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Research Article

APPARENT MOLAR VOLUMES AND VISCOSITY B COEFFICIENTS OF IMIDACLOPRID PESTICIDE IN BINARY MIXTURE OF DMF AND DMSO AT DIFFERENT TEMPERATURES

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ABSTRACT

Apparent molar volumes (ϕ_v) and viscosity B-coefficients for imidacloprid in Dimethylformamide (DMF) and Dimethyl sulphoxide (DMSO) was evaluated from density (ρ) and viscosity (η) at 298.15 to 313.15 K using a bicapillary pycnometer and Ubbelohde viscometer respectively. The density data were analyzed in terms of limiting apparent molar volume (ϕ_v^o) and experimental slopes (S_v) obtained from Masson equation. The viscosity data were analyzed in term of A and B coefficient obtained from Jone-Dole equation. The evaluated parameters were interpreted in terms of different interactions exists therein.

Keywords: Apparent molar volume, B-coefficient, density, viscosity, pesticide imidacloprid.

INTRODUCTION

It is known that ever growing use of pesticides in the agricultural sector has led to several environmental problems. Pesticides residues or their toxic metabolites could affect man's health. The occurrence of appreciable amounts of certain pesticides in human tissues of general population gives sufficient reason for concern[1] in recent years, an increased awareness of the possible accumulation or persistence of toxic compounds in the environment has stimulated research into the fate of pesticides within plant tissues and also into the uptake and distribution of other exogenous materials[2]. Insecticides like DDT, dieldrin and melatonin at high concentration showed toxicity to nitrifying bacteria and retard the nitrification activity[3]. Imidacloprid is a chloronicotinyl nitroguanidine insecticide, with the IUPAC name 1-[(6-chloropyridin-3-yl) methyl]-N-nitro-4, 5-dihydroimidazol-2-amine and a CAS Number of 105827–78–9. The technical product is a colorless, odorless crystal. Imidacloprid is one of synthetic systemic insecticides with worldwide use in the last three decades[4,5]. Imidacloprid is an insecticide that enters the target pest via ingestion or direct contact. It acts by disrupting nicotinic acetylcholine receptors in the insect central nervous system. Imidacloprid is used for controlling sucking insects, soil insects, termites, and some chewing insects.

Imidacloprid initially get absorbed by pests or humans, transported to the target site and finally interact with the target receptors or enzymes. Hydrophobicity is very important for absorption, transport and interaction with receptors. Electronic and structural properties are also important factors for receptor-ligand interaction[6]. The transfer of a compound or solute from one phase to another is a very important process. Sorption-desorption processes are important in determining the fate and distribution of agrochemicals in the soil and water environment, since they determine the amount of pesticide that can reach the target organism and the amounts that can be volatilized, degraded and leached. However, there is no information available on sorption-desorption of imidacloprid or any of its metabolites. The rate and amount of pesticides absorption depends on biological and physicochemical factors. Physicochemical factors include solubility, salt complexation, dissolution rate, viscosity and toxicity.

The aim of the present study is to understand solvation behavior and molecular interactions of imidacloprid in binary mixture of DMF and DMSO at different temperature.

MATERIAL AND METHODS

The chemicals DMSO and DMF employed were of analytical grade and purchased from E. Merck, Germany (99.5%), used without further purification. Pesticide imidacloprid was purified by standard methods and then used to prepare various solutions.

Density Measurements

The densities of the sample solutions were measured by using a bicapillary pycnometer (made of borosil glass) having a bulb capacity of ~ 15 mL at different temperatures. The pycnometer was calibrated by using triply distilled water.

Viscosity measurements

The dynamic viscosities were evaluated by measuring flow time of solution using an Ubbelohde suspended-level viscometer, calibrated with water. Electronic digital stopwatch with readability of 0.01 s was used for the flow time measurements. At least three repetitions of each data measurement carried out. Viscosity values were determined using the relation[7,8].

$$\eta_1/\eta_2 = \rho_1 t_1/\rho_2 t_2 \qquad (1)$$

RESULT AND DISCUSSION

The apparent molar volume was calculated from density data using the following equation[9-12].

$$\Phi_V = \left[1000(\rho_0 - \rho)/C\rho_0\right] + \left[M/\rho_0\right] \quad (2)$$

