25 + 0.75	1.1773	1.6382	31.65	19.29	0.3516	-73.62	1.03	1.67
6	0.3 + 0.7	1.1752	1.6368	31.76	19.24	0.3522	-48.64	1.03	1.59
7	0.5 + 0.5	1.1700	1.6300	32.17	19.07	0.3545	38.62	1.03	1.28
8	0.75 + 0.25	1.1619	1.6220	32.71	18.85	0.3575	155.23	1.02	0.89
9	0.8 + 0.2	1.1603	1.6216	32.77	18.82	0.3578	173.68	1.02	0.84
10	0.9 + 0.1	1.1573	1.6180	33.01	18.73	0.3591	222.01	1.02	0.68
11	0.95 + 0.05	1.1558	1.6160	33.13	18.68	0.3597	246.19	1.02	0.59
12	1.0 + 0.0	1.1542	1.6152	33.21	18.64	0.3602	266.64	1.02	0.54
13	Pure Solvent	1.134	1.6100	34.02	------	-----	---------	---------	----

$CH_3COOK + KNO_3$ MIXED ELECTROLYTE SYSTE

S.NO.	Mixed	ρ	u 10^{-5}	$\beta_{ad} 10^{12}$	Z 10^{-4}	L_f	$\phi_k 10^{11}$	R_A	S_N
	Electrolyte	gm $c.c^{-1}$	cm sec^{-1}	cm^2 $dyne^{-1}$	$gm.cm^{-2} sec^{-1}$	Å	$cm^2 mol^{-1}$		
1	0 .0 + 1.0	1.1871	1.6296	31.72	19.35	0.3520	-86.00	1.04	1.63
2	0.05 + 0.95	1.1858	1.6293	31.77	19.32	0.3523	-77.55	1.04	1.59
3	0.1 + 0.9	1.1846	1.6285	31.83	19.29	0.3526	-68.40	1.04	1.55
4	0.2 + 0.8	1.1822	1.6272	31.95	19.24	0.3533	-50.07	1.04	1.46
5	0.25 + 0.75	1.1813	1.6266	31.99	19.22	0.3535	-43.82	1.04	1.43
6	0.3 + 0.7	1.1801	1.6258	32.06	19.19	0.3539	-33.67	1.04	1.38
7	0.5 + 0.5	1.1755	1.6237	32.27	19.09	0.3550	-0.64	1.03	1.23
8	0.75 + 0.25	1.1695	1.6202	32.57	18.95	0.3567	45.14	1.03	1.01
9	0.8 + 0.2	1.1683	1.6188	32.66	18.91	0.3572	57.29	1.03	0.95
10	0.9 + 0.1	1.1659	1.6174	32.79	18.86	0.3579	76.62	1.03	0.86
11	0.95 + 0.05	1.1647	1.6167	32.85	18.83	0.3582	85.77	1.03	0.82
12	1.0 + 0.0	1.1637	1.6160	32.91	18.81	0.3585	94.32	1.02	0.77
13	Pure Solvent	1.134	1.6100	34.02	----------	-----	---------	-------	---

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