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Original Research Article

Determination of the Dielectric Constant of CuSO4.5H2O (%) Solutions using Visible Light

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Abstract

Optical constants such as refractive index, absorption coefficient, extinction coefficient and the real (εr) and imaginary (εi) components of the dielectric constant for CuSO4.5H2O (10-100%) concentrations were determined from the visible light Optical transmission data. Results of visible light transmission analysis in the solutions have shown that in dilute solutions the dielectric constant real and imaginary parts are linear. The addition of dissolved cu^{+2} and $so4^{-2}$ ions above (80%) concentrations results in a drop in dielectric constant.

Keywords: Optical transmission method; refractive index (n); extinction coefficient (k); CuSO4.5H2O; dielectric constant.

INTRODUCTION

Dielectric constant or relative permittivity is the ability of a medium to distort the electric field between two point charges. It is a material property that expresses the force between two point charges in the material. Therefore, it is the factor by which the electric field between the charges is decreased relative to vacuum. The dielectric constant affects the solubility of an ionic compound. This can be understood due to the fact that water has a very high dielectric constant (80) and this allows salts to dissolve in water with dissociation. The dielectric constant is an indicator for the strength of solvent as to ions separation (see Figure 1).

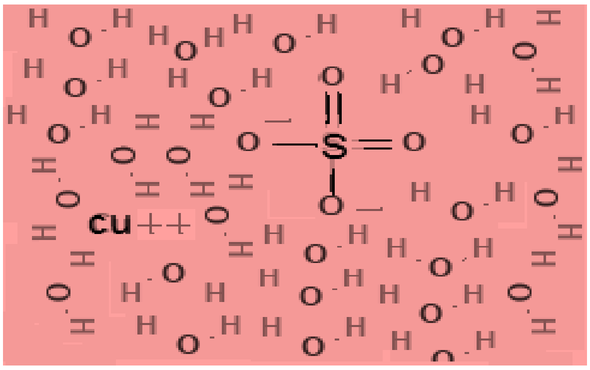

Figure 1: Shows the effect of solvent with high dielectric constant on the dissociation of ionic solutions

The strength of a ionic bond is directly proportional to the product of the charges on the ions, inversely proportional to the square of their distance, and inversely proportional to the dielectric constant (ϵ) of the solvent, ($F \propto Q_1Q_2/r^2\epsilon$). A study of the CuSO4 · 5H2O Single Crystals and Some of their Properties were carried out in [1]. The study has shown that Large single crystals of CuSO4 · 5H2O can be used as broadband UV optical filters [1].

This study represents the measurements carried out for the optical constants of cuso4.5h2o (%) solutions, such as the dielectric constant (the real (εr) and imaginary (εi)) components, absorption coefficients, and the extinction coefficients. The absorption coefficient is defined as the rate of decrease in the intensity of electromagnetic radiation (as light) as it passes through a given substance; the fraction of incident radiant energy absorbed per unit mass or thickness of an absorber [2, 3]. The extinction coefficient is a measure of the damping of the electromagnetic wave (as light) as it passes into a medium or the net loss, or attenuation, of light through a material [4-6].

MATERIALS AND METHODS

CuSO4.5H2O solutions were made from distilled water with CuSO4.5H2O concentration (gram/liter) from (10-100%). The 5H2O that are present in the CuSO4 solution is called water(s) of crystallization. These are water molecules that are present inside crystals without getting chemically bonded to the compound cation. Water that is chemically bound with some compounds and when combined in the proper ratio, will create a crystal structure unique to the combined compound and water. The compounds usually resist heat so that when the hydrated crystals are heated enough, the water leaves and the compound is dehydrated. When heating CuSO4·5H2O crystals, it will lose two water molecules at 60 °C firstly. And another two is at 100 °C, and then the last one is at 260 °C [7]. Figure 2 shows the main units of the optical system.

