

Study of solvation parameters of Lead Nitrate in a mixture of Acetone-H₂O solvents at different temperature

Esam A Gomaa^{1*}, Elsayed M Abou Elleef ², Ahmed F Fekri¹, Reham M Abou Karn¹

¹Chemistry Department, Faculty of Science, Mansoura University, 35516-Mansoura, Egypt.

²Basic Science Departments, Delta Higher Institute for Engineering & Technology, 35681-Dakhlia, Mansoura, Egypt.

Abstract

The aim of present study was to determine the thermodynamics of the solvation of Pb(NO₃)₂ in a mixture of mixed acetone-H₂O at different temperature. The Gibbs free energy, liberated Gibbs free energy, and lattice energy were evaluated for Pb(NO₃)₂ in mixed acetone-H₂O solvents at different temperature. Libration Gibbs free energy associated with the moving Pb(NO₃)₂ in standard gas state to standard state in solution was evaluated according to specific cycle for the solvation process using the solubility product. Results from the present work indicate that the data obtained from determined parameters are useful in various experimental purposes.

Keywords:

Thermodynamics, Gibbs free energy of salvation, Lead nitrate, aqueous-acetone mixtures, conventional free energies

Cite this article as

Esam A Gomaa^{1*}, Elsayed M Abou Elleef ², Ahmed F Fekri¹, Reham M Abou Karn¹. Study of solvation parameters of Lead Nitrate in a mixture of Acetone-H₂O solvents at different temperature. Annalen der Chemschen Forshung. 2014; 2(2): 54-67

1.0 Introduction

For neutral reaction species, experimental solvation Gibbs free energies have been tabulated by large number of solutes in both aqueous [1-7] and non-aqueous [7, 8] solvents. Typically, these solvation free energies are determined experimentally [8] and their uncertainty is relatively low (~ 0.8 KJ/mol) [9]. Determining accurate values for the Gibbs free energies of ionic solutes like Pb(NO₃)₂ is important than that of neutral solutes. Single-ion solvation free energies are well defined in statistical mechanics, and determining their values is an important step in understanding the structure of solutions. Understanding the partitioning of single ions between different liquid phases is important in many areas of biology. For example, the electrical signals sent by nerve cells are activated by changes in cell potential that are caused by the movement of various ions (sodium and potassium) across the neuronal membrane [10]. The division of thermodynamic Gibbs free energies of solvation of electrolytes into ionic constituents is conventionally accomplished by using the single ion solvation Gibbs free energy of one reference ion, conventionally, the proton, to set the single ion scales [11,12]. Sums of solvation free energies of cations and anions are well defined through the use of thermochemical cycles involving calorimetric or electrochemical measurements [13-17]. A number of different extra thermodynamic approximations have been used [18-

22] for partition the salt Gibbs free energies into single ion contribution. The aim of this work is to estimate the single ion Gibbs free energies for Pb²⁺ & NO₃⁻ ions in mixed acetone-H₂O solvents at different temperature.

1.1 Relative and Conventional Solvation Free Energies of Ions

The Gibbs solvation free energies of ions are often tabulated as relative free energies by setting the free energy of solvation of some reference ion equal zero [23]. Proton was chosen as reference ion. For ions, this result in a set of conventional free energies of solvation that the cations are shifted from their absolute values by the value for the absolute Gibbs solvation free energy of the proton. The conventional Gibbs free energies of solvation for anions are shifted by an equal amount in the opposite direction.

1.2 Conventional Gibbs free Energies from Reduction Potentials

When the convention for the absolute Gibbs free energy of the proton is followed, the solution-phase free energy change associated with the half cell for reaction of hydrogen gas is equal to zero. Reduction potentials following this convention for hydrogen electrode are referred as standard reduction potentials. From the half cell reaction for the reduction of metal cation to crystalline phase and the half reduction reaction of hydrogen gas, the redox reaction can be illustrated through the use of thermochemical cycle [12]. This last procedure can be used to estimate

Study of solvation parameters of Lead Nitrate in a mixture of Acetone-H₂O solvents at different temperature

the gas free energy of formation of NO₃⁻ ion, to explain the ionic behavior.

