OPTO MECHANICAL PROPERTIES OF $FeCl_3$ IN ABSENCE AND PRESENCE OF PVA (POLYVINYL ALCOHOL) AND 50% (V/V) ETHANOL – WATER MIXTURES

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Abstract. The optical and mechanical properties for the different solutions were studied at room temperature. From the measured refractive indices of $FeCl_3$ solutions in absence and presence of 10% PVA (Polyvinyl alcohol), the molar refraction (R_M), specific refractivity (ε) and the polarizabilities were estimated. The same parameters were also evaluated in presence of 50% mixed ethanol – water solvents. The mechanical tension parameters like elastic modulus (E) and Shear modulus for $FeCl_3$+10% PVA solutions in absence and presence of 50% ethanol – water mixtures were evaluated. The opto-mechanical properties of $FeCl_3$ solutions in the title conditions were discussed.

Keywords: ferric chloride, polyvinyl alcohol, optical properties, mechanical properties

Introduction

Polymer solutions are important in electrochemistry due to their applications for preparing electrodes, especially when doped with metals [1,2]. Adding transition metals to the polymer solutions improve the conducting properties and also play important role in forming thin films [3]. Conductivity and refractive index methods are good methods for explaining ion – ion and ion – solvent interactions and also the association of ions. In various media [4,5]. Estimation of the optical and mechanical properties of the polymers in absence and presence of metals are very important to give relations between the opto – mechanical characteristics [6]. The aim of the present work is to study the optical and mechanical properties of $FeCl_3$ solutions in absence and presence of both PVA (polyvinyl alcohol) and 50% ethanol – water mixtures together or separately.

Experimental

Ferric chloride from Merck Co. and polyvinyl alcohol, M.W.17000, water soluble polymer from Arondate was BDH supplement and the water used was secondly distilled one. Bidestilled water of 5 ml was put in test tubes, and then different concentrations of solid $FeCl_3$, with or without 10% by weight PVA were added and dissolved. Also other solutions were prepared by adding different concentrations of $FeCl_3$ to 50% ethanol – water solvents (% by volume) in absence and presence of 10% PVA. The solutions were left for more than one day in water thermostat of the type (Polyscience 8105, USA) at 298.15 K. The densities were measured by taking 1 ml of the prepared solutions and put in specific gravity bottle (1ml capacity) and weight them by the use of Mettler Toledo USA four digital weighing balance. The densities have been used to evaluate the solvated radii [7]. The refractive indices of the different solutions used here in this work were measured using a refractometer of the type ATAGO-3T (No 52507) at 298.15 K.

Results and discussions

From densities of $FeCl_3$ aqueous solutions in absence and presence of 10% by weight PVA, the molar volumes were evaluated by dividing the molecular weight of $FeCl_3$. By the densities, and the evaluated volumes (V) are represented in Table 1. From the experimental refractive indices (n) and the molar refraction (R_M) were calculated [8] by means of Eq (1).

$$R_M = \frac{n^2 - 1}{n^2 + 2} V \qquad (1)$$

where V is the measured molar volumes. The evaluated R_M values are listed also in Table 1. The specific refractivities of the isotropic dielectric (ε) were calculated by de Vries equation [9,10] as seen in Eq (2).

$$\frac{n^2-1}{n^2+2} = \varepsilon d \qquad (2)$$

where d is the density of solution. The mean values of molecular dipole polarizability (α) (i.e., dipole moment induced by electric field) were calculated from Lorenz - Lorenz formula [11] following Eq (3).

$$\frac{n^2-1}{n^2+2} = \frac{4}{3}\pi N\alpha \qquad (3)$$

The number of molecular chains (N), the moduli of elasticity in tension E and in Shear G were calculated by using Eqs (4,5) after Fouda et al. [10,11].