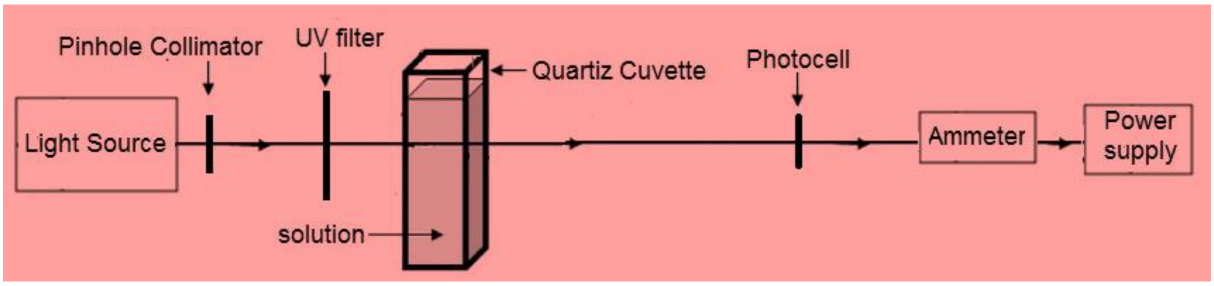

Fig 2: The experimental set-up

However, measurements of CuSO4.5H2O solutions were taken on two consecutive days in order to achieve solution equilibrium, and average results were taken. Three measurements were carried out in CuSO4.5H2O solutions, one at normal (%) solutions, the second measurement was carried out after heating the compound solution up to 100^0C, and the third measurement was carried out on the heated solution subjected to static magnetic field of 75mT. Measurements were taken at 16^0C. The transmission data was recorded with ammeter with a light filter, yellow in the wavelength of maximum transparency (580 nm). The theory of optical properties can be found in [8-12].

RESULTS AND DISCUSSION

Table 1 summarizes the optical data obtained for $CuSO_4.5H_2O$ with concentration (%). It can be seen from table1 that the relative refractive index increases with compound concentration. The same applies for the real and imaginary parts of the refractive index (see Fig 3).

Table 1: Data for normal $CuSO_4.5H_2O$, Using light filter with maximum transparency wavelength (580nm)

Concentration (%)	**T(I/I_0)**	**Refractive index (n)**	**Absorption coefficient** $\alpha(10^{-4})$	**Extinction coefficient** $K(10^{-9})$	**Dielectric constant (ε') real part**	**Dielectric constant imaginary part (ε'') (10^{-9})**
10	0.74	2.26	276.36	1.276	5.1076	5.77
20	0.35	5.533	690.95	3.19	30.61	35.35
30	0.163	12.2	886.66	4.09	148.84	99.85
40	0.098	20.36	955.75	4.41	414.53	179.63
50	0.087	22.9	967.26	4.46	488.41	197.13
60	0.065	30.74	990.29	4.57	944.95	281.03
70	0.054	37.01	1001.81	4.62	1369.74	342.27
80	0.054	37.01	1001.81	4.62	1369.74	342.27
90	0.054	37.01	1001.81	4.62	1369.74	342.27
100	0.043	46.5	1013.32	4.68	2140.38	434.96

It can be seen from Table 1; that in dilute solutions the dielectric constant real (ε') and imaginary (ε'') are linear. The addition of dissolved cu++ and so_4^{--} ions to water results in a drop in dielectric constant of water (~80) due to the fact that the densities of solution reach a saturation level and the solution become an electrically conductive, there are more molecules for the visible light to hit when it penetrates through the solutions. The dielectric constant is an indicator of how easily an insulating material can be polarized as a result of an external electric field applied to it. The $cuso_4$ ions produce electric fields that polarize the water dipoles, which is opposite to electric components of the light electromagnetic wave. As a result the penetration of light waves in the solution is blocked

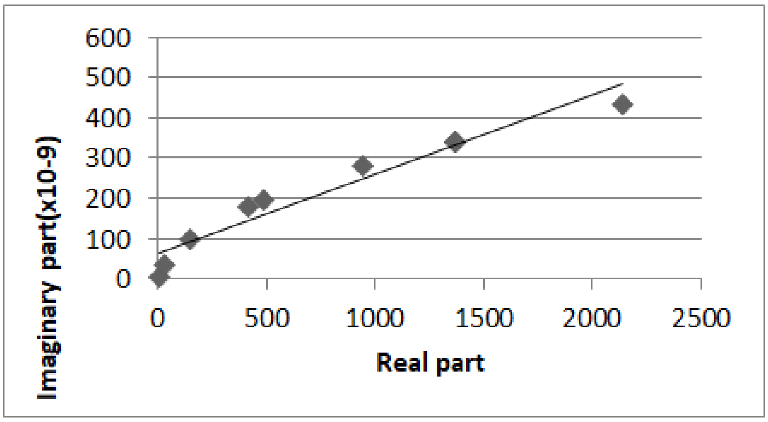

Figure 3: Data shows the relationship between real and imaginary parts of the refractive index for $CuSO_4.5H_2O$ is linear

Table 2 presents the optical data obtained for $CuSO_4.5H_2O$ with concentration (%) after heating at 100^0C. This heating will reduce the water crystallization ($5H_2O$). It can be seen from Table 2 that the relative refractive index increases with compound concentration up to (80%) after that no change in the optical propertied of the $CuSO_4$ solution. The same applies for the real and imaginary parts of the refractive index (see Fig 4).

