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Apparent Molar Volumes of Succinimide in Water and in the Presence of Electrolytes and non-electrolytes at 283.15, 293.15, 303.15, 313.15 and 323.15 K

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Abstract—*Apparent molar volumes(V_ϕ) of succinimide have been determined in water as a function of molality (m) in the presence of electrolytes (such as NaCl, $NaNO_3$, Na_2SO_4, KCl, KI, $BaCl_2$, $SrCl_2$) and non-electrolytes (such as D(+)-Glucose, D(-)-Fructose, Sucrose and Urea) at different temperatures (283.15, 293.15, 303.15, 313.15 and 323.15 K). The limiting apparent molar volumes (V_ϕ^0) and experimental slope (S_v) have been obtained in each case. The partial molar volumes (V_2^0) have been used to calculate the partial molar volumes of transfer (ΔV_ϕ^0) of succinimide from water to aqueous solutions of electrolytes and non-electrolytes at different temperatures. The values of limiting apparent molar expansibilities (ϕ_E^0) and that of $(\partial^2 V_\phi^0 / \partial T^2)_P$ have been determined from the temperature-dependence of V_ϕ^0. The results of the studies show that succinimide behaves as a structure breaker in water while it behaves as a structure maker in aqueous solutions of electrolytes and non-electrolytes.*

Keywords: *Apparent molar volumes, partial molar volumes of transfer, succinimide, aqueous solutions of electrolytes and non-electrolytes.*

1. INTRODUCTION

Shahidi and co-workers[1] have reported partial molar volumes of malonamide, succinamide, N,N-dimethyl formamide, N,N-dimethyl acetamide in water at 25^0C and the results of their studies show that the experimental values compare fairly well with calculated values obtained from the theoretical relationship[2]. A survey of literature shows that volumetric studies relating to the solute-solvent and solute-solute interactions in aqueous solutions of succinimide in the presence of electrolytes and non-electrolytes at different temperatures are still lacking. With this aim in view the title study has been undertaken.

2. RESULTS AND DISCUSSION

The apparent molar volumes (V_ϕ) of succinimide in water and in aqueous solutions of electrolytes and non-electrolytes of varying molality (m_s) have been determined from the density data, as a function of molality (m) of the solutions of the acids at different temperatures using Eq. (1).

$$V_\phi = \frac{1000(\rho_0 - \rho)}{m\rho\rho_0} + \frac{M}{\rho} \qquad \ldots(1)$$

where M is the molecular weight of solute (succinimide), m is the molality of the solution, ρ and ρ_0 are the densities of solution and solvent respectively. The representative data are presented in Table 1.

Table 1. Densities(ρ) and apparent molar volumes(V_ϕ) of Succinimide as a function of molality(m) in purely aqueous medium and in aqueous solutions D(+) glucose at different temperatures

	283.15 K		293.15K		303.15K		313.15K		323.15K	
m	$10^{-3}.\rho$	$10^6 \cdot V_\phi$	$10^{-3}.\rho$	$10^6 \cdot V_\phi$	$10^{-3}.\rho$	$10^6 \cdot V_\phi$	$10^{-3}.\rho$	$10^6 \cdot V_\phi$	$10^{-3}.\rho$	$10^6 \cdot V_\phi$
(mol.kg^{-1})	(kg. m^{-3})	(m^3.mol^{-1})	(kg. m^{-3})	(m^3.mol^{-1})	(kg. m^{-3})	(m^3.mol^{-1})	(kg. m^{-3})	(m^3.mol^{-1})	(kg. m^{-3})	(m^3.mol^{-1})
D(+)-Glucose										
ms =0.0mol.kg^{-1}										