2. Materials and methods

Lead nitrate Pb(NO₃)₂ GCC-laboratory reagent and acetone (Ac) from Merck Co. were used. Saturated solutions of Pb(NO₃)₂ were prepared by dissolving different amounts in closed test tubes containing different acetone-H₂O mixtures. These mixtures were then saturated with nitrogen gas in an

inert atmosphere. The tubes were placed in a shaking thermostat (ModelDW101S) for a period of four days till equilibrium reached. The solubility of Pb(NO₃)₂ in each mixture was measured gravimetrically by evaporating 1 ml of the saturated solution in small beaker using IR lamp. The measurements were done by three readings for each solution at 293.15K, 298.15K, 303.15K and 308.15K.

Table-1: Solubility, activity coefficient, solubility product, Gibbs free energies change and transfer Gibbs free energies change for Pb(NO₃)₂ in mixed acetone-H₂O solvents at 293.15 K.

X _s , Ac	S, mol/L	log γ _±	pK _{sp}	ΔG _s , KJ/mol	ΔG _t , kJ/mol
0	1.4095	-0.379	0.0889	0.4992	0
0.071	1.0237	-0.39	0.5366	3.0118	2.513
0.1667	0.5351	-0.393	1.3855	7.777	7.278
0.3044	0.2465	-0.401	2.4133	13.546	13.047
0.5255	0.1012	-0.447	3.6912	20.719	20.219
1.0	0.069	-1.124	6.1023	34.252	33.753

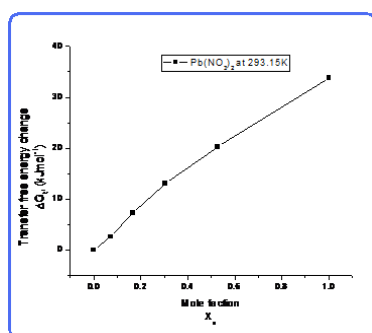


Figure-1: Gibbs free energies of transfer (ΔG_t) for Pb(NO₃)₂ versus the mole fraction (X_s) of acetone at 293.15K.

3. Results and discussion

The molar solubility (S) for Pb(NO₃)₂ at 293.15K, 298.15K, 303.15K and 308.15 K were measured gravimetrically with average of the second number after comma in

water, acetone and their mixtures. The solubility values for Pb(NO₃)₂ are cited in Table-1, Table-2, Table-3 and Table-4. The mean activity coefficient (log γ_±) of ions which can

Study of solvation parameters of Lead Nitrate in a mixture of Acetone-H₂O solvents at different temperature

be estimated from the Debye-Hückel limiting law, as modified by Robinson and Stokes [27-90].

$$\log \gamma_{\pm} = - \frac{AZ_+Z_- \sqrt{I}}{I + Br^0 \sqrt{I}} \dots\dots\dots(2)$$

Where Z_+ and Z_- are the charges of ions in solutions, $A = 1.823 \times 10^6 (\epsilon.T)^{-3/2}$, $B = 50.29 (\epsilon.T)^{-1/2}$, r^0 is the solvated radius, ϵ is the dielectric constant of the solvents and S is the molar solubility.

The values of ϵ for acetone-water mixtures were taken from previous publication [26]. These data ($\log \gamma_{\pm}$) were tabulated also in Table-1,

Table-2 and Table-3. The solubility product was calculated by the use of equation (2) [27-28].

$$pK_{sp} = - \log 4(S. \gamma_{\pm})^3 \dots\dots\dots(2)$$

The solubility product (pK_{sp}) data are given in Table-1, Table-2, Table-3 and Table-4 from these solubility products, the Gibbs free energies of solvation and the transfer Gibbs free energies from water to organicsolvent and mixed solvents were calculated by using equations (3) and (4) [29,48-57]. Their values are tabulated also in Table-1, Table-2, Table-3 and Table-4.

$$\Delta G = 2.303 RT pK_{sp} \dots\dots\dots(3)$$

$$\Delta G_t = \Delta G_s - \Delta G_w \dots\dots\dots(4)$$

Where (s), (w) denote solvent and water, respectively.

Table-2: Solubility, activity coefficient, solubility product, Gibbs free energies change and transfer Gibbs free energies change for Pb(NO₃)₂ in mixed acetone-H₂O solvents at 298.15 K.

X _{s, Ac}	S, mol /L	log γ_{\pm}	pK _s _p	$\Delta G_s, K$ J/mol	ΔG_t kJ/mol
0	1.4	-	0.0	0.4417	0
0.0	1.0	-	0.6	3.5158	3.07
0.1	0.5	-	1.2	7.3199	6.87
0.3	0.3	-	1.9	11.023	10.5
0.5	0.1	-	3.1	17.803	17.3
1.0	0.1	-	5.8	33.633	33.1

It was concluded that the Gibbs free energies of transfer increases negativity by increasing the mole fraction of acetone in the mixed acetone-H₂O solvents indicating the spontaneous nature of Pb(NO₃)₂ solubilization. This is due to more solvation behaviour in the mixed solvents than that of water where the Gibbs free energy values provide information on whether the process conditions favor or disfavor Pb(NO₃)₂ solubilization in the aqueous carrier solution. Negative Gibbs free energy values indicate favorable conditions. (Figure-1),(Figure-2),(Figure-3),(Figure- 4).

