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Revealing the Toxicity of Chlorate Through the Analysis of Molecular Interaction using Viscosity Measurements and Apparent Molar Volumes

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ABSTRACT

While chlorate has the ability to induce flowering in longan, it also has adverse impacts on the crop. Revealing the toxicity of chlorate in the environment is more than just about the environment and about human health, as well. Because of the large introduction of this chemical into the environment from the paper processing industry, there is indeed a lot of concern about its toxicity. Chlorate toxicology in the longan plant has been thoroughly investigated in solutions using viscosities and apparent molar volumes. The hydration of molecules and volume changes are involved in various chemical and biological processes in plant tissues, and their complete understanding demands a good idea for volumetric and viscometric study. It offers good data acquisition techniques for solute, solvent and solvent-solvent interactions. Multi-component systems containing $KClO_3$+ water + ionic solid (ionic solids = KCl, KNO_3, NH_4NO_3 and KH_2PO_4, are currently being worked out to study the dependence of transport properties of potassium chlorate in aqueous electrolyte solutions, with concentrations and temperature of solutions. The assessed kd values are used to predict whether the solvolysis of $KClO_3$ in the presence of other electrolytes is a quick or slow process.

Keywords: Toxicity, $KClO_3$, Volumetric and Viscometric properties, Diffusion controlled Reaction Rate Constant k_d.

INTRODUCTION

Lychees and longans are close family members. longans and lychees are comparable in nutritional composition. Both are minimal in calories and carbohydrates and are nil in fat. The antioxidants and fibres are abundant in longan and lychee similarly are great source of vitamin C.

Fig. 1. Lychee Fruit

Fig. 2. Longan Fruit

Longan *(Dimocarpus longan)*, a subtropical fruit plant belonging to the Sapindaceae family, is ideally suited to tropical regions with distinct wet/dry seasons as well as subtropical locales with a cool, nonfreezing fall/winter period. In India, it is one of the minor fruits. There is currently insufficient documentation on longan production in India to analyze the real scenario. The longan is an important crop in Southeast Asia economically. Although leaves and flowers are sold in markets, they are not used in traditional medicine. The dried flowers are shipped to Malaysia to be used as medicine.

Off-season flowering and fruit production is a desirable economic and scientific goal for many subtropical fruit plants. The discovery of potassium chlorate to induce off-season flowering in longan, as well as off-season longan production methods in Thailand, including soil drench (Manochai S. W.-a., 1999) ((Sritontip C. Y., 1999)), foliar spray ((Sritontip C. Y., 1999)), and truck or stem injection ((Viriya-alongkorn, 1999)).

Though chlorate is able to precisely induce flowering in longan, it also causes toxic effects on the crop. $KClO_3$ serves as a herbicide or a defoliant on many other plants. (Nahar, 2010) (Manochai P. J., August 2008)

While chlorate is able to specifically induce flowering in longan, it also causes toxic effects on the crop. (Sritontip C. Y., 2003). Great concern is paid upon the toxicity of chlorate (Daniel, 1990) because of heavy introduction of this chemical into the environment from paper making industry. (Moore & Calabrese, 1982). An increasing demand from end user industries, such as farming, explosives, laboratories and disinfectants is predicted to contribute significantly to the growth of the potassium chlorate market in the forecast time frame. The explosives based on potassium chlorate are more effective than ordinary powder. The production of fireworks and matching bands also involves extensively utilised potassium chlorate. In smoke compositions such as smoke grenades it is utilised as a component. In laboratories and educational facilities, potassium chlorate is used to generate oxygen, other than explosives. It is also utilised for the destruction of pests as a pesticide in agriculture. (https://www.businesswire.com/portal/site/home/my-business-wire/, 2020).

A significant amount of information is needed on the properties of transport, thermodynamic and solution to comprehend how the co-solvent or co-solute can change the nature and structure of the water. (Bahadur, 2019).

