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Calculating Relative Sound Velocities of Sea Salts by A New Method

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Relative sound velocity ($U-U_0$) of several solutions were measured from 0.01 to 1.0 at 25 °C. The sound velocities were fitted to a function of molality (maximum standard deviation 0.05 m/s) $U = U_0 + Am + Bm^{3/2} + Cm^2$, where U_0 is the sound velocity in pure water, U = sound speed in given solution, m = molality and A, B and C = temperature dependent parameters. The sound speed of sea water calculated with the direct measurement.

Key Words: Sound velocities, Sea salts.

INTRODUCTION

Although the sound velocity of various electrolytes have been measured by several workers[1,2]. Few studies have been made on the sea salts at low concentrations (< 1 molal)[3,4]. The speed of sound in electrolyte solutions can be very useful for various thermodynamic calculations. In addition, the sound velocity of sea water can be estimated from the additive contributions of the various sea salt components[1-3]. We observed useful results from different equations of sound velocity in sea water, but none of them has the reasonable accuracy. Determination of sound velocity could be useful in telecommunication, topography of bottom, hydrography, military, *etc*. The present paper contains the relative sound velocity at 25 °C of 28 aqueous electrolytes solutions ranging from 0.1 to 1.0 molal[3-5].

EXPERIMENTAL

Sea water consists of various complexes with different densities and sizes. The most important factors which can alter the speed of sound are water molecules and suspended particles in it. Sound velocity in sea water is one of the most important parameters which is needed in most research activities.

At the first step we studied the concentration of various sea salt components present in sea water. Each of these salts may alter the sound velocity in a low extent comparing with that in pure water. The sound velocity measurements were made at 2 MHz. The sound velocimeter was used to measure the relative sound velocities ($U-U_0$), where U is the speed of sound in the solution and U_0 is the speed of sound in pure water. The velocimeter was calibrated by using the sound speed of water determined by Del Grosso and Mader (1496.69 m/s at 25 °C)[6]. Accuracy of this equipment, is between ± 0.002 to ± 0.17 m/s. The temperature was set to 25.000 ± 0.002 °C with a platinum resistance thermometer. Sound velocimeter sends a sonic pulse and 4 cm away from it, will be sensed by a receiver. Since, the sound travel distance is known and also by measuring the time for the sound to pass through this distance, using v = x/t formula, sound velocity can be measured.

The salts were dried in a vacuum oven and the solutions were made by weight stock solutions of the hydrated salts were analyzed by gravimetric techniques, atomic absorption and density.

RESULTS AND DISCUSSION

By plotting the $U-U_0/m$ against $m^{1/2}$ (where U_0 is the sound velocity in pure water, U sound speed in given solution and m is molality) for the various sea salt and determination of $U-U_0$, we can calculate the relative sound velocity in sea water. The relative sound velocities at various molalities (m), can be written as follows:

$$U = U_0 + Am + Bm^{3/2} + Cm^2 \quad (1)$$

where A, B, C are temperature dependent parameters. When molality of salt is determined for a given solution, these solutions are prepared in the laboratory and by using sound velocimeter we can measure sound speed in those solutions. Sound velocity in following sea salt solutions comparing with pure water in 25 °C from 0.1 to 1 molal are calculated.

HCl, LiCl, NaF, NaCl, NaBr, NaI, $NaNO_3$, NaOH, $NaHCO_3$, Na_2CO_3, Na_2SO_4, KF, KCl, KBr, KI, KNO_3, $KHCO_3$, K_2CO_3, K_2SO_4, RbCl, CsCl, NH_4Cl, NH_4Br, $MgCl_2$, $CaCl_2$, $SrCl_2$, $BaCl_2$, $MgSO_4$. The results are as per Table-1.

Until now, all of the equations are useful in a specific area with constant contents which can not be used for all other solutions and they are limited to a specific area. For example, Medvin equation is used in temperature from 0 °C up to 35 °C, 0 to 45 ppt of salinity and 0 to 1000 m in depth, which does not give an accurate result if the temperature goes beyond the specified limit[7-10].

In order to calculate the sound speed in a solution consisting of different concentrations of salts, like sea water, we have to calculate the concentration of salt in that specific solution first. Then, a sample of the solution with a constant molality should be prepared in laboratory. The sound velocimeter gives the relative sound velocity for that solution.

Relative sound speed for 28 types of salts (sea water mostly consists of 6 types of KCl, $MgCl_2$, $MgSO_4$, K_2SO_4, Na_2SO_4, NaCl) with different molalities are given in Table-1. Using plotting softwares, one can plot the $U-U_0/m$ diagram against $m^{1/2}$ for each type of salt and then using linear or parabolic equations (it is linear for all salts, except: NaI, Na_2CO_3, Na_2SO_4, KI, K_2CO_3, NH_4Br, $BaCl_2$, $MgSO_4$), we can observe coefficient A, B for linear and C for parabolic equations. Table-2 and Fig. 1 show the results. Maximum standard deviation is 0.05 m/s and can be used at 25 °C for aqueous electrolytes solutions from 0.1 to 1.0 molal.