Where M, C, ρ and ρ_0 are the molar mass of the Imidacloprid, concentration ($mol.L^{-1}$) and the densities of the solution and solvent, respectively

The apparent molar volume may be considered to be the sum of the geometric volume of the solute molecules and changes that occur in to the solution due to its interaction with solvent. The limiting partial molar volumes were evaluated by Masson equation[13] and experimental slope by least square method[14].

$$\Phi_v = \Phi_v^0 + S_v\sqrt{C} \quad (3)$$

Where ϕ_v^0 is the limiting apparent molar volume and S_v a semi-empirical parameter which depends on the nature of solvent, solute and temperature

The relative viscosities have been analyzed by Jones-Dole equation[15].

$$(\eta_r - 1)/\sqrt{C} = A + B\sqrt{C} \quad (4)$$

Where $\eta_r = (\eta/\eta_o)$ and η, η_o are viscosities of the solution and solvent respectively, C is molar concentration, A is the Falkenhagen coefficient which is the measure of solute-solute interactions[16] and B is the Jones-Dole coefficient which is the measure of solute - solvent interaction.

Moulik and Roots parameters were evaluated by the following equations[17, 18].

$$\eta_r^2 = M + KC^2 \quad (5)$$
$$(\rho - \rho_0)/C = R - SC^{1/2} \quad (6)$$

The values of the densities (ρ), viscosities (η) and apparent molar volumes (ϕ_v) of imidacloprid solution in binary liquid mixture of DMF and DMSO at 298.15, 303.15, 308.15 and 310.15 K temperature are shown in Table 1 to Table 4.

The densities of solutions of imidacloprid increase with percentage of DMSO in the binary liquid mixture. The ϕ_v values of imidacloprid pesticide for all the system are large and positive which indicate strong solute-solvent interaction[19,20]. These ϕ_v values increases slowly with increase in concentrations of imidacloprid in binary mixtures.

The plot of apparent molar volumes (ϕ_v) versus √C were found to be linear with positive slopes in different compositions of binary liquid mixture of DMF and DMSO and is shown in Figure 1 at 298.15 K. Similar such plots were observed for imidacloprid in different compositions of binary liquid mixture of DMF + DMSO solutions at 303.15, 308.15 and 313.15 K and are not shown to avoid repetition.

The limiting apparent molar volumes (ϕ_v^o) were calculated from the intercept of linear plots using equation (3). They are listed in Table 5. The (ϕ_v^o) values provide information regarding the solute-solvent interactions, a close perusal of Table 5, shows the positive values of limiting apparent molar volume (ϕ_v^o). The positive values of (ϕ_v^o) show presence of strong solute-solvent interactions[21,22]. The positive values of S_v indicate strong solute-solute interactions. The S_v values increase with increase in temperature indicates an increased solute-solute interaction in solution with rise in temperature.

The viscosities (η) increases with concentration and decreases with rise in temperature. This suggests the existence of molecular interactions occurring in the system. The viscosity data have been analyzed by using Jones –Dole equation (4). Figures 2 shows the variation of $(\eta_r\text{-}1)/C^{½}$ against square root of concentration C for imidacloprid in binary liquid mixture of DMF + DMSO solution at 298.15 K. Similar such plots were observed for imidacloprid in binary liquid mixture of DMF + DMSO solutions at 303.15, 308.15, and 313.15 K. The values of 'A' and 'B' coefficients are recorded in Table 5. All the values of 'A' coefficient are positive showing solute-solute interaction[23-25]. The value of 'A' coefficient increases with increase in concentration of imidacloprid in binary liquid mixture of DMF + DMSO solutions. Further the value of 'A' coefficient increases with rise in temperature form 298.15 K to 313.15 K.

The viscosity 'B' coefficients are positive for all the composition of imidacloprid in binary liquid mixture of DMF + DMSO solutions. The value of 'B' coefficient increases with increase in concentration of imidacloprid in DMF + DMSO solutions. Further the value of 'B' coefficient increases with rise in temperature which might be due to solute-solvent interaction[26, 27].

The values of 'R' and 'S' coefficients of Root's equation are recorded in Table 6. The 'R' coefficients of Root's equation for all compositions are positive. The positive values show strong solute-solute interactions. The 'S' coefficients of Root's equation for all compositions are negative. The values of 'M' and 'k' coefficients of Moulik equation were tabulated in Table 6. 'M' and 'K' coefficients are positive in all solvent systems and temperatures. 'M' values are of low magnitudes and 'K' values are of higher magnitudes. These models support the presence of strong solute-solute interactions.