Table 2: Data for $CuSO_4.5H_2O$ after heating at 100^0C, Using light filter with maximum transparency wavelength (580nm)

Concentration (%)	T(I/I_0)	Refractive index (n)	Absorption coefficient $\alpha(10^{-4})$	Extinction coefficient K(10^{-9})	Refractive index (ε') real part	Refractive index imaginary part (ε'') (10^{-9})
10	0.652	2.7142	264.85	1.226	7.29	006.588
20	0.106	18.8231	679.43	3.142	353.44	118.064
30	0.136	14.6406	656.42	3.030	214.33	88.7264
40	0.106	18.8621	679.46	3.146	353.44	118.064
50	0.091	22.263	690.94	3.214	484.35	140.867
60	0.076	26.3377	702.42	3.242	691.69	170.538
70	0.061	32.8303	713.93	3.306	1075.84	216.515
80	0.045	44.4403	725.45	3.351	1971.36	297.482
90	0.045	44.4403	725.45	3.351	1971.36	297.482
100	0.045	44.4403	725.45	3.351	1971.36	297.482

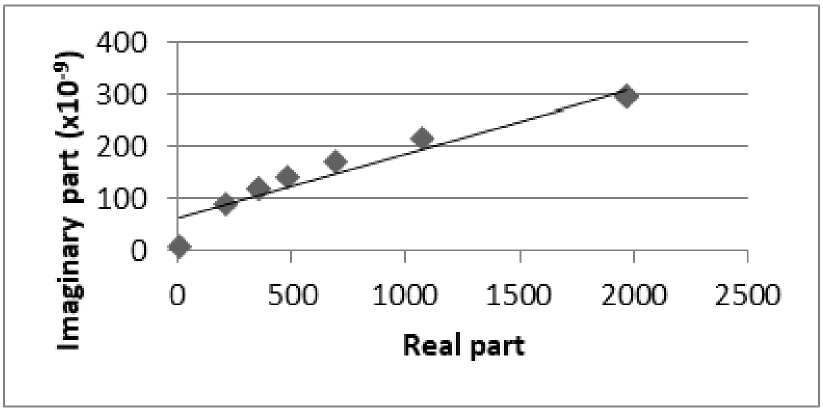

Figure 4: Data shows the relationship between real and imaginary parts of the refractive index for $CuSO_4$ (%) solution is linear

Table 3: Presents the optical data obtained for $CuSO_4$ with concentration (%) after heating at 100^0C and magnetic field (75mT) for (10min) was applied to $cuso_4$ (%) solutions

Concentration (%)	$T(I/I_0)$	Refractive index (n)	Absorption coefficient $\alpha(10^{-4}$	Extinction coefficient $K(10^{-9})$	Refractive index (ε') real part	Refractive index imaginary part (ε'') (10^{-9})
10	0.74	2.2618	264.85	1.24	5.11	5.53
20	0.522	3.5521	495.15	2.29	12.72	16.26
30	0.56	3.2743	460.62	2.13	10.73	14.07
40	0.522	3.5623	495.15	2.29	12.72	16.31
50	0.50	3.7306	518.18	2.39	14.16	17.82
60	0.48	3.9067	541.21	2.50	15.21	19.54
70	0.48	3.9067	541.21	2.50	15.21	19.54
80	0.43	4.4321	587.36	2.77	19.62	24.42
90	0.41	4.6707	610.38	2.82	21.81	26.34
100	0.39	5.2531	633.33	2.54	25.54	25.41

It can be seen from table3 that the refractive index of cuso4 solution drops rapidly under the action of static magnetic field. The effect of magnetic field on the physical and chemical properties of liquid water was reported in numerous papers. Some studies findings suggested that such an approach should improve cooling and power generation efficiency in industry [13]. Others have suggested that the surface tension of water should be considered as a reliable indicator for studying the effects of magnetic field on water [14]. Other works have showed that applying a static magnetic field on liquid water increases the evaporation rate of water [15]. Other studies have suggested that magnetic fields change the distribution of molecules, causes displacements and polarization of molecules, influences the hydrogen bond, structure of water, and should attribute to symmetric and antisymmetric stretching vibration of HO [16-18]. It can be stated that the effect of static field on the optical properties of liquid water remains under debate topic. Since water has high dielectric constant, it has the ability to separate ions from their compound structure. These ions produce electric fields which polarize water molecules. The effect of magnetic field on water is to reduce the rotational movement of water molecules, effects the vibrational modes of water molecules (hydrogen bond mechanism).

CONCLUSION

Optical constants such as refractive index, absorption coefficient, extinction coefficient and the real (εr) and imaginary (εi) components of the dielectric constant for $CuSO_4.5H_2O$ (10-100%) concentrations were determined from the visible light Optical transmission data. Results of visible light transmission analysis in the solutions have shown that in dilute solutions the dielectric constant real and imaginary parts are linear. The addition of dissolved cu^{+2} and so_4^{-2} ions above (80%) concentrations results in a drop in dielectric constant. Results also showed the effect of static magnetic field on optical properties of $CuSO_4.5H_2O$ solution.

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