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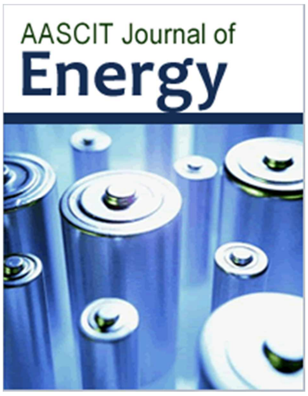

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Thermodynamic Interaction Parameters for Bulk and Nano $CuSO_4$ with Cresol Red in Mixed DMF-H_2O Solvents

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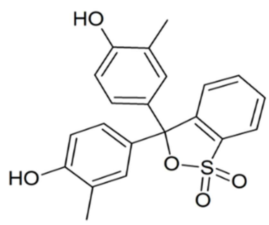
Abstract
Characterization of nano $CuSO_4$ is done by transmission electron microscopy (TEM) and the thermodynamic parameters were evaluated by using condutometric measurements. The association and complex formation parameters of both bulk (normal) and nano-Cu SO_4 salts in DMF + H_2Owere calculated in presence of cresol red, non isothermally at different temperatures, 292.15, 303.15, 308.15 and 313.15K. The thermodynamics of the complexation reactions for bulk and nano $CuSO_4$ salts were compared.

1. Introduction

Nanoparticles are very important for medicine and environment, because of their increased behaviours. The increasing in the physical and chemical properties of nanomaterials are due to theirs high surface area and small volume, makes them very reactive, catalytic and able to pass through cell membranes. Copper sulphate is used in the treatment of some bacteria, algae, fungus and some fish parasites such as Ich. It can also be used to kill snails, accidentally or on purpose. The disadvantage of copper sulphate is that it is extremely toxic in water of low alkalinity [1].

2. Experimental

2.1. Chemicals and Ligand



Formula: $C_{21}H_{17}NaO_5S$
Molecular weight: 404.41 g.mol^{-1}

Copper Sulfate ($CuSO_4.5H_2O$) was provided from Al Nasr chemicals Co. while nano-$CuSO_4$ salt was prepared by ball milling method using copper sulfate salt. The ball milling was a Retsch MM 2000 Swing mill with 10 cm^3 stainless steel, double-walled tube. Two balls (stainless steel) with diameter of 12 mm were used. Ball milling was performed at 20225 Hz and shaking were used, usually at room temperature without circulating liquid and the temperature did not rise above 30 °C.

2.2. Experimental

2.2.1. Transmission Electron Microscopy (TEM) Images

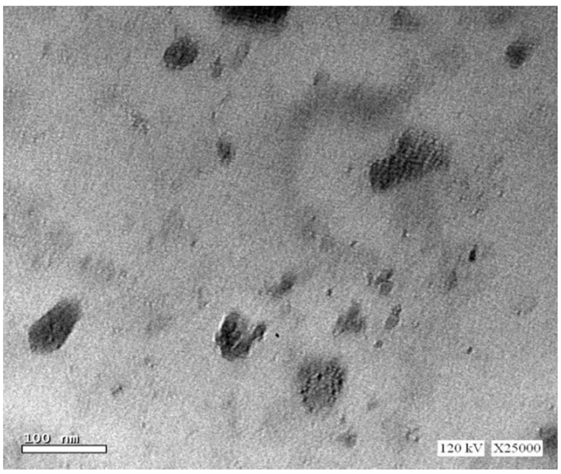
Transmission electron microscope is a special kind of electron microscope for imaging of different objects. The electrons interact with atoms of the sample. Due to this interaction the electrons are being scattered. The final image is very complicated interference pattern of incident and diffracted beams. The images were measured by using JEOL HRTEM – JEM 2100 (JAPAN) show that TEM of $CuSO_4$ obtained in water are diffused ones.

