Volume-04
Issue-02
February-2019

ISSN: 2455-3085 (Online)
RESEARCH REVIEW International Journal of Multidisciplinary
www.rrjournals.com[UGC Listed Journal]

Polarographic Studies 0f Mixed Complexes of Cd(II) with o-Chloro Benzoyl Glycine and Some Carboxylate Ions Using KCl as Supporting Electrolyte

Ratna Sherry

Department of Chemistry, MMH College Ghaziabad, India

ARTICLE DETAILS

Article History
Published Online: 20 February 2019

Keywords
Polarographic Study, Mixed Ligand Complexes.

ABSTRACT

Mixed ligand complexes of biological relevant carboxylate ions like succinate, malonate and citrate ions and o-Chloro Benzoyl Glycine with Cd(II) have been studied polarographically at constant ionic strength u = 2.0 (KCl) and at pH 6.4.
The system was studied at a constant temperature of 25±0.1℃.

Introduction

Cadmium, which is not an essential trace element in biological systems, is highly toxic to a number of living beings. The liver and kidney are the two main organs where cadmium accumulates. The half-life of cadmium in Mall has been estimated to be 16 - 33 years (Kjellstrom and Norberg, 1978) and with constant exposure, accumulation may take place over a lifetime. The survey of literature on cadmium toxicity clearly shows that this heavy metal is implicated as a causative agent of several pathological disorders in human beings. Brief exposure develops a persistent cough and chest pain. Heating of cadmium metal or alloys caused cadmium poisoning Dusts or fumes produced during the smelting; of cadmium being ores in the preparation and used in paints and alloys containing cadmium are also poisonous, poisoning by cadmium may also cause the dermatitis, skin ulceration and teeth decolorization. The removal of metal by proper complex formation is the only possible treatment for cadmium poisoning. Cadmium forms a number of complexes with various ligands. Studies of mixed ligand complexes of cadmium has huge potential for the possible pathways for the removal of cadmium from human and animal bodies.

The studies on the mixed ligand complexes of cadmium with carboxylates, polycarboxylates, thiocyanates thiosulphates, salicylates evitamins and amino acids have been carried out polarographically by many workers[1-16] Taneja and coworkers[17-18] investigated mixed ligand complexes of cadmium with reactive methylene compounds of malonic acid series and carboxylic acid.

The complexation of Cd(II) and Zn(II) with solochrome mordent dye were studied by Gupta and Raina[19]. The mixed ligand complexes of Cu(II) and Cd(II) with acids and 2- amino-3-hydroxy pyridine were studied by Bansal and co-workers[20]. Agarwal and Kumar[21] investigated the polarographic behavior of Cd(II) and Pb(II) with 2-amino-3- hydroxy pyridine. Thermodynamic parameters have been evaluated in the mixed ligand complexes of propylenediamine and malonate, succinate by Gaur et al.[22-26]. Abdul Hamid and co-workers[27] carried out a polarographic study of binary and ternary complexes of Cd(II) salicylic methyl amine chloride. Singh and co-workers[28] studied polarographically the mixed ligand complexes of Cd(II) with picolines and carboxylate ions. Mixed system of cadmium with dicarboxylic acids, amino acids with O, N containing donor atoms have been studied by Gupta and co-workers[29-31].

Simple complexes of Cd(II) with Hippuric acid have been studied prior to this study. Present study deals with mixed ligand complexes of Cd(II) with o-Chloro Benzoyl glycine (2-Chloro Hippuric acid) with carboxylate ions such as citrate, malonate and succinate. A comprehensive polarographic study of the following mixed systems has been undertaken:

- Cd(II)-Succinate-o-Chloro Benzoyl Glycinate System
- Cd (II)-Malonate-o-Chloro Benzoyl Glycinate Sys
- Cd(II)-o-Chloro Benzoyl Glycine-Citrate System

Experimental

The concentration of Cd(II) (from $CdC1_2$) was maintained at 1.0 x 10^{-3} M. Sodium salts of succinic acid, citric acid and malonic acid were used as sources of Succinate ($Succ^{2-}$), Citrate ($Citr^{3-}$) and Malonate (Mal^{2-}) respectively, KCl was used as a supporting electrolyte and also to maintain a constant ionic strength (μ = 2.0). o-Chloro Benzoyl Glycine was prepared by standard procedures.

The polarograms of the solutions were taken in the presence of increasing concentrations of the ligand at constant ionic strength and pH . Triton X-100 (1 x 10^{-3} %) was used as a maxima suppressor. The measurements were made at a constant temperature

(25 ± 0.1 °C). All the current and potential values were corrected for residual current and IR drop of the cell respectively. Throughout the measurements, the current at the end of the drop life (i.e. the maximum current value) was recorded. The capillary characteristics of the d.m.e. have been mentioned in the subsequent tables.