$$N = N_A d / M \qquad (4)$$

$$E = NkT = 3G \qquad (5)$$

where k is Boltzmann's constant, T – the absolute temperature, N_A is Avogadro's number and M is the molecular weight of $FeCl_3$. All the measured and evaluated data for $FeCl_3$ were gathered separately for aqueous solutions in Table 1 and in presence of 10% PVA in Table 2, in 50% ethanol – water solvents in Table 3 and in 50% ethanol – water plus 10% PVA solutions in Table 4. All the given data are evaluated at 298.15 K. The increase of ferric chloride concentrations in aqueous solutions favors increase in the optical properties in absence and presence of 10% PVA like molar refraction (R_M) specific refractivity [9], molecular dipole polarizability (α) due to the increase of the refractive indices (n) in the same direction.

The mechanical properties of ferric chloride aqueous solutions were decreased by increasing the salt concentrations in absence and presence of 10% PVA due mainly to the decrease in the number of molecular chains N. The optical properties of $FeCl_3$ solutions in 50% by volume ethanol – water mixtures are increase by adding more salt concentrations in absence and presence of 10% by weight PVA due also to the increase in refractive index values. All the optical properties of $FeCl_3$, like molar refraction, the specific refractivities and molar polarizability are greater in using 50% ethanol – water solvents than in aqueous solutions. On the contrary the mechanical properties of $FeCl_3$ solutions in 50% ethanol – water solvents like elastic modulus (E) and Shear modulus (G) are less than that in aqueous solutions due to the decrease in the number of molecular chains per unit volume (N).

Table 1. Densities (*d*), molar volume (*V*), refractive index (*n*), molar refraction (R_M), specific refractivity (ε) number of chain molecules (*N*), polarizability (α), elastic modulus (*E*) and Shear modulus (*G*) for $FeCl_3$ in aqueous solutions at 298.15K

Conc. of $FeCl_3$	Density *d* (g/cm^3)	Volume *V* (cm^3mol^{-1})	Refractive index *n*	R_M ($Cm^3.mol^{-1}$)	ε	$N.10^{21}$	$\alpha .10^{-3}$ (cm^{-3})	$E .10^8$	$G .10^8$
0.084	0.950	170.743	1.336	35.408	0.2182	2.53	1.55	4.318	1.439
0.1	0.925	175.358	1.337	36.464	0.2247	3.42	1.61	4.`94	1.394
0.15	0.899	180.429	1.338	37.618	0.2433	3.33	1.67	4.071	1.357
0.21	0.857	189.272	1.340	39.674	0.2446	3.17	1.75	3.947	1.315
0.25	0.842	192.643	1.342	40.595	0.2503	3.12	1.79	3.824	1.274
0.34	0.795	204.033	1.344	43.222	0.2665	2.94	1.94	3.577	1.192
0.42	0.743	218.312	1.347	46.611	0.2874	2.74	2.06	3.454	1.151
0.52	0.689	232.387	1.350	50.000	0.3083	2.58	2.21	3.207	1.069

Table 2. Densities (*d*), molar volume (*V*), refractive index (*n*), molar refraction (R_M), specific refractivity (ε), number of chain molecules (*N*), polarizability (α), elastic modulus (*E*) and Shear modulus (*G*) for $FeCl_3$ in aqueous solutions in presence of 10% PVA (polyvinyl alcohol) at 298.15K

Conc. of $FeCl_3$	Density *d* (g/cm^3)	Volume *V* (cm^3mol^{-1})	Refractive index *n*	R_M ($cm^3.mol^{-1}$)	ε	$N.10^{21}$	$\alpha .10^{-3}$ (cm^{-3})	$E .10^8$	$G .10^8$
0.084	0.830	195.429	1.3500	42.051	0.2592	3.07	186	3.824	1.274
0.1	0.823	197.091	1.3510	42.179	0.2693	3.05	1.87	3.824	1.274
0.15	0.801	202.504	1.3530	43.909	0.2706	2.96	1.97	3.577	1.192
0.21	0.772	210.111	1.3550	45.792	0.2823	2.86	2.02	3.577	1.192
0.25	0.750	216.217	1.3560	47.254	0.2913	2.78	2.08	3.454	1.151
0.34	0.710	228.450	1.3595	50.355	0.3105	2.63	2.22	3.207	1.069
0.42	0.671	241.738	1.3625	53.684	0.3309	2.48	2.37	3.084	1.028
0.52	0.632	256.655	1.3660	57.490	0.3544	2.34	2.54	3.837	0.945

