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Excess Molar Enthalpies and Excess Molar Volumes of Diethyl Carbonate + Some *n*-Alkoxyethanols at (298.15 and 313.15) K

Romolo Francesconi,*,† Carlo Castellari,† and Fabio Comelli‡

Dipartimento di Chimica "G. Ciamician", Università degli Studi, via Selmi 2, I-40126 Bologna, Italy, and
Centro di Studio per la Fisica delle Macromolecole del CNR, via Selmi 2, I-40126 Bologna, Italy

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Excess molar enthalpies H_m^E and excess molar volumes V_m^E of diethyl carbonate + some alkoxyethanol mixtures have been determined by an LKB flow microcalorimeter and an Anton Paar density meter as a function of mole fraction of diethyl carbonate at (298.15 and 313.15) K. The alkoxyethanols are 2-methoxyethanol, 2-ethoxyethanol, 2-buthoxyethanol, 2-(2-methoxyethoxy)ethanol, 2-(2-ethoxyethoxy)-ethanol, and 2-(2-butoxyethoxy)ethanol, respectively.

Introduction

Knowledge of the thermodynamic properties of organic liquid mixtures is very important in understanding the molecular interactions between the components for theoretical models and also industrial applications.

Continuing our research program involving a systematic study of the thermodynamic excess properties of binary mixtures containing diethyl carbonate + some series of organic compounds (Francesconi et al., 1997; Francesconi and Comelli, 1997; Comelli et al., 1999), in the present paper we report the excess molar enthalpies H_m^E and the excess molar volumes V_m^E for the binary mixtures formed by diethyl carbonate and *n*-alkoxy- and (*n*-alkoxyethoxy)-ethanols at atmospheric pressure and at (298.15 and 313.15) K over the entire composition range.

The alkoxyethanols considered in this paper are namely 2-methoxyethanol, 2-ethoxyethanol, 2-butoxyethanol, 2-(2-methoxyethoxy)ethanol, 2-(2-ethoxyethoxy)ethanol, and 2-(2-butoxyethoxy)ethanol.

Dialkyl carbonates are used as solvents for a variety of extractions of industrial importance, in the synthesis of pharmaceuticals, and in agricultural chemistry (Annesini et al., 1984; *Merck Index*, 1989; Martindale, 1989).

On the other hand, the thermodynamic study of mixtures containing the oxy (−O−) and hydroxy (−OH) functional groups has been of great interest (Douhèret and Pal, 1988; Pal and Sing, 1996) if the information required to characterize the molecular interactions of these groups is available.

No literature results have been found for these mixtures.

Experimental Section

Chemicals. Chemicals were Aldrich and Fluka products. Diethyl carbonate has been purified as described previously (Francesconi and Comelli, 1997) while alkoxy- and (alkoxyethoxy)ethanols were used as received, owing to their high-purity grade, from the purchaser.

Before measurements, pure liquids were degassed by ultrasound (ultrasonic bath, Hellma, type 460, Milan, Italy), kept in dark bottles, and dried over molecular sieves (Union Carbide, type 4A, 1/16 in. pellets) to reduce the water content.

The analyses of the products were performed on a Hewlett-Packard gas chromatograph model 5890 using an HP (cross-linked 5% Me siloxane) capillary column. The purities of the samples were also checked by comparing the measured density data with those reported in the literature.

Table 1 reports the origins and density values of the chemicals, together with comparison with literature and stated purities from GCL analysis.

Calorimetric Measurements. The excess molar enthalpies H_m^E were determined with an LKB flow microcalorimeter (LKB Produkter, model 2107, Bromma, Sweden) equipped with two automatic burets (ABU, Radiometer, Copenhagen, Denmark) which pump liquids into the mixing cell of the calorimeter.

Details of the equipment, electrical calibration, and experimental procedure have been described previously (Monk and Wadso, 1968; Francesconi and Comelli, 1986).