2.2.2. Condutometric Measurements

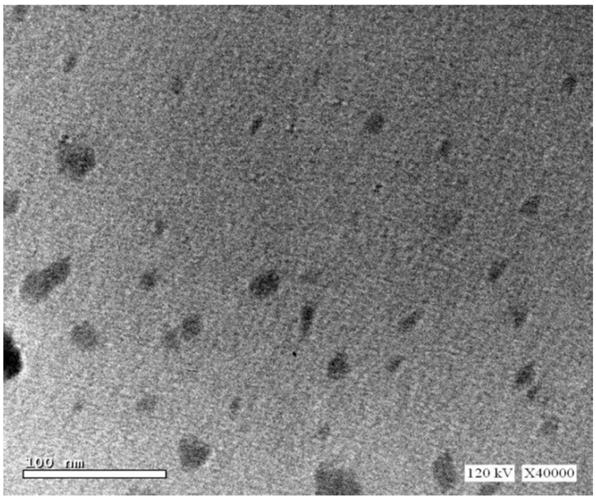
A solution of bulk and nano-$CuSO_4$ ($1x10^{-4}$ N) was placed in a titration cell, thermostated at a given temperature and the conductance of the solution was measured [2-21]. The ligand (Cresol red)($1X10^{-3}$ N) was transferred step by step to the titration cell using a precaliberated micropipette and the conductance of the solution was measured after each transfer. The addition of the ligand solution was continued until the total concentration of the ligand was approximately four times higher than that of the metal ions. The conductance of the solution was measured by titration of ligand (cresol red) with metal salt solution. The complex formation constant K_f, and the molar conductance of the complex ML, were evaluated by computer fitting to the molar conductance mole ratio data. The temperatures used are (292.15, 303.15, 308.15 and 313.15K). The specific conductivity K_s was achieved by using a conductivity bridge of the type (JENCO – 3173 COND).

3. Data Results and Discussion

3.1. Transmission Electron Microscopy (TEM) Images



(a)



(b)

Fig. (1). *TEM images of nano $CuSO_4$*

The photographs from (TEM) are presented for nano-$CuSO_4$ salt. The images show that the nano $CuSO_4$ in the form irregular spheres or deformed spheres, little diffusion with water solvent, the boundaries were seen and the sizes ranging from 20-40 nm.

3.2. Conductometric Results

The stability of a transition metal complex with ligand (Cresol red) depends on the number and the type of the donor atoms presented the number and the size of chelate rings formed on the complexation [21-25]. In addition, the stability and the selectivity of the complexities are strongly depend on the donor ability and the dielectric constant of the solvent [25-36], the shape, the size of the solvent molecules [37-45].

3.2.1. Calculation of Thermodynamic Parameters of Association for Bulk and Nano-$CuSO_4$ in DMF

The specific conductance values (K_s) of different concentrations for bulk and nano-$CuSO_4$ in DMF-H_2O were measured experimentally in absence of ligand (cresol red) at different temperatures (292.15, 303.15, 308.15 and 313.15K). The molar conductance (Λ_m) values were calculated [46-59] using equation (1):

$$\wedge_m = \frac{(K_s - K_{solv}) \times K_{cell} \times 1000}{C} \qquad (1)$$

Where K_s and K_{solv} are the specific conductance of the solution and the solvent, respectively; Kcell is the cell constant and C is the molar concentration of the bulk and nano-$CuSO_4$ solutions.

The limiting molar conductance (Λ_o) at infinite dilutions was estimated for bulk and nano-$CuSO_4$ in DMF in absence of ligand at different temperatures by extrapolating the relation between Λ_m and $C_m^{½}$ to zero concentration. The relation between Λ_m and $C_m^{½}$ at 313.15K is shown in

Fig.(2)and Fig. (3).

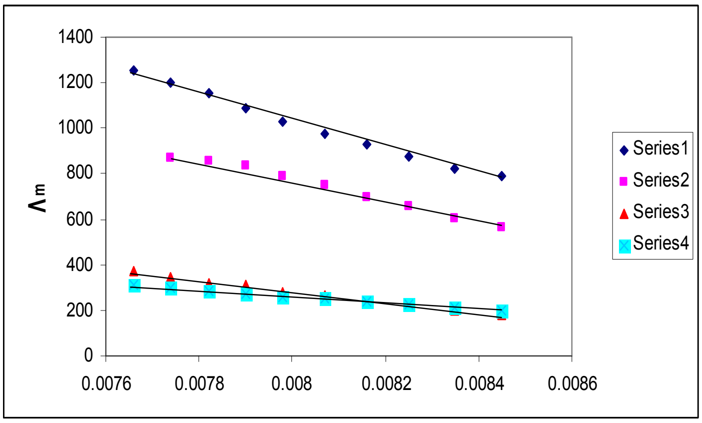


Fig. (2). *The relation between Λm and Cm½ for nano copper sulfate in presence of cresol red at 313.15K*

Series 1: 20%DMF + 80% H_2O
Series 2: 40%DMF + 60% H_2O
Series 3: 60%DMF + 40% H_2O
Series 4: 80%DMF + 20% H_2O

