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TEMPERATURE DEPENDENCE OF EXCESS MOLAR VOLUMES OF ETHANOL+WATER+1-PROPANOL

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In the scope of design and optimise the equipment for alcoholic distillate beverages production, a sufficient knowledge of physical properties and phase equilibria is necessary. In this paper we present the temperature dependence of excess molar volumes of the ternary system ethanol+water+1-propanol at the range 288.15–323.15 K and atmospheric pressure, due to the importance of the 1-propanol among the flavour compounds contained into this type of beverages. Derived properties were computed due to its importance in the study of specific molecular interactions.

Keywords: *equation of state, ethanol, excess molar volume, prediction, 1-propanol, temperature, water*

Introduction

Knowledge of thermophysical properties of ethanol, water and the different flavour components in distillated alcoholic beverages is of practical interest to the food industry since thermal/mechanical procedures applied are close related on their temperature and pressure dependence to obtain a quality final product. Thermodynamics studies provide the additional advantage of an interesting trend of analysis. Currently it can be observed a considerable lack of accuracy or thermodynamic consistency in the disposable open literature data. Simulation and optimization are not used in a right way in this matter, an overestimation of equipment or high energy-consuming conditions being usually applied due to inaccurate calculations. The difficulties of simulation in these types of processes have been commented upon previously [1, 2], due to the infinite dilution of key compounds.

In the scope of investigating physical properties related to equipment design of distillated alcoholic beverages processes, as well as, energy optimization and quality and flavouring ensurement, we present in this paper the temperature dependence of excess molar volumes of the mixture ethanol+water+1-propanol at the range 288.15–323.15 K and atmospheric pressure, as a function of molar fraction. Study of speed of sound for this system has been published in [3].

Experimental

All chemical solvents used in the preparation of samples were of Merck quality with richness better than 99.5 mol%. The pure components were stored in sun light protected form and constant humidity and temperature. In order to reduce fraction molar errors, the vapour space into the vessels was minimized during samples preparation. Mixtures were prepared by mass using a Salter ER-182A balance, the whole composition range of the ternary mixture being covered. The accuracy in molar fractions was obtained as

Table 1 Comparison of experimental density (g cm^{-3}) with literature data for chemicals at the studied temperatures

Comp.	Mol. mass	288.15 K	293.15 K	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K	lit. (298.15 K)[a]
Ethanol	46.070	0.79444	0.79016	0.78589	0.78159	0.77724	0.77285	0.76848	0.76402	0.78493 0.78730[b]
Water	18.015	0.9991	0.99820	0.99704	0.99565	0.99403	0.99221	0.99021	0.98804	0.99705 0.99712[b]
1-propanol	60.096	0.80742	0.80350	0.79951	0.79544	0.79137	0.78727	0.78320	0.77904	0.79960[a] 0.79952[b]

[a]Ref. [4], [b]Ref. [5]

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Table 2 Densities (ρ) excess molar volumes (V^E) excess isobaric expansibilities (α^E) and isothermal pressure dependence of excess molar enthalpies ($(\partial H^E/\partial P)_T$) on mixing for the mixture ethanol+water+1-propanol at different temperatures