0.0000	0.99823	---	0.99568	---	0.99224	---	0.98807	---	0.99224	---
0.4120	1.01055	71.98	1.00879	72.82	1.00588	73.91	1.00212	74.97	0.99773	75.84
0.6273	1.01594	72.05	1.01403	72.88	1.01093	73.99	1.00702	75.04	1.00252	75.91
0.8492	1.02129	72.13	1.01922	72.98	1.01593	74.10	1.01187	75.13	1.00727	76.00
1.0781	1.02661	72.20	1.02436	73.09	1.02094	74.15	1.01670	75.21	1.01201	76.06
1.3143	1.03192	72.26	1.02945	73.20	1.02588	74.24	1.02151	75.28	1.01671	76.13
1.5583	1.03714	72.37	1.03455	73.28	1.03089	74.26	1.02632	75.33	1.02139	76.20
1.8105	1.04226	72.51	1.03964	73.34	1.03579	74.34	1.03110	75.39	1.02605	76.26
2.0712	1.04742	72.60	1.04476	73.37	1.04061	74.45	1.03579	75.48	1.03071	76.31
2.3411	1.05248	72.72	1.04973	73.47	1.04538	74.56	1.04045	75.57	1.03531	76.38
				ms =0.5297 mol.kg^{-1}						
0.0000	1.04086	---	1.03895	---	1.03600	---	1.03236	---	1.02794	---
0.3984	1.04377	72.37	1.04158	73.36	1.03831	74.45	1.03438	75.56	1.02968	76.64
0.6066	1.04854	72.50	1.04619	73.46	1.04274	74.54	1.03865	75.63	1.03382	76.68
0.8213	1.05331	72.56	1.05077	73.55	1.04717	74.60	1.04290	75.69	1.03792	76.74
1.0428	1.05802	72.66	1.05533	73.62	1.05159	74.64	1.04712	75.76	1.04201	76.80
1.2716	1.06258	72.85	1.05987	73.68	1.05596	74.70	1.05132	75.82	1.04601	76.90
1.5078	1.06724	72.91	1.06433	73.78	1.06030	74.77	1.05554	75.85	1.05007	76.94
1.7518	1.07186	72.98	1.06877	73.87	1.06468	74.80	1.05959	75.98	1.05417	76.94
2.0043	1.07642	73.07	1.07328	73.90	1.06880	74.96	1.06371	76.04	1.05797	77.10
2.2658	1.08086	73.20	1.07764	74.00	1.07292	75.09	1.06774	76.13	1.06184	77.20
				ms =1.1267 mol.kg^{-1}						
0.0000	1.02040	---	1.01870	---	1.01594	---	1.01242	---	1.00809	---
0.3859	1.07619	73.01	1.07363	74.13	1.07011	75.14	1.06606	76.10	1.06118	77.16
0.5877	1.08032	73.15	1.07757	74.25	1.07392	75.20	1.06973	76.15	1.06469	77.22
0.7959	1.08442	73.27	1.08146	74.37	1.07766	75.32	1.07338	76.21	1.06811	77.37
1.0107	1.08849	73.36	1.08531	74.48	1.08139	75.40	1.07690	76.36	1.07153	77.45
1.2325	1.09254	73.44	1.08918	74.54	1.08499	75.55	1.08030	76.56	1.07491	77.54
1.4619	1.09641	73.62	1.09303	74.60	1.08864	75.63	1.08386	76.59	1.07829	77.60
1.6991	1.10022	73.79	1.09671	74.74	1.09203	75.84	1.08738	76.64	1.08156	77.71
1.9445	1.10403	73.92	1.10015	74.97	1.09564	75.89	1.09074	76.76	1.08490	77.76
2.1989	1.10772	74.08	1.10368	75.12	1.09914	75.98	1.09405	76.88	1.08812	77.86
				ms=1.8108 mol.kg^{-1}						
0.0000	1.06106	---	1.05898	---	1.05583	---	1.05213	---	1.04757	---
0.3751	1.10596	73.50	1.10571	74.60	1.10124	75.68	1.09678	76.70	1.09215	77.63
0.5714	1.10956	73.61	1.10905	74.72	1.10442	75.79	1.09980	76.81	1.09509	77.66
0.7738	1.11309	73.73	1.11240	74.77	1.10756	75.88	1.10278	76.90	1.09781	77.92
0.9828	1.11662	73.81	1.11569	74.86	1.11068	75.96	1.10580	76.92	1.10052	78.08
1.1987	1.12000	73.98	1.11895	74.94	1.11375	76.05	1.10865	77.07	1.10322	78.20
1.4219	1.12335	74.12	1.12199	75.14	1.11679	76.13	1.11153	77.15	1.10593	78.28
1.6527	1.12663	74.26	1.12524	75.17	1.11954	76.36	1.11428	77.29	1.10858	78.37
1.8917	1.12990	74.38	1.12826	75.31	1.12252	76.42	1.11706	77.38	1.11128	78.42
2.1395	1.13300	74.55	1.13109	75.51	1.12547	76.48	1.11963	77.55	1.11387	78.51
				ms =2.5940 mol.kg^{-1}						
0.0000	1.09862	---	1.09886	---	1.09475	---	1.09060	---	1.08625	---
0.3644	1.13748	73.97	1.13727	74.96	1.13232	76.00	1.12755	77.11	1.12266	78.09
0.5550	1.14051	74.04	1.14007	75.03	1.13491	76.14	1.12993	77.29	1.12497	78.17
0.7518	1.14341	74.23	1.14281	75.14	1.13744	76.29	1.13238	77.31	1.12720	78.29
0.9549	1.14634	74.31	1.14551	75.24	1.13998	76.36	1.13474	77.40	1.12946	78.34
1.1647	1.14922	74.40	1.14808	75.40	1.14239	76.51	1.13699	77.54	1.13164	78.43
1.3817	1.15198	74.54	1.15065	75.52	1.14482	76.60	1.13931	77.60	1.13383	78.49
1.6061	1.15477	74.63	1.15323	75.60	1.14730	76.64	1.14142	77.76	1.13579	78.66
1.8386	1.15736	74.80	1.15559	75.77	1.14970	76.71	1.14364	77.83	1.13780	78.77
2.0796	1.15989	74.96	1.15806	75.86	1.15175	76.92	1.14580	77.91	1.13985	78.84