This work examines the interaction like ion-solvent, ion-ion and solvent-solvent of potassium chlorate with aqueous ionic salts, as both the solute and solvents are utilised for agricultural operations. In this study the chemical and the electrostatic effect due to dielectric constant of the co-solute which are already present in soil like KCl, KNO_3 and NH_4NO_3, KH_2PO_4 would play vital role in influencing solute-solvent interaction. (Ganjare, 2020). Viscosity data can be used to determine the diffusion controlled reaction rate constant k_d.

The current study used multi-component systems containing an ionic solid, water, and $KClO_3$ (ionic solids = KCl, KNO_3, and NH_4NO_3, KH_2PO_4)) to evaluate the relationship between the transport properties of $KClO_3$ solutions in aqueous electrolyte solutions and solution concentrations and temperature.

The densities of aqueous solutions were measured using 15 cm^3 double arm pycnometer in a transparent glass walled water bath. (Kharat, 2007) Triple distilled water was used to calibrate the pycnometer. At desired temperatures, the densities of $KClO_3$ solutions in aqueous 1% KCl, KNO_3 and $NHNO_3$, KH_2PO_4, and pure water were determined using a bi-capillary pycnometer. An average of triplicate measurements was the final result and the density was calculated with an accuracy of $\pm 1.25 \times 10^{-4}$ $g.cm^{-3}$. The thermostat temperature is maintained at the appropriate temperatures using a demerstat with an accuracy of ±0.1 K.

Viscosities of all salt solutions of ten different concentrations in water were measured using Ubbelohde viscometer at temperatures of 298.15, 303.15, 308.15, and 313.15K. Measurements to monitor reproductibility of results have been repeated at least three times The overall precision of viscosity measurements was $\pm 2.0\times10^{-4}$ mPa.s. At 0.01 second intervals the flow time is accurately recorded.

All chemicals were taken from Sigma Aldrich, Germany, with more than 99% purity and was further desiccated over anhydrous $CaCl_2$ before use. (Nanda, Nanda, & Mohanty, 2012), The sample specification is given in Table 1a,b.

Table 1(a): Specification of Chemicals

Chemicals	Source	Mass fraction Purity	Purification Method	CAS No.	Mol. Mass g.Mol^{-1}	Chemical Formula
Potassium Chlorate	Sigma Aldrich	≥99.0%	desiccated over anhydrous $CaCl_2$	4/9/3811	122.55	$KClO_3$
Potassium Nitrate	Sigma Aldrich	ACS reagent , ≥99.0%	Used as obtained	7757-79-1	101.1	KNO_3
Potassium Chloride	Sigma Aldrich	≥99.0%	Used as obtained	7447-40-7	74.55	KCl
Ammonium Nitrate	Sigma Aldrich	ACS reagent, ≥98%	Used as obtained	6484-52-2	80.04	NH_4NO_3
Potassium phosphate monobasic	Sigma Aldrich	≥98.0%	Used as obtained	7778-77-0	136.1	KH_2PO_4,

It is known the properties like density, viscosity, etc., are influenced by the presence of oxygen atom in a molecule. The presence of such groups increases the hydrophilicity and electrostriction between water and solute particles. (Nanda, Nanda, & Dalai, 2021).

Data Evaluation

The apparent molar volumes $\varnothing_V$, were obtained from the density results using the following equation (Cui, *et al.,* 2020) (Langore, Nikumbh, Patil, & Gaikwad, 2019).

$$\varnothing_V = \frac{1000(\rho_0-\rho)}{C\rho_0} + \frac{M}{\rho} \tag{1}$$

Where M is the molar mass of the $KClO_3$ in g mol^{-1}, C is the concentration (mol.L^{-1}), ρ and ρ_0 and the densities of the solution and the solvent, respectively in g cm^{-3}

The apparent molar volumes ($\varnothing_V$) were plotted against the square root of concentration ($C^{½}$) in accordance with the Masson's equation. Partial molar volumes at infinite dilution were obtained by least-squares fitting to the equation: (Caro, 2020).

$$\varnothing_V = \varnothing_V^0 + Sv.C^{½} \tag{2}$$

Where $\varnothing_V^0$ is the limiting apparent molar volume and S_v a semi-empirical parameter which depends on the nature of solute, solvent as well as temperature.