x_1	x_2	ρ/ g cm^{-3}	V^E/ cm^3 mol^{-1}	$10^6\,\alpha^E$/ K^{-1}	$(\partial H^E/\partial P)_T$/ JMPa^{-1} mol^{-1}	x_1	x_2	ρ/ g cm^{-3}	V^E/ cm^3 mol^{-1}	$10^6\,\alpha^E$/ K^{-1}	$(\partial H^E/\partial P)_T$/ JMPa^{-1} mol^{-1}
					318.15 K						
0.9049	0.0452	0.77392	–0.105	–10.944	0.099	0.3006	0.1987	0.79653	–0.399	0.424	–0.409
0.0501	0.9004	0.94645	–0.461	–19.467	–0.322	0.3003	0.2987	0.80726	–0.550	–4.109	–0.483
0.0514	0.0480	0.78621	–0.107	–0.045	–0.107	0.3006	0.3983	0.82012	–0.672	–10.261	–0.519
0.7990	0.1021	0.78160	–0.292	–13.042	–0.057	0.2975	0.5029	0.83726	–0.782	–17.379	–0.556
0.7027	0.0970	0.78237	–0.263	–11.727	–0.044	0.2993	0.6012	0.85843	–0.870	–23.869	–0.603
0.6989	0.2004	0.79369	–0.530	–15.523	–0.272	0.2010	0.1027	0.78884	–0.216	4.615	–0.316
0.6023	0.1967	0.79411	–0.493	–13.299	–0.264	0.1997	0.2021	0.79758	–0.376	4.156	–0.459
0.5987	0.3005	0.80703	–0.702	–18.069	–0.427	0.1994	0.3028	0.80792	–0.510	1.215	–0.533
0.6018	0.0978	0.78369	–0.245	–8.584	–0.081	0.1999	0.3990	0.81972	–0.611	–3.640	–0.556
0.4989	0.4009	0.82182	–0.808	–20.494	–0.524	0.1990	0.6006	0.85463	–0.754	–17.499	–0.549
0.4973	0.3031	0.80739	–0.647	–15.028	–0.410	0.1995	0.7008	0.88130	–0.807	–23.901	–0.571
0.4981	0.2020	0.79537	–0.461	–9.319	–0.297	0.0988	0.0960	0.78935	–0.194	3.945	–0.282
0.5003	0.0982	0.78501	–0.235	–4.462	–0.148	0.0984	0.2008	0.79824	–0.354	6.199	–0.480
0.3994	0.1010	0.78646	–0.230	–0.428	–0.223	0.1007	0.3994	0.81934	–0.551	2.404	–0.593
0.4008	0.1979	0.79572	–0.427	–4.319	–0.349	0.1002	0.4987	0.83341	–0.615	–2.716	–0.579
0.4001	0.3006	0.80724	–0.596	–9.974	–0.434	0.1001	0.5989	0.85127	–0.652	–9.359	–0.538
0.3989	0.3989	0.82083	–0.739	–16.231	–0.505	0.0994	0.7016	0.87562	–0.670	–16.503	–0.499
0.3991	0.5004	0.83873	–0.871	–22.511	–0.589	0.1006	0.7993	0.90792	–0.663	–21.839	–0.475
0.2991	0.1003	0.78758	–0.222	2.886	–0.284						
					313.15 K						
0.9049	0.0452	0.77825	–0.105	–5.675	–0.002	0.3006	0.1987	0.80085	–0.413	7.980	–0.562
0.0501	0.9004	0.94969	–0.469	–6.911	–0.420	0.3003	0.2987	0.81162	–0.567	3.520	–0.627
0.0514	0.0480	0.79034	–0.113	4.989	–0.227	0.3006	0.3983	0.82448	–0.688	–2.602	–0.651
0.7990	0.1021	0.78596	–0.295	–6.599	–0.179	0.2975	0.5029	0.84158	–0.797	–9.661	–0.673
0.7027	0.0970	0.78673	–0.269	–4.286	–0.191	0.2993	0.6012	0.86270	–0.884	–15.913	–0.708
0.6989	0.2004	0.79812	–0.539	–8.496	–0.401	0.2010	0.1027	0.79305	–0.225	11.243	–0.461
0.6023	0.1967	0.79851	–0.503	–5.469	–0.412	0.1997	0.2021	0.80187	–0.391	10.924	–0.600
0.5987	0.3005	0.81147	–0.713	–10.681	–0.554	0.1994	0.3028	0.81226	–0.528	8.071	–0.667