CONCLUSION

From the density and viscosity of imidacloprid pesticide solutions in binary mixture DMF and DMSO are at 298.15, 303.15, 308.15 and 310.15 K temperatures. All the values of ϕ_v^0 at all temperatures are positive and higher; suggest the strong solute-solvent interactions in binary mixture DMF + DMSO. The S_v values are positive and suggesting strong solute-solute interactions. The positive values of Jones-Dole coefficient 'B' indicate strong interactions between solute and solvent at high temperature. The B coefficient for the imidacloprid pesticides increases with a rise of temperatures. A positive value of the B coefficient for imidacloprid pesticide indicates a structure-forming effect. The Masson's equations and Jones-Dole equations were found to be obeyed for imidacloprid pesticide in binary mixture DMF + DMSO. Root's and Moulik equations were found to be obeyed for imidacloprid in binary liquid mixture DMSO and DMF.

Table 1: Concentration (C), Density (ρ), Viscosity (η), Apparent molar volume (ϕ_v) of imidacloprid in DMF and 10% DMSO

C/ mol/dm^3	ρ/ g.cm^3	η/ Nm^{-3}.s.	ϕ_v/ cm^3.mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3}.s.	ϕ_v/ cm^3.mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3}.s.	ϕ_v/ cm^3.mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3}.s.	ϕ_v/ cm^3.mol^{-1}
DMF												
	298.15 K			**303.15 K**			**308.15 K**			**313.15 K**		
0.0150	0.94721	0.8110	45.54	0.94461	0.7719	52.04	0.93829	0.7293	58.09	0.93415	0.6975	65.50
0.0231	0.94886	0.8142	48.68	0.94622	0.7761	54.79	0.93985	0.7349	61.18	0.93566	0.7034	68.42
0.0329	0.95082	0.8183	51.74	0.94814	0.7816	57.37	0.94168	0.7408	64.88	0.93744	0.7105	71.72
0.0445	0.95308	0.8233	55.05	0.95039	0.7874	59.50	0.94384	0.7479	67.35	0.93950	0.7188	74.88
0.0577	0.95564	0.8285	57.46	0.95282	0.7947	63.32	0.94623	0.7555	70.23	0.94183	0.7281	77.23
0.0727	0.95848	0.8349	60.09	0.95549	0.8022	67.27	0.94886	0.7656	73.45	0.94431	0.7379	81.31
0.0894	0.96149	0.8419	63.84	0.95853	0.8100	69.36	0.95172	0.7744	76.64	0.94703	0.7493	84.78
0.1079	0.96492	0.8493	65.58	0.96174	0.8193	72.35	0.95479	0.7861	79.87	0.95002	0.7599	87.49
0.1281	0.96847	0.8578	68.59	0.96516	0.8284	75.41	0.95811	0.7969	82.67	0.95317	0.7726	90.58
0.1500	0.97215	0.8673	72.17	0.96877	0.8386	78.52	0.96157	0.8102	85.89	0.95647	0.7865	93.85
10% DMSO												
	298.15 K			**303.15 K**			**308.15 K**			**313.15 K**		
0.0150	0.96357	0.8842	49.62	0.96085	0.8452	59.50	0.95431	0.7917	66.21	0.95019	0.77802	72.12
0.0231	0.96518	0.8887	52.81	0.96241	0.8501	61.55	0.95582	0.7972	68.34	0.95164	0.78516	75.03
0.0329	0.96711	0.8934	55.29	0.96422	0.8558	65.28	0.95759	0.8045	71.48	0.95335	0.79342	78.21
0.0445	0.96934	0.8996	58.09	0.96629	0.8617	69.28	0.95963	0.8126	74.71	0.95531	0.80241	81.68
0.0577	0.97179	0.9068	61.53	0.96862	0.8694	72.37	0.96187	0.8206	78.33	0.95753	0.81245	84.15
0.0727	0.97452	0.9136	64.65	0.97121	0.8772	75.31	0.96438	0.8307	81.32	0.95982	0.82377	89.21
0.0894	0.97751	0.9208	67.52	0.97397	0.8878	78.92	0.96713	0.8402	84.04	0.96247	0.83571	91.71
0.1079	0.98065	0.9306	71.21	0.97701	0.8979	81.66	0.96982	0.8527	89.43	0.96534	0.84936	94.12
0.1281	0.98398	0.9397	74.89	0.98014	0.9083	85.37	0.97291	0.8655	92.35	0.96831	0.86359	97.36
0.1500	0.98761	0.9503	77.66	0.98348	0.9203	88.66	0.97613	0.8777	95.57	0.97150	0.88035	100.13