The temperature inside the equilibrium cell was been measured by means of an electronic unit, and the mole fraction x_1 of diethyl carbonate (component 1) was determined from flow rates.

The estimated errors are $\delta x_1 < 0.0002$ and $\delta T/\mathrm{K} = 0.01$ (Francesconi and Comelli, 1998).

Prior to measurements, the apparatus was checked against hexane + cyclohexane (Gmehling, 1993) and hexane + tetrachloromethane (Grolier et al., 1975), the agreement with the data reported in the literature being better than 0.5% over the central range of composition.

Volumetric Measurements. The excess molar volumes V_m^E for the binary mixtures were determined from the densities ρ using a digital density meter (Anton Paar, model DMA 60, Graz, Austria) equipped with a measuring cell (Anton Paar, type 602) whose operating procedure has been described previously (Fermeglia and Lapasin, 1988). All the measurements were made at a constant temperature using an external ultrathermostat bath circulator (Heto, type 01 DBT 623, Birkeròd, Denmark), precision ±0.005 K, and temperatures were detected with two digital thermometers (Anton Paar, DT-25, DT-40). Densities were measured with an accuracy of 1×10^{-5} g·cm^{-3}, leading to

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* To whom correspondence should be addressed.
† Università degli Studi.
‡ Centro di Studi per la Fisica delle Macromolecule del CNR.

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Table 1. Source, Purity, Density (ρ), and Comparison with Literature Data of Pure Liquids

		ρ/(g·cm^{-3})		
		this work		lit.
compound	source and purity	T/K = 298.15	T/K = 313.15	T/K = 298.15
diethyl carbonate	Aldrich, 99.8%	0.969 26	0.952 30	0.969 26[a] 0.969 25[b]
2-methoxyethanol	Aldrich, +99.9%	0.960 04	0.946 11	0.960 24[a] 0.960 15[c] 0.96 00[d]
2-ethoxyethanol	Fluka, +99.5%	0.925 05	0.911 30	0.925 20[a]
2-butoxyethanol	Fluka, +99.8%	0.896 31	0.883 61	0.896 25[a]
2-(2-methoxyethoxy)ethanol	Aldrich, 99%	1.015 91	1.002 60	1.01 67[a] 1.01 64[e] 1.014 87[f]
2-(2-ethoxyethoxy)ethanol	Aldrich, +99%	0.984 29	0.970 91	0.98 41[d] 0.98 39[e]
2-(2-butoxyethoxy)ethanol	Aldrich, +99%	0.948 08	0.935 48	0.94 79[e] 0.949 16[d]

[a] Riddick et al., 1986. [b] Francesconi et al., 1997. [c] Rubio et al., 1998. [d] Cobos et al., 1989. [e] Pal and Sharma, 1998. [f] Cobos et al., 1988.

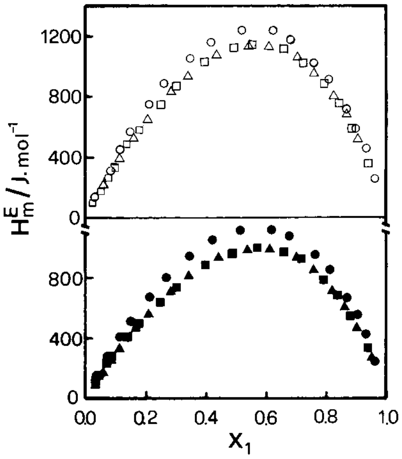

Figure 1. Experimental excess molar enthalpies H_m^E for diethyl carbonate (1) + 2-methoxyethanol (2) (■, □), + 2-ethoxyethanol (2) (▲, △), and + 2-butoxyethanol (2) (●, ○). Closed and open points are at (298.15 and 313.15) K, respectively.