Study of solvation parameters of Lead Nitrate in a mixture of Acetone-H₂O solvents at different temperature

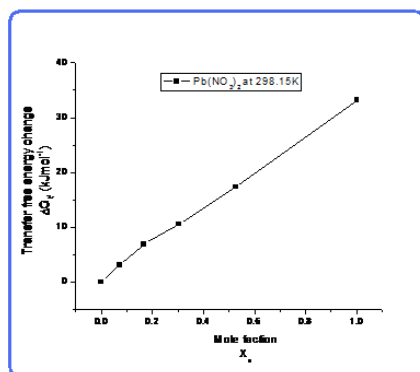


Figure-2: Gibbs free energies of transfer (ΔG_t) for $Pb(NO_3)_2$ versus the mole fraction (X_s) of acetone at 298.15 K

3.1 Single Ion Gibbs Free Energies and Conventional Gibbs Free Energies for Pb^{2+} and NO_3^- Ions

It was well known that the preferential single ion thermodynamic parameters depend on the ionic radii of two ions (cation and anion). Therefore the ionic radii ratio between Pb^{2+} and NO_3^- was evaluated from exact radii values given in literature [34] and found to be (132 nm/179 nm = 0.737). Multiplying this ratio by the Gibbs free energies of $Pb(NO_3)_2$ we get the

$$\Delta G_s^{*con} (Pb^{2+}) = \Delta G_s (Pb^{2+}) - 2 \Delta G_s (H^+) \dots\dots(5)$$

and for NO_3^- anion is shifted by an equal amount in the opposite direction (equation 6).

$$\Delta G_s^{*con} (NO_3^-) = \Delta G_s (NO_3^-) + 2 \Delta G_s (H^+) \dots\dots(6)$$

Where $\Delta G_s (Pb^{2+})$, $\Delta G_s (NO_3^-)$ and $\Delta G_s (H^+)$ are the Gibbs free energies of solvation for lead, nitrate and proton in solvents.

From the mean values of proton solvation free energies in water and other solvents in literature [12,35,36] relation between these values and the diameter for each solvent taken from literature [37-38,40], a straight line was obtained.

ionic Gibbs free energies of Pb^{2+} ion. This last value was subtracted from the $Pb(NO_3)_2$ Gibbs free energy and we obtain the Gibbs free energy for NO_3^- anion. The obtained values for single ions are presented in Table 4. The conventional Gibbs free energies (ΔG_s)^{*con}(Pb^{2+}) for Pb^{2+} ion in solvents are shifted from their absolute values by the absolute free energy of the proton [35-47] according to equation (5)

From this line, the proton solvation free energies in pure water and acetone were obtained and found to be -252 to -263 kcal/mol, (this is about -1053 and -1099 kJmol⁻¹), respectively. Multiplying each value

Study of solvation parameters of Lead Nitrate in a mixture of Acetone-H₂O solvents at different temperature

by its mole fraction in the mixture and then summing the results. The mixed solvent proton free energies were obtained and their values are given in Table 5. With

equations (5) and (6) we get the conventional Gibbs free energies for the cation and anion and their values are given also in Table 5.

Table-3: Solubility, activity coefficient, solubility product, Gibbs free energies change and transfer Gibbs free energies change for Pb(NO₃)₂ in mixed acetone-H₂O solvents at 303.15 K.

X _s , Ac	S, mol/L	log γ _±	pK _{sp}	ΔG _s , KJ/mol	ΔG _t , kJ/mol
0	1.4355	-0.386	0.0851	0.4938	0
0.071	0.9532	-0.392	0.635	3.6858	3.192
0.1667	0.5793	-0.402	1.3109	7.6088	7.115
0.3044	0.3545	-0.432	2.0318	11.793	11.299
0.5255	0.1903	-0.513	3.0675	17.805	17.312
1.0	0.0697	-1.159	6.1851	35.901	35.407

Cation conventional free energy values are negative indicating exothermic character and anion values are positive indicating endothermic character. Both values increase with increase in the mole fraction of acetone due to more solvation and the sum of them gives the values for the neutral salt.