The plots of V_ϕ versus m are linear at different temperatures. Hence, the variation of V_ϕ of succinimide with m in water as well as in aqueous solutions of electrolytes and non-electrolytes can be represented by the following equation

$$V_\phi = V_\phi^0 + S_v m \quad \text{...(2)}$$

where V_ϕ^0 is the limiting apparent molar volume (which is equal to the partial molar volume of the solute, V_2^0 at infinite dilution) and S_v is the experimental slope[3] (sometimes[4,5] considered to be the volumetric pairwise interaction coefficient). V_ϕ^0 is a measure of solute-solvent interactions[6] while S_v is a measure of solute-solute interactions[7]. The values of V_ϕ^0 and S_v in respect of succinimide have been obtained by the least squares fitting of $V_\phi - m$ data to Eq. (2) using a computer. The results with regard to the values of V_ϕ^0 and S_v for succinimide are presented in Table 2 along with the standard errors (in the parentheses).

Table 2: Limiting apparent molar volume ($V_\square^0$) and experimental slope (S_v) of Succinimide in purely aqueous medium and in aqueous solutions of electrolytes and non-electrolytes of varying molality at different temperatures

Molality (m_s) (mol.kg^{-1}) of electrolytes and non-electrolytes	$10^6 \cdot V_\phi^0$ (m.^{3}mol^{-1})					$10^6 \cdot S_V$ (m.^{3}kg.mol^{-2})				
	283.15 K	293.15K	303.15K	313.15K	323.15K	283.15 K	293.15K	303.15K	313.15K	323.15K
					D(+)-Glucose					
0.0000	71.80 (±0.06)	72.70 (±0.11)	73.80 (±0.08)	74.86 (±0.06)	75.75 (±0.07)	0.38 (±0.03)	0.34 (±0.04)	0.31 (±0.06)	0.30 (±0.02)	0.27 (±0.02)
0.5297	72.22 (±0.08)	73.26 (±0.07)	74.32 (±0.12)	75.44 (±0.06)	76.51 (±0.12)	0.44 (±0.04)	0.33 (±0.02)	0.31 (±0.04)	0.29 (±0.02)	0.28 (±0.03)
1.1267	72.78 (±0.05)	73.93 (±0.10)	74.93 (±0.07)	75.92 (±0.11)	76.04 (±0.08)	0.58 (±0.03)	0.51 (±0.05)	0.49 (±0.03)	0.44 (±0.05)	0.38 (±0.03)
1.8108	73.26 (±0.03)	74.40 (±0.08)	75.51 (±0.08)	76.52 (±0.07)	77.65 (±0.09)	0.60 (±0.02)	0.49 (±0.04)	0.47 (±0.04)	0.46 (±0.03)	0.41 (±0.04)
2.5940	73.76 (±0.05)	74.74 (±0.04)	75.88 (±0.10)	76.98 (±0.08)	77.93 (±0.06)	0.57 (±0.03)	0.55 (±0.02)	0.49 (±0.05)	0.45 (±0.03)	0.43 (±0.03)
					D(-)-Fructose					
0.5295	71.95 (±0.12)	73.00 (±0.11)	73.95 (±0.07)	74.99 (±0.07)	76.05 (±0.07)	0.39 (±0.05)	0.37 (±0.04)	0.34 (±0.02)	0.32 (±0.02)	0.31 (±0.02)
1.1268	72.77 (±0.07)	73.37 (±0.07)	74.97 (±0.05)	75.98 (±0.03)	77.01 (±0.15)	0.49 (±0.03)	0.48 (±0.04)	0.43 (±0.02)	0.38 (±0.01)	0.36 (±0.05)
1.8052	73.35 (±0.05)	74.34 (±0.02)	75.42 (±0.07)	76.50 (±0.09)	77.61 (±0.05)	0.54 (±0.03)	0.47 (±0.01)	0.44 (±0.03)	0.35 (±0.03)	0.33 (±0.02)
2.5857	73.85 (±0.03)	74.85 (±0.06)	75.96 (±0.07)	77.06 (±0.09)	78.32 (±0.12)	0.58 (±0.02)	0.49 (±0.03)	0.43 (±0.03)	0.39 (±0.03)	0.37 (±0.05)
					Sucrose					
0.5592	72.28 (±0.06)	73.49 (±0.06)	74.57 (±0.06)	75.62 (±0.06)	76.60 (±0.06)	0.49 (±0.06)	0.48 (±0.06)	0.47 (±0.06)	0.46 (±0.06)	0.42 (±0.06)
1.2703	73.18 (±0.06)	74.18 (±0.06)	75.23 (±0.06)	76.31 (±0.06)	77.39 (±0.06)	0.47 (±0.06)	0.45 (±0.06)	0.40 (±0.06)	0.37 (±0.06)	0.34 (±0.06)
2.2157	73.79 (±0.06)	74.79 (±0.06)	75.82 (±0.06)	77.03 (±0.06)	78.17 (±0.06)	0.48 (±0.06)	0.45 (±0.06)	0.42 (±0.06)	0.44 (±0.06)	0.40 (±0.06)
3.5229	74.26 (±0.06)	75.42 (±0.06)	76.53 (±0.06)	77.64 (±0.06)	78.65 (±0.06)	0.60 (±0.06)	0.58 (±0.06)	0.56 (±0.06)	0.55 (±0.06)	0.51 (±0.06)
					Urea					
0.6171	74.37 (±0.04)	75.59 (±0.04)	76.66 (±0.06)	77.70 (±0.04)	78.80 (±0.04)	0.56 (±0.02)	0.54 (±0.02)	0.49 (±0.02)	0.46 (±0.02)	0.43 (±0.01)
1.2709	74.82 (±0.06)	75.93 (±0.06)	77.10 (±0.06)	78.75 (±0.09)	79.22 (±0.07)	0.59 (±0.04)	0.56 (±0.04)	0.50 (±0.03)	0.47 (±0.04)	0.43 (±0.03)
1.9657	75.32 (±0.05)	76.50 (±0.03)	77.63 (±0.06)	78.78 (±0.04)	79.86 (±0.05)	0.62 (±0.03)	0.51 (±0.02)	0.47 (±0.03)	0.44 (±0.02)	0.43 (±0.02)