Table 2: Concentration (C), Density (ρ), Viscosity (η), Apparent molar volume (ϕ_v) of imidacloprid in 30% DMSO and 50% DMSO

C/ mol/dm^3	ρ/ g.cm^3	η/ Nm^{-3}.s.	ϕ_v/ cm^3.mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3}.s.	ϕ_v/ cm^3.mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3}.s.	ϕ_v/ cm^3.mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3}.s.	ϕ_v/ cm^3.mol^{-1}
30% DMSO												
	298.15 K			**303.15 K**			**308.15 K**			**313.15 K**		
0.0150	0.99709	1.0399	56.66	0.99336	1.00094	62.25	0.98681	0.9214	67.41	0.98232	0.8183	76.55
0.0231	0.99863	1.0443	59.74	0.99485	1.00637	65.65	0.98823	0.9275	72.24	0.98369	0.8262	80.53
0.0329	1.00043	1.0506	63.52	0.99662	1.01301	68.66	0.98993	0.9346	75.61	0.98536	0.8342	82.46
0.0445	1.00253	1.0567	66.53	0.99868	1.02065	71.31	0.99189	0.9421	78.87	0.98698	0.8451	84.98
0.0577	1.00485	1.0638	69.73	1.00094	1.02927	74.54	0.99407	0.9515	81.90	0.98935	0.8549	88.64
0.0727	1.00738	1.0721	73.40	1.00344	1.03874	77.70	0.99641	0.9620	85.90	0.99171	0.8653	91.05
0.0894	1.01015	1.0818	76.60	1.00607	1.04921	81.74	0.99902	0.9734	88.76	0.99418	0.8792	94.63
0.1079	1.01318	1.0924	79.25	1.00896	1.06062	84.88	1.00166	0.9852	93.16	0.99671	0.8950	99.16
0.1281	1.01621	1.1050	83.51	1.01193	1.07481	88.79	1.00463	0.9983	95.88	0.99942	0.9095	103.08
0.1500	1.01971	1.1184	85.43	1.01502	1.08865	92.75	1.00762	1.0121	99.59	1.00239	0.9274	105.95
50% DMSO												
	298.15 K			**303.15 K**			**308.15 K**			**313.15 K**		
0.0150	1.02947	1.2295	61.36	1.02477	1.1335	67.51	1.01842	1.0576	73.18	1.01451	1.0189	78.07
0.0231	1.03095	1.2357	64.60	1.02619	1.1405	71.25	1.01981	1.0658	76.38	1.01585	1.0292	81.81
0.0329	1.03268	1.2423	68.32	1.02787	1.1478	74.58	1.02143	1.0747	80.13	1.01742	1.0395	85.55
0.0445	1.03468	1.2510	71.65	1.02981	1.1578	77.69	1.02329	1.0865	83.71	1.01923	1.0518	88.91
0.0577	1.03689	1.2597	74.96	1.03197	1.1685	80.55	1.02534	1.0977	87.19	1.02121	1.0639	92.49
0.0727	1.03934	1.2701	78.04	1.03425	1.1792	84.86	1.02759	1.1115	90.66	1.02338	1.0813	96.04
0.0894	1.04192	1.2813	81.91	1.03686	1.1915	87.21	1.03002	1.1247	94.02	1.02573	1.0994	99.35
0.1079	1.04473	1.2938	85.14	1.03945	1.2054	91.64	1.03262	1.1413	97.28	1.02817	1.1165	103.24
0.1281	1.04771	1.3073	88.32	1.04233	1.2196	94.64	1.03526	1.1582	101.34	1.03078	1.1348	106.66
0.1500	1.05091	1.3231	91.04	1.04507	1.2370	99.47	1.03802	1.1768	105.21	1.03341	1.1547	110.68

Table 3: Concentration (C), Density (ρ), Viscosity (η), Apparent molar volume (ϕ_v) of imidacloprid in 70% and 90% DMSO