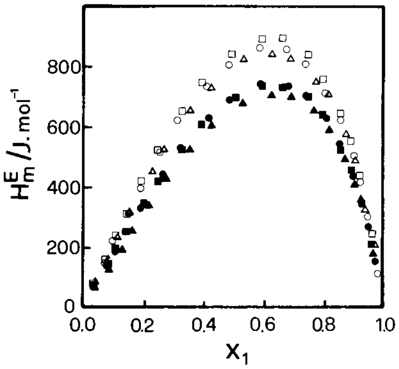

Figure 2. Experimental excess molar enthalpies H_m^E for diethyl carbonate (1) + 2-(2-methoxyethoxy)ethanol (2) (■, □), + 2-(ethoxyethoxy)ethanol (2) (▲, △) and + 2-(2-butoxyethoxy)ethanol (2) (●, ○). Closed and open points are at (298.15 and 313.15) K, respectively.

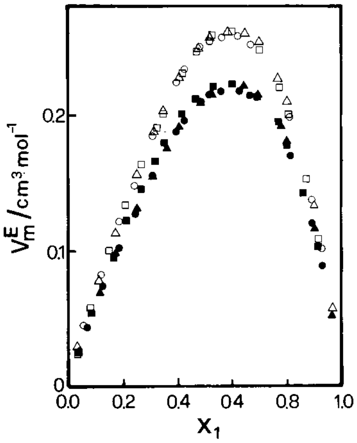

Figure 3. Experimental excess molar volumes V_m^E for diethyl carbonate (1) + 2-methoxyethanol (2) (■, □), + 2-ethoxyethanol (2) (▲, △) and + 2-butoxyethanol (2) (▲, △). Closed and open points are at (298.15 and 313.15) K, respectively.

V_m^E values with an error of ±0.003 cm^3·mol^{-1}. Mole fractions x_1 of diethyl carbonate were determined by mass using a Mettler balance (type AE 160) with an accuracy of ±0.0001 g, charging the heavier component first to minimize the error due to vaporization and following the same procedure described by Fermeglia and Lapasin (1988). Corrections were made for buoyancy and evaporation of the components, but only the fourth decimal digit was affected. The technique was checked by determining V_m^E for a benzene + cyclohexane mixture at 298.15 K. Our results are in good agreement with literature values (Wilhelm, 1985), showing a discrepancy of ±0.5% in the central range of mole fractions of benzene.

Results and Discussion

Excess molar volumes V_m^E were computed from densities of mixtures ρ using the relation

$$V_m^E = (x_1M_1 + x_2M_2)/\rho - x_1M_1/\rho_1 - x_2M_2/\rho_2 \qquad (1)$$

where M_i and ρ_i are the molar mass and density of component i.

Excess molar enthalpies H_m^E and excess molar volumes V_m^E are listed in Tables 2 and 3, respectively.

Experimental data have been correlated as a function of composition using the Redlich–Kister polynomial

$$Q_m^E = x_1x_2\sum_{k\geq 0}A_k(x_1 - x_2)^k \qquad (2)$$

where $Q_m^E = H_m^E$/J·mol^{-1} or V_m^E/cm^3·mol^{-1}, x_1 and x_2 are the

Table 2. Experimental Excess Enthalpies H_m^E, of Diethyl Carbonate + *n*-Alkoxy- and *n*-(Alkoxyethoxy)ethanols at (298.15 and 313.15) K

