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Densities and Ultrasonic Studies of Binary Mixtures of (ortho-, meta- and para-)Xylenes with Pentan-1-ol at Different Temperature (298.15, 303.15, 308.15 and 313K)

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ABSTRACT: Density and ultrasonic velocity for binary mixtures of ortho-, meta- and para -xylenes with pentan-1-ol have been measured over the entire range of composition at different temperatures (298.15, 303.15, 308.15 and 313.15K) and atmospheric pressure. From the experimental data, the parameters isentropic compressibility (K_s), specific acoustic impedance (Z), intermolecular free length (L_f), relative association (R_A) and molar sound velocity (R) have been calculated. In the present binary liquid mixtures, it has been observed that the ultrasonic velocity increases and L_f decreases in all binary systems suggesting strong specific interactions between xylenes and pentan-1-ol molecules, the acoustic impedance (Z) increases with addition of xylene molecule, suggesting strong specific interaction between unlike molecules. The decrease of K_s with x_1 (Xylenes) supports the formation of donor-acceptor complexes between xylenes and 1-pentanol molecules.

KEYWORDS: Pentan-1-ol, Xylenes, Isentropic compressibility (K_s), Specific acoustic impedance (Z), Relative association (R_A), Intermolecular free length (L_f), Molar sound velocity (R).

I. INTRODUCTION

A thorough knowledge of thermodynamic and transport properties of multicomponent liquid mixtures is essential in many industrial applications such as design calculation, heat transfer, mass transfer, fluid flow. Ultrasonic velocity measurement through liquid mixtures of non electrolytes provides an excellent tool to investigate intra and intermolecular interactions between unlike and like molecules. Alcohols exist in the form of aggregates. When they are mixed with other non electrolyte molecules, the aggregates of alcohols dissociate and form intermolecular complexes with unlike molecules. In order to investigate depolymerisation of these alcohols in the presence of other non nonelectrolyte molecules, extensive studies of ultrasonic measurements through binary liquid mixtures with alcohols as one of the components have been reported.

The excess molar volumes for all binary mixtures of 1-propanol or 2-propanol + benzene, + toluene, + o-xylene, + m-xylene and + p-xylene have been measured over the entire range of composition¹ at 298.15K. The speed of sound was measured²⁻⁴ for primary alcohols at different temperatures. Isentropic compressibilities for binary mixtures of alcohols with methylcyclohexane were reported by Naidu and Rao⁵. The results have been discussed in terms of depolymerisation of polymerized alcohols by methyl cyclohexane. Many attempts⁶⁻¹⁰ were made to measure the ultrasonic behavior of binary mixtures of cycloalkanes with alcohols. Swamy et al.¹¹ measured Ultrasonic velocities of binary mixtures of toluene with n-propanol, iso-propanol, n-butanol, iso-propanol, n-pentanol, n-hexanol, n-heptanol and cyclohexanol over the whole range of composition at 303.15K. Isentropic compressibilities and the deviations from linear dependence of isentropic compressibility on volume fraction of toluene have been calculated. Ultrasonic behaviour of binary liquid mixtures of benzene, toluene, o-, m-, p-xylenes with triethyl amine was reported by Reddy et al.¹² Ultrasonic velocities in binary liquid mixtures of m-xylene, o-xylene, carbon tetrachloride and toluene in nitrobenzene were obtained by Jajoo et al.¹³ More work has been reported about excess, sonochemical and thermodynamic properties of binary liquid mixtures.¹⁴⁻²¹

II. EXPERIMENTAL SECTION

All the chemicals were used from s.d fine chemicals having purity > 99%. Binary mixtures were prepared by mass in airtight stoppard glass bottles. The densities of pure liquids and their mixtures are determined with bicapillary pycnometer of bulk capacity 15 cm³ and capillary of internal diameter 1 mm. At least three to four measurements were made, which had an average deviation of $\pm 5 \times 10^{-5}$ g.cm⁻³. The Table 1 reveals that literature values and our measured values match very well. An ultrasonic interferometer is a simple and direct device to determine the ultrasonic velocity (U) in liquids with high degree of accuracy. From the knowledge of wavelength and frequency U can be obtained by the relation

$$\text{Velocity} = \text{Wavelength} \times \text{Frequency}$$

$$U = \lambda \times f$$

In present investigation F-81 ultrasonic interferometer operating at frequency of 2MHz. The accuracy in velocity measurement was $\pm 0.03\%$. The interferometer cell is a specially designed double walled cell for maintaining the temperature of the liquid constant during the experiment.