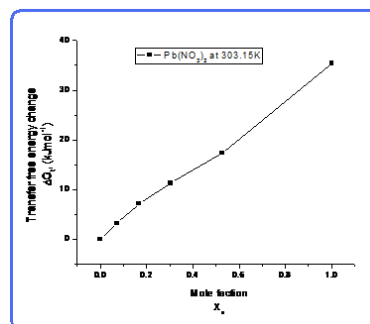
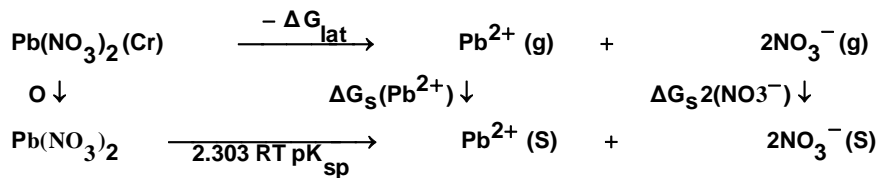


Figure-3: Gibbs free energies of transfer (ΔG_t) for Pb(NO₃)₂ versus the mole fraction (X_s) of acetone at 303.15K

3.2 Libration Gibbs Free Energies for Pb(NO₃)₂ in Mixed Acetone-H₂O Solvents

The libration Gibbs free energies for Pb(NO₃)₂ in mixed acetone-H₂O solvents at 293.15 K, 298.15 K, 303.15 K and 308.15 K were calculated following cycle 1 (thermochemical cycle 1) as done before [12] for silver salts following solubility product concept.

Study of solvation parameters of Lead Nitrate in a mixture of Acetone-H₂O solvents at different temperature



Cycle 1

Where ΔG_{lat} is the lattice free energy, (g) and (s) denote the gas and solution cases. The lattice energy was calculated following Bartlett's relationship following equation (7) [40].

$$\Delta G_{\text{lat}} = \frac{232.8}{\sqrt[3]{V}} + 110 \text{ K J/mol} \dots\dots(7)$$

The volume of Pb(NO₃)₂ was calculated by dividing its molecular weight by the density of solid given in literature [37] and applied into the equation (7) to obtain 165.675 kJmol⁻¹ as ΔG_{lat} for Pb(NO₃)₂.

Table-4: Solubility, activity coefficient, solubility product, Gibbs free energies change and transfer Gibbs free energies change for Pb(NO₃)₂ in mixed acetone-H₂O solvents at 308.15 K.

X _s , Ac	S, mol/L	log γ_{\pm}	pK _{sp}	ΔG_{S} , KJ/mol	ΔG_{t} , kJ/mol
0	1.4865	-0.39	0.0510	0.3007	0
0.071	1.018	-0.398	0.5668	3.3443	3.0443
0.1667	0.7068	-0.416	1.0932	6.4504	6.1500
0.3044	0.4173	-0.447	1.8643	11.000	10.699
0.5255	0.2287	-0.537	2.8991	17.105	16.804
1.0	1.6917	-1.693	3.7229	21.966	21.665

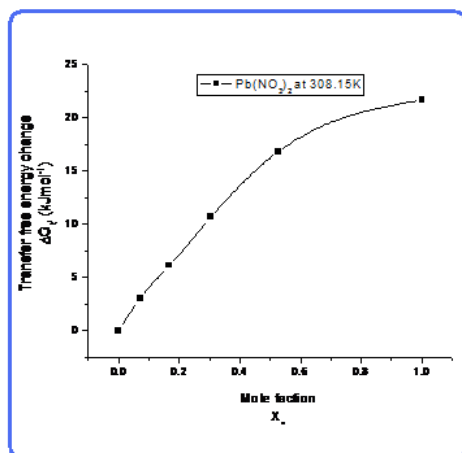


Figure-4: Gibbs free energies of transfer (ΔG_{t}) for Pb(NO₃)₂ versus the mole fraction (X_s) of acetone at 308.15K.

Study of solvation parameters of Lead Nitrate in a mixture of Acetone-H₂O solvents at different temperature

On the use of equation (8) after cycle (1), the libration free energies for Pb(NO₃)₂ was obtained (82.837 kJmol⁻¹).

$$\Delta G_s (\text{Pb}^{2+}) + 2\Delta G_s (\text{NO}_3^-) = 2.303 RTpK_{sp} - \Delta G_{lat} - 2\Delta G^{0 \rightarrow *} \dots(8)$$

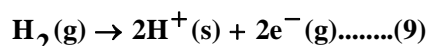
The $2\Delta G^{0 \rightarrow *}$, the free energy change associated with moving Pb(NO₃)₂ from standard gas phase of 1 atmosphere to solution phase. This free energy change has been referred as "compression" work of the gas or libration free energy.