x_1	H_m^E/J·mol^{-1}	x_1	H_m^E/J·mol^{-1}	x_1	H_m^E/J·mol^{-1}	x_1	H_m^E/J·mol^{-1}	x_1	H_m^E/J·mol^{-1}	x_1	H_m^E/J·mol^{-1}
diethyl carbonate (1) + 2-methoxyethanol (2)											
T/K = 298.15											
0.0264	80	0.2454	642	0.7223	914	0.0978	281	0.4939	964	0.8864	539
0.0514	152	0.3023	746	0.7960	788	0.1398	407	0.5653	993	0.9398	321
0.0752	221	0.3941	881	0.8388	688	0.1781	498	0.6611	964		
T/K = 313.15											
0.0263	94	0.2448	747	0.7217	1033	0.0975	334	0.4931	1123	0.8861	595
0.0512	183	0.3017	872	0.7955	885	0.1395	468	0.5646	1147	0.9396	352
0.075	254	0.3933	1028	0.8384	763	0.1777	579	0.6605	1110		
diethyl carbonate (1) + 2-ethoxyethanol (2)											
T/K = 298.15											
0.0322	94	0.2855	714	0.7618	844	0.1175	335	0.5454	979	0.9056	466
0.0624	181	0.3476	815	0.8275	712	0.1666	460	0.6252	982	0.9505	270
0.0908	260	0.4442	931	0.8648	607	0.2104	570	0.7057	924		
T/K = 313.15											
0.0321	117	0.2850	831	0.7613	969	0.1173	398	0.5447	1128	0.9054	518
0.0623	222	0.3469	946	0.8271	808	0.1662	535	0.6146	1134	0.9503	300
0.0906	315	0.4436	1072	0.8645	692	0.2099	662	0.7052	1062		
diethyl carbonate (1) + butoxyethanol (2)											
T/K = 298.15											
0.0431	159	0.3510	959	0.8123	846	0.1527	517	0.6138	1117	0.9285	416
0.0827	296	0.4189	1047	0.8665	665	0.2129	681	0.6839	1084	0.9629	231
0.1191	410	0.5196	1122	0.8964	560	0.2650	800	0.7644	950		
T/K = 313.15											
0.0430	168	0.3503	1062	0.8118	911	0.1523	570	0.6180	1235	0.9283	444
0.0824	318	0.4181	1163	0.8661	723	0.2123	742	0.6832	1176	0.9228	248
0.1188	448	0.5188	1237	0.8961	596	0.2644	890	0.7639	1027		
diethyl carbonate (1) + 2-(2-methoxyethoxy)ethanol (2)											
T/K = 298.15											
0.0388	73	0.3267	529	0.7951	630	0.1392	251	0.5929	737	0.9209	346
0.0748	141	0.3927	612	0.8534	521	0.1952	346	0.6600	733	0.9588	197
0.1082	201	0.5075	699	0.8859	456	0.2444	429	0.7443	692		
T/K = 313.15											
0.0387	84	0.3257	657	0.7944	775	0.1386	309	0.5918	895	0.9164	440
0.0745	164	0.3916	747	0.8529	651	0.1945	421	0.6589	898	0.9587	244
0.1077	241	0.4914	846	0.8854	555	0.2436	521	0.7435	842		
diethyl carbonate (1) + 2-(2-ethoxyethoxy)ethanol (2)											
T/K = 298.15											
0.0445	65	0.3587	534	0.8173	590	0.1571	257	0.6266	707	0.9307	313
0.0852	131	0.4271	611	0.8703	495	0.2185	350	0.6911	701	0.9641	178
0.1227	192	0.5280	684	0.8995	412	0.2716	426	0.7704	654		
T/K = 313.15											
0.443	83	0.3578	658	0.8167	698	0.1566	321	0.6257	846	0.9304	365
0.0849	168	0.4261	733	0.8699	582	0.2313	457	0.6902	828	0.9640	208
0.1222	240	0.5270	825	0.8991	488	0.2708	527	0.7697	771		
diethyl carbonate (1) + 2-(2-butoxyethoxy)ethanol (2)											
T/K = 298.15											
0.0553	91	0.4125	630	0.8488	549	0.1896	332	0.6781	734	0.9440	268
0.1047	181	0.4834	690	0.8939	437	0.2598	445	0.7374	703	0.9712	149
0.1493	251	0.5840	736	0.9182	370	0.3188	523	0.8081	628		
T/K = 313.15											
0.0550	113	0.4114	733	0.8483	622	0.1889	397	0.6772	854	0.9438	299
0.1043	218	0.4823	809	0.8935	501	0.2590	519	0.7366	806	0.9711	164
0.1488	311	0.5830	858	0.9179	407	0.3179	625	0.8075	716		

mole fractions of diethyl carbonate and component 2, and A_k are the adjustable parameters. The values of A_k have been obtained by a least-squares method with all points weighted equally. The parameters A_k and the standard deviation $\sigma(Q_m^E)$ are listed in Table 4.