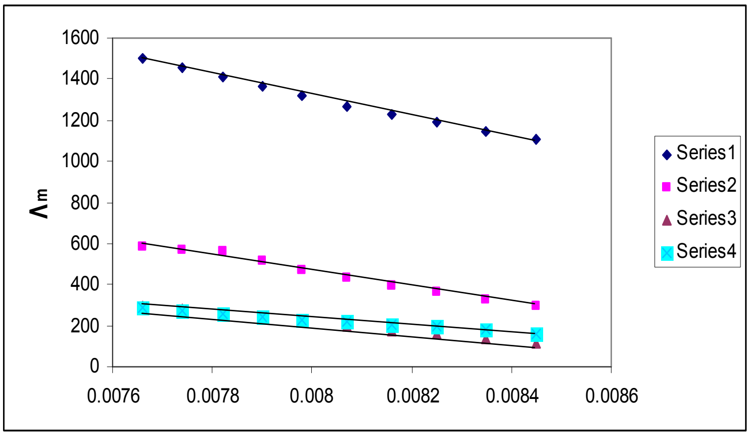


Fig. (3). *The relation between Λm and Cm½ for bulk copper sulfatein presence of cresol red at 313.15K*

Series 1: 20%DMF + 80% H_2O
Series 2: 40%DMF + 60% H_2O
Series 3: 60%DMF + 40% H_2O
Series 4: 80%DMF + 20% H_2O

The values of association constants for nano and bulk $CuSO_4$ were calculated from equation (2) in presence of cresol red and tabulated in Table (1) and (2).

$$K_A = \frac{\wedge_0 (\wedge_0 - S(Z)\wedge_m)}{C_m \wedge_m^2 S(Z)^2 \gamma_\pm^2} \quad (2)$$

The values of free energy of association (ΔG_A) for bulk and nano-$CuSO_4$ in DMF at 313.15K were calculated [60-78] from the association constant (K_A) values by using equation (3) and reported in Table (1) and (2).

$$\Delta G_A = -\ 2.303\ RT \log K_A \quad (3)$$

Where *R* is the gas constant and T is the absolute temperature.

The values of Gibbs free energies for the solutions of bulk and nano-$CuSO_4$ in DMF – H_2O at 313.15K were calculated and reported in Table (1) and (2).

The dissociation degree (α) for bulk and nano-$CuSO_4$ in DMF in presence of cresol red at 313.15K were calculated from equation 4 and reported in Table (1) and (2).

$$\alpha = \Lambda_m / \Lambda_0 \quad (4)$$

Table (1). *The association constant, free energies and degree of dissociation for bulk $CuSO_4$ at different concentration of DMF- H_2O in presence of cresol red at 313.15K.*

X_s(DMF mole fraction)	C	$C_M^{1/2}$	Λ_m	Λ_0	α	log $\gamma_\pm$	$\gamma_\pm$	K_A	$\Delta G_{A(k.J/mole)}$
0.0621	6.122×10^{-5}	0.0078	1412.937	4650	0.303	-0.0039	0.9911	1.253×10^5	-30.546
0.1346	6.122×10^{-5}	0.0078	560.274	3750	0.149	-0.0039	0.9911	6.336×10^5	-34.764
0.2595	6.122×10^{-5}	0.0078	261.352	1800	0.145	-0.0039	0.9911	6.742×10^5	-34.926
0.4831	6.122×10^{-5}	0.0078	259.719	1300	0.199	-0.0039	0.9911	3.333×10^5	-33.093

Table (2). *The association constant, free energies and degree of dissociation for nano $CuSO_4$ at different concentration of DMF- H_2O in presence of cresol red at 313.15K.*

X_sDMF mole fraction	C	$C_M^{1/2}$	Λ_m	Λ_0	α	log $\gamma_\pm$	$\gamma_\pm$	K_A	$\Delta G_{A(k.J/mole)}$
0.0621	6.122×10^{-5}	0.0078	1153.218	4850	0.238	-0.0039	0.9911	2.241×10^5	-32.060
0.1346	6.122×10^{-5}	0.0078	854.296	4000	0.213	-0.0039	0.9911	2.867×10^5	-32.700
0.2595	6.122×10^{-5}	0.0078	321.790	1700	0.189	-0.0039	0.9911	3.762×10^5	-33.408
0.4831	6.122×10^{-5}	0.0078	282.587	1050	0.269	-0.0039	0.9911	1.677×10^5	-31.306

3.2.2. Calculation of Thermodynamic Parameters of Complex Formation for Bulk and Nano-$CuSO_4$ with Cresol red in DMF

The specific conductance values (K_s) of different concentrations of bulk and nano-$CuSO_4$ in DMF were measured experimentally in the presence of ligand at different temperatures (292.15, 303.15, 308.15 and 313.15 K). The molar conductance (Λ_m) values were calculated [21-70] using equation (1).