2.7023	75.49 (±0.03)	76.69 (±0.06)	77.74 (±0.06)	78.77 (±0.04)	77.85 (±0.07)	0.65 (±0.02)	0.63 (±0.04)	0.62 (±0.03)	0.59 (±0.02)	0.54 (±0.04)
3.4881	75.62 (±0.04)	76.78 (±0.03)	77.78 (±0.03)	78.81 (±0.04)	77.85 (±0.03)	0.70 (±0.04)	0.66 (±0.03)	0.60 (±0.03)	0.56 (±0.03)	0.53 (±0.02)
					Sodium Nitrate					
0.6081	73.53 (±0.05)	74.59 (±0.04)	74.26 (±0.04)	75.31 (±0.06)	76.32 (±0.06)	0.62 (±0.03)	0.58 (±0.02)	0.52 (±0.02)	0.49 (±0.03)	0.42 (±0.03)
1.2329	75.71 (±0.04)	76.83 (±0.03)	74.26 (±0.06)	75.85 (±0.05)	76.88 (±0.06)	0.65 (±0.03)	0.62 (±0.02)	0.60 (±0.04)	0.58 (±0.03)	0.57 (±0.03)
1.8759	76.31 (±0.05)	77.44 (±0.03)	78.46 (±0.04)	79.55 (±0.03)	80.56 (±0.06)	0.67 (±0.04)	0.64 (±0.02)	0.61 (±0.03)	0.60 (±0.01)	0.55 (±0.03)
2.5375	76.76 (±0.05)	77.87 (±0.03)	79.03 (±0.03)	80.11 (±0.05)	81.21 (±0.06)	0.69 (±0.04)	0.67 (±0.02)	0.56 (±0.02)	0.58 (±0.03)	0.54 (±0.04)
3.2213	76.85 (±0.06)	78.00 (±0.06)	79.12 (±0.04)	80.23 (±0.05)	81.29 (±0.06)	0.72 (±0.05)	0.68 (±0.05)	0.65 (±0.03)	0.63 (±0.04)	0.60 (±0.04)
					Sodium Sulphate					
0.4111	74.58 (±0.05)	75.69 (±0.05)	76.75 (±0.06)	77.71 (±0.05)	78.75 (±0.41)	0.97 (±0.03)	0.96 (±0.03)	0.95 (±0.03)	0.90 (±0.02)	0.81 (±0.01)
0.8454	75.19 (±0.06)	76.22 (±0.07)	77.30 (±0.11)	78.31 (±0.13)	79.28 (±0.39)	0.98 (±0.03)	0.95 (±0.03)	0.90 (±0.04)	0.87 (±0.05)	0.85 (±0.03)
1.3053	76.01 (±0.06)	77.01 (±0.05)	78.02 (±0.04)	79.13 (±0.03)	80.09 (±0.38)	1.01 (±0.04)	.98 (±0.03)	0.96 (±0.02)	0.92 (±0.01)	0.88 (±0.03)
1.7935	76.38 (±0.03)	77.35 (±0.03)	78.36 (±0.05)	79.43 (±0.06)	80.44 (±0.37)	1.09 (±0.02)	1.05 (±0.03)	1.02 (±0.03)	0.99 (±0.04)	0.90 (±0.03)
2.3128	76.52 (±0.04)	77.53 (±0.03)	78.54 (±0.03)	79.57 (±0.03)	80.58 (±0.36)	1.11 (±0.03)	1.08 (±0.03)	1.03 (±0.03)	1.01 (±0.02)	0.94 (±0.04)
					Potassium Chloride					