Table 1(b): Densities and Apparent molar volumes of $KClO_3$ solution in 1% KNO_3 and distilled water at different temperatures

Molar Conc. (C) mol/dm^3	$KClO_3$ in 1% KCl	$KClO_3$ in 1% NH_4NO_3	$KClO_3$ in 1% KNO_3	$KClO_3$ in 1% KH_2PO_4	$KClO_3$ in 1% KCl	$KClO_3$ in 1% NH_4NO_3	$KClO_3$ in 1% KNO_3	$KClO_3$ in 1% KH_2PO_4
	Density, (ρ) (g.cm^{-3})				Apparent molar volumes, ($\varnothing_v$)cm^3.mol^{-1}			
				298.15K				
0.0055	1.00376	1.00578	1.00766	1.01016	121.43	121.25	121.11	120.91
0.0085	1.00462	1.00632	1.0085	1.01173	121.34	121.1	120.9	120.71
0.0125	1.0055	1.00718	1.00954	1.01304	121.2	120.93	120.69	120.51
0.0175	1.0066	1.00889	1.0111	1.01459	121.09	120.76	120.45	120.15
0.0235	1.0079	1.01026	1.01246	1.01626	120.92	120.59	120.29	119.93
0.0305	1.00945	1.01162	1.01395	1.01845	120.82	120.4	120.1	119.76
0.0385	1.0111	1.0135	1.01623	1.02043	120.65	120.23	119.84	119.54
0.0475	1.0129	1.0158	1.01825	1.02297	120.45	120.11	119.72	119.32
0.0555	1.0144	1.0176	1.0201	1.02519	120.32	120	119.58	119.18
				303.15K				
0.0055	1.00318	1.00421	1.00615	1.00856	121.61	121.45	121.33	121.12
0.0085	1.00384	1.00485	1.00692	1.00931	121.52	121.32	121.12	120.92
0.0125	1.00491	1.00589	1.00807	1.01044	121.37	121.14	120.91	120.72

0.0175	1.00597	1.00695	1.00913	1.01159	121.25	120.96	120.67	120.36
0.0235	1.00706	1.00817	1.01069	1.01356	121.11	120.78	120.51	120.14
0.0305	1.00837	1.00992	1.01231	1.01535	121	120.61	120.32	119.97
0.0385	1.00995	1.01157	1.0142	1.01743	120.8	120.43	120.06	119.75
0.0475	1.0118	1.01324	1.01621	1.01957	120.65	120.32	119.94	119.53
0.0555	1.0136	1.01516	1.01812	1.02159	120.51	120.22	119.8	119.39
				308.15K				0.0055
1.00268	1.00381	1.00515	1.00784	121.76	121.59	121.45	121.28	
0.0085	1.00325	1.00456	1.00639	1.00871	121.64	121.47	121.25	121.07
0.0125	1.00393	1.00558	1.00708	1.00994	121.53	121.3	121.02	120.85
0.0175	1.00486	1.00646	1.00853	1.01119	121.41	121.11	120.78	120.53
0.0235	1.00613	1.00762	1.00989	1.01276	121.28	120.91	120.64	120.32
0.0305	1.00738	1.00912	1.01161	1.01475	121.15	120.76	120.43	120.15
0.0385	1.00866	1.01117	1.0134	1.01693	120.93	120.57	120.16	119.9
0.0475	1.01045	1.01304	1.01581	1.01885	120.81	120.46	120.03	119.67
0.0555	1.01185	1.01436	1.01752	1.02081	120.67	120.38	119.94	119.56
				313.15K				0.0055
1.00196	1.00329	1.00475	1.00726		121.92	121.75	121.64	121.53
0.0085	1.00265	1.00406	1.00589	1.00818	121.82	121.63	121.47	121.32
0.0125	1.00326	1.00518	1.00666	1.00932	121.69	121.46	121.24	121.1
0.0175	1.00419	1.00597	1.00808	1.01079	121.57	121.27	121.01	120.78
0.0235	1.00543	1.00712	1.00916	1.01216	121.43	121.07	120.83	120.57
0.0305	1.00658	1.00872	1.01111	1.01405	121.29	120.92	120.66	120.4
0.0385	1.00814	1.01017	1.01294	1.01624	121.16	120.73	120.41	120.15
0.0475	1.00988	1.01224	1.01521	1.01835	120.97	120.62	120.26	119.92
0.0555	1.01105	1.01376	1.01687	1.02014	120.87	120.54	120.19	119.81