Table-5: Single ion Gibbs free energies for Pb²⁺ and NO₃⁻¹ and their half conventional free energies at 293.15K in mixed acetone-H₂O solvents (kJmol⁻¹).

X _s , acetone	Δ G(Pb ²⁺)	Δ G(NO ₃ ⁻)	$\frac{1}{2}\Delta G_s^{*con}(\text{Pb}^{2+})$	$\frac{1}{2}\Delta G_s^{*con}(\text{NO}_3^-)$	- Δ G _s [*] (H ⁺)
0	2.6268	12.9273	-1520.30	1538.92	1052.3
0.069	2.0132	9.8921	-1520.98	1532.89	1052.3
0.1595	2.018	9.8805	-1520.98	1532.88	1052.3
0.2873	2.5852	12.7027	-1526.41	1541.78	1052.4
0.4886	3.1752	15.6020	-1534.82	1553.6	1053.8
1.0	3.4032	16.7516	-1537.59	1557.75	1054.1

3.3 Conventional Free Energies from Reduction Potentials

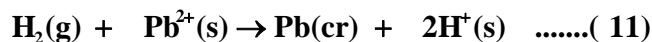
The absolute Gibbs free energy of the proton is followed solution phase free energy change associated with the following half cell.



The half cell reaction for the reduction of cation is:



The symbol (cr) denotes the crystalline phase the sum of the two half cells is:

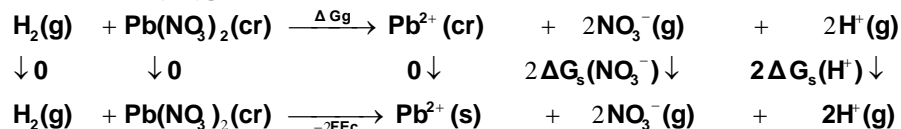


Through the use of thermochemical cycle 2, the conventional free energy for Pb²⁺ can be written as:

$$\Delta G_s^{*con}(\text{Pb}^{2+}) = 2 \Delta f G(\text{H}^+)_g - \Delta f G(\text{Pb}^{2+})_g - 2 FEc\dots\dots(12)$$

Study of solvation parameters of Lead Nitrate in a mixture of Acetone-H₂O solvents at different temperature

Where $\Delta fG(H^+)g$ and $\Delta fG(Ca^{2+})g$ are the gas free energy of formation for H⁺ and Pb²⁺ ions, F (faraday constant) = 96.485 kJ per volt gram equivalent and E_c is the standard reduction potential of Pb²⁺, $\Delta fG(Pb^{2+})g$ is difficult to evaluate because of the lack of exact $\Delta fG(H^+)g$ value.



(Cycle2)

Also the conventional free energy of the nitrate anion NO₃⁻ can be written following Truhlar [41] explanation as:

$$\Delta G_s^* \text{con}(NO_3^-) = -\Delta fG_g - FE_c - 2\Delta G^0 \dots\dots\dots(13)$$

Applying equation (13) the ΔfG_g , the gas free energies of formation for the anion NO₃⁻ was estimated in the mixed acetone-H₂O solvents and their values are given in Table 3 and Fig. 2. the ΔfG_g , value increase by increasing the mole fraction of acetone that favouring less solvation.

Table-6: Gas formation free for NO₃⁻ anion in mixed acetone-H₂O solvents at 293.15 K

X _s , acetone	$\frac{1}{2} \Delta fG_g$
0	-1727.51
0.0253	-1727.43
0.0909	-1727.33
0.1975	-1748.20
0.3527	-1748.20
0.4828	-1752.37
0.6993	-1763.43
1.0	-1765.45

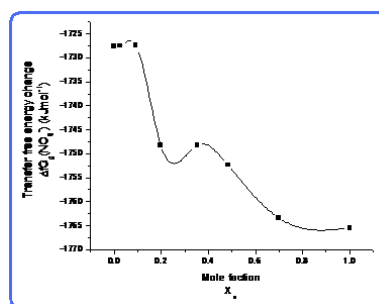


Figure-5: Relation between $\Delta fG_g(NO_3^-)$ against the mole fraction of acetone at 293.15K.