0.6109	72.20 (±0.10)	73.13 (±0.06)	74.12 (±0.09)	75.14 (±0.08)	76.35 (±0.06)	0.50 (±0.06)	0.42 (±0.03)	0.37 (±0.05)	0.36 (±0.03)	0.31 (±0.02)
1.2450	72.63 (±0.07)	73.66 (±0.07)	74.66 (±0.05)	75.67 (±0.05)	76.76 (±0.06)	0.50 (±0.05)	0.41 (±0.05)	0.33 (±0.04)	0.27 (±0.03)	0.25 (±0.03)
1.9045	73.04 (±0.04)	74.05 (±0.07)	75.16 (±0.05)	76.28 (±0.04)	77.34 (±0.06)	0.64 (±0.03)	0.51 (±0.06)	0.48 (±0.03)	0.45 (±0.03)	0.42 (±0.04)
2.5922	73.83 (±0.06)	74.91 (±0.08)	75.99 (±0.08)	76.93 (±0.07)	77.92 (±0.09)	0.61 (±0.05)	0.55 (±0.06)	0.53 (±0.05)	0.48 (±0.04)	0.40 (±0.05)
3.3095	74.61 (±0.05)	75.85 (±0.06)	76.88 (±0.04)	77.94 (±0.09)	78.98 (±0.06)	0.92 (±0.05)	0.90 (±0.06)	0.87 (±0.03)	0.81 (±0.07)	0.77 (±0.04)
					Potassium Iodide					
0.6174	74.64 (±0.05)	75.71 (±0.05)	76.64 (±0.05)	77.76 (±0.04)	78.76 (±0.08)	0.52 (±0.03)	0.49 (±0.03)	0.45 (±0.02)	0.43 (±0.02)	0.41 (±0.04)
1.2721	75.58 (±0.06)	76.72 (±0.05)	77.76 (±0.09)	78.78 (±0.07)	79.79 (±0.07)	0.67 (±0.04)	0.64 (±0.03)	0.62 (±0.06)	0.60 (±0.04)	0.56 (±0.04)
1.9696	75.83 (±0.04)	76.83 (±0.04)	77.88 (±0.03)	78.88 (±0.05)	79.90 (±0.03)	0.65 (±0.03)	0.59 (±0.02)	0.49 (±0.02)	0.47 (±0.03)	0.44 (±0.01)
2.7201	76.55 (±0.03)	77.62 (±0.04)	78.68 (±0.04)	79.71 (±0.06)	80.72 (±0.05)	0.71 (±0.02)	0.68 (±0.03)	0.65 (±0.03)	0.63 (±0.04)	0.58 (±0.03)
3.5298	77.07 (±0.03)	78.13 (±0.02)	79.17 (±0.05)	80.26 (±0.03)	81.25 (±0.02)	0.83 (±0.02)	0.79 (±0.02)	0.78 (±0.04)	0.70 (±0.02)	0.65 (±0.01)
					Barium Chloride					
0.2026	72.66 (±0.05)	73.70 (±0.09)	74.87 (±0.09)	75.94 (±0.05)	76.99 (±0.07)	0.40 (±0.02)	0.39 (±0.04)	0.38 (±0.03)	0.35 (±0.02)	0.38 (±0.02)
0.4104	73.25 (±0.07)	74.21 (±0.07)	75.30 (±0.07)	76.37 (±0.07)	77.49 (±0.09)	0.51 (±0.04)	0.48 (±0.03)	0.42 (±0.03)	0.40 (±0.03)	0.38 (±0.04)
0.6236	74.04 (±0.05)	75.06 (±0.08)	76.18 (±0.11)	77.32 (±0.05)	78.28 (±0.06)	0.47 (±0.02)	0.39 (±0.03)	0.34 (±0.04)	0.32 (±0.02)	0.34 (±0.02)