Table 2 Continued

x_1	x_2	ρ/ g cm^{-3}	V^E/ cm^3 mol^{-1}	$10^6\ \alpha^E$/ K^{-1}	$(\partial H^E/\partial P)_T$/ JMPa^{-1} mol^{-1}	x_1	x_2	ρ/ g cm^{-3}	V^E/ cm^3 mol^{-1}	$10^6\ \alpha^E$/ K^{-1}	$(\partial H^E/\partial P)_T$/ JMPa^{-1} mol^{-1}
0.6018	0.0978	0.78800	–0.251	–0.598	–0.241	0.1999	0.3990	0.82406	–0.629	3.304	–0.682
0.4989	0.4009	0.82624	–0.821	–12.905	–0.645	0.1990	0.6006	0.85883	–0.769	–9.977	–0.653
0.4973	0.3031	0.81181	–0.660	–7.066	–0.552	0.1995	0.7008	0.88542	–0.821	–15.461	–0.670
0.4981	0.2020	0.79975	–0.474	–1.175	–0.454	0.0988	0.0960	0.79355	–0.204	9.558	–0.411
0.5003	0.0982	0.78931	–0.243	3.659	–0.315	0.0984	0.2008	0.80250	–0.370	11.908	–0.604
0.3994	0.1010	0.79071	–0.236	7.475	–0.386	0.1007	0.3994	0.82364	–0.571	8.258	–0.704
0.4008	0.1979	0.80006	–0.439	3.714	–0.508	0.1002	0.4987	0.83769	–0.635	3.314	–0.683
0.4001	0.3006	0.81164	–0.611	–1.955	–0.581	0.1001	0.5989	0.85544	–0.669	–2.879	–0.635
0.3989	0.3989	0.82524	–0.754	–8.327	–0.637	0.0994	0.7016	0.87966	–0.685	–9.016	–0.592
0.3991	0.5004	0.84311	–0.884	–14.773	–0.703	0.1006	0.7993	0.91172	–0.675	–12.382	–0.569
0.2991	0.1003	0.79184	–0.231	10.266	–0.442						
					308.15 K						
0.9049	0.0452	0.78264	–0.107	–0.299	–0.101	0.3006	0.1987	0.805	–0.428	15.675	–0.712
0.0501	0.9004	0.95295	–0.480	5.829	–0.518	0.3003	0.2987	0.81601	–0.584	11.294	–0.768
0.0514	0.0480	0.79452	–0.119	10.126	–0.344	0.3006	0.3983	0.82887	–0.706	5.206	–0.781
0.7990	0.1021	0.79034	–0.299	–0.033	–0.298	0.2975	0.5029	0.84595	–0.814	–1.790	–0.790
0.7027	0.0970	0.79110	–0.274	3.288	–0.333	0.2993	0.6012	0.86704	–0.901	–7.798	–0.814
0.6989	0.2004	0.80258	–0.548	–1.334	–0.527	0.2010	0.1027	0.79731	–0.234	17.994	–0.602
0.6023	0.1967	0.80294	–0.514	2.504	–0.555	0.1997	0.2021	0.80619	–0.407	17.821	–0.739
0.5987	0.3005	0.81594	–0.725	–3.152	–0.678	0.1994	0.3028	0.81660	–0.545	15.063	–0.798
0.6018	0.0978	0.79236	–0.258	7.527	–0.397	0.1999	0.3990	0.82841	–0.648	10.389	–0.804
0.4989	0.4009	0.83071	–0.835	–5.168	–0.765	0.1990	0.6006	0.86308	–0.786	–2.300	–0.758
0.4973	0.3031	0.81625	–0.675	1.044	–0.690	0.1995	0.7008	0.88957	–0.838	–6.854	–0.769
0.4981	0.2020	0.80414	–0.485	7.116	–0.606	0.0988	0.0960	0.79779	–0.215	15.284	–0.537
0.5003	0.0982	0.79363	–0.250	11.920	–0.476	0.0984	0.2008	0.80680	–0.387	17.735	–0.726
0.3994	0.1010	0.79500	–0.244	15.515	–0.545	0.1007	0.3994	0.82795	–0.591	14.242	–0.812
0.4008	0.1979	0.80444	–0.453	11.891	–0.663	0.1002	0.4987	0.84197	–0.655	9.481	–0.784