C/ mol/dm^3	ρ/ g.cm^3	η/ Nm^{-3}.s.	ϕ_v/ cm^3.mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3}.s.	ϕ_v/ cm^3.mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3}.s.	ϕ_v/ cm^3.mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3}.s.	ϕ_v/ cm^3.mol^{-1}
70%DMSO												
	298.15 K			**303.15 K**			**308.15 K**			**313.15 K**		
0.0150	1.05652	1.5682	65.48	1.05234	1.4264	73.35	1.04614	1.2892	78.25	1.04294	1.2347	85.53
0.0231	1.05794	1.5760	69.11	1.05369	1.4353	77.22	1.04746	1.2995	81.82	1.04419	1.2464	89.56
0.0329	1.05962	1.5842	72.33	1.05528	1.4458	80.73	1.04901	1.3116	85.28	1.04564	1.2596	93.72
0.0445	1.06151	1.5941	76.42	1.05711	1.4578	84.00	1.05075	1.3257	89.45	1.04733	1.2734	96.84
0.0577	1.06362	1.6065	79.77	1.05909	1.4692	87.84	1.05266	1.3403	93.34	1.04913	1.2917	100.95
0.0727	1.06589	1.6196	83.74	1.06130	1.4858	91.01	1.05478	1.3557	96.68	1.05112	1.3125	104.51
0.0894	1.06834	1.6363	87.45	1.06352	1.5015	95.88	1.05697	1.3748	100.95	1.05322	1.3303	108.34
0.1079	1.07097	1.6530	90.86	1.06599	1.5198	99.34	1.05939	1.3938	104.10	1.05543	1.3536	112.16
0.1281	1.07376	1.6701	94.13	1.06851	1.5395	103.34	1.06172	1.4164	108.89	1.05754	1.3766	117.39
0.1500	1.07662	1.6886	97.74	1.07124	1.5591	106.50	1.06421	1.4403	112.88	1.05981	1.4017	121.61
90% DMSO												
	298.15 K			**303.15 K**			**308.15 K**			**313.15 K**		
0.0150	1.08379	1.8606	67.52	1.08012	1.6822	70.84	1.07421	1.5241	74.34	1.07104	1.4469	81.42
0.0231	1.08517	1.8702	71.37	1.08167	1.6932	74.81	1.07553	1.5356	78.47	1.07231	1.4597	85.18
0.0329	1.08678	1.8812	75.29	1.08305	1.7040	78.65	1.07706	1.5498	82.77	1.07378	1.4755	89.26
0.0445	1.08861	1.8947	79.27	1.08483	1.7181	82.88	1.07881	1.5654	86.69	1.07545	1.4924	93.25
0.0577	1.09059	1.9082	83.53	1.08682	1.7328	86.22	1.08071	1.5828	90.74	1.07727	1.5149	97.16
0.0727	1.09278	1.9237	87.22	1.08892	1.7526	90.58	1.08282	1.6041	94.15	1.07918	1.5363	101.89
0.0894	1.09512	1.9433	90.93	1.09121	1.7725	94.24	1.08503	1.6255	98.10	1.08126	1.5619	105.81
0.1079	1.09767	1.9623	93.97	1.09359	1.7956	98.24	1.08724	1.6494	103.02	1.08352	1.5876	109.04
0.1281	1.10028	1.9839	97.60	1.09594	1.8184	103.14	1.08965	1.6753	106.84	1.08552	1.6199	114.97
0.1500	1.10302	2.0083	101.01	1.09874	1.8440	105.43	1.09196	1.7037	111.73	1.08768	1.6514	119.66

Table 4: Concentration (C), Density (ρ), Viscosity (η), Apparent molar volume (ϕ_v) of imidacloprid in DMSO