Table 1 : Comparison of experimental and literature values of densities and ultrasonic velocities for pure liquids .

Liquid	Temp. (K)	ρ (g.cm ⁻³)		η (mPa.s)		
		Expt.	Lit.	Expt.	Lit.	
o-xylene	298.15	0.87596	0.87594 ^a	0.748	0.756 ^a	
	303.15	0.87161	0.87174 ^a	0.702	0.709 ^c	
	308.15	0.86724	0.86754 ^a	0.660	0.662 ^f	
	313.15	0.86275	0.86320 ^b	0.622	0.629 ^d	
m-xylene	298.15	0.86050	0.86009 ^a	0.578	0.579 ^f	
	303.15	0.85608	0.85581 ^a	0.546	0.546 ^a	
	308.15	0.85158	0.85154 ^a	0.515	0.517 ^f	
	313.15	0.84707	0.84726 ^a	0.492	0.496 ^a	
p-xylene	298.15	0.85674	0.85661 ^a	0.598	0.605 ^a	
	303.15	0.85226	0.85225 ^a	0.565	0.566 ^a	
	308.15	0.84773	0.84778 ^e	0.528	0.545 ^e	
	313.15	0.84317	0.84352 ^a	0.502	0.514 ^a	
Pentan-1-ol	298.15	0.81128	0.811120 ^b	3.465	3.421 ^a	
	303.15	0.80745	0.80740 ^a	3.021	3.054 ^b	
	308.15	0.80360	0.80399 ^b	2.648	2.607 ^a	
	313.15	0.79970	0.79987 ^a	2.324	2..344 ^a	
^a Ref 38.		^b Ref 39.	^c Ref 40.	^d Ref 41.	^e Ref 42.	^f Ref 43.

[Continued---

Table No.2 : Ultrasonic Velocity Data for the o-Xylene + Pentan-1-ol Systems .