4. Conclusion

Using a combination of experimental gas-phase free energies of formation

and solution phase reduction potentials, in the present work, conventional solvation free energies

Study of solvation parameters of Lead Nitrate in a mixture of Acetone-H₂O solvents at different temperature

of Pb(NO₃)₂ in mixed acetone-H₂O solvents at 293.15K, 298.15K, 303.15K and 308.15K from the experimental solubility was determined. Libration Gibbs free energy associated with moving Pb(NO₃)₂ in standard gas state to standard state in solution was evaluated according to thermochemical cycle for the solvation process using the solubility product. An attempt has also been done to calculate the lattice energy for Pb(NO₃)₂ and used for further evaluation. These conventional solvation free energies

were then combined with experimental and calculated gas-phase free energies to determine conventional solvation free energies of ion-solvent clusters containing up to solvent molecules. The values for the absolute solvation free energy of the proton obtained in this work should be useful as standard against which the absolute solvation free energies of other single ions can be derived. For example, Table-5 shows the absolute single-ion solvation free energies of the ions considered in this work.

Reference

1. Gabani S, Gianni P, Mollica V, Lepori L. Group contributions to the thermodynamic properties of non-ionic organic solutes in dilute aqueous solution. *J Sol Chem.* 1981;10: 563-595
2. Abraham MH, Whiting GS, Fuchs R, Chambers EJ. Thermodynamics of solute transfer from water to hexadecane. *J Chem Soc Perkin Trans-2.* 1990; 291-300
3. Leo AJ. Masterfile from Med ChemSoftware; Biobytc.: Claremont, C.A.; 1994
4. Syracuse Research Corporation. Physical/Chemical Property Database (PHYSPROP); SRC Environmental Science Center: Syracuse NY. 1994
5. Yaffe D, Cohen Y, Espinosa G, Arenas AA, Giralt F. Fuzzy ARTMAP and back-propagation neural networks based quantitative structure-property relationships (QSPRs) for octanol-water partition coefficient of organic compounds. *J Chem Inf Comput Sci.* 2002; 42(2):162-83
6. Kelly CP, Cramer CJ, Truhlar DG. A density functional theory continuum solvation model for calculating aqueous solvation free energies of neutrals, ions, and solute water clusters. *J Chem Theory Comput.* 2005; 1: 1133-1152
7. Rizzo RC, Aynechi T, Case DA, Kuntz ID. Estimation of absolute free energies of hydration using continuum methods: Accuracy of partial charge models and optimization of nonpolar contributions. *J Chem Theory Comput.* 2006; 2: 128-139
8. Cramer CJ, Truhlar DG. In free energy calculation in rational drug design, Reddy MR. Eds. Kluwer/Plenum: New York; 2001:63-95

Study of solvation parameters of Lead Nitrate in a mixture of Acetone-H₂O solvents at different temperature

9. Thompson JD, Cranier CJ, Truhlar DG. New universal solvation model and comparison of the accuracy of three continuum solvation models, SM5.42R, SM5.43R, and C-PCM, in aqueous solution and organic solvents and for vapor pressures. *J Phys Chem-A*. 2004; 108: 6532-6542
10. Hodgkin AL. Ionic movements and electrical activity in giant nerve fibres. *Biol Rev*. 1951; 26: 339
11. Kelly CP, Cramer CJ, Truhlar DG. Single ion solvation free energies and the normal hydrogen electrode potential in methanol, acetonitrile and dimethylsulphoxide. *J Phys Chem-B*. 2007; 111(1): 408-422
12. Klotz IM, Rosenbery RM. *Chemical Thermodynamics*. 5th ed. Wiley: New York; 1994; P459
13. Tissandier MD, Cowen KA, Feng WY, Gundlach E, Cohen MH, Earhart AD, Coe JV, Tuttle TR. Jr. The Proton's absolute aqueous enthalpy and Gibbs free energy of solvation from cluster ion solvation data. *J Phys Chem-A*. 1998; 102: 7787-7794
14. Pliego Jr, Riveros JM. New values for the absolute solvation free energy of univalent ions in aqueous solution. *Chem Phys Lett*. 2000; 332: 597 - 602
15. Llano J, Eriksson LE. First principles electrochemistry: electrons and protons reacting as independent ions. *J Chem Phys*. 2002; 117: 10193
16. Doménech A, Montoya N, Scholz F. Estimation of individual Gibbs energies of cation transfer employing the insertion electrochemistry of solid Prussian blue. *J Electroanal Chem*. 2011; 657:117-122
17. Krestov GA. *Thermodynamics of solvation: Solution and dissolution, ions and solvents, structure and energetics*. Ellis Horwood Ltd.: New York, 1991
18. Conway BE. Electrolyte solutions: Solvation and structural aspects. *Ann Rev Phys Chem*. 1966; 17: 481-528
19. Parker AJ. The effects of solvation on the properties of anions in dipolar aprotic solvents. *Quart Rev Chem Soc*. 1962;16:163-187
20. Friedman HL, Krishnan CV. *Thermodynamics of ion hydration in water: A comprehensive treatise*; Franks F. Ed.; Plenum Press: New York, 1973
21. Lewis GN, Randall M, Pitzer KS, Brewer L. *Thermodynamics*, 2nd ed.; McGraw-Hill: New York; 1961; R: 399
22. Pradyot P. *Handbook of Inorganic Chemicals*. McGraw-Hill; 2002, ISBN 049439-8
23. Gomaa EA. Single ion free energies of some ion and the hydrophobic interactions of Ph₄ AsBPh₄ and Ph₄SbBPh₄ in mixed ethanol-water solvents. *Thermochimica Acta*. 1989; 156:91-99
24. El-Khouly AA, Gomaa EA, and Abou El-leef S. Conductometry and solubility study of Cd²⁺-Kryptofix-22 complexes in various hydroorganic solvents. *Bull Electrochem*. 2003; 19(4):153-164