The pH of the solutions was adjusted by adding a very dilute solution of NaOH or HC1 by Systronics Digital pH meter (Type 335).

The experimental data obtained on the different systems have been summarized in the following Tables:

Table 1: Polarographic Characteristics and F_j[X] Function of Cd(II) - Succinate System

[Cd^{2+}] = 1 x 10^{-3} M; μ = 2.0 (KC1); pH = 6.4; Temp.= 25 ± 0.1˚C; m = 2.38 mg/sec $m^{2/3}$ $t^{1/6}$ = 2.1 $mg^{2/3}$ $sec^{-1/2}$ (in 2.0 M.KC1, open circuit); h_{corr} = 62.5 cm; [Triton X-100] = 1 x 10^{-3} %.

[Succ2-] M	I_d µA	-$E_{1/2}$ V (S.C.E)	Slope mV	$F_\circ$[X]	F_1[X] x 10^{-2}	F_2 [X] x 10^{-4}	F_3 [X] X 10^{-4}
0.00	9.80	0.600	30	--	--	1M. MO	--
0.02	9.48	0.630	30	10.67	--	--	--
0.05	9.21	0.648	31	44.57	8.71	-	--
0.1	8.75	0.665	31	176.28	17.52	1.25	--
0.2	8.35	0.667	32	1024.5	51.17	2.30	-
0.3	8.07	0.700	32	2920.11	97.30	3.07	7.60
0.4	7.75	0.710	33	6615.15	165.36	4.01	7.52
0.5	7.75	0.718	33	12357.3	247.12	4.84	7.70
0.6	7.61	0.724	32	20041.7	334.01	5.48	7.48

Table 2: Polarographic Characteristics and F_j[X] Function of Cd(II) - Malonate System

[Cd^{2+}] = 1 x 10^{-3} M; μ = 2.0 (KCl); pH = 6.4; Temp.= 25 ± 0.1˚C; m = 2.38 mg/sec; $m^{2/3}$ $t^{1/6}$ = 2.1 $mg^{2/3}$ $sec^{-1/2}$ (in 2.0 M.$NaNo_3$, open circuit); h_{corr} = 62.5 cm; [Triton X-100] = 1 x 10^{-3} %.

[Mal^{2-}] M	I_d µA	-$E_{1/2}$ V (S.C.E)	Slope mV	F_0[X]	F1[X]	F_2[X] x 10^{-1}	F_3[X] x 10^{-3}
0.00	10.2	0.600	30	--	--	--	--
0.10	9.70	0.631	31	11.22	102.2	52.2	--
0.20	8.80	0.646	31	41.63	203.15	76.57	3.01
0.30	8.80	0.661	32	135.41	448.03	132.6	3.75
0.40	8.70	0.670	32	272.88	679.7	157.42	3.43
0.50	8.40	0.677	33	526.61	1051.22	200.24	3.60
0.60	8.00	0.682	32	754.65	1256.0	201.10	3.10

Table 3: Polarographic Characteristics and F_j[X] Function of Cd(II)- Citrare System

[Cd^{2+}] = 1 x 10^{-3} M; μ = 2.0 (KCl); pH = 6.4; Temp.= 25 ± 0.1˚C; m = 2.38 mg/sec; $m^{2/3}$ $t^{1/6}$ = 2.1 $mg^{2/3}$ $sec^{-1/2}$ (in 2.0 M.KCL, open circuit); h_{corr} = 62.5 cm.; [Triton X-100] = 1 x 10^{-3} %.

[$Citr^{3-}$] M	I_d µA	-$E_{1/2}$ V (S.C.E)	Slope mV
0.00	9.22	0.600	30
0.05	6.42	0.605	30
0.10	6.15	0.620	31
0.15	5.88	0.635	31
0.10	5.82	0.655	32
0.30	5.68	0.662	32

Table 4: Polarographic Characteristics and $F_j[X]$ Function of Cd(II) -o- Chloro Benzoyl Glycinate System