Temp	X ₁	ρ	U	K _S	Z x 10 ⁻³	L _f	R _A	R	ΔK_S
298.15	0.0000	0.81128	1277.5	755.3	1036.4	0.5431	1.000	1.179	0.00
	0.1050	0.81906	1286.9	737.2	1054.0	0.5365	0.986	1.196	-3.63
	0.2025	0.82602	1295.3	721.6	1069.9	0.5308	0.976	1.211	-6.18
	0.3069	0.83292	1300.6	709.8	1083.3	0.5264	0.979	1.228	-4.26
	0.4036	0.83892	1304.8	700.2	1094.6	0.5229	0.981	1.243	-1.45
	0.5068	0.84525	1308.2	691.3	1105.8	0.5195	0.986	1.259	2.67
	0.6035	0.85111	1311.6	683.0	1116.3	0.5164	0.994	1.274	6.24
	0.7077	0.85748	1315.5	673.9	1128.0	0.5130	1.004	1.289	9.68
	0.8017	0.86319	1320.5	664.4	1139.8	0.5093	1.011	1.304	11.24
	0.9051	0.86973	1329.4	650.6	1156.2	0.5040	1.014	1.321	9.37
	1.0000	0.87596	1345.6	630.5	1178.7	0.4962	1.000	1.338	1.00
303.15	0.0000	0.80745	1260.0	780.1	1017.4	0.5572	1.000	1.179	0.00
	0.1050	0.81508	1268.9	762.0	1034.3	0.5507	0.988	1.196	-2.70
	0.2025	0.82197	1277.2	745.8	1049.8	0.5448	0.979	1.212	-4.88
	0.3069	0.82877	1282.7	733.4	1063.1	0.5403	0.981	1.228	-2.70
	0.4036	0.83474	1286.9	723.4	1074.2	0.5366	0.982	1.243	0.56
	0.5068	0.84101	1291.2	713.2	1085.9	0.5328	0.988	1.260	4.24
	0.6035	0.84684	1295.0	704.1	1096.7	0.5294	0.996	1.275	7.86
	0.7077	0.85315	1299.8	693.8	1108.9	0.5255	1.005	1.291	10.87
	0.8017	0.85880	1305.3	683.4	1121.0	0.5215	1.012	1.306	12.32
	0.9051	0.86525	1315.0	668.4	1137.8	0.5158	1.014	1.323	9.98
	1.0000	0.87161	1331.7	646.9	1160.7	0.5074	1.000	1.340	1.00
308.15	0.0000	0.80360	1247.2	800.0	1002.2	0.5679	1.000	1.181	0.00
	0.1050	0.81111	1254.9	782.9	1017.9	0.5618	0.989	1.197	-2.20
	0.2025	0.81791	1262.0	767.7	1032.2	0.5564	0.981	1.213	-3.88
	0.3069	0.82457	1266.6	756.0	1044.4	0.5521	0.982	1.229	-1.44
	0.4036	0.83049	1270.0	746.5	1054.7	0.5486	0.985	1.244	1.97
	0.5068	0.83673	1273.9	736.5	1065.9	0.5449	0.990	1.260	5.26
	0.6035	0.84253	1276.8	728.1	1075.7	0.5418	0.999	1.275	9.14
	0.7077	0.84879	1280.9	718.1	1087.2	0.5381	1.007	1.291	12.08
	0.8017	0.85437	1285.7	708.1	1098.5	0.5343	1.014	1.306	13.50
	0.9051	0.86081	1294.8	692.9	1114.6	0.5286	1.015	1.323	10.66
	1.0000	0.86724	1310.7	671.2	1136.7	0.5202	1.000	1.340	1.00
313.15	0.0000	0.79970	1233.5	821.9	986.4	0.5820	1.000	1.182	0.00
	0.1050	0.80710	1239.8	806.1	1000.6	0.5763	0.991	1.198	-1.50
	0.2025	0.81380	1245.6	792.0	1013.7	0.5713	0.984	1.214	-2.60
	0.3069	0.82036	1249.0	781.4	1024.6	0.5675	0.986	1.230	0.36
	0.4036	0.82623	1251.9	772.3	1034.4	0.5641	0.989	1.245	3.50
	0.5068	0.83253	1254.8	763.0	1044.5	0.5607	0.994	1.261	7.04
	0.6035	0.83817	1257.2	754.8	1053.7	0.5577	1.002	1.275	10.67
	0.7077	0.84436	1260.8	745.0	1064.6	0.5541	1.009	1.291	13.25
	0.8017	0.84990	1265.0	735.3	1075.1	0.5505	1.016	1.306	14.43
	0.9051	0.85624	1273.0	720.7	1090.0	0.5450	1.016	1.322	11.63
	1.0000	0.86275	1288.2	698.5	1111.4	0.5365	1.000	1.339	1.00

Table No 3: Ultrasonic Velocity Data for the m-Xylene + Pentan-1-ol Systems.