Study of solvation parameters of Lead Nitrate in a mixture of Acetone-H₂O solvents at different temperature

25. El-Khouly AA, Gomaa EA, and Abou El-leef S. Apparent association constants of HgCl₂ in presence of kryptofix -22 in mixed aqueous-organic solvents. Bull Electrochem. 2003; 19(5):193-202
26. Gomaa EA. AbouElleef EM, and Mahmoud EH. Gibbs free energies for the solvation of KClO₃ in DMF-H₂O at 301.15 K. Eur Chem Bull. 2013; 2(10): 732-735
27. Gomaa EA. Solubility and solvation parameters of barium sulphate in mixed ethanol-water mixtures at 301.15 K. Int J Mater Chem. 2012; 2(1): 16-18
28. GomaaEA, and Al-Jahdali BM. Association of Cu(NO₃)₂ with Kryptofix-221 in mixed (MeOH-DMF) solvents at different temperatures. Am J Fluid Dyna. 2011; 1(1): 4-8
29. Gomaa EA. Solvation parameters of lead acetate in mixed, N,N-dimethylformamide-water mixtures at 298.15K. Analele Universitate din Bucuresti Chimie. 2010;19: 45-48
30. Handbook of Chemistry and Physics. 91st ed. 2010–2011
31. Marcus Y. Ion Properties. Dekker, New York. 1999
32. Marcus Y. Solvent mixtures. Dekker, New York. 2005
33. Kim JI, Bruckl J. On the temperature dependence of solubilities of inert Gases from the scaled particle theory. Z Phys Chem Neue Folge. 1978; 110: 197-208
34. Tawa GJ, Topol IA, Burt SK, Caldwell RA, and. Rashin AA. Calculation of the aqueous solvation free energy of the proton. J Chem Phys. 1998; 109: 4852-4859
35. Camaioni DM, Scherdtfeger CA. Measurement of particle size by novel methods. J Phys Chem-A. 2005; 109: 10795-10799
36. Casey PK, Christopher JC, and Donald GT. Aqueous solvation free energies of ions and ion-water clusters based on an accurate value for the absolute aqueous solvation free energy of the proton. J Phys Chem-B. 2006; 110: 16066-16081
37. Shen C, Hagiwara R, Mallouk TE, Bartlett N. Thermodynamic aspects of the remarkable oxidizing capabilities of Fluorine-Lewis-Fluoroacid Mixtures. ACS Symposium, Inorganic Fluorine Chemistry Ser. 1994; 555:26-39
38. Kelly CP, Cramer CJ, Truhlar DG. Single-ion solvation free energies and the normal hydrogen electrode potential in Methanol, Acetonitrile, and Dimethyl Sulfoxide. J Phys Chem-B. 2007; 111(2): 408-422
39. Gomaa Esam A, Molal solubility, dissociation and solvation parameters for saturated benzoic acid solutions in various solvents. Phy Chem Liq. 2012; 50:279-283
40. Gomaa Esam A, Solubility and solvation parameters of barium sulphate in mixed ethanol-water mixtures at 301.15K. Int J Mater Chem. 2012; 2(1) :16-18