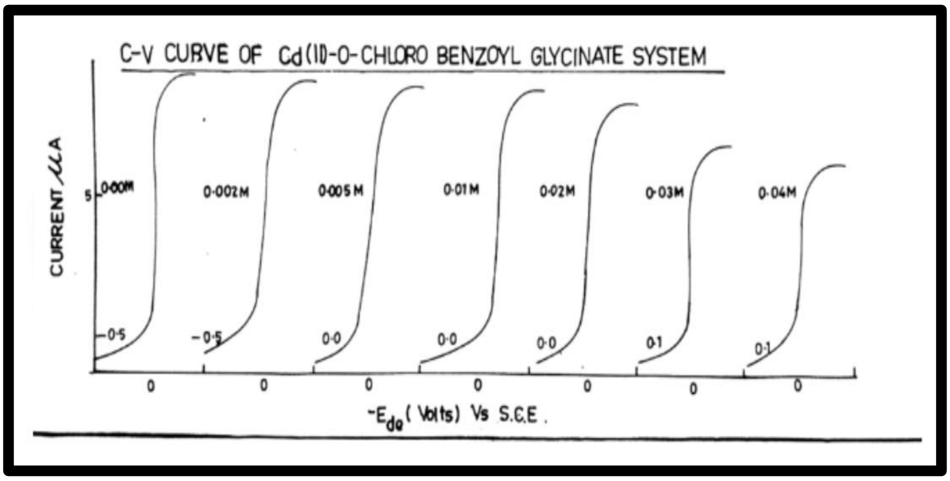
$[Cd^{2+}] = 1 \times 10^{-3}$ M; $\mu = 2.0$ (KCl); pH = 6.4; Temp.= 25 ± 0.1˚C; m = 2.38 mg/sec; $m^{2/3} t^{1/6} = 2.1$ $mg^{2/3} sec^{-1/2}$ (in 2.0 M.KCL, open circuit); $h_{corr} = 62.5$ cm.; [Triton X-100] = 1×10^{-3} %.

[o-NBG] M	I_d μA	$-E_{1/2}$ V (S.C.E)	Slope mV	$F_0[X]$	F1[X] x 10^{-2}	$F_2[X]$ x 10^{-5}
0.00	8.42	0.600	33	--	--	--
0.002	8.28	0.635	30	15.53	--	--
0.005	8.17	0.645	30	34.27	66.55	7.20
0.01	8.04	0.675	31	100.2	99.20	6.90
0.02	7.62	0.673	31	326.06	162.50	6.98
0.03	6.81	0.682	32	734.4	244.48	7.14
0.04	6.02	0.686	33	1335.0	302.61	6.84

Table 5: Polarographic Characteristics and $F_{ij}[X,Y]$ Function of Cd(II) - Succinate-o-Chloro Benzoyl Glycinate System

$[Cd^{2+}] = 1 \times 10^{-3}$ M; $\mu = 2.0$ (KCl); pH = 6.4; Temp.= 25 ± 0.1˚C; m = 2.38 mg/sec; $m^{2/3} t^{1/6} = 2.1$ $mg^{2/3} sec^{-1/2}$ (in 2.0 M.KCL, open circuit); $h_{corr} = 62.5$ cm; [Triton X-100] = 1×10^{-3} %.

$[Succ^{2-}]$ M	I_d μA	$-E_{1/2}$ V (S.C.E)	Slope mV	$F_{00}[X,Y]$	$F_{10}[X,Y]$ x 10^{-2}	$F_{20}[X,Y]$ x 10^{-3}	$F_{30}[X,Y]$ x 10^{-4}
Series-I [o-CBG⁻] = 0.005 M							
0.10	9.09	0.670	31	287.32	24.73	--	--
0.20	9.02	0.682	32	1005.54	48.76	--	--
0.30	8.88	0.704	33	3571.85	117.07	34.03	8.5
0.40	8.75	0.714	32	7251.04	179.53	42.12	8.1
0.50	8.62	0.720	30	12696.9	252.32	47.37	7.9
0.60	8.54	0.725	32	22042.2	365.24	58.42	8.1
Series-II [o-CBG⁻] = 0.01 M							
0.10	9.23	0.670	30	242.36	--	--	--
0.20	9.08	0.686	31	852.28	38.21	--	--
0.30	8.88	0.700	31	2595.12	83.57	20.85	--
0.40	8.68	0.714	32	8689.80	217.22	46.75	8.4
0.50	8.55	0.722	33	14516.0	290.30	53.66	8.1
0.60	8.41	0.720	33	24194.2	403.2	62.2	8.1