Temp	X ₁	ρ	U	K _S	Z x 10 ⁻³	L _r	R _A	R	ΔK_S
298.15	0.0000	0.81128	1277.5	755.3	1036.4	0.5431	1.000	1.179	0.00
	0.1051	0.81730	1283.2	743.1	1048.8	0.5386	0.990	1.197	-1.79
	0.2026	0.82243	1287.8	733.2	1059.1	0.5350	0.984	1.214	-2.29
	0.3072	0.82766	1289.6	726.5	1067.4	0.5326	0.987	1.232	0.87
	0.4035	0.83226	1290.7	721.3	1074.2	0.5307	0.991	1.248	4.43
	0.5070	0.83709	1292.4	715.2	1081.9	0.5285	0.997	1.266	7.62
	0.6035	0.84152	1293.8	709.9	1088.8	0.5265	1.004	1.282	10.70
	0.7078	0.84628	1295.4	704.2	1096.3	0.5244	1.013	1.300	13.81
	0.8019	0.85057	1297.9	697.9	1104.0	0.5220	1.020	1.316	15.34
	0.9051	0.85558	1306.3	684.9	1117.6	0.5171	1.016	1.335	10.70
	1.0000	0.86050	1320.2	666.8	1136.0	0.5102	1.000	1.354	1.00
303.15	0.0000	0.80745	1260.0	780.1	1017.4	0.5572	1.000	1.179	0.00
	0.1051	0.81331	1264.9	768.5	1028.8	0.5530	0.991	1.197	-1.31
	0.2026	0.81833	1268.8	759.1	1038.3	0.5496	0.986	1.214	-1.41
	0.3072	0.82349	1269.9	753.0	1045.7	0.5474	0.989	1.232	2.24
	0.4035	0.82806	1270.7	747.9	1052.2	0.5456	0.994	1.248	5.85
	0.5070	0.83283	1272.0	742.1	1059.4	0.5435	1.000	1.266	9.18
	0.6035	0.93723	1273.0	737.1	1065.8	0.5416	1.007	1.282	12.41
	0.7078	0.84196	1274.8	730.8	1073.3	0.5393	1.014	1.299	14.94
	0.8019	0.84620	1277.4	724.2	1080.9	0.5369	1.020	1.316	16.01
	0.9051	0.85107	1284.4	712.3	1093.1	0.5324	1.018	1.334	12.28
	1.0000	0.85608	1298.7	692.6	1111.8	0.5250	1.000	1.353	1.00
308.15	0.0000	0.80360	1247.2	800.0	1002.2	0.5679	1.000	1.181	0.00
	0.1051	0.80932	1251.2	789.3	1012.6	0.5641	0.992	1.199	-0.85
	0.2026	0.81425	1254.2	780.7	1021.2	0.5611	0.988	1.216	-0.47
	0.3072	0.81931	1254.8	775.2	1028.1	0.5591	0.992	1.233	3.27
	0.4035	0.82382	1254.9	770.8	1033.8	0.5575	0.997	1.249	7.27
	0.5070	0.82856	1255.8	765.3	1040.5	0.5555	1.002	1.267	10.49
	0.6035	0.83287	1256.5	760.5	1046.5	0.5537	1.009	1.283	13.62
	0.7078	0.83756	1257.6	754.9	1053.3	0.5517	1.017	1.300	16.41
	0.8019	0.84174	1259.9	748.4	1060.5	0.5493	1.022	1.316	17.29
	0.9051	0.84648	1266.4	736.6	1072.0	0.5450	1.020	1.335	13.37
	1.0000	0.85158	1280.5	716.2	1090.4	0.5374	1.000	1.354	1.00
313.15	0.0000	0.79970	1233.5	821.9	986.4	0.5820	1.000	1.182	0.00
	0.1051	0.80524	1237.6	810.8	996.6	0.5780	0.993	1.201	-0.38
	0.2026	0.81009	1240.4	802.3	1004.8	0.5750	0.990	1.218	0.77
	0.3072	0.81508	1241.7	795.7	1012.1	0.5726	0.993	1.235	4.25
	0.4035	0.81953	1241.7	791.4	1017.6	0.5711	0.999	1.251	8.95
	0.5070	0.82424	1243.0	785.2	1024.5	0.5689	1.004	1.269	12.23
	0.6035	0.82852	1244.2	779.7	1030.8	0.5668	1.011	1.285	15.25
	0.7078	0.83313	1246.2	772.9	1038.2	0.5644	1.017	1.303	17.50
	0.8019	0.83726	1261.0	751.1	1055.8	0.5564	0.994	1.324	18.40
	0.9051	0.84193	1265.0	742.2	1065.0	0.5531	0.999	1.342	14.92
	1.0000	0.84707	1270.6	731.2	1076.3	0.5489	1.000	1.358	1.00

Table No 4: Ultrasonic Velocity Data for the p-Xylene + Pentan-1-ol System.