Figures 1−4 report all 24 mixtures. For the sake of clarity, we have represented graphically only the experimental points and not the Redlich−Kister curves, which in many cases overlap. Figures 1−3 show that all excess values are positive over the whole range of composition, with the exception of the V_m^E values represented in Figure 4, referring to mixtures containing (*n*-alkoxyethoxy)ethanols and showing an inversion of sign.

Figure 1 shows overlapping of H_m^E data for binary mixtures of diethyl carbonate with 2-methoxyethanol and 2-ethoxyethanol, whereas 2-butoxyethanol gives values 10% greater. The same trend is observed at (298.15 and 313.15) K.

Table 3. Densities ρ and Experimental Excess Volumes, V^{E}_{m} of Diethyl Carbonate + n-Alkoxy- and n-Alkoxyethoxyethanols at (298.15 and 313.15) K

x_1	ρ/g·cm^{-3}	V^E_m/cm^3·mol^{-1}	x_1	ρ/g·cm^{-3}	V^E_m/cm^3·mol^{-1}	x_1	ρ/g·cm^{-3}	V^E_m/cm^3·mol^{-1}	x_1	ρ/g·cm^{-3}	V^E_m/cm^3·mol^{-1}
diethyl carbonate (1) + 2-methoxyethanol (2)											
T/K = 298.15											
0.0363	0.960 25	0.024	0.4686	0.963 30	0.210	0.2656	0.961 78	0.147	0.7641	0.966 04	0.195
0.0879	0.960 58	0.056	0.5319	0.963 83	0.220	0.3182	0.962 16	0.168	0.7995	0.966 45	0.179
0.1578	0.961 04	0.095	0.6023	0.964 44	0.223	0.3500	0.962 39	0.179	0.8638	0.967 22	0.141
0.2143	0.961 43	0.124	0.6976	0.965 34	0.214	0.4224	0.962 93	0.200	0.9122	0.967 87	0.101
T/K = 313.15											
0.0363	0.946 18	0.023	0.4686	0.947 35	0.248	0.2656	0.946 60	0.164	0.7641	0.949 43	0.221
0.0879	0.946 29	0.055	0.5319	0.947 68	0.259	0.3182	0.946 79	0.191	0.7995	0.949 78	0.201
0.1578	0.946 42	0.100	0.6023	0.948 11	0.263	0.3500	0.946 89	0.205	0.8638	0.950 49	0.153
0.2143	0.946 53	0.134	0.6976	0.948 83	0.247	0.4224	0.947 18	0.231	0.9122	0.951 09	0.107
diethyl carbonate (1) + 2-ethoxyethanol (2)											
T/K = 298.15											
0.0418	0.927 10	0.026	0.5248	0.948 85	0.215	0.3110	0.939 60	0.157	0.7783	0.959 47	0.192
0.1202	0.930 87	0.068	0.5889	0.951 54	0.221	0.3643	0.941 95	0.176	0.8084	0.960 74	0.179
0.1775	0.933 56	0.097	0.6474	0.953 98	0.221	0.4085	0.943 87	0.191	0.9025	0.964 80	0.116
0.2520	0.936 97	0.132	0.7004	0.956 20	0.214	0.4827	0.947 06	0.208	0.9629	0.967 51	0.052
T/K = 313.15											
0.0418	0.913 17	0.028	0.5248	0.932 97	0.258	0.3110	0.924 50	0.187	0.7783	0.942 90	0.228
0.1202	0.916 60	0.077	0.5889	0.935 50	0.261	0.3643	0.926 65	0.210	0.8084	0.944 11	0.212
0.1775	0.919 03	0.113	0.6474	0.937 76	0.261	0.4085	0.928 43	0.224	0.9025	0.948 01	0.134
0.2520	0.922 11	0.157	0.7004	0.939 81	0.256	0.4827	0.931 33	0.248	0.9629	0.950 64	0.057
diethyl carbonate (1) + 2-butoxyethanol (2)											
T/K = 298.15											
0.0689	0.900 70	0.041	0.5123	0.930 67	0.214	0.3051	0.916 24	0.158	0.8141	0.953 49	0.170
0.1281	0.904 52	0.075	05654	0.934 53	0.217	0.3957	0.922 45	0.188	0.8928	0.959 93	0.120
0.1880	0.908 45	0.103	0.6214	0.938 65	0.218	0.4276	0.924 68	0.197	0.9265	0.962 79	0.089
0.2375	0.911 71	0.129	0.6639	0.941 83	0.215	0.4851	0.928 73	0.210			
T/K = 313.15											
0.0689	0.887 73	0.044	0.5123	0.915 71	0.253	0.3051	0.902 21	0.185	0.8141	0.937 25	0.199