The apparent molar volumes of transfer at infinite dilutions $\Delta \phi_v^0$ (tr) of $KClO_3$ obtained from the relation.

$\Delta\varnothing_V 0(tr) = \varnothing_V^0$ ($KClO_3$ in solvent system)–$\varnothing_V^0$ ($KClO_3$ in water)

The positive $\Delta\varnothing_V^0$(tr) studied in the present investigation suggest that the ion-ion and ion-hydrophilic group interactions are stronger than the ion hydrophobic interaction that results in an increase in volume.

The viscosity results for the aqueous solutions of $KClO_3$ in aqueous solute systems and pure water solvent systems were plotted in accordance with Jones-Dole equation (Lomesh, Nathan, Bala , & Thakur, 2019).

$$\eta_r\text{-}1 / C^{1/2} = A + BC^{1/2} \quad (3)$$

Where $\eta_r = (\eta/\eta_o)$ and η, η_o are viscosities of the solution and solvent respectively, C is the molar concentration.

Table 2: Viscosities and Relative Viscosities of $KClO_3$ solution in 1% KNO_3 and distilled water at different temperatures

Molar Conc. (C) mol/dm³	$KClO_3$ in 1% KCl	$KClO_3$ in 1% NH_4NO_3	$KClO_3$ in 1% KNO_3	$KClO_3$ in 1% NH_4NO_3	$KClO_3$ in 1% KCl	$KClO_3$ in 1% NH_4NO_3	$KClO_3$ in 1% KNO_3	$KClO_3$ in 1% KH_2PO_4
	Viscosities (η) (Nm-3.s) 298.15K				Relative viscosities (ηr) 298.15K			
0.0055	0.9296	0.9324	0.9359	0.9439	1.0358	1.0224	1.025	1.0239
0.0085	0.9349	0.9368	0.9411	0.9491	1.0418	1.0283	1.0307	1.0289
0.0125	0.9417	0.9448	0.9476	0.9556	1.0494	1.0356	1.0378	1.0335
0.0175	0.9497	0.9508	0.9554	0.9624	1.0583	1.0444	1.0463	1.0474
0.0235	0.9562	0.9601	0.9645	0.9715	1.0688	1.0546	1.0563	1.0579
0.0305	0.9659	0.9708	0.9749	0.9799	1.0808	1.0664	1.0676	1.0699
0.0385	0.9767	0.9817	0.9865	0.9915	1.0965	1.0785	1.0823	1.0856
.0475	0.9878	0.9938	0.9985	1.0045	1.1106	1.0924	1.1012	1.0997
0.0555	0.9979	1.0023	1.0069	1.0136	1.1224	1.1064	1.1165	1.1115
		303.15K			303.15K	0.0055		
0.8461	0.8504	0.8547	0.8637	1.0312	1.0261	1.0293	1.0258	
0.0085	0.8516	0.8558	0.8604	0.8674	1.0381	1.0325	1.0361	1.0306
0.0125	0.8586	0.8626	0.8674	0.8734	1.0466	1.0407	1.0446	1.0358
0.0175	0.8669	0.8707	0.8759	0.8829	1.0567	1.0505	1.0548	1.0493
0.0235	0.8747	0.8802	0.8858	0.8908	1.0687	1.0619	1.0668	1.0596
0.0305	0.8858	0.8911	0.8972	0.9021	1.0824	1.075	1.0804	1.0716
0.0385	0.8962	0.9021	0.9086	0.9132	1.1022	1.0914	1.0985	1.0874