TABLE-1
RELATIVE SOUND VELOCITY VALUES IN SOLUTIONS
WITH DIFFERENT MOLALITIES

m	$U–U_0$	m	$U–U_0$	m	$U–U_0$	m	$U–U_0$
$MgSO_4$		**$CaCl_2$**		**RbCl**		**$KHCO_3$**	
0.05389	7.20	0.01006	0.97	0.199081	4.48	0.09806	7.34
0.08403	11.04	0.05039	4.93	0.299860	6.67	0.20005	14.61
0.10241	13.35	0.10014	9.64	0.400140	8.66	0.29836	21.41
0.11655	15.09	0.20012	18.98	0.499909	10.59	0.40001	28.17
0.18044	22.92	0.29995	28.07	0.599758	12.59	0.49975	34.66
0.23730	29.81	0.39922	37.00	0.798508	16.32	0.69927	47.17
0.30775	38.35	0.49986	45.84	0.996517	19.94	0.80015	53.34
0.47929	59.17	**NaCl**		**K_2CO_3**		0.99247	64.60
0.48764	60.16	0.01011	0.65	0.30004	45.60	**KNO_3**	
0.69876	86.20	0.05002	3.20	0.39988	60.29	0.010347	0.31
0.91591	113.66	0.10039	6.38	0.49976	74.92	0.100904	3.49
1.00112	124.64	0.20009	12.54	0.59989	89.47	0.201495	6.86
KCl		0.29972	18.65	0.69969	103.96	0.300997	10.12
0.09974	5.47	0.40009	24.76	0.79944	118.50	0.39972	13.30
0.1991	10.71	0.49946	30.75	0.89994	133.08	0.498781	16.38
0.30304	16.14	0.59971	36.77	**Na_2SO_4**		0.599216	19.49
0.40037	21	0.69917	42.61	0.09962	15.91	0.69984	22.56
0.50389	26.1	0.79957	48.54	0.19836	30.97	0.798286	25.56
0.61488	31.5	0.90125	54.44	0.30040	45.85	0.898592	28.54
0.72503	36.86	1.0001	60.21	0.39961	60.16	0.999685	31.52
0.82477	41.57	**CsCl**		0.50013	74.28	**Na_2CO_3**	
0.92801	46.34	0.099966	-0.8	0.56504	83.38	0.2001	32.20
1.00491	49.9	0.299901	-2.47	0.69926	102.04	0.29998	47.60
NaBr		0.399651	-3.39	0.79944	115.77	0.39969	62.74
0.10079	2.73	0.499096	-4.17	0.89984	129.58	0.49927	77.75
0.20023	5.41	0.599079	-5.14	1.00034	143.01	0.59974	92.80
0.29966	8.06	0.699529	-5.95	**$NaNO_3$**		0.69957	107.65
0.39954	10.72	**NaI**		0.051760	2.26	0.79952	122.47
0.49932	13.37	0.100677	-0.71	0.101107	4.41	0.89963	137.36
0.59956	16.03	0.200029	-1.43	0.200333	8.68	**$NaHCO_3$**	
0.69869	18.65	0.300304	-2.06	0.298821	12.81	0.10029	9.26
NaF		0.399862	-2.59	0.400891	17.08	0.19854	18.04
0.10084	8.87	0.499648	-3.06	0.498377	21.20	0.29909	26.80
0.20120	17.56	0.599737	-3.41	0.598955	25.40	0.39916	35.41
0.29634	25.68	0.698274	-3.65	0.699736	29.59	0.60053	52.37
0.49991	42.83	0.799093	-3.88	0.798943	33.67	0.69427	60.02
0.59012	50.29	0.899269	-4.08	0.896968	37.64	0.79985	68.57
0.70804	60.03	0.994570	-4.14	1.000043	41.88	**NaOH**	
0.79744	67.37	**$MgCl_2$**		**NH_4Br**		0.100181	9.86
KI		0.048375	5032	0.100414	1.06	0.200333	19.60
0.048926	-0.83	0.095954	10.50	0.299540	2.76	0.300243	29.24
0.200165	-3.16	0.191064	20.80	0.399200	3.53	0.400185	38.78