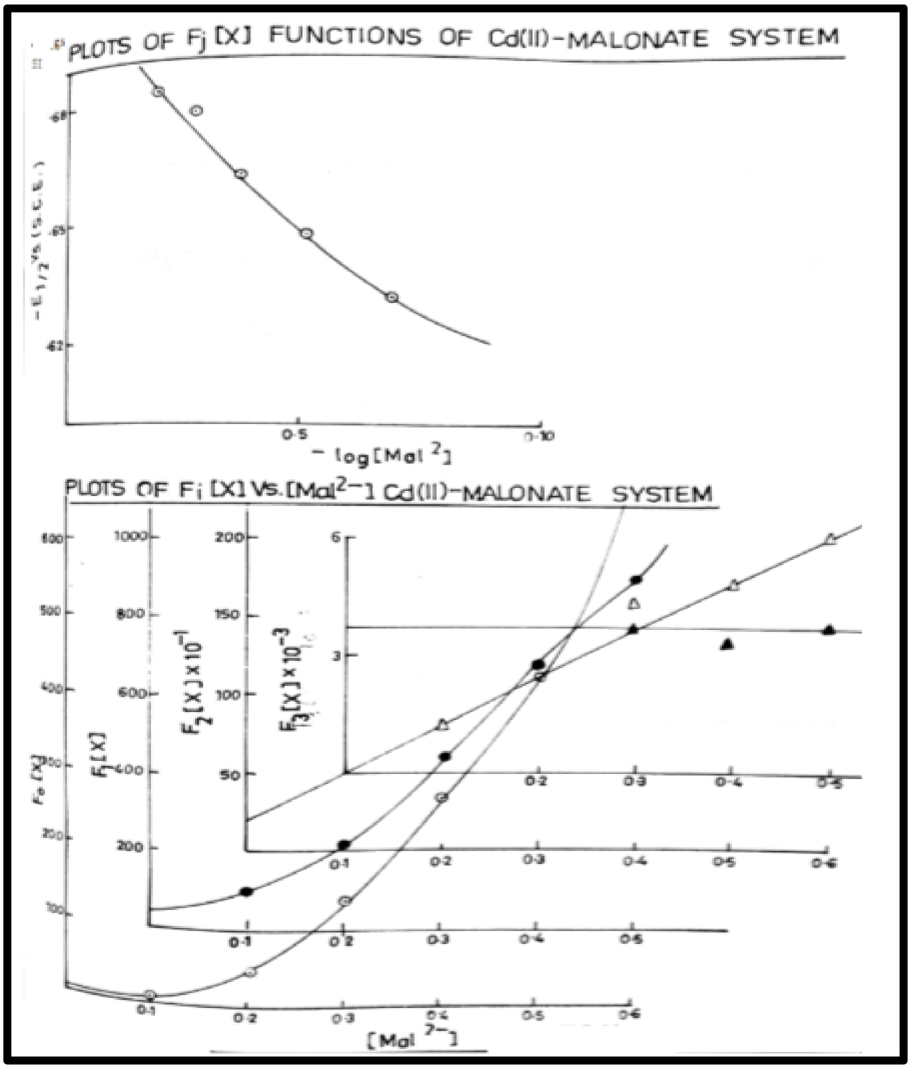
Results and Discussion

The morphology of C -V curves of Cd(II) in the presence of single as well as mixed ligand systems shows that polarographic waves are well defined.

Plots of i_d VS $h_{corr}^{1/2}$ are linear and pass through the origin showing that the polarographic waves are diffusion- controlled. Slope values of linear plots of log $i/(i_d-i)$ vs $E_{d.e.}$ reveal that these lie in the range 30-33 mV thereby showing the reversible nature of the polarographic reduction of Cd(II) in the presence of single as well as mixed ligand systems.

The composition and stability constant of simple complexes of Cd(II) with o-Chloro Benzoyl glycinate (o-CBG$^-$) and Succinate (Succ^{2-}), Malonate(Mal^{2-}) and Citrate were determined separately prior to the study of mixed complexes. Identical conditions were maintained in both the simple and mixed ligand systems.

Polarogram of solutions containing (i) 1.0 x 10^{-3} M Cd(II) and 0.005 M o-CBG$^-$ were taken at different pH values keeping ionic strength constant at μ= 2.0(KCl). (ii) It was found that the negative shift in $E_{1/2}$ was maximum at pH 6.4 Hence this pH was chosen for studying the simple and mixed systems.



Cd (II)- Carboxylate Ion Systems

The polarographic characteristics of Cd(II)-Succ^{2-}, Cd(II)-Mal^{2-} and Cd(ll)- Ctrl^{3-} systems have been presented in tables 1-3.

With the addition of increasing amounts of the carboxylate ions, $E_{1/2}$ of Cd(II) is shifted, in each case, to more negative potentials thereby showing the formation of complexes.

In Cd(I1)-Succ^{2-} and Cd(11)-Mal^{2-} The plots of $E_{1/2}$ vs concentration of carboxylate ion are smooth curves thereby indicating the formation of successive complexes.