By drawing the relation between molar conductance (Λ_m) for bulk and nano-$CuSO_4$ in presence of ligand at different temperatures and the molar ratio of metal to ligand [M]/[L] concentrations, Fig.(3) different lines are obtained with breaks indicating the formation of 1:2 and 1:1 (M:L) stoichiometric complexes ,as done in previous works [7-75].

The formation constants (K_f) for bulk and nano-CuSO4 complexes were calculated for each type of complexes (1:2) and (1:1) (M: L) by using equation (5) [75-78]:

$$K_f = \frac{\wedge_m - \wedge_{obs}}{(\wedge_{obs} - \wedge_{ML})[L]} \quad (5)$$

Where Λ_m is the limiting molar conductance of the bulk and nano-Cu SO_4 alone, Λ_{obs} is the molar conductance of solution during titration, Λ_{ML} is the molar conductance of the complex and [L] is the ligand concentration.

The Gibbs free energies of formation for each stoichiometry complex (ΔG_f) were calculated by using the equation (6) [10-25]:

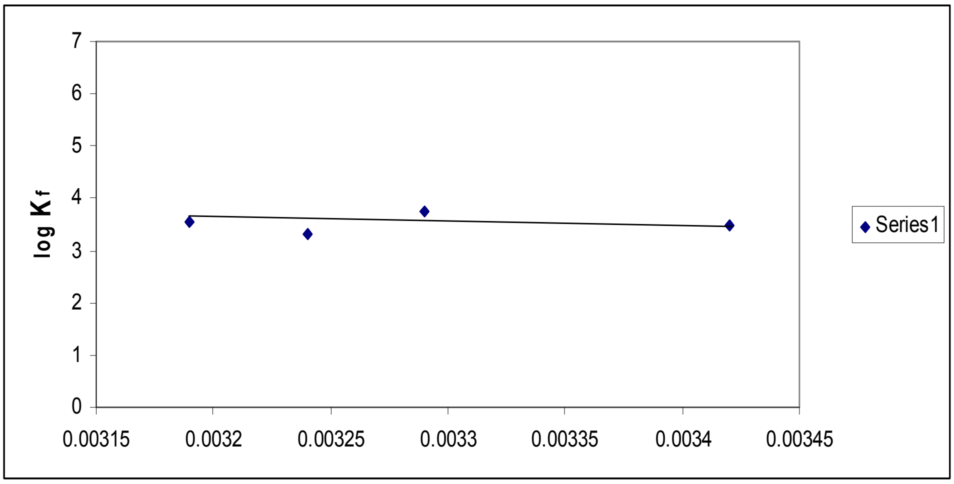
$$\Delta G_f = - 2.303 \, RT \log K_f \quad (6)$$

The obtained values (K_f) for bulk and nano-$CuSO_4$stoichiometry complexes and their calculated ΔGf values at 313.15K are presented in Tables.3 and 4 respectively.

Table (3). *The formation constants and Gibbs free energies of formation for bulk $CuSO_4$in presence of cresol red at different concentration of DMF- H_2O at 313.15K:*