m	$U–U_0$	m	$U–U_0$	m	$U–U_0$	m	$U–U_0$
0.300091	-4.63	0.28316	30.56	0.499063	4.30	0.49942	48.29
0.399180	-6.06	0.46068	49.43	0.598980	5.03	0.599544	57.72
0.499213	-7.36	0.54762	58.44	0.699660	5.76	0.70006	67.24
0.599512	-8.63	0.63237	67.19	0.799330	6.53	0.800065	76.77
0.699251	-9.80	0.71535	75.85	0.898912	7.22	0.900243	85.93
0.799754	-10.84	0.796266	84.09	0.999310	7.94	**LiCl**	
0.894038	-11.88	0.971316	102.02	**HCl**		0.10782	5.91
0.999171	-12.99	**KBr**		0.051517	0.68	0.21689	11.74
NH_4Cl		0.10162	1.87	0.100150	1.30	0.32518	17.40
0.20027	9.00	0.20111	3.65	0.199890	2.57	0.43406	23.02
0.40722	17.63	0.30093	5.39	0.300180	3.79	0.65179	34.04
0.49999	21.40	0.40087	7.11	0.400250	4.94	0.76073	39.44
0.59872	25.34	0.49930	8.78	0.613159	7.48	0.87037	44.86
0.69941	29.20	0.59868	10.44	0.697270	8.36	0.97888	50.16
0.79957	33.10	0.69913	12.11	0.799170	9.54	1.08789	55.42
0.89964	36.83	0.79956	13.73	0.900260	10.65		
1.00084	40.48	0.89170	15.35	1.276120	14.70		
$SrCl_2$		0.99952	16.96	**$CaCl_2$**			
0.20015	17.61	**K_2SO_4**		0.60027	54.57		
0.29983	26.21	0.09954	13.74	0.70010	63.08		
0.40021	34.77	0.20022	26.83	0.79980	71.46		
0.49956	43.19	0.29965	39.22	0.89932	79.71		
0.59995	51.59	0.40000	51.33	0.98390	86.64		
0.69902	59.90	0.50094	63.17				
0.79999	68.30						
0.89963	76.58						
0.99622	84.42						

TABLE-2

CONSTANTS OF FORMULA 1 FOR DIFFERENT TYPES OF SALTS

Salt	A	B	C	SD (m/s)
HCl	13.6209	-1.8815	0	0.02
LiCl	56.6270	-5.4529	0	0.01
NaF	89.9770	-6.1463	0	0.02
NaCl	64.8880	-4.6992	0	0.02
NaBr	27.3440	-0.7905	0	0.01
NaI	-6.5510	-3.9550	6.4582	0.04
$NaNO_3$	44.2880	-2.4383	0	0.03
NaOH	99.8570	-4.5432	0	0.05
$NaHCO_3$	93.1330	-1.1084	0	0.03
Na_2CO_3	174.5500	-37.1010	14.8040	0.02
Na_2SO_4	171.9800	-42.5910	13.6350	0.05
KF	74.7901	-6.1670	0	0.04
KCl	57.2490	-7.5761	0	0.03
KBr	19.0480	-2.0523	0	0.01

Salt	A	B	C	SD (m/s)
KI	-17.6580	3.1011	1.5632	0.03
KNO_3	32.9550	-4.6567	0	0.03
$KHCO_3$	79.4490	-14.3240	0	0.03
K_2CO_3	164.1600	-29.1420	12.6330	0.02
K_2SO_4	147.6400	-30.4930	0	0.02
RbCl	24.6430	-4.6973	0	0.04
CsCl	-7.6896	-1.0555	0	0.04
NH_4Cl	48.4590	-7.9706	0	0.03
NH_4Br	13.0710	-9.3162	4.2238	0.02
$MgCl_2$	111.5166	-6.5402	0	0.05
$CaCl_2$	101.0900	-13.1330	0	0.03
$SrCl_2$	90.5800	-5.8298	0	0.03
$BaCl_2$	60.7841	-11.0149	5.8371	0.03
$MgSO_4$	147.2417	-73.2317	68.2371	0.06

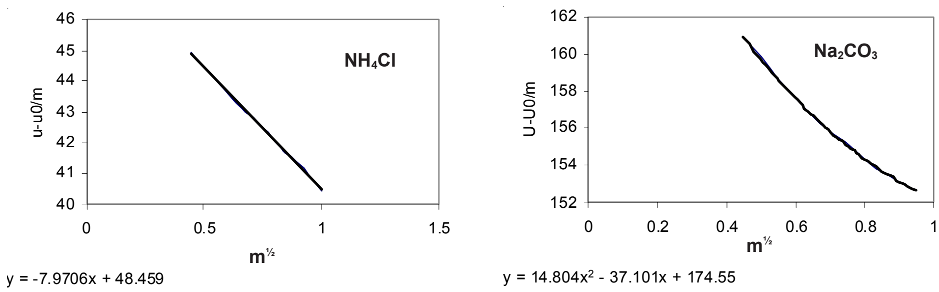

Fig. 1. Relative sound speeds divided by m for Na_2CO_3 and NH_4Cl solutions at 25 °C plotted *versus* $m^{1/2}$

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