Temp	X ₁	ρ	U	K _S	Z x 10 ⁻³	L _f	R _A	R	ΔK_S
298.15	0.0000	0.81128	1277.5	755.3	1036.4	0.5431	1.000	1.179	0.00
	0.1046	0.81696	1282.8	743.8	1048.0	0.5389	0.989	1.197	-3.07
	0.2018	0.82202	1286.9	734.6	1057.9	0.5356	0.981	1.215	-4.79
	0.3067	0.82691	1288.4	728.5	1065.4	0.5333	0.982	1.233	-2.90
	0.4032	0.83104	1288.5	724.8	1070.8	0.5320	0.986	1.249	0.48
	0.5058	0.83525	1288.9	720.7	1076.6	0.5305	0.991	1.267	3.73
	0.6035	0.83933	1289.4	716.6	1082.2	0.5290	0.997	1.284	6.49
	0.7075	0.84371	1289.8	712.5	1088.2	0.5274	1.005	1.302	9.41
	0.8017	0.84766	1290.4	708.5	1093.8	0.5260	1.013	1.318	11.68
	0.9050	0.85228	1297.0	697.5	1105.4	0.5219	1.009	1.337	7.37
	1.0000	0.85674	1306.2	684.1	1119.1	0.5168	1.000	1.355	1.00
303.15	0.0000	0.80745	1260.0	780.1	1017.4	0.5572	1.000	1.179	0.00
	0.1046	0.81299	1264.7	769.0	1028.2	0.5532	0.990	1.198	-2.48
	0.2018	0.81794	1268.5	759.8	1037.6	0.5499	0.983	1.215	-3.94
	0.3067	0.82271	1269.7	754.0	1044.6	0.5478	0.984	1.233	-1.63
	0.4032	0.82676	1269.8	750.2	1049.8	0.5464	0.988	1.250	1.85
	0.5058	0.83096	1270.0	746.1	1055.3	0.5449	0.993	1.268	5.37
	0.6035	0.83501	1270.2	742.3	1060.6	0.5435	1.000	1.284	8.52
	0.7075	0.83934	1271.1	737.4	1066.9	0.5417	1.007	1.302	10.91
	0.8017	0.84323	1272.2	732.7	1072.8	0.5400	1.014	1.318	12.65
	0.9050	0.84772	1278.4	721.8	1083.7	0.5360	1.011	1.337	8.57
	1.0000	0.85226	1288.2	707.1	1097.9	0.5305	1.000	1.355	1.00
308.15	0.0000	0.80360	1247.2	800.0	1002.2	0.5679	1.000	1.181	0.00
	0.1046	0.80900	1251.0	789.8	1012.1	0.5643	0.991	1.199	-1.95
	0.2018	0.81382	1254.1	781.3	1020.6	0.5613	0.985	1.216	-3.08
	0.3067	0.81850	1254.8	775.9	1027.1	0.5593	0.986	1.234	-0.63
	0.4032	0.82249	1254.3	772.8	1031.6	0.5582	0.991	1.251	3.19
	0.5058	0.82664	1254.4	768.8	1036.9	0.5568	0.996	1.269	6.40
	0.6035	0.83062	1254.0	765.6	1041.6	0.5556	1.003	1.286	9.89
	0.7075	0.83489	1254.4	761.2	1047.3	0.5540	1.010	1.303	12.43
	0.8017	0.83873	1255.6	756.3	1053.1	0.5522	1.015	1.320	13.63
	0.9050	0.84317	1260.9	746.0	1063.2	0.5484	1.013	1.338	9.88
	1.0000	0.84773	1271.0	730.2	1077.5	0.5426	1.000	1.357	1.00
313.15	0.0000	0.79970	1233.5	821.9	986.4	0.5820	1.000	1.182	0.00
	0.1046	0.80496	1235.8	813.4	994.8	0.5790	0.992	1.200	-1.41
	0.2018	0.80965	1237.5	806.5	1001.9	0.5765	0.988	1.217	-2.03
	0.3067	0.81422	1237.0	802.6	1007.2	0.5761	0.989	1.235	0.72
	0.4032	0.81816	1235.8	800.3	1011.1	0.5743	0.994	1.252	4.35
	0.5058	0.82227	1234.8	797.9	1015.2	0.5734	1.000	1.269	8.03
	0.6035	0.82621	1233.6	795.4	1019.2	0.5725	1.006	1.285	11.21
	0.7075	0.83041	1233.2	791.8	1024.1	0.5712	1.012	1.303	13.61
	0.8017	0.83419	1233.8	787.5	1029.2	0.5697	1.017	1.319	14.49
	0.9050	0.83852	1237.3	779.0	1037.5	0.5666	1.016	1.337	11.55
	1.0000	0.84317	1247.2	762.5	1051.6	0.5605	1.000	1.355	1.00