0.0475	0.9072	0.9152	0.9202	0.9262	1.1217	1.1087	1.1185	1.1016
0.0555	0.9187	0.9267	0.9329	0.9399	1.1418	1.1293	1.1344	1.1137
	308.15K			308.15K				
0.0055	0.769	0.7749	0.7817	0.7837	1.0344	1.0379	1.0391	1.035
0.0085	0.7752	0.7799	0.7869	0.7899	1.0434	1.0446	1.0461	1.0398
0.0125	0.7824	0.7862	0.7934	0.7954	1.0548	1.0531	1.0546	1.045
0.0175	0.7924	0.7957	0.8011	0.8057	1.0683	1.0631	1.0649	1.0585
0.0235	0.8015	0.8062	0.8102	0.8162	1.0843	1.0749	1.0769	1.0688
0.0305	0.8115	0.8177	0.8205	0.8255	1.1014	1.0884	1.0907	1.0808
0.0385	0.8202	0.8242	0.8312	0.8362	1.1132	1.1062	1.1048	1.0966
0.0475	0.8322	0.8382	0.8422	0.8482	1.1265	1.1156	1.1123	1.1108
0.0555	0.8457	0.8517	0.8547	0.8577	1.1398	1.1258	1.1221	1.1229
	313.15K				313.15K			0.0055
0.6832	0.6939	0.7056	0.7147	1.0293	1.0346	1.0398	1.037	
0.0085	0.6901	0.7006	0.7125	0.7236	1.0396	1.0447	1.0498	1.0418
0.0125	0.701	0.7091	0.7211	0.7323	1.056	1.0573	1.0624	1.0473
0.0175	0.7127	0.7192	0.7323	0.7437	1.0735	1.0724	1.0776	1.0605
0.0235	0.7265	0.7356	0.7442	0.7562	1.0939	1.0901	1.0952	1.0708
0.0305	0.741	0.7496	0.7629	0.7735	1.1175	1.1102	1.1154	1.0828
0.0385	0.7613	0.7693	0.7814	0.7932	1.1256	1.1234	1.1278	1.0986
0.0475	0.7798	0.7928	0.8022	0.8139	1.1387	1.1343	1.1366	1.1128
0.0555	0.7974	0.8094	0.8178	0.8313	1.1475	1.1433	1.1458	1.1249

The B-coefficients were obtained from the linear plots using the least-square fitting method. The A- coefficient reflects solute-solute interaction (Pérez-Durán, 2019) and the B-coefficient reflect the solute-solvent interactions. Since in general, A/B <<1, the Jones –Dole equation reduces to,

$$\eta_r = l + \beta.C \tag{4}$$

The relative viscosity data of these solutions have also been fitted in Moulik equation,

$$\eta_r^2 = M + K\,C^2 \tag{5}$$

The density data of these solutions have also been fitted in Root's equation,

$$(d-d_0)/C = R - SC^{½} \tag{6}$$

where R and S are constants.

The diffusion controlled reaction rate constant k_d can be evaluated by using the viscosity data as (Rathi & Nikumbh, 2019).