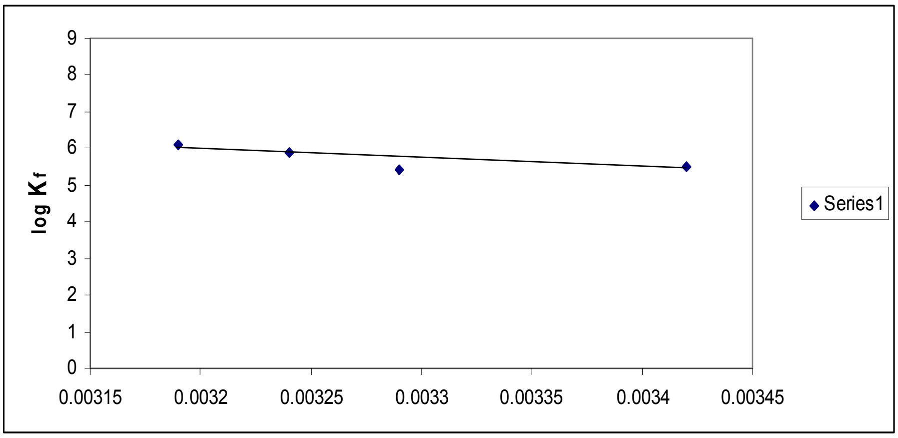
X_s(Vol % DMF)	M/L	[L]	$\Lambda_{obs.}$	Λ_{ML}	Λ_M	K_f	$\Delta G_{f(k.J/mole)}$
0.0621	1:2	4.000×10^{-4}	1453.333	930	2190	3.519×10^3	-21.250
		4.117×10^{-4}	1501.190	930	2190	2.929×10^3	-20.772
		4.231×10^{-4}	1530.595	930	2190	2.594×10^3	-20.456
	1:1	1.176×10^{-4}	848.918	840	2190	1.278734×10^6	-36.591
		1.428×10^{-4}	864.543	840	2190	3.78189×10^5	-33.421
		1.667×10^{-4}	903.636	840	2190	1.21262×10^5	-30.461
0.1346	1:2	3.617×10^{-4}	473.132	130	1050	4.648×10^3	-21.974
		3.750×10^{-4}	513.600	130	1050	3.728×10^3	-21.400
		3.877×10^{-4}	560.274	130	1050	2.935×10^3	-20.777
	1:1	1.176×10^{-4}	69.137	60	1050	9.12845×10^5	-35.714
		1.428×10^{-4}	100.338	60	1050	1.64864×10^5	-31.260
		1.667×10^{-4}	110.404	60	1050	1.11825×10^5	-30.250
0.2595	1:2	4.000×10^{-4}	280.000	60	680	4.545×10^3	-21.915
		4.117×10^{-4}	297.518	60	680	3.911×10^3	-21.524
		4.231×10^{-4}	329.346	60	680	3.076×10^3	-20.899
	1:1	1.176×10^{-4}	14.734	12	680	2.069138×10^6	-37.843
		1.428×10^{-4}	18.667	12	680	6.94642×10^5	-35.003
		1.667×10^{-4}	22.801	12	680	3.65003×10^5	-33.329
0.4831	1:2	4.000×10^{-4}	273.333	125	460	3.146×10^3	-20.958
		4.117×10^{-4}	289.017	125	460	2.532×10^3	-20.393
		4.231×10^{-4}	294.678	125	460	2.302×10^3	-20.145
	1:1	1.176×10^{-4}	82.738	68	460	2.17669×10^5	-31.983
		1.428×10^{-4}	89.838	68	460	1.18700×10^5	-30.405
		1.667×10^{-4}	100.804	68	460	6.5685×10^4	-28.866

By drawing the relation between log K_f and 1/T, different lines are obtained indicating the formation of 1:2 and 1:1 (M:L) stoichiometry complexes Fig.(4,5,6 and 7) as explained in previous works [26-60].



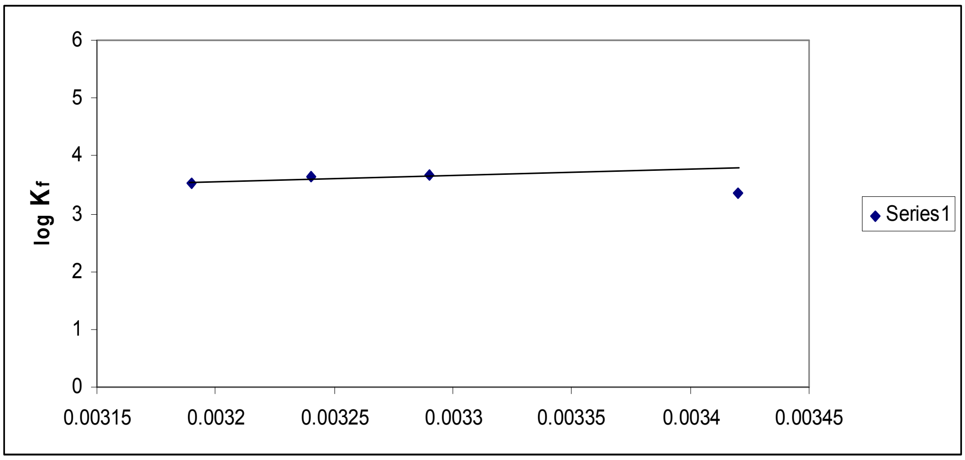
1/T

Fig. (4). *The relation between log K_f and 1/T for 1:2 complex ratio of bulk $CuSO_4$ in presence of cresol red.*



1/T

Fig. (5). *The relation between log K_f and 1/T for 1:1 complex ratio of bulk $CuSO_4$ in presence of cresol red*



1/T

Fig. (6). *The relation between log K_f and 1/T for 1: 2 complex ratio of nano $CuSO_4$*