Table 3. Densities (*d*), molar volume (*V*), refractive index (*n*), molar refraction (R_M), specific refractivity (ε), number of chain molecules (*N*), polarizability (α), elastic modulus (*E*) and Shear modulus (*G*) for $FeCl_3$ in 50% mixed ethanol water solutions at 298.15K

Conc. of $FeCl_3$	Density *d* (g/cm^3)	Volume *V* (cm^3mol^{-1})	Refractive index *n*	R_M ($cm^3.mol^{-1}$)	ε	$N.10^{21}$	$\alpha.10^{-3}$ (cm^{-3})	$E.10^8$	$G.10^8$
0.084	0.765	212.034	1.3560	46.398	0.2860	2.83	2.05	3.454	1.151
0.1	0.755	214.842	1.3570	47.059	0.2901	3.79	2.08	3.442	1.147
0.15	0.731	221.896	1.3595	48.911	0.3015	2.70	2.16	3.331	1.110
0.21	0.700	231.723	1.3620	51.396	0.3168	2.57	2.27	3.195	1.065
0.25	0.681	238.188	1.3640	53.092	0.3273	2.52	2.34	3.108	1.036
0.34	0.642	252.657	1.3675	56.802	0.3502	2.40	2.40	2.960	0.912
0.42	0.601	264.894	1.3710	60.061	0.3772	2.22	2.71	2.738	0.912
0.52	0.553	293.320	1.3755	67.225	0.4144	2.05	296	2.590	0.863

Table 4. Densities (*d*), molar volume (*V*), refractive index (*n*), molar refraction (R_M), specific refractivity (ε), number of chain molecules (*N*), polarizability (α), elastic modulus (*E*) and Shear modulus (*G*) for $FeCl_3$ in 50% ethanol – water + 10% PVA (polyvinyl alcohol) solutions at 298.15K

Conc. of $FeCl_3$	Density *d* (g/cm^3)	Volume *V* (cm^3mol^{-1})	Refractive index *n*	R_M ($cm^3.mol^{-1}$)	ε	$N.10^{21}$	$\alpha.10^{-3}$ (cm^{-3})	$E.10^8$	$G.10^8$
0.084	0.775	209.298	1.3690	47.224	0.2911	2.87	2.08	3.540	1.180
0.1	0.782	207.125	1.3700	46.848	0.2892	2.89	2.07	3.565	1.188
0.15	0.810	200.254	1.3720	45.513	0.2806	2.99	2.01	3.688	1.229
0.21	0.800	202.758	1.3740	46.304	0.2855	2.96	2.04	3.651	1.217
0.25	0.795	204.033	1.3760	46.817	0.2885	2.94	2.07	3.627	1.209
0.34	0.820	197.812	1.3795	45.766	0.2821	2.03	2.03	3.735	1.246
0.42	0.800	202.758	1.3830	47.296	0.2916	2.96	2.09	3.651	1.217
0.52	0.800	202.758	1.3870	47.735	0.2942	2.96	2.11	3.651	1.217

Conclusion

The conclusion is that the best optical properties for $FeCl_3$ solutions are in the case of 50% ethanol – water plus 10% PVA. The best mechanical properties of $FeCl_3$

solutions are in the case of aqueous solutions. It is also concluded that the optical properties of polyvinyl alcohol increase on adding $FeCl_3$ and 50% mixed ethanol – water solutions. Whereas the mechanical properties of PVA decrease by more increasing in $FeCl_3$ concentrations and adding 50% mixed ethanol – water solutions.

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