Table 2 Continued

x_1	x_2	ρ/ g cm^{-3}	V^E/ cm^3 mol^{-1}	10^6 α^E/ K^{-1}	$(\partial H^E/\partial P)_T$/ JMPa^{-1} mol^{-1}	x_1	x_2	ρ/ g cm^{-3}	V^E/ cm^3 mol^{-1}	10^6 α^E/ K^{-1}	$(\partial H^E/\partial P)_T$/ JMPa^{-1} mol^{-1}
0.4001	0.3006	0.81604	–0.626	6.212	–0.724	0.1001	0.5989	0.85964	–0.687	3.746	–0.730
0.3989	0.3989	0.82964	–0.769	–0.272	–0.765	0.0994	0.7016	0.88373	–0.702	–1.369	–0.686
0.3991	0.5004	0.84749	–0.899	–6.881	–0.814	0.1006	0.7993	0.91560	–0.692	–2.750	–0.666
0.2991	0.1003	0.79612	–0.241	17.778	–0.596						
					303.15 K						
0.9049	0.0452	0.78696	–0.106	5.184	–0.195	0.3006	0.1987	0.80949	–0.441	23.507	–0.856
0.0501	0.9004	0.95610	–0.492	18.747	–0.613	0.3003	0.2987	0.82031	–0.599	19.211	–0.902
0.0514	0.0480	0.79865	–0.124	15.364	–0.455	0.3006	0.3983	0.83320	–0.723	13.164	–0.906
0.7990	0.1021	0.79472	–0.304	6.656	–0.415	0.2975	0.5029	0.85026	–0.832	6.237	–0.904
0.7027	0.0970	0.79544	–0.279	10.997	–0.470	0.2993	0.6012	0.87124	–0.916	0.478	–0.915
0.6989	0.2004	0.80700	–0.558	5.963	–0.649	0.2010	0.1027	0.80152	–0.243	24.867	–0.738
0.6023	0.1967	0.80732	–0.525	10.620	–0.695	0.1997	0.2021	0.81048	–0.423	24.848	–0.872
0.5987	0.3005	0.82034	–0.736	4.520	–0.798	0.1994	0.3028	0.82089	–0.562	22.189	–0.923
0.6018	0.0978	0.79665	–0.263	15.792	–0.546	0.1999	0.3990	0.83273	–0.668	17.615	–0.923
0.4989	0.4009	0.83511	–0.850	2.719	–0.882	0.1990	0.6006	0.86728	–0.805	5.534	–0.861
0.4973	0.3031	0.82062	–0.687	9.304	–0.822	0.1995	0.7008	0.89365	–0.855	1.921	–0.867
0.4981	0.2020	0.80850	–0.497	15.553	–0.754	0.0988	0.0960	0.80198	–0.225	21.120	–0.658
0.5003	0.0982	0.79791	–0.257	20.322	–0.632	0.0984	0.2008	0.81105	–0.402	23.679	–0.843
0.3994	0.1010	0.79922	–0.249	23.691	–0.697	0.1007	0.3994	0.83220	–0.610	20.353	–0.916
0.4008	0.1979	0.80877	–0.466	20.213	–0.812	0.1002	0.4987	0.84620	–0.675	15.784	–0.883
0.4001	0.3006	0.82040	–0.642	14.529	–0.862	0.1001	0.5989	0.86376	–0.705	10.516	–0.823
0.3989	0.3989	0.83400	–0.785	7.936	–0.889	0.0994	0.7016	0.88773	–0.720	6.436	–0.778
0.3991	0.5004	0.85182	–0.914	1.165	–0.923	0.1006	0.7993	0.91940	–0.709	7.060	–0.760
0.2991	0.1003	0.80034	–0.248	25.420	–0.742						
					298.15 K						
0.9049	0.0452	0.79125	–0.108	10.774	–0.288	0.3006	0.1987	0.81377	–0.455	31.478	–0.996
0.0501	0.9004	0.95916	–0.506	31.836	–0.708	0.3003	0.2987	0.82458	–0.614	27.270	–1.033
0.0514	0.0480	0.80276	–0.128	20.705	–0.562	0.3006	0.3983	0.83750	–0.742	21.271	–1.030
0.7990	0.1021	0.79903	–0.308	13.468	–0.527	0.2975	0.5029	0.85453	–0.851	14.418	–1.016
0.7027	0.0970	0.79977	–0.287	18.840	–0.606	0.2993	0.6012	0.87542	–0.934	8.912	–1.016