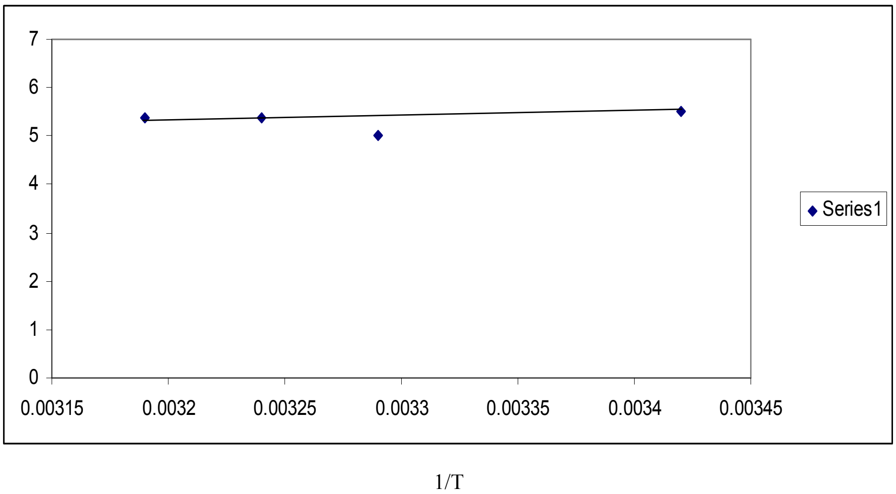


Fig. (7). *The relation between log K_f and 1/T for 1: 1 complex ratio of nano $CuSO_4$ in presence of cresol red*

From the relation between logK_f and 1/T, ΔH_f can be calculated for each type of complexes, from the slope of each line which equal ($-\Delta H_f/2.303R$). The entropy (ΔS_f) for bulk and nano-$CuSO_4$ stoichiometric complexes were calculated [32, 33] for each type of complexes (1:2) and (1:1) (M:L) by using by using Gibbs-Helmholtz equation (7) [44-50]:

$$\Delta G_f = \Delta H_f - T\Delta S_f \quad (7)$$

The calculated values of (ΔH_f), ($T\Delta S_f$) and (ΔS_f) for bulk and nano-$CuSO_4$at 3131.15K stoichiometric complexes are presented in Table (4) and (5) respectively.

Table (4). *The values iof (ΔH_f), ($T\Delta S_f$) and (ΔS_f)in (k.J/mole)for bulk $CuSO_4$in presence of Cresol red at 3131.15K*

Complex ratio	ΔH	TΔS	ΔS
1:2	6.157	27.407	0.087
1:1	40.083	76.674	0.245

Table (5). *The values iof (ΔH_f), ($T\Delta S_f$) and (ΔS_f) in (k.J/mole) for nano $CuSO_4$at 313.15K*

Complex ratio	ΔH	TΔS	ΔS
1:2	-28.898	-7.790	-0.025
1:1	- 14.247	20.799	0.066

It was found that irregular spheres are seen in TEM images for nano $CuSO_4$which explain that the association of nano $CuSO_4$ is small in solution phase. If the association is big the boundaries of the particles between solvent and saltcan not befound. Therefore the association thermodynamic parameters for bulk $CuSO_4$ is bigger than nano $CuSO_4$ in presence of cresol red.

The association constants and free energies of association for both bulk and nano $CuSO_4$ are bigger than complex formation in presence of cresol red because both complexation and association are proceed which seen in association parameter.

The entropies of complex formation and degree of ionization are bigger in case of bulk $CuSO_4$ than that of nano $CuSO_4$ which support the above explanation.

4. Conclusion

The association and complex formation parameters for bulk$CuSO_4$ are bigger than that of nano $CuSO_4$ because of the bigger in both entropies and dissociation degrees for the former. Comparison between the nano and bulk electrolyte thermodynamics are very important to discuss their behaviors in solutions. The aim of this work is to give & study the properties of some nano salts like $CuSO_4$ that can help in determination easily and fast.

References

[1] David A. Wright and Pamela Welbourn, Cambridge Environmental Chemistry Series 111, Cambridge University Press, Cambridge UK (2002)

[2] A.E. Williams, in: H.F. Mark, D.F. Othmer, C.G. Overberger, G.T. Seaborg (Eds.), Kirk-Othmer Encyclopedia of Chemical Technology, vol. 3, 3rd ed., Wiley, New York, 1978, pp. 778–792.

[3] J.L. Opgrande, C.J. Dobratz, E.E. Brown, J.C. Liang, G.S. Conn, J. Wirth, J. Shelton, in: J.I. Kroschwitz, M. Howe-Grant (Eds.), Kirk- Othmer Encyclopedia of Chemical Technology, vol. 4, 4th ed., Wiley, New York, 1992, pp. 103–115.

[4] C.M. Park, R.J. Shechan, in: B. Elvers, S. Hawkins, G. Schultz (Eds.), Ullmann's Encyclopedia of Industrial Chemistry, vol. 18, fifth rev. ed, Basel, 1991, pp. 991–1043.

[5] D.E. Read, C.B. Purves, J. Am. Chem. Soc. 74 (1952) 116–119.