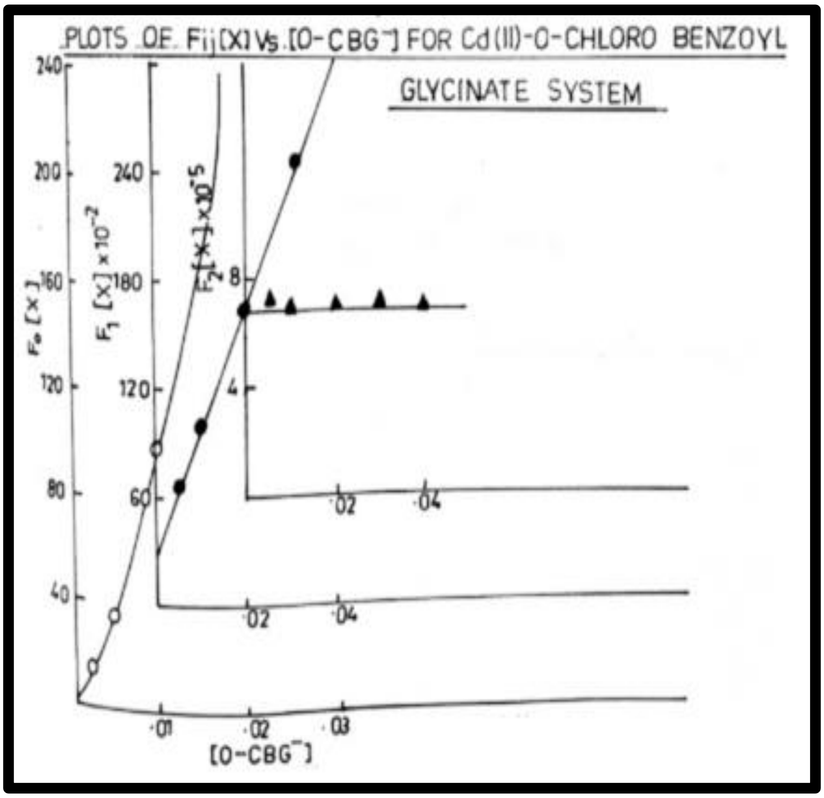
In Cd(II)-Citr^{3-} system, plot of $E_{1/2}$ vs log[Citr^{3-}] is a straight line showing the formation of a single complex.

The composition and stability constants of the complexes of former two systems have been determined by Deford & Hume's method while that of the later by Lingane's method. An analysis of $F_j[X]$ functions (Tables 1-3) shows the formation of following complexes of Cd(II) with Succ^{2-}, Mal^{2-} and Citr^{3-}

System	Complex Species	Stability Constant
Cd(II)- Succ^{2-}	[Cd(Succ)] [Cd(Succ)]^{2} [Cd(Succ)$_3$]$^{4.}$	**Log β$_1$**=2.6 **Log β2**=3.9 **Log β$_3$**=4.8
Cd(II)- Mal^{2-}	[Cd(Mal)] [Cd(Mal)$_2$]^{2} [Cd(Mal)$_3$]$^{4-}$	**Log β$_1$**=1.69 **Log β$_2$**=2.3 **Log β$_3$**=3.53
Cd(II)- Citr^{3-}	[Cd(Citr)$_3$]$^{7-}$	**Log β** =3.82

The result shows that the values of **Log β$_1$**, **Log β$_2$** and **Log β$_3$** in respect of Cd(II)- succinate system are in close agreement with the values reported by Schaap and Mc-Masters on this system. These values (log) at 25˚C and $\mu = 1.0$ are 2.61±0.1, 4.41±0.1 and 5.04 ± 0.1 respectively. The degree of formation α_j(%) of various complex species as a function of logarithm of [Succ $^{2-}$] shows that the percentage of 1:1 species decreases as the concentration of carboxylate ion increases. On the other hand the percentage of species 1:2 increases with increasing concentration of carboxylate ions but beyond a certain concentration of the ligand, the degree of formation of this species gets retarded. However, the percentage of the species 1:3 goes on increasing as the concentration of carboxylate ions increases.

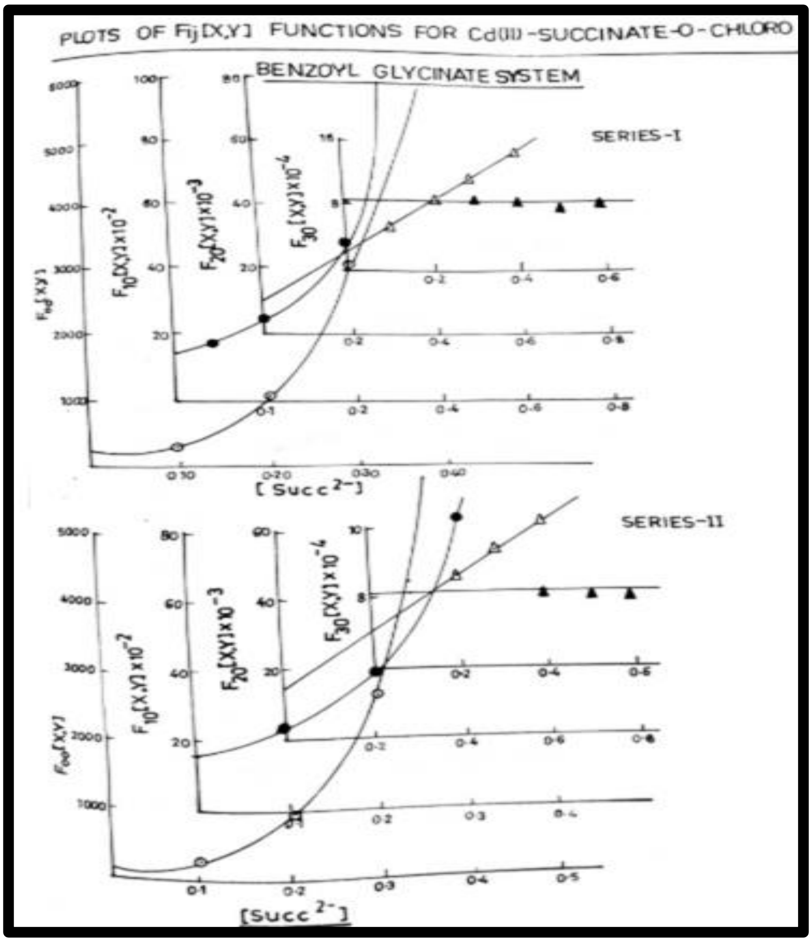
The values of **Log β$_1$**, **Log β$_2$** and **Log β$_3$** in the Cd(II)-malonate system are 1.69, 2.3 and 3.53 respectively. The successive complexes are formed. The plot of α_j(%) (percentage distribution) as a function of log[Ma1^{2-}] shows the same trend as represented by the Cd(II)-Succ^{2-} system. The composition of single complex Cd(II) with [Citr^{3-}] works out to be [Cd(Citr)$_3$]$^{7-}$ with the stability constant **Log β$_3$** = 3.82