0.1281	0.891 29	0.083	0.5654	0.919 34	0.256	0.3957	0.908 00	0.224	0.8928	0.943 39	0.138
0.1880	0.894 92	0.122	0.6214	0.923 20	0.258	0.4276	0.910 09	0.233	0.9265	0.946 11	0.102
0.2375	0.898 00	0.148	0.6639	0.926 22	0.252	0.4851	0.913 89	0.249			
diethyl carbonate (1) + 2-(2-methoxyethoxy)ethanol (2)											
T/K = 298.15											
0.0319	1.014 40	−0.003	0.5314	0.990 48	0.036	0.2541	1.003 76	0.004	0.7975	0.977 98	0.063
0.0651	1.012 82	−0.004	0.5699	0.988 64	0.042	0.2946	1.001 82	0.007	0.8898	0.97384	0.054
0.1234	1.010 03	−0.004	0.6378	0.985 43	0.050	0.3852	0.997 47	0.017	0.9310	0.972 06	0.042
0.1799	1.007 32	−0.001	0.6821	0.983 33	0.056	0.4116	0.996 20	0.020	0.9671	0.970 56	0.025
0.2191	1.005 54	0.001	0.7767	0.978 93	0.063	0.4555	0.994 11	0.025			
T/K = 313.15											
0.0319	1.000 98	−0.005	0.5314	0.97514	0.038	0.2542	0.989 50	−0.002	0.7975	0.961 68	0.070
0.06511	0.999 28	−0.007	0.5699	0.973 16	0.045	0.2946	0.987 41	0.002	0.8898	0.957 13	0.060
0.1234	0.996 37	−0.008	0.6378	0.969 69	0.056	0.3852	0.982 71	0.014	0.9310	0.955 33	0.045
0.1799	0.993 37	−0.009	0.6821	0.967 45	0.061	0.4116	0.981 34	0.018	0.9671	0.953 72	0.025
0.2191	0.991 31	−0.004	0.7767	0.951 69	0.071	0.4555	0.979 06	0.025			
diethyl carbonate (1) + 2-(2-ethoxyethoxy)ethanol (2)											
T/K = 298.15											
0.0376	0.933 81	−0.004	0.5630	0.975 89	0.046	0.3288	0.979 64	0.009	0.8124	0.971 77	0.072
0.0965	0.983 03	−0.007	0.6131	0.975 06	0.054	0.3515	0.979 30	0.011	0.9011	0.970 43	0.059
0.1542	0.982 22	−0.006	0.6771	0.973 99	0.064	0.3915	0.978 68	0.016	0.9506	0.969 79	0.036
0.2392	0.981 00	−0.001	0.7176	0.973 32	0.068	0.4728	0.977 36	0.032	0.9728	0.969 54	0.022
0.2849	0.980 31	0.003	0.8007	0.971 96	0.073	0.4890	0.977 11	0.032			
T/K = 313.15											
0.0376	0.970 33	−0.007	0.5630	0.960 56	0.060	0.3288	0.965 14	0.014	0.8124	0.955 47	0.087
0.0965	0.969 35	−0.009	0.6131	0.959 49	0.069	0.3515	0.964 69	0.019	0.9011	0.953 82	0.071
0.1542	0.968 35	−0.007	0.6772	0.958 20	0.077	0.3915	0.963 92	0.025	0.9506	0.953 02	0.043
0.2391	0.966 81	0.001	0.7176	0.957 37	0.084	0.4728	0.962 32	0.041	0.9728	0.952 69	0.026
0.2849	0.965 96	0.007	0.8007	0.955 70	0.088	0.4890	0.962 00	0.045			
diethyl carbonate (1) + 2-(2-butoxyethoxy)ethanol (2)											
T/K = 298.15											
0.0880	0.949 46	−0.003	0.7118	0.961 23	0.051	0.450 71	0.956 88	0.024	0.9299	0.966 93	0.040
0.1518	0.950 51	−0.006	0.7668	0.962 52	0.056	0.5249	0.957 24	0.026	0.9633	0.967 99	0.026
0.2932	0.952 92	−0.002	0.8246	0.963 97	0.057	0.6202	0.959 19	0.041	0.9788	0.968 52	0.016
0.3666	0.954 23	0.006	0.8781	0.965 42	0.052	0.6668	0.960 21	0.047			
0.4433	0.955 66	0.014	0.9027	0.966 12	0.048						
T/K = 313.15											
0.0880	0.936 61	−0.009	0.7118	0.945 82	0.059	0.5071	0.942 44	0.027	0.9299	0.950 39	0.042
0.1518	0.937 47	−0.014	0.7668	0.946 85	0.063	0.5249	0.942 71	0.031	0.9633	0.951 27	0.026
0.2932	0.939 35	−0.003	0.8246	0.948 01	0.062	0.6202	0.944 24	0.046	0.9788	0.951 70	0.015
0.3666	0.940 37	0.005	0.8781	0.949 16	0.056	0.6668	0.945 04	0.052			
0.4433	0.091 48	0.017	0.9027	0.949 73	0.051						