0.8426	74.66	75.67	76.80	77.92	78.98	0.53	0.50	0.42	0.39	0.37
	(±0.05)	(±0.08)	(±0.07)	(±0.03)	(±0.08)	(±0.02)	(±0.04)	(±0.03)	(±0.03)	(±0.03)
1.0676	75.32	76.33	77.44	78.49	79.52	0. 615	0.62	0.52	0.46	0.44
	(±0.03)	(±0.04)	(±0.04)	(±0.05)	(±0.07)	(±0.02)	(±0.02)	(±0.02)	(±0.02)	(±0.03)
					Strontium Chloride					
0.5225	71.944	73.043	74.072	75.138	76.20	0.2481	0.24	0.1858	0.1498	0.1424
	(±0.04)	(±0.05)	(±0.04)	(±0.09)	(±0.07)	(±0.02)	(±0.03)	(±0.02)	(±0.04)	(±0.04)
1.0944	72.11	73.204	74.258	75.276	76.312	0.3101	0.2923	0.2818	0.2735	0.2437
	(±0.03)	(±0.03)	(±0.03)	(±0.05)	(±0.05)	(±0.02)	(±0.02)	(±0.02)	(±0.02)	(±0.02)
1.7399	72.44	73.5	4.597	75.662	76.695	0.3476	0.3355	0.3091	0.287	0.2288
	(±0.02)	(±0.04)	(±0.04)	(±0.04)	(±0.01)	(±0.02)	(±0.02)	(±0.02)	(±0.03)	(±0.01)
2.5097	72.921	74.0	75.039	76.019	77.104	0.3628	0.3519	0.3407	0.3198	0.272
	(±0.05)	(±0.06)	(±0.06)	(±0.04)	(±0.04)	(±0.04)	(±0.04)	(±0.04)	(±0.03)	(±0.02)

Standard errors are given in parentheses

It is worth mentioning here the fact that the experimental values of V_ϕ^0 at different temperatures reported in this paper (vide table 2) are compatible with the theoretical value 73.7 cm^3mol^{-1} at 25 ^{0}C, of V_ϕ^0 obtained by Shahidi et al. keeping in view the mode of of V_ϕ^0 with temperature, characterised by the value of $(\partial V_\phi^0 / \partial T)_P$ which in the present study is ~0.17$cm^3mol^{-1}K^{-1}$

From Table 2 it is seen that the values of V_ϕ^0 for succinimide, in water as well as in aqueous solutions of electrolytes and non-electrolytes are largely positive at different temperatures thereby suggesting the presence of strong solute-solvent interactions in these solvent systems. On the other hand, from the values of S_v for succinimide it is found that these are very small in comparison to the values of V_ϕ^0. From this it is inferred that the strength of solute-solute interactions is much smaller as compared to that of solute-solvent interactions.