Table 3: Different parameters of $KClO_3$ in water and 1% KCl, KNO_3, NH_4NO_3 and KH_2PO_4 solution

Temp	Massons Parameters $\varnothing_V^0$ cm³.mol⁻¹ L¹ᐟ²	S_v cm³.mol⁻¹	Jone-Dole's Parameters A/ dm³ᐟ²mol⁻¹ᐟ²	B/ dm³.mol⁻¹	Moulik Parameters K	M	Roots Parameter R	S	'β' values β	$\Delta \varnothing_V^0$ (tr)
				$KClO_3$ in Water						
298.15K	121.3	-10.21	-0.01	0.32	12.61	1	0.24	0.29	0.28	0
303.15K	121.2	-8.85	-0.04	1.09	43.44	1.01	0.26	0.3	0.95	0
308.15K	121.9	-10.92	-0.05	2.01	84.38	1.03	0.24	0.27	1.81	0
313.15K	121.3	-10.19	-0.03	1.32	55.23	1.02	0.26	0.3	1.2	0
				$KClO_3$ in 1% KCl						
298.15K	121.7	-4.05	0.03	0.35	40.18	1.04	0.52	-1.39	0.87	0.4
303.15K	121.9	-4.03	0.05	0.93	55.7	1.03	0.53	-1.5	1.22	0.7
308.15K	122.1	-3.89	-0.03	1.58	74.91	1.03	0.54	-1.5	1.61	0.2
313.15K	122.2	-3.16	0.03	1.79	99.02	1.04	0.55	-1.6	2.1	0.9
				$KClO_3$ in 1% NH_4NO_3						
298.15K	121.8	-7.71	0	1.14	52.04	1.02	1.45	-5.53	1.13	0.5
303.15K	122.1	-7.81	0.02	1.21	58.8	1.02	1.47	-5.7	1.27	0.9
308.15K	122.2	-7.56	0.01	1.52	72.89	1.03	1.28	-4.75	1.57	0.3
313.15K	122.4	-7.77	0.01	2.06	97.91	1.04	1.53	-6.03	2.08	1.1
				$KClO_3$ in 1% KNO_3						
298.15K	121.9	-10.63	-0.03	1.57	57.27	1.03	1.45	-5.17	1.47	0.6
303.15K	122.1	-10.53	0.1	0.86	68.16	1.02	1.46	-5.21	1.24	0.9
308.15K	122.3	-10.69	0.06	1.17	64	1.03	1.5	-5.5	1.38	0.4
313.15K	122.6	-11.18	-0.02	1.94	86.68	1.03	1.39	-4.86	1.86	1.3
				$KClO_3$ in 1% KH_2PO_4						
298.15K	123.1	-10.25	0.02	1.57	56.32	1.03	1.46	-5.27	1.27	1.8
303.15K	123.3	-9.73	0.15	0.86	66.17	1.02	1.45	-5.23	1.23	2.1
308.15K	123.5	-10.55	0.03	1.17	71.24	1.03	1.53	-5.51	1.27	1.6
313.15K	123.7	-10.7	0.02	1.94	89.35	1.03	1.29	-4.76	1.46	2.4

$$k_d = \frac{8RT}{3\eta} \quad (7)$$

The evaluated values are used to predict whether the solvolysis is fast or slow process.

Table 4: Diffusion reaction rate constant k_d (L mol^{-1} s^{-1}) values of $KClO_3$ water and 1 % KCl, KNO_3, NH_4NO_3 and KH_2PO_4 solution