Table 4. Least-Squares Parameters a_k and Standard Deviations $\sigma(Q_m^E)$ of Diethyl Carbonate + Alkoxyethanols at (298.15 and 313.15) K

function	a_0	a_1	a_2	a_3	a_4	$\sigma(Q_m^E)$
diethyl carbonate (1) + 2-methoxyethanol (2)						
T/K = 298.15						
H_m^E /J·mol^{-1}	3888.2	1053.1	729.4	482.6		3.6
V_m^E/cm^3·mol^{-1}	0.8620	0.3001	0.1770	0.0690		0.0009
T/K = 313.15						
H_m^E/J·mol^{-1}	4513.9	1095.7	576.0	393.1		2.7
V_m^E/cm^3·mol^{-1}	1.0174	0.3881				0.0008
diethyl carbonate (1) + 2-ethoxyethanol (2)						
T/K = 298.15						
H_m^E/J·mol^{-1}	3865.0	1010.6	682.5			3.7
V_m^E/cm^3·mol^{-1}	0.8432	0.3500	0.1988	0.1163		0.0009
T/K = 313.15						
H_m^E/J·mol^{-1}	4465.8	1170.2	754.7	361.3		3.7
V_m^E/cm^3·mol^{-1}	1.0064	0.4181	0.1792	0.1277		0.0014
diethyl carbonate (1) + 2-butoxyethanol (2)						
T/K = 298.15						
H_m^E/J·mol^{-1}	4457.9	1032.8	811.4	439.2		4.5
V_m^E/cm^3·mol^{-1}	0.8443	0.3018	0.1620	0.1279		0.0012
T/K = 313.15						
H_m^E/J·mol^{-1}	4932.4	997.8	661.6	580.5		4.1
V_m^E/cm^3·mol^{-1}	1.0010	0.3018	0.1620	0.1279		0.0012
diethyl carbonate (1) + 2-(2-methoxyethoxy)ethanol (2)						
T/K = 298.15						
H_m^E/J·mol^{-1}	2781.5	1216.4	806.5	534.4		4.4
V_m^E/cm^3·mol^{-1}	0.1250	0.2651	0.2115	0.1972		0.0008
T/K = 313.15						
H_m^E/J·mol^{-1}	3408.1	1429.3	969.6	813.1		1.6
V_m^E/cm^3·mol^{-1}	0.1278	0.3309	0.2094	0.1965		0.0008
diethyl carbonate (1) + 2-(2-ethoxyethoxy) ethanol(2)						
T/K = 298.15						
H_m^E/J·mol^{-1}	2652.6	1251.5	787.5	824.7		3.4
V_m^E/cm^3·mol^{-1}	0.1367	0.3395	0.2269	0.1766		0.0009
T/K = 313.15						
H_m^E/J·mol^{-1}	3198.6	1354.3	914.8	985.2		4.2
V_m^E/cm^3·mol^{-1}	0.1844	0.3861	0.2261	0.2603		0.0010
diethyl carbonate (1) + 2-(2-butoxyethoxy)ethanol (2)						
T/K = 298.15						
H_m^E/J·mol^{-1}	2796.9	1208.2	769.8	853.8		3.4
V_m^E/cm^3·mol^{-1}	0.0920	0.2865	0.1186	0.1206	0.1966	0.0007
T/K = 313.15						
H_m^E/J·mol^{-1}	3275.4	1356.1	810.8	748.5		3.9
V_m^E/cm^3·mol^{-1}	0.1028	0.3266	0.1792	0.1774		0.0007