[6] E.E. Schrier, M. Pottle, H.A. Scheraga, J. Am. Chem. Soc. 86 (1964) 3444–3449.

[7] E. Suzuki, Y. Taniguchi, T. Watanabe, J. Phys. Chem. 77 (1973) 1918–1922.

[8] K. Yamamoto, N. Nishi, J. Am. Chem. Soc. 112 (1990) 549–558.

[9] P. Debye, E. Hückel, Z. Phys. 24 (1923)185, 305.

[10] EsamA.Gomaa and R.M.Galal, Basic Sciences of Medicine, 1(2), (2012), 1-5.

[11] EsamA.Gomaa, Physics and Chemistry of Liquids, 50(2012)279-283.

[12] EsamA.Gomaa, International Journal of Materials and Chemisty, 2(1), (2012)16-18.

[13] EsamA.Gomaa, American Journal of Environmental Engineering, 2(3), (2012)54-57.

[14] EsamA.Gomaa. American Journal of Polymer Science, 2(3), (2012),35-38.

[15] EsamA.Gomaa. Eur. Chem. Bull., 1(2013) 259-261.

[16] EsamA.Gomaa, ElsayedabouElleef and E.A.Mahmoud, Eur . Chem. Bull, 2(2013),732-735.

[17] Esam A Gomaa and ElsayedM.AbouElleef, American Chemical Science Journal, 3(2013), 489-499.

[18] Esam A. Gomaa, ElsayedM.AbouElleef, Science and Technology, 3(2013)118-122.

[19] Esam A Gomaa and M.G.AbdelRazek, International Research Journal of Pure and Applied Chemistry,3(2013)320-329

[20] EsamA.Gomaa, International Journal of Theoretical and Mathematical Physcics,3(2013)151-154.

[21] EsamA.Gomaa and B.A.AlJahdali, Education., 2(3),(2012)37-40.

[22] Esam A Gomaa, American Journal of Biochemistry, 2(3), 92012),25-28.

[23] Esam A. Gomaa, Food and Public Health, 2(3),2012, 65-68.

[24] EsamA.Gomaa, Global Advanced Research Journal of Chemistry and Material Science, 1(2012)35-38.

[25] EsamA.Gomaa, Frontiers in Science, 2(2012)24-27.

[26] Esam A Gomaa, ElsayedM.AbouElleef, E.T.Helmy and Sh.M. Defrawy, Southern Journal of Chemistry, 21(2013)1-10.

[27] E.A.Gomaa, K.M.Ibrahim , N.M.Hassan,Frontiers in Science, 2(2012) 76-85.

[28] E.A.Gomaa,K.M.Ibrahim and N.M.Hassan, The International Journal of Engineering and Science (IJES), 3(20144)44-51.

[29] E A. Gomaa,H.M.Abu El-Nader and Sh.E.Rashed, The International Journal of Engineering and Science (IJES), 3(2014) 64-73.

[30] E.A.Gomaa, K.M.Ibrahim and N.M.Hassan, Research and Reviews: Journal of Chemistry, 3(2014) 47-55.

[31] Esam A. Gomaa and Elsayed M. Abou Elleef, Thermal and Power engineering, 3 (2014), 222-226.

[32] Esam A Gomaa ,Elsayed M. Abou Elleef, Elsayed T. Helmy, Research and reviews: Journal of Chemistry, 3(2014)22-27.

[33] Esam A. Gomaa,.Science and Technology,3(2013)123-126.

[34] E.A.Gomaa, Research and Reviews:Journal of Chemistry, 3(2014),28-37.

[35] E. A. Gomaa, A. H. El-Askalany and M. N. H. Moussa, Rev.Roum. Chim, 32 (1987)243.

[36] Esam A Gomaa, Thermochimica Acta,128(1988)99.

[37] E.A.Gomaa, Indian J.of Tech.,24(1986)725.

[38] EsamA.Gomaa,ThermochimicaActa ,142(1989)19.

[39] Esam A. Gomaa,CroaticaChimicaActa ,62(1989)475.

[40] Esam A. Gomaa, Thermochimica Acta,147(1989)313.

[41] E.A.Gomaa,A.M.Shallapy and M.N.H.Moussa, J.IndianChem.Soc., 68(1991)339.

[42] E.A.Gomaa, A.M.Shallapy and M.N.H.Moussa,AsianJ.of Chem., 4(1992)518.

[43] H.M. Abu El-Nader and E.A.Gomaa, Mansoura Science Bulletin.(A Chem.) Vol .23 (1) July1996.