Table 2 Continued

x_1	x_2	ρ/ g cm^{-3}	V^E/ cm^3 mol^{-1}	$10^6\,\alpha^E$/ K^{-1}	$(\partial H^E/\partial P)_T$/ JMPa^{-1} mol^{-1}	x_1	x_2	ρ/ g cm^{-3}	V^E/ cm^3 mol^{-1}	$10^6\,\alpha^E$/ K^{-1}	$(\partial H^E/\partial P)_T$/ JMPa^{-1} mol^{-1}
0.6989	0.2004	0.81139	–0.570	13.394	–0.769	0.2010	0.1027	0.80569	–0.250	31.861	–0.868
0.6023	0.1967	0.81167	–0.536	18.879	–0.830	0.1997	0.2021	0.81472	–0.436	32.003	–1.000
0.5987	0.3005	0.82471	–0.749	12.335	–0.916	0.1994	0.3028	0.82513	–0.578	29.449	–1.044
0.6018	0.0978	0.80094	–0.270	24.197	–0.693	0.1999	0.3990	0.83701	–0.688	24.983	–1.040
0.4989	0.4009	0.83949	–0.867	10.755	–0.997	0.1990	0.6006	0.87139	–0.822	13.521	–0.960
0.4973	0.3031	0.82495	–0.701	17.710	–0.951	0.1995	0.7008	0.89769	–0.875	10.863	–0.964
0.4981	0.2020	0.81284	–0.511	24.137	–0.899	0.0988	0.0960	0.80615	–0.233	27.067	–0.774
0.5003	0.0982	0.80218	–0.265	28.864	–0.784	0.0984	0.2008	0.81524	–0.415	29.738	–0.954
0.3994	0.1010	0.80342	–0.253	32.003	–0.844	0.1007	0.3994	0.83642	–0.629	26.593	–1.017
0.4008	0.1979	0.81306	–0.479	28.678	–0.957	0.1002	0.4987	0.85039	–0.695	22.222	–0.980
0.4001	0.3006	0.82473	–0.658	22.994	–0.998	0.1001	0.5989	0.86782	–0.723	17.428	–0.914
0.3989	0.3989	0.83829	–0.800	16.295	–1.010	0.0994	0.7016	0.89168	–0.740	14.399	–0.869
0.3991	0.5004	0.85609	–0.930	9.363	–1.030	0.1006	0.7993	0.92314	–0.728	17.043	–0.855
0.2991	0.1003	0.80455	–0.256	33.193	–0.885						
					293.15 K						
0.9049	0.0452	0.79550	–0.109	16.471	–0.377	0.3006	0.1987	0.81795	–0.467	39.581	–1.130
0.0501	0.9004	0.96209	–0.521	45.086	–0.801	0.3003	0.2987	0.82878	–0.629	35.469	–1.160
0.0514	0.0480	0.80680	–0.132	26.145	–0.666	0.3006	0.3983	0.84171	–0.759	29.522	–1.148
0.7990	0.1021	0.80328	–0.312	20.401	–0.635	0.2975	0.5029	0.85869	–0.869	22.747	–1.124
0.7027	0.0970	0.80400	–0.292	26.813	–0.734	0.2993	0.6012	0.87954	–0.953	17.502	–1.116
0.6989	0.2004	0.81567	–0.577	20.956	–0.882	0.2010	0.1027	0.80981	–0.259	38.974	–0.995
0.6023	0.1967	0.81594	–0.546	27.278	–0.960	0.1997	0.2021	0.81888	–0.450	39.283	–1.124
0.5987	0.3005	0.82899	–0.760	20.287	–1.029	0.1994	0.3028	0.82931	–0.595	36.839	–1.162
0.6018	0.0978	0.80513	–0.274	32.736	–0.832	0.1999	0.3990	0.84119	–0.707	32.486	–1.152
0.4989	0.4009	0.84376	–0.881	18.934	–1.106	0.1990	0.6006	0.87547	–0.843	21.662	–1.060
0.4973	0.3031	0.82919	–0.713	26.261	–1.075	0.1995	0.7008	0.90165	–0.896	19.966	–1.060
0.4981	0.2020	0.81707	–0.521	32.861	–1.036	0.0988	0.0960	0.81025	–0.243	33.122	–0.887
0.5003	0.0982	0.80636	–0.271	37.541	–0.929	0.0984	0.2008	0.81938	–0.430	35.912	–1.063
0.3994	0.1010	0.80757	–0.260	40.448	–0.988	0.1007	0.3994	0.84055	–0.648	32.956	–1.115
0.4008	0.1979	0.81728	–0.491	37.282	–1.097	0.1002	0.4987	0.85395	–0.688	28.756	–1.046
0.4001	0.3006	0.82896	–0.672	31.603	–1.127	0.1001	0.5989	0.87181	–0.744	24.481	–1.004
0.3989	0.3989	0.84253	–0.816	24.801	–1.128	0.0994	0.7016	0.89555	–0.760	22.514	–0.959
0.3991	0.5004	0.86030	–0.946	17.711	–1.134	0.1006	0.7993	0.92678	–0.749	27.193	–0.947
0.2991	0.1003	0.80867	–0.262	41.091	–1.021						