Partial molar volumes of transfer, ΔV_ϕ^0, of succinimide from water to aqueous solutions of electrolytes and non-electrolytes have been obtained from the following relation, and the representative data are presented in Table 3:

Table 3. Partial molar volumes of transfer (ΔV_ϕ^0) for Succinimide from water to aqueous solutions of electrolytes and non-electrolytes of varying molality (m_s) at different temperatures

m_s (mol.kg^{-1})	ΔV_ϕ^0 (m.^{3}mol^{-1})				
	283.15 K	293.15 K	303.15 K	313.15K	323.15K
			D(□)-Glucose		
0.5297	0.42	0.56	0.52	0.58	0.76
1.1267	0.99	1.23	1.13	1.05	1.29
1.8108	1.47	1.70	1.71	1.66	1.74
2.5940	1.96	2.04	2.08	2.12	2.18
			D(□)-Fructose		
0.5295	0.15	0.30	0.15	0.13	0.30
1.1268	0.97	1.17	1.17	1.11	1.26
1.8052	1.55	1.64	1.62	1.63	1.85
2.5857	2.05	2.15	2.16	2.20	2.57
			Sucrose		
0.5592	0.48	0.79	0.77	0.75	0.92
1.2703	1.38	1.48	1.43	1.45	1.64
2.2157	2.00	2.07	2.02	2.19	2.42
3.5229	2.46	2.72	2.73	2.77	2.90
			Sodium Nitrate		
0.6081	1.73	1.89	1.81	1.81	2.05
1.2329	3.91	4.13	4.05	4.02	4.19
1.8759	4.52	4.74	4.66	4.68	4.91
2.5375	4.96	5.17	5.23	5.24	5.46
3.2212	5.05	5.30	5.32	5.36	5.54

			Sodium Sulphate		
0.4111	2.79	2.99	2.95	2.85	3.00
0.8454	3.39	3.52	3.51	3.45	3.52
1.3053	4.21	4.31	4.22	4.27	4.34
1.7935	4.59	4.65	4.57	4.56	4.69
2.3128	4.72	4.83	4.74	4.71	4.82

$$\Delta V_{\phi}^{0} = [V_{\phi}^{0} \text{(in aq. solutions of electrolytes and non-electrolytes} - V_{\phi}^{0} \text{(in water)}] \quad \ldots (3)$$

It is seen that the values of ΔV_{ϕ}^{0} are positive and increase with increasing concentration of the cosolute(m_s) [electrolytes and non-electrolytes]. In other words, there occurs an increase in the volume in going from water to aqueous solutions of electrolytes and non-electrolytes. The increasing positive values of ΔV_{ϕ}^{0} suggest that in the systems involving succinimide–water–cosolute (electrolytes and non-electrolytes), the ion–hydrophilic and hydrophilic–hydrophilic group interactions are predominant over hydrophilic–hydrophobic group interactions[8]. From the fact that ΔV_{ϕ}^{0} increases with the increasing concentration of cosolute (electrolytes and non-electrolytes) it may be inferred that in these systems the increased concentration of the electrolytes and non-electrolytes leads to the greater ion-hydrophilic and hydrophilic–hydrophilic interactions which are not compensated by hydrophilic–hydrophobic interactions; and this accounts for the predominance of the former over the latter

The temperature dependence of V_{ϕ}^{0} is given by following equation[9,10]

$$V_{\phi}^{0} = a_0 + a_1 T + a_2 T^2 \quad \ldots(5)$$

The values of coefficients a_0, a_1 and a_2 have been calculated by the least squares fitting of the V_{ϕ}^{0}-temperature (T) data into Eq. (5). The limiting apparent molar expansibilities, ϕ_E^o of succinimide have been calculated [9] from the following equation(6) of ϕ_E^o and the representative data are listed in Table 4 .

$$\phi_E^o = (\partial V_{\phi}^{0} / \partial T)_P = a_1 + 2\, a_2 T \quad \ldots(6)$$

Table 4. Limiting apparent molar expansibilities (ϕ_E^o) for Succinimide in purely aqueous medium and in aqueous solutions of electrolytes and non-electrolytes of varying molality (m_s) at different temperatures.

m_s (mol.kg^{-1})	$10^6 \cdot \phi_E^0$ (m^3.mol^{-1}K^{-1})				
	283.15 K	293.15 K	303.15 K	313.15K	323.15K
		D(+)-Glucose			
0.0(water)	0.1025	0.1016	0.1007	0.0998	0.0989
0.5297	0.0764	0.1079	0.1394	0.1708	0.2023
1.1267	0.0900	0.1109	0.1317	0.1526	0.1734
1.8108	0.0959	0.1144	0.1328	0.1513	0.1698
2.5940	0.0777	0.1076	0.1375	0.1674	0.1973
		D(−)-Fructose			
0.5295	0.0762	0.1035	0.1308	0.1581	0.1854
1.1268	0.0901	0.1121	0.1341	0.1561	0.1781
1.8052	0.0738	0.1061	0.1384	0.1707	0.2030
2.5857	0.0709	0.1081	0.1454	0.1827	0.2199