C/ mol/dm^3	ρ/ g.cm^3	η/ Nm^{-3}.s	ϕ_v/ cm^3.mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3}.s	ϕ_v/ cm^3.mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3}.s	ϕ_v/ cm^3.mol^{-1}	ρ/ g.cm^3	η/ Nm^{-3}.s	ϕ_v/ cm^3.mol^{-1}
DMSO												
	298.15 K			**303.15 K**			**308.15 K**			**313.15 K**		
0.0150	1.09778	2.0149	72.13	1.09383	1.8213	76.05	1.08794	1.6482	84.44	1.08503	1.5474	90.82
0.0231	1.09907	2.0263	77.57	1.09513	1.8326	79.83	1.08916	1.6615	88.64	1.08619	1.5627	95.27
0.0329	1.10064	2.0395	80.43	1.09659	1.8452	85.18	1.09059	1.6764	92.35	1.08757	1.5801	98.49
0.0445	1.10239	2.0527	84.41	1.09832	1.8597	88.42	1.09221	1.6944	96.14	1.08908	1.6009	103.03
0.0577	1.10424	2.0693	89.26	1.10019	1.8767	92.12	1.09393	1.7156	100.59	1.09074	1.6233	106.94
0.0727	1.10633	2.0897	92.76	1.10221	1.8943	95.99	1.09581	1.7385	104.61	1.09249	1.6493	111.36
0.0894	1.10852	2.1091	96.70	1.10433	1.9147	100.12	1.09776	1.7615	109.00	1.09422	1.6740	116.82
0.1079	1.11067	2.1344	101.90	1.10655	1.9356	104.22	1.09982	1.7873	113.06	1.09624	1.7022	119.94
0.1281	1.11324	2.1602	104.33	1.10876	1.9623	108.92	1.10194	1.8195	117.12	1.09791	1.7342	126.23
0.1500	1.11562	2.1846	108.72	1.11089	1.9873	114.24	1.10393	1.8496	122.21	1.09983	1.7694	130.47

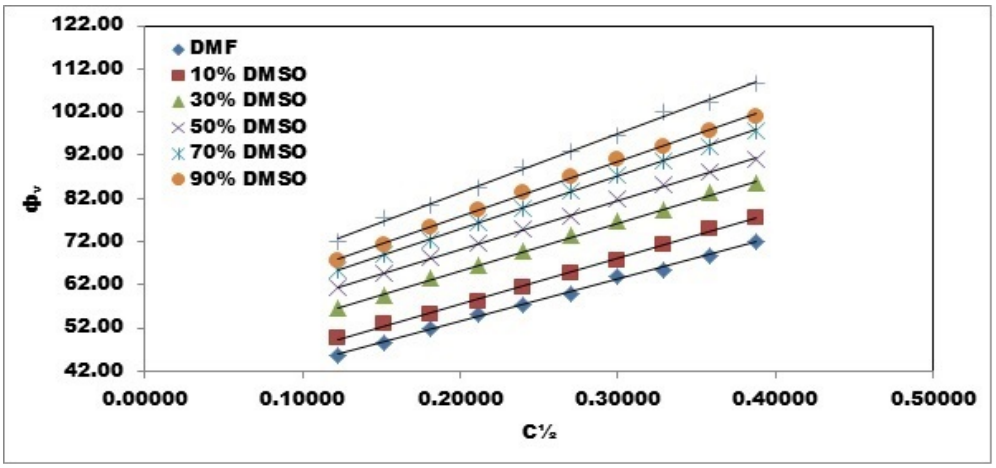

Figure 1: **Plots of apparent molar volume ϕ_v against square root of concentration, C for imidacloprid in binary liquid mixture of DMF + DMSO solution at 298.15 K**

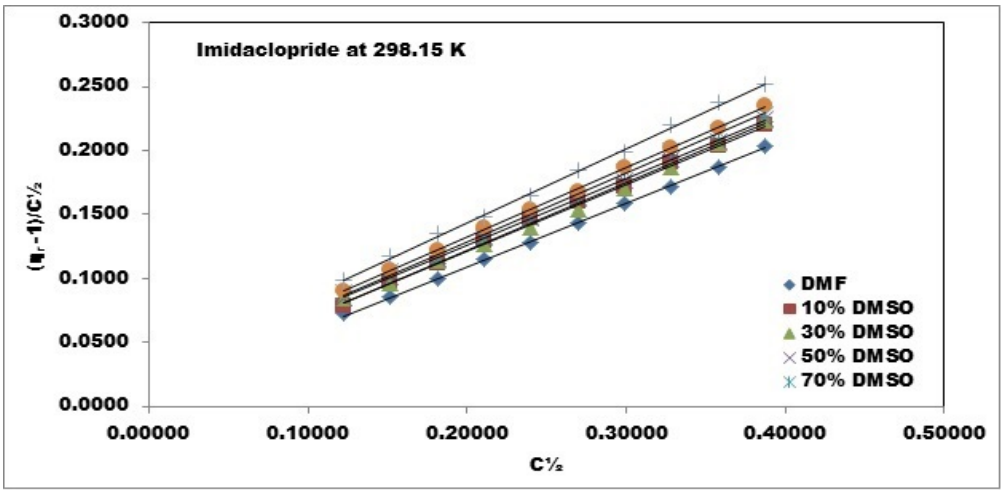

Figure 2: Plots of apparent molar volume (ηr-1)/C½ against square root of concentration, C for Imidacloprid in binary liquid mixture of DMF + DMSO solution at 298.15 K