The degree of formation (%) of various complexes species as a function of log of [o-CBG$^-$] show that as the concentration of ligand increases, the degree of formation of 1:1 and 1:2 species decreases as that of 1:3 increases.

Composition and Stability Constants (overall) of Mixed Complexes:

The method of Schaap and Mc-Master has been applied to determine the composition and stability constants of the mixed ligand systems. Polarographic reduction of Cd(II) in all their mixed ligand systems is reversible and diffusion controlled and these systems have been studied under the same experimental conditions as those maintained in simple ones. Cd(II) is hexa co-ordinated. The equilibrium constant, K (log value) is given in each case for each equilibrium.



PLOTS OF Fij[X,Y] FUNCTIONS FOR Cd(II)-SUCCINATE-O-CHLORO BENZOYL GLYCINATE SYSTEM

(ii) Cd(II)-Succinate -o- Chloro Benzoyl Glycinate System:

The concentration of Succ^{2-} was varied from 0 to 0.6 M keeping [o-CBG^{-}] Constant at 0.005M. The $E_{1/2}$ values were more negative than those obtained in the absence of Succ^{2-} (Table 1 & 7) thereby showing the formation of mixed ligand complexes. The system was repeated at another concentration of o-CBG^{-} (0.01M). Polarographic characteristics of $F_{ij}[X, Y]$ function (X=Succ^{2-}, Y=o-CBG^{-}) of this system at fixed concentration of o-CBG^{-} (0.005M and 0.01M) have been presented in Table 5. From the plots of $F_{ij}[X, Y]$ data vs [Succ^{2-}] the following intercept values for constants A,B,C and D have been obtained for both the series:

Series I: [o-CBG^{-}] = 0.005M (Fixed)

log A = 1.47; log B = 3.22; log C = 3.89; log D = 4.91

Series II: [o-CBG^{-}] = 0.01M (Fixed)

log A= 1.98; log B= 3.30; log C = 4.12, log D = 4.90

The stability constant of two complexes formed has been worked out to be

[Cd(Succ)(o-CBG)$^{-}$ $\log\beta_{11}$ = 5.42

[Cd(Succ)2(o-CBG)]$^{3-}$ $\log\beta_{21}$= 5.51

The formation of the species [Cd(Succ)(o-CBG)$_2$]$^{2-}$ is excluded as the values of β_{21}, works out to be negative the mixing constant K_M for the reaction

1/2[Cd(Succ)$_2$]$^{2-}$ + $^{1}/_{2}$ [Cd(o-CBG)$_2$] ⇌ [Cd(Succ)(o-CBG)]$^{-}$

is given by the relation

$$\mathbf{Log\ K_M = log\ \beta_{11} - ½ (log\ \beta_{20} + log\ \beta_{02})}$$

This works out to be +0.572. a positive value of log K_M indicates that the mixed complex, $[Cd(Succ)(o\text{-}CBG)]^-$ is more stable than the simple complexes, $(Cd(Succ)_2]^{2-}$ and $[Cd(o\text{-}CBG)_2]$.

The equilibrium constants for the following disproportionate reactions

$2[Cd(Succ)(o\text{-}CBG)]^- \rightleftharpoons [Cd(Succ)_2]^{2-} + [Cd(o\text{-}CBG)_2]$ (1)

$2[Cd(Succ)_2(o\text{-}CBG)]1^{3-} \rightleftharpoons [Cd(Succ)]^{4-} + [Cd(o\text{-}CBG)_2] + Succ^{2-}$ (2)

Work out to be -1.14 and -0.42 respectively, The negative log value of the equilibrium constant.