III. RESULTS AND DISCUSSIONS

The thermodynamic functions are highly useful in understanding the interactions in binary liquid mixtures. Ultrasonic velocity measurement through liquid mixtures of non-electrolytes provide an excellent tool to investigate inter and intramolecular interactions between like and unlike molecules. Ultrasonic velocity (U) is a thermodynamic function. Many other thermodynamic functions such as isentropic compressibility [K_s], specific acoustic impedance [Z], relative association [R_A], intermolecular free length [L_f], Rao's constant [R] are calculated from ultrasonic velocity with use of following relation.

$$K_s = 1 / (\rho U^2)$$

$$Z = \rho U$$

$$R_A = (L_f / L_f^0)^3$$

$$L_f = K (K_s)^{1/2}$$

$$R = (M/\rho) U^{1/3}$$

Where M is the average molecular weight, K is the temperature dependent constant whose values are 1.976×10^{-6} , 1.995×10^{-6} , 2.008×10^{-6} , 2.030×10^{-6} at 298.15, 303.15, 308.15, 313.15 K. L_f^0 is the free length of ideal mixture.

Tables 2,3 and 4 contains values of U and all the calculated parameters viz. K_s , Z , L_f , R_A , R for the all binary mixtures as a function of X (xylenes) at 298.15, 303.15, 308.15, 313.15 K temperature. It is observed from the tables that ultrasonic velocity increases with increases of xylene concentrations in binary mixtures at all temperature. On the basis of a model of sound propagation proposed by Eyring and Kincaid²², U should increase if L_f decreases and vice versa as a result of mixing the two components. It has been indicated that L_f is a predominant factor in determining the variation of U in a mixture and a change in the former parameter also indicates that there is significant interaction between the constituent molecules due to which structural arrangement is considerably affected.

In the present binary mixtures it has been observed that intermolecular free length decreases and ultrasonic velocity increases with increase of mole fractions of xylenes at all temperatures. The nature of variation of L_f strongly depends on the size of molecules of both the components in the mixture²³. Acoustic impedance [Z], for alcohols + xylenes increases with increase of mole fraction of xylene at all temperatures. The increase of Z values with increase of X_1 suggests the presence of intermolecular interactions between alcohol-xylene molecules forming π ---HO donor-acceptor complexes. As expected K_s decreases with increase of xylene concentrations in all binary mixtures at all temperatures. Rajendran²⁴ suggested that K_s should decrease with increase of ultrasonic velocity which gives insight into structure making and structure breaking capacity of in binary mixture as observed in the present investigation. The molar sound velocity, also known as Rao's constant [R].²⁵ The slight increase in R with increase of X_1 may be caused due to specific interactions between xylene and alcohol molecules forming donor-acceptor complexes through π ---HO bond formation.²⁶⁻³² Alcohols are associated through H-bonding.³³⁻³⁶ When a small quantity of xylene is added to alcohol, the breaking of H-bonding of alcohols takes place leading to close packing of monomers, which is responsible for the continuous decrease in internal pressure in all binary mixtures. It is further seen that internal pressure in all binary mixtures decreases with increase of temperature due to dissociation of alcohol-xylene and alcohol-alcohol aggregates. Nikam et al.³⁷ showed that relative association (R) is influenced by two factors i) the breaking of solvent molecules on mixing and ii) the specific interactions leading to complex formation between molecules of the system. The former resulting in decrease and latter an increase of relative association. In the present investigation xylenes + 1-pentanol show positive deviation in R_A . These deviations in R_A decrease with decrease in chain length of alcohols.

Graphical representation of ΔK_s and R_A as a function of ϕ (xylene) at 298.15 K for the binary mixtures of xylenes (o-, m- and p-) with pentan-1-ol illustrated in figure 1 and 2. The values of ΔK_s for the mixtures of alcohols with xylenes are negative in mixtures rich in alcohols and positive in mixtures rich in xylenes. ΔK_s values for all binary systems of xylenes with n-alkanols are negative in lower concentration region of xylene molecules. This implies that there are

strong specific interactions between xylene and alkanol molecules in this region. The benzene ring in xylene has high π electron cloud density due to presence of two electron donating- CH_3 groups. This makes xylene molecules proton acceptor and alkanol proton donors, thus forming π ---HO donor- acceptor complexes. The ΔK_s values increase with increase of temperatures.