Table 5: ϕ_v^0 ($cm^3.mol^{-1}$), S_V ($cm^3.mol^{-2/3}.L^{1/2}$), A ($dm^{3/2}.mol^{-1/2}$) and B ($dm^3.\ mol^{-1}$) of Imidacloprid in different compositions of DMF and DMSO at different temperatures

Temp. (K)	DMF	10% DMSO	30% DMSO	50% DMSO	70% DMSO	90% DMSO	DMSO
	ϕ_v^0 ($cm^3.mol^{-1}$)						
298.15	33.81	36.12	43.19	47.59	50.44	52.36	55.93
303.15	39.20	45.27	47.84	53.03	57.72	54.57	58.72
308.15	45.41	51.13	53.65	58.29	61.92	57.28	66.82
313.15	52.12	58.90	62.48	63.25	68.94	63.32	71.78
	S_V ($cm^3.mol^{-2/3}.L^{1/2}$)						
298.15	98.29	106.7	110.8	113.5	122.6	127.1	136.8
303.15	101.1	111.8	113.6	117.3	126.3	133.0	140.3
308.15	104.3	113.9	118.7	120.1	130.4	138.8	141.2
313.15	107.6	107.7	110.6	121.7	133.8	142.9	149.6
	A ($dm^{3/2}.mol^{-1/2}$)						
298.15	0.010	0.016	0.017	0.020	0.021	0.024	0.028
303.15	0.026	0.028	0.025	0.028	0.029	0.031	0.035
308.15	0.063	0.054	0.060	0.064	0.066	0.067	0.069
313.15	0.079	0.076	0.080	0.082	0.083	0.085	0.088
	B ($dm^3.\ Mol^{-1}$)						
298.15	0.495	0.526	0.521	0.524	0.535	0.542	0.578
303.15	0.602	0.611	0.602	0.626	0.644	0.659	0.612
308.15	0.707	0.719	0.624	0.723	0.748	0.756	0.788
313.15	0.813	0.837	0.841	0.857	0.868	0.902	0.913

Table 6: Moulik constants (M and K) and Roots parameters (R and S) of Imidacloprid in different compositions of DMF and DMSO at different temperatures

Temp. (K)	DMF	10% DMSO	30% DMSO	50% DMSO	70% DMSO	90% DMSO	DMSO
	M						
298.15	1.033	1.038	1.036	1.039	1.039	1.041	1.044
303.15	1.046	1.046	1.045	1.048	1.049	1.051	1.049
308.15	1.065	1.063	1.059	1.067	1.069	1.069	1.072
313.15	1.078	1.078	1.079	1.082	1.083	1.084	1.087
	K						
298.15	6.382	6.856	6.982	6.996	7.182	7.328	7.903
303.15	8.049	8.332	8.175	8.462	8.733	9.087	8.517
308.15	10.55	10.36	9.323	10.72	11.14	11.31	11.78
313.15	12.29	12.63	12.85	12.96	13.16	13.88	13.94
	R						
298.15	-0.233	-0.221	-0.212	-0.206	-0.202	-0.199	-0.194
303.15	-0.218	-0.212	-0.208	-0.201	-0.195	-0.196	-0.191
308.15	-0.213	-0.207	-0.202	-0.196	-0.191	-0.194	-0.183
313.15	-0.207	-0.199	-0.194	-0.191	-0.183	-0.188	-0.177
	S						
298.15	0.092	0.102	0.110	0.116	0.129	0.137	0.149
303.15	0.095	0.107	0.112	0.119	0.132	0.143	0.153
308.15	0.097	0.108	0.116	0.122	0.136	0.148	0.153
313.15	0.100	0.102	0.108	0.123	0.139	0.152	0.162

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