Table 3 Parameters of Cibulka equation in the range 288.15–323.15 K and σ in accordance to reference [5]

C_{00}= 34681.1607	C_{01}= –340.3062	C_{02}= 1.1085	C_{03}= –0.001	
C_{10}= –58129.9367	C_{11}= 570.0468	C_{12}= –1.8598	C_{13}= –0.002	
C_{20}= –55385.2504	C_{21}= 542.6686	C_{22}= –1.7670	C_{23}= –0.002	σ=0.60

higher than $\pm 5 \cdot 10^{-4}$. The densities of pure components and their mixtures were measured with an Anton Paar DSA-48 vibrational tube densimeter and sound analyzer, with an uncertainty density measurement $5 \cdot 10^{-5}$ g cm^{-3}. Apparatus calibration was performed periodically in accordance with vendor instructions using a double reference (Millipore quality water and ambient air at each temperature). Uncertainty in the calculation of excess molar volumes was estimated as better than $\pm 2 \cdot 10^{-2}$ cm^3 mol^{-1}. The temperature is measured with uncertainty of $\pm 10^{-2}$ K. The experimental and literature densities of solvents are gathered in Table 1. More details about techniques and procedure in our laboratory could be obtained from previously published works [6].

Data correlation

The excess molar volumes of the ternary mixture, were computed applying the following equation (Table 2):

$$V^{\mathrm{E}} = \sum_{\mathrm{i}=1}^{\mathrm{N}} x_{\mathrm{i}} M_{\mathrm{i}} (\rho^{-1} - \rho_{\mathrm{i}}^{-1}) \qquad (1)$$

where ρ is the density of the mixture, ρ_i the property of the pure components, and x_i is the molar fraction. N stands for the number of components in the mixture. Densities of the mixture are also given in Table 2 as a function of temperature. The computed excess molar volumes of the binary mixtures were fitted using a temperature dependent Cibulka expression. All data correlation details are published in [7].

Derived properties

A frequently applied derived magnitude for industrial mixtures is the temperature dependence of volumetry which is expressed as isobaric expansibility or thermal expansion coefficient (α). The data reported in literature normally give only values of thermal expansion coefficients both of pure compounds and its mixtures, showing the relative changes in density, calculated by means of $(-\Delta\rho/\rho)$ as a function of temperature and assuming that α remains constant in any thermal range. As in the case of pure chemicals it can be computed at a molar fraction by way of the expression:

$$\alpha = -\left(\frac{\partial \ln \rho}{\partial T}\right)_{\mathrm{P,x}} \qquad (2)$$

The isothermal coefficient of pressure excess molar enthalpy can be derived accurately from volumetric measurements by application of the following expression:

$$\left(\frac{\partial H^{\mathrm{E}}}{\partial P}\right)_{\mathrm{T,x}} = V^{\mathrm{E}} - T\left(\frac{\partial V^{\mathrm{E}}}{\partial T}\right)_{\mathrm{P,x}} \qquad (3)$$

All data correlation details are published in [7].

Results and conclusions

In Table 2 it can see measurements of density at range of temperature 323.15–288.15 K, excess molar vol-

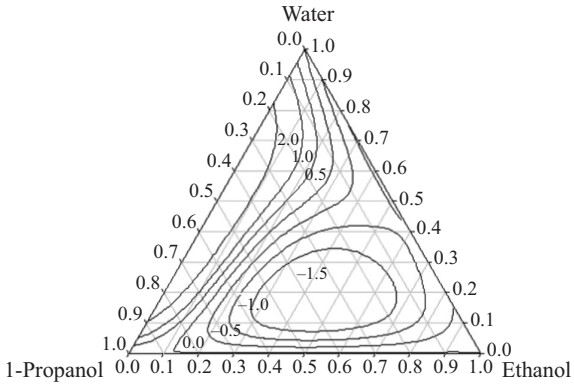

Fig. 1 Curves of constant excess molar volumes (cm^3 mol^{-1}), attending to Cibulka equation of ethanol+ water+1-propanol at temperature 298.15 K