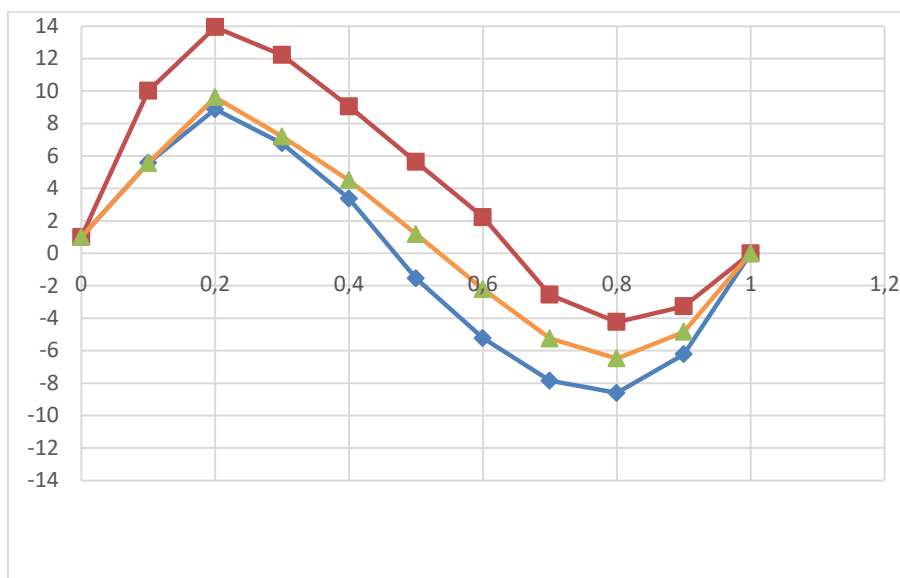


Fig. 1. ΔK_s values at 298.15K for X_1 pentan-1-ol + $(1-X_1)$ o-xylene(♦), m-xylene(■), p-xylene(▲).

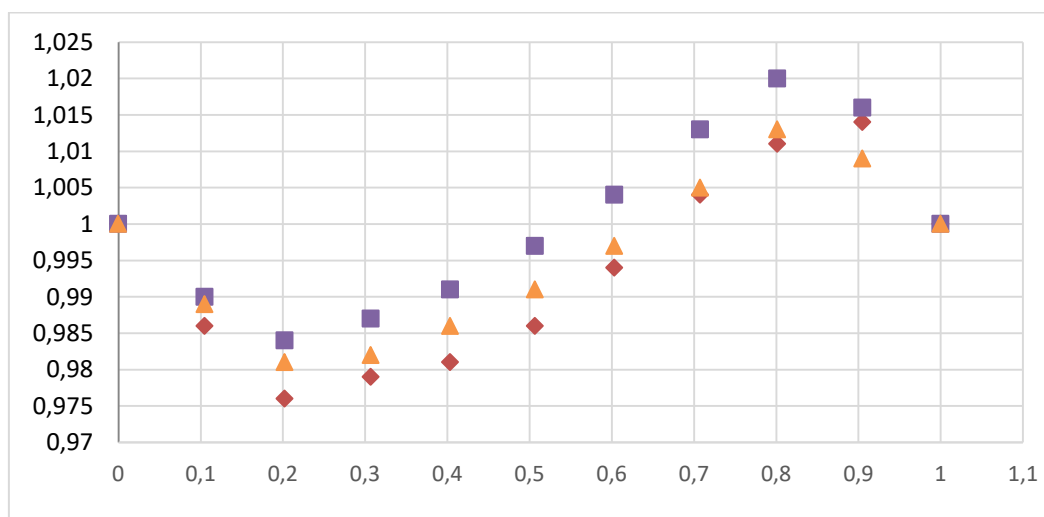


Fig. 2. R_A values at 298.15K for X_1 pentan-1-ol + $(1-X_1)$ o-xylene(♦), m-xylene(■), p-xylene(▲).

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