The reactions indicated that the formation of mixed complexes $[Cd(Succ)(o\text{-}CBG)]^-$ and $[Cd(Succ)_2(o\text{-}CBG)]^{3-}$ is strongly favored over the simple complexes. Further, the simple complex species, $[Cd(Succ)_2(o\text{-}CBG)1^{3-}$ is more stable than the species $[Cd(Succ)(o\text{-}CBG)]^-$.

(iii) Cd(II)- Malonate -o- Chloro Benzoyl Glycinate System:

The concentration of $Ma1^{2-}$ was varied from 0 to 0.5 M keeping [o-CBG] constant at 0.005M. The $E_{1/2}$ values were more negative than those obtained in the absence of $Ma1^{2-}$ (thereby showing the formation of mixed ligand complexes. Table shows the Polarographic characteristics of $F_{ij}[X, Y]$ function of $o\text{-}CBG^-$(.005M). From the plots of $F_{ij}[X, Y]$ data vs $[Ma1^{2-}]$. the equilibrium constant for the complexes formed

$[Cd(Mal)(o\text{-}CBG)]^-$ is 3.86

$[Cd(Mal)(o\text{-}CBG)]^-$ log $ß_{11}$ =3.86

Numerical values are the logarithms of equilibrium constants for the reaction indicated.

The mixing constant K_M for the reaction

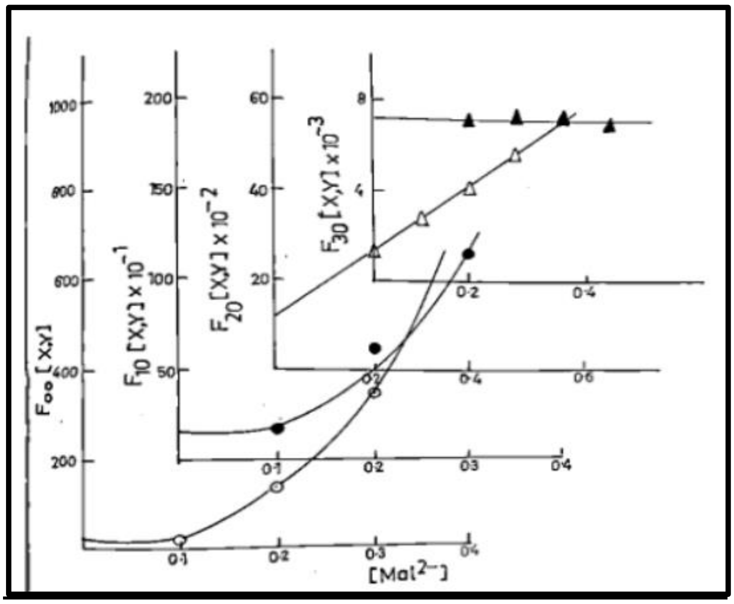
$1/2[Cd(Mal)_2]^{2-} + 1/2\ [Cd(o\text{-}CBG)_2] \rightleftharpoons [Cd(Mal)(o\text{-}CBG)]^-$

is given by the relation log K_M = log $ß_{11}$ - 1/2(log $ß_{20}$ + log $ß_{02}$). This work out to be +0.19, a positive value of log K_M indicates that the mixed complex, $[Cd(Mal)(o\text{-}CBG)]^-$ is more stable than the simple complexes $Cd(Mal)_2]^2$ and $[Cd(o\text{-}CBG)_2]$.

The equilibrium constant for the following disproportionation reactions a positive value

$2[Cd(Mal)(o\text{-}CBG]^- \rightleftharpoons [Cd(Mal)_2]^{2-} + [Cd(o\text{-}CBG)_2$

works out to be -0.38. The negative log value of the equilibrium constant the reactions indicated that the formation of mixed complexes is favored.



Plots of F_{ij}[X, Y] Function of Cd(II)- Malonate-o-Chloro Benzoyl Glycinate System

Table 6: Polarographic Characteristics and F_{ij}[X, Y] Function of Cd(II)- Malonate-o-Chloro Benzoyl Glycinate System
$[Cd^{2+}] = 1 \times 10^{-3}$ M; μ = 2.0 (KCl); pH = 6.4; Temp.= 25 ± 0.1°C; m = 2.38 mg/sec; $m^{2/3} t^{1/6} = 2.1$ $mg^{2/3} sec^{-1/2}$ (in 2.0 M.KCL, open circuit); h_{corr} = 62.5 cm; [Triton X-100] = 1x 10^{-3} %.