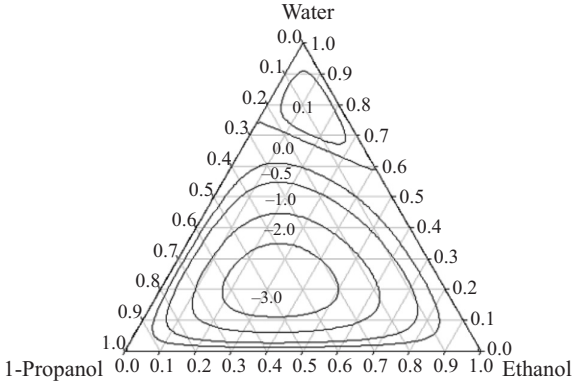

Fig. 2 Curves of constant ternary contribution to the excess molar volumes of ethanol+water+1-propanol at temperature 298.15 K

umes, isobaric expansibility or thermal expansion coefficient, isothermal coefficient of pressure excess molar enthalpy have been calculated too.

To correlate these experimental data Cibulka equation has been used [7]. The parameter of this equation have been reported in Table 3. Standard deviation is very good for these experimental data.

Trend for this system for excess molar volume is gathered in Fig. 1. In Fig. 2 it can see ternary contribution. There are two big regions seen in Fig. 1, there is one contractive region near of binary ethanol+water, this binary has this behavior and other near of binary 1-propanol+water that is expansive region.

In Fig. 2 can be seen two parts of ternary contribution one of them small and positive near of pure water and the other negative.

Figure 3 shows isobaric expansibility or thermal expansion coefficient and Fig. 4 shows isothermal coefficient of pressure excess molar enthalpy represented *vs. z* which expresses the product of total mole fractions in mixture.

$$z=\prod_{1}^{n} x_{n} \tag{4}$$

being n number of system compounds and x mole fraction. In Fig. 3 the following facts are observed: influence of temperature, which decreases the negative for higher temperatures, secondly, it may be observed three pseudobinary trends.

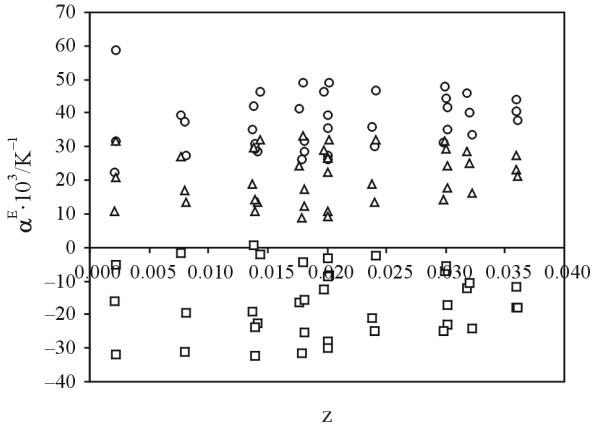

Fig. 3 Curves of constant excess isobaric expansibility (α^E, K^{-1}) of ethanol+water+1-propanol at the temperatures ○ – 288.15 K, Δ – 298.15 K and □ – 323.15 K as a function of *z*

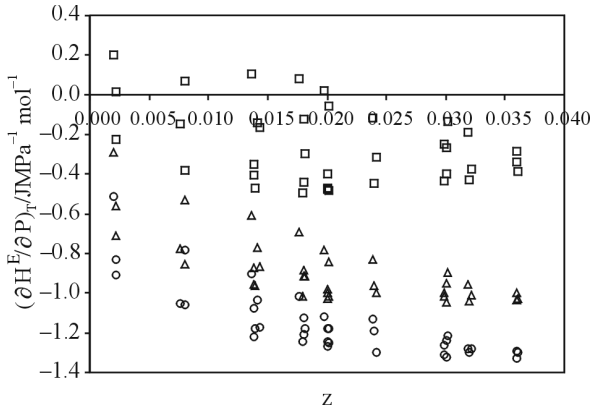

Fig 4 Curves of constant isothermal coefficient of pressure excess molar enthalpy $(\partial H^E/\partial P)_T$/JMPa^{-1} mol^{-1} of the mixture of ethanol+water+1-propanol at the temperatures ○ – 288.15 K, Δ – 298.15 K and □ – 323.15 K (same symbols used above) as a function of *z*

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