		Sucrose			
0.5592	0.0989	0.1178	0.1367	0.1556	0.1745
1.2703	0.0745	0.1057	0.1368	0.1680	0.1991
2.2157	0.0627	0.1047	0.1466	0.1886	0.2306
3.5229	0.0933	0.1166	0.1398	0.1631	0.1863
		Sodium Nitrate			
0.6081	0.0780	0.1073	0.1367	0.1660	0.1953
1.2329	0.0874	0.1104	0.1333	0.1563	0.1793
1.8759	0.0841	0.1110	0.1378	0.1646	0.1914
2.5375	0.0892	0.1156	0.1420	0.1685	0.1949
3.2212	0.0914	0.1164	0.1415	0.1666	0.1916
		Sodium Sulphate			
0.4111	0.0914	0.1107	0.1300	0.1494	0.1687
0.8454	0.0841	0.1075	0.1309	0.1542	0.1776
1.3053	0.0734	0.1036	0.1338	0.1639	0.1941
1.7935	0.0704	0.1015	0.1327	0.1638	0.1949
2.3128	0.0769	0.1037	0.1306	0.1574	0.1842

The values of ϕ_E^o are positive in water as well as in aqueous solutions of electrolytes and non-electrolytes, and that the values of ϕ_E^o for succinimide in water decrease with rise in temperature while in the case of aqueous solutions of electrolytes and non-electrolytes the values of ϕ_E^o increase with the rise in temperature thereby showing that succinimide behaves as structure breaker in water while structure maker in aqueous solutions of electrolytes and non-electrolytes.

The values of the derivative, $(\partial^2 V_\phi^0 / \partial T^2)_P$ for succinimide have been obtained from Eq. (5). It is seen that the values are negative in water and in aqueous solutions of electrolytes and non-electrolytes, the values are positive.

Hepler[11] has proposed a method, by which qualitative information on hydration of solutes can be obtained from thermal expansion of aqueous solution by the following relation,

$$(\partial C_P^0 / \partial P)_T = -T(\partial^2 V_\phi^0 / \partial T^2)_P \quad ...(7)$$

According to this, the left hand side of the above equation should be positive for all structure breaking solutes and therefore, structure breaking solutes posses negative values of $(\partial^2 V_\phi^0 / \partial T^2)_P$. On the other hand, positive value of $(\partial^2 V_\phi^0 / \partial T^2)_P$ should be associated with structure making solutes. In the present study the positive values of $(\partial^2 V_\phi^0 / \partial T^2)_P$ support the structure making tendency of succinimide in purely aqueous solutions as well as in aqueous solutions of electrolytes and non-electrolytes. Thus, the positive values of ϕ_E^o and $(\partial^2 V_\phi^0 / \partial T^2)_P$ lead to the identical conclusion in regard to the structure making tendency of succinimide in water as well as in aqueous solutions of electrolytes and non-electrolytes.

EXPERIMENTAL

Succinimide, (*Mol.wt.* 99.09), of purity (99.9 %) were B.D.H. products of analytical reagent grade and were used as such. Electrolytes, such as Sod. chloride, Sod. nitrate, Sod. sulphate, Pot. chloride, Pot.iodide, Barium chloride and Strontium chloride and non-electrolytes (such as D(+)-Glucose, D(-)-Fructose, Sucrose and Urea) used in this study. These were Merck products of analytical reagent grade of 99.9% purity.

Solutions of succinimide were prepared on molality (*m*) concentration scale using an electronic balance (Mettler) having an accuracy of $\pm 1X10^{-4}$ g. Double distilled water (specific conductivity~10^{-6} $ohm^{-1}cm^{-1}$) was used in the preparation of solutions of the solutes.

The densities of solutions were measured by using digital vibrating tube densimeter (model 60/602 Anton Parr, Austria). The measured densities were accurate to (± 0.005 $kg.m^{-3}$) and the precision of measurement was (± 0.002 $kg.m^{-3}$). The temperature of the water flowing around the densimeter cell was controlled within ± 0.01K using an efficient temperature bath.

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