Molar Conc. mol/dm^3	$KClO_3$ in Water	$KClO_3$ in 1% KCl	$KClO^3$ in 1% NH_4NO_3	$KClO_3$ in 1% KNO_3	$KClO_3$ 1% KH_2PO_4	$KClO_3$ in Water	$KClO_3$ in 1% KCl	$KClO_3$ in 1% NH_4NO_3	$KClO_3$ in 1% KNO_3	$KClO_3$ 1% KH_2PO_4
			298.15K					298.15K		
0.0055	7.38	7.23	7.21	7.18	7.16	9.35	9.12	9.05	8.97	8.21
0.0085	7.37	7.21	7.18	7.14	7.13	9.28	9.06	9.01	8.92	8.14
0.0125	7.36	7.18	7.14	7.09	7.06	9.2	8.99	8.93	8.86	7.92
0.0175	7.35	7.14	7.09	7.03	7.04	9.1	8.91	8.85	8.79	7.84
0.0235	7.34	7.11	7.03	6.96	6.94	8.99	8.81	8.75	8.71	7.74
0.0305	7.32	7.09	6.97	6.88	6.86	8.87	8.7	8.65	8.62	7.65
0.0385	7.31	7.06	6.83	6.74	6.73	7.91	7.83	8.56	8.38	7.56
0.0475	7.3	7.04	6.76	6.56	6.56	7.87	7.71	8.34	8.17	7.38
0.0555	7.29	7.01	6.45	6.43	6.4	7.68	7.64	8.11	8.01	7.29
			303.15K					303.15K		
0.0055	8.27	8.09	8.03	7.98	8.19	10.55	10.28	10.12	10.12	10.23
0.0085	8.24	8.05	7.99	7.94	8.04	10.5	10.19	10.05	10.05	10.14
0.0125	8.2	8.01	7.94	7.9	7.89	10.44	10.09	9.96	9.96	9.95
0.0175	8.15	7.95	7.88	7.84	7.74	10.37	9.97	9.85	9.85	9.86
0.0235	8.1	7.88	7.82	7.77	7.63	10.28	9.83	9.73	9.73	9.72
0.0305	8.04	7.81	7.74	7.7	7.55	10.19	9.68	9.59	9.59	9.68
0.0385	7.89	7.23	7.66	7.68	7.46	10	9.46	9.33	9.47	9.57
0.0475	7.67	7.11	7.54	7.43	7.31	9.89	9.32	9.24	9.33	9.45
0.0555	7.43	6.89	7.23	7.1	7.2	9.76	9.21	9.12	9.28	9.29

RESULT AND DISCUSSION

The values of densities and viscosities of $KClO_3$ solutions decrease with increase in temperature and increases with increase in concentration. The apparent molar volume values of $\varnothing_V$ decrease with concentration while the relative viscosities are found to increase with concentrations. The $\varnothing_V^0$ values of $KClO_3$ under investigation in all solvent systems are large and positive. The S_v is negative. These results indicate that there is presence of strong solute-solute interactions. (Shekaari, 2019) The Diffusion reaction rate constant (k_d) values are positive and decrease with increase in temperature as well as concentration. Positive Kd values reveals that the solvolysis of $KClO_3$ in aqueous electrolyte studied is diffusion controlled rather than activated controlled process.

CONCLUSION

The increase in densities and viscosities with concentration may be due to strengthening of solute-solvent interactions. (Gupta, 2019). All the investigated parameters has been revealed that there exist strong solute–solvent interaction. This molecular interaction data help to reveal the toxicity of chlorate. When chlorate is added in the soil or injected in the stem of Longan plants, it creates a strong solute–solvent interaction with the other aqueous ionic solids which are already present in the soil or plant tissues. Chlorate acts as a structure maker and form a tight solvation layer as well as high compactness around the solute. Over-application of flower-inducing chlorate failed to induce flower but caused toxic effects such as leaf chlorosis and drop in longan. The solvolysis of $KClO_3$ in water and KNO_3 or other nitrate and phosphate solutions at different temperatures is diffusion controlled process. The co-sphere of solvent significantly suppressed nitrate reducing activity in the leaves. This suggested that chlorate not only inhibited photosynthesis due to stomata closure but also due to breakdown of photosynthetic apparatus in chloroplasts. (Sritontip C. Y., 1999) The higher values of densities of $KClO_3$ in KCl, KNO_3, NH_4NO_3 and KH_2PO_4 are due to the relative salvation, corresponding relative volumes of system and molar mass of the salts. Strong molecular interactions induces chlorate stress (LU Jiemei, 2017) due to occurrence of osmotic adjustment which results in massive accumulation of soluble amino acids and sugars. Excessive use of chlorate as a bleaching agent toxifies the water (Lubbers, Chauhan, & Bianchine, 1981), soil and disturbs the environment's equilibrium. (Kanitz, 1996). Reducing the usage of chlorate, used in the production of colours, safety matches, and explosives for tanning and finishing leather, is important in order to conserve and save the environment.

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