Due to hydrogen bonding, the maximum values of H_m^E are all over 1000 J·mol^{-1} with an increase of H_m^E with increasing temperature.

A different pattern results for the H_m^E's of the mixtures diethyl carbonate + 2-(2-alkoxyethoxy)ethanols, as given in Figure 2. Here, the values of the H_m^E maxima are smaller than the ones of alkoxyethanols of Figure 1, with the same temperature dependence.

In conclusion, the increased number of alkoxy groups linearly chained to ethanol seems to decrease the heat of mixing with diethyl carbonate, the differences among various (alkoxyethoxy)ethanols being very small.

As to the V_m^E data, the curves of V_m^E versus x_1 for both the 2-alkoxyethanols and (2-alkoxyethoxy)ethanols practically overlap, with larger values displayed by the former mixtures, whereas the latter mixtures show a sign inversion in the V_m^E versus data x_1 in the diethyl carbonate-poor region.

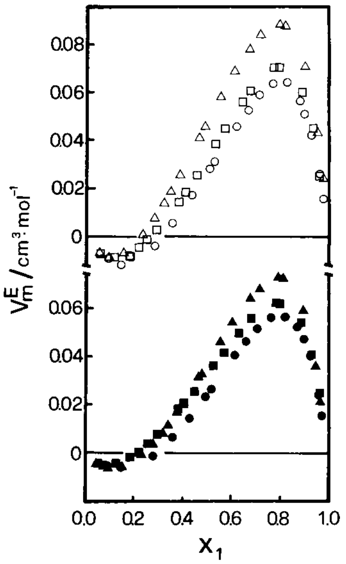

Figure 4. Experimental excess molar volumes V_m^E for diethyl carbonate (1) + 2-(2-methoxyethoxy)ethanol (■, □), + 2-(2-ethoxyethoxy)ethanol (2) (▲, △), and + 2-(2-butoxyethoxy)ethanol (2) (●, ○). Closed and open points are at (298.15 and 313.15) K, respectively.

The temperature dependence of V_m^E is again positive but more marked than that for the H_m^E data.

It must be pointed out that the 2-alkoxyethanols studied in this paper show V_m^E curves with sign inversion in mixtures with trichloroethylene and similar to Figure 3 in mixtures with tetrachloroethylene (Venkatesulu and Rao, 1992).

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