[44] J.I. Kim, A. Cecal, H.J. Born, and E.A. Gomaa, Z. Physik Chemic, NeueFolge 110, 209(1978).

[45] J.I.Kim and E.A.Gomaa, Bull.Soci.Chim.Belg.,90(1981)391.

[46] E.A.Gomaa,A.A.El-Khouly and M.A.Mousa, Indian Journal of Chemistry, 23((1984)1033.

[47] E.A.Gomaa, M.A.Mousa and A.A.El-Khouly,Thermochimica Acta,86 (1985)351.

[48] E.A.Gomaa,M.A.Mousa and A.A.El-Khouly,ThermochimicaActa ,89(1985)133.

[49] Esam A. Gomaa, Thermochimica Acta,91(1985)235.

[50] Esam A. Gomaa,Thermochimica acta,128(1988)287.

[51] Esam A. Gomaa,Thermochimica Acta,140(1989)7.

[52] Esam A. Gomaa, Bull.Soc.Chim.Fr. 5 (1989)620.

[53] EsamA.Gomaa, Bull.Soc.Chim.Fr., 5(1989)623.

[54] Esam A Gomaa, Thermochimica acta,152(1989)371.

[55] EsamA.Gomaa, Thermochimica Acta,156(1989)91.

[56] I. S. Shehatta, A. H. El-Askalany and E. A. Gomaa, Thermochimica Acta, 219(1993)65.

[57] E.A.Gomaa and G.Begheit, Asian Journal of Chemistry, 2(1990)444.

[58] A.A. El-Khouly, E.A. Gomaa, and S. Abou-El-Leef, Bull. Electrochem 19, 153 (2003).

[59] A.A. El-Khouly, E.A. Gomaa, and S. Abou El-Leef, Bull. Electrochem 19, 193 (2003).

[60] M. A. Hamada, E. A. Gomaa and N. A. El-Shishtawi, International Journal of Optoelectronic Enegineering, 1(2012)1-3.

[61] Kamal M.Ibrahim, Esam A. Gomaa, Rania R.Zaky and M.N.Abdel El-Hady, American Journal of Chemistry, 2(2012)23-26.

[62] A.A.El-Khouly, E.A.Gomaa and S.E.Salem, Southern Brazilian Journal of Chemistry, vol.20 (2012)43-50.

[63] E.A.Gomaa and B. A. M.Al –Jahdali, American Journal of Environmrntal Engineering, 2(2012)6-12.

[64] S.L. Oswal, J.S. Desai, S.P. Ijardar, and D.M. Jain, J. Mol. Liquids 144, 108 (2009).

[65] D. Bobicz, W. Grzybkowski, and A. Lwandowski, J. Mol. Liquids 105, 93 (2003).

[66] Y. Marcus. The Properties of Solvents (Wiley, London, 1998).

[67] E.A.Gomaa, A.H.El-Askalany, M.N.H.Moussa, Asian Journal of Chemistry,4(1992)553.

[68] EsamA.Gomaa, Rev.Roum.de Chimie,36(1991)11.

[69] EsamA.Gomaa, Journal of King Saud University, 3(1),1991,1411.

[70] EsamA.Gomaa,Oriental Journal of Chemistry,6(1990)12.

[71] E.A.Gomaa, M.A.Hamada and R.Galal, Avances en Quimica,5(2),117-121(2010).

[72] EsamA .Gomaa,AnaleleUni.din Bucuresti-Chimie,vol.19 no1 ,pag.45-48(2010).

[73] Nagah A. El-Shishtawi, Maany A. Hamada and Esam A. Gomaa, Physical Chemistry,1(1),(2011,14-16.

[74] E.A.Gomaa and B.A.M.AlJahdali, American Journal of Condensed Matter Physics, 2(1),(2012),16-21.

[75] Esam A. Gomaa, Elsayed M. Abou Elleef, Ahmed Fekri, Mohamed Khairy and Reham Abou Karn, Annalen der Chemischen Forschung,2, (2014) 55-64.

[76] Esam A. Gomaa, Eslayed M. Abou Elleef, Kamal S. Shalaby and Shereen E. Salem, Journal of Environment,2 ,4 (2014) 44-53.

[77] Mohamed N.H. Hamed, Esam A. Gomaa and SamehG.Sanad, International Journal of Engineering Sciences & Research Technology,3, 9 (2014) 97-105.

[78] Mohamed N. H. Hamed, Esam A. Gomaa and Sameh G. Sanad, Indian Journal of Applied Research,4,10(2014)193-197.

[79] Mohamed N. H. Hamed, Esam A. Gomaa and Sameh G. Sanad, International Journal of Engineering and Innovative Technology (IJEIT), vol4,2(2014)203-207.