Study of solvation parameters of Lead Nitrate in a mixture of Acetone-H₂O solvents at different temperature

41. Gomaa Esam A. Electrical conductance of Cu(NO₃)₂ with Kryptofix-222 in mixed (MeOH-DMF) solvents at different temperatures. Am J Environ Engin. 2012; 2(3) :54-57
42. Gomaa Esam A. Thermodynamic and polarization parameters of dibenzo-18-crown-6 in mixed methanol-water solvents. Am J Polymer Sci. 2012; 2(3) : 35-38
43. Gomaa Esam A. Solvation parameters for sodium oxalate in mixed ethanol-water solvents at 301.15K. Eur Chem Bull. 2013;1 : 259-261
44. Gomaa Esam A , Abou Elleef Elsayed, Mahmoud EA. Gibbs free energies for solvation of KClO₃ in mixed DMF-H₂O solvents at 301.15 K., Eur Chem Bull. 2013; 2:732-735
45. Gomaa Esam A , Abou Elleef Elsayed. Thermodynamics of the solvation of lead nitrate in mixed DMF-H₂O solvents at 301.15K. Am Chem Sci J. 2013, 3: 489-499
46. Gomaa Esam A , Abou Elleef Elsayed. Thermodynamics of the solvation of potassium thiocyanate in mixed DMF-H₂O solvents at 301.15K. Sci Technol. 2013, 3: 118-122
47. Gomaa Esam A, Abou Elleef Elsayed, Abdel Razek MG. Thermodynamics of the solvation of CaSO₄ in mixed DMF-H₂O solvents at 301.15K, Int J Pure App Chem. 2013,3:320-329
48. Abu El-Nader HM, Gomaa EA, Solvation of AgCl in mixed water- DMF solvents. Mansoura Sci Bull-A Chem. 1996 ; 23 :1-9
49. Kim JI, Cecal A., Born H.J., and Gomaa EA. Preferential solvation of single ion : a critical study of the Ph₄AsBPh₄ assumption for single ion thermodynamics in mixed aqueous-acetonitrile and aqueous-dimethyl formamide solvents. Z Physik Chemic Neue Folge. 1978; 110: 209-217
50. Kim JI, Gomaa EA. Preferential solvation of single ion : The Ph₄AsPh₄B assumption for single ion thermodynamics in mixed dimethylsulphoxide-water solvents. Bull Soci Chim Belg. 1981;90:391-397
51. Gomaa EA, Begheit G. Polarographic and conductometric studies of uranyl ion in sulphuric acid-ethanol media. Asian J Chem. 1990; 2:444-451
52. El-Khouly AA, Gomaa EA, Abou-El-Leef S, Conductivity and Solubility studies of (Cd-Kryptofix-22) complexes in various hydroorganic solvents. Bull Electrochem. 2003;19: 153-162
53. Hamada MA, Gomaa EA, El-Shishtawi NA. Optomechanical properties of 10% PVA in presence of CoCl₂ and 44% ethanol-water composition. Int J Optoelec Engin. 2012; 1:1-3
54. Ibrahim Kamal M, Gomaa Esam A, Zaky Rania R, Abdel El-Hady MN. The association and formation constants for CuCl₂ stoichiometric complexes with (E)-3-oxo-N-(thiazol-2-yl)propanamide in absolute ethanol solution. Am J Chem. 2012,2:23-26
55. El-Khouly AA , Gomaa EA, Salem SE. Conductometric study of complex formation between 2,3 -pyrazine dicarboxylic acid and some transition metal ions in methanol. Sou Braz J Chem. 2012; 20 :43-50

Study of solvation parameters of Lead Nitrate in a mixture of Acetone-H₂O solvents at different temperature

56. A. Gomaa EA, Al-Jahdali BAM. Electrical conductance of Cu(NO₃)₂ with Kryptofix-222 in mixed (MeOH-DMF) solvents at different temperatures. .Am J Environ Engin. 2012; 2:6-12
B. Gomaa EA, El-Askalany AH, Moussa MNH. Polarographic electroreduction of uranyl on in glycine,DI-Aspartic acid and phenylalanine. Asian J Chem. 1992;4:553-567
57. Gomaa Esam A. Application of the scaled particle theory for the solvation of silver tetraphenyl boride in dimethylformamide-water mixtures at 298.15K. J King Saud Uni. 1991, 3(1) : 69-74