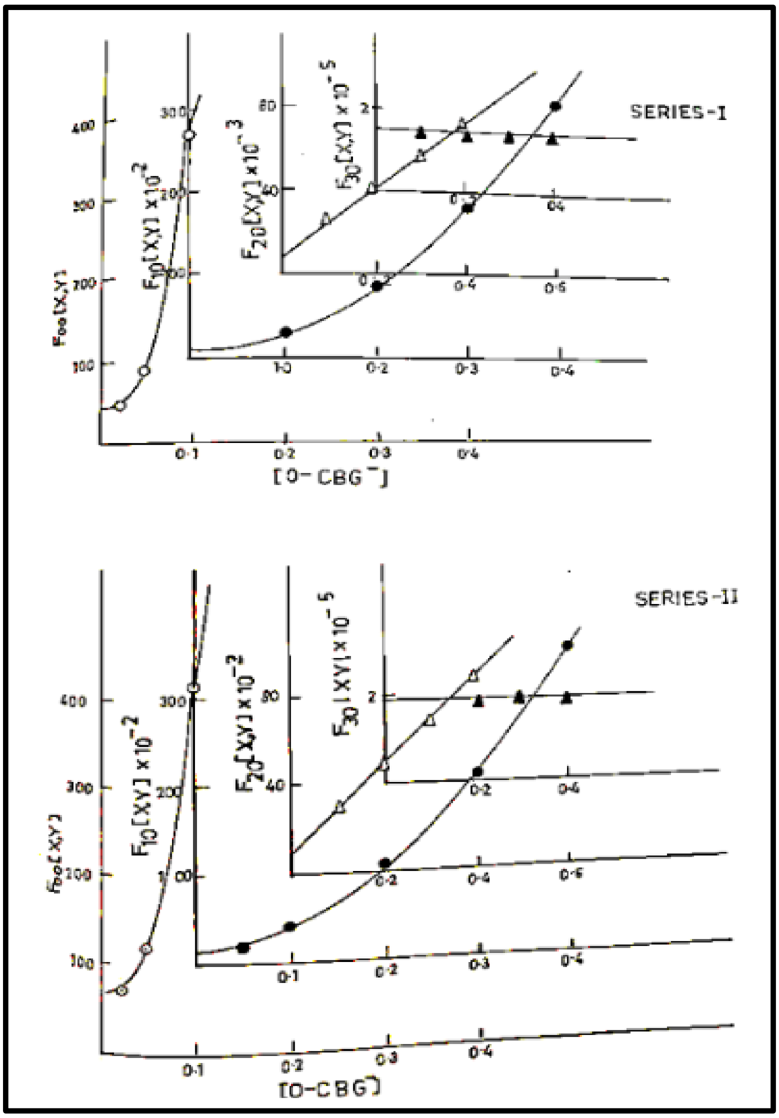
$[Mal^{2-}]$ M	I_d μA	$-E_{1/2}$ V (S.C.E)	Slope mV	F_{00}[X,Y]	F_{10}[X,Y] x 10^{-1}	F_{20}[X,Y] x 10^{-2}	F_{30}[X,Y] x 10^{-3}
0.10	9.92	0.635	31	17.68	16.68	--	--
0.20	9.88	0.661	33	134.4	66.70	26.47	7.2
0.30	9.65	0.673	33	350.28	116.40	34.23	7.4
0.40	9.41	0.682	32	724.00	180.75	41.76	7.4
0.50	9.42	0.689	31	1245.70	248.90	47.00	7.6

(vi) Cd(II)- Citrate-o-Chloro Benzoyl Glycinate System

Table 7: Polarographic Characteristics and F_{ij}[X,Y] Function of Cd(II) Citrate-o-Chloro Benzoyl Glycinate
$[Cd^{2+}] = 1 \times 10^{-3}$ M; μ = 2.0 (KCl); pH = 6.4; Temp.= 25 ± 0.1°C; m = 2.38 mg/sec; $m^{2/3} t^{1/6} = 2.1$ $mg^{2/3} sec^{-1/2}$ (in 2.0 M.KCL, open circuit); h_{corr} = 62.5 cm; [Triton X-100] = 1x 10^{-3} %.

$[o\text{-}CBG^{-}]$ M	I_d μA	$-E_{1/2}$ V (S.C.E)	Slope mV	F_{00}[X,Y]	F_{10}[X,Y] x 10^{-2}	F_{20}[X,Y] x 10^{-3}	F_{30}[X,Y] x 10^{-4}
Series-I $[o\text{-}CBG^{-}]$ = 0.002 M							
0.02	8.35	0.650	30	49.8	--	-	--
0.05	8.22	0.657	30	87.19	17.23	--	--
0.10	8.15	0.675	32	357.27	31.62	26.62	1.47
0.20	8.01	0.695	31	1721.86	85.00	40.02	1.37
0.30	7.95	0.710	31	5584.70	184.79	59.93	1.59
0.40	7.75	0.720	32	12473.8	310.82	76.45	1.61
Series-II $[o\text{-}CBG^{-}]$ = 0.005 M							
0.02	8.45	0.651	31	81.60	--	--	--
0.05	8.31	0.661	32	117.66	23.33	--	--
0.10	8.25	0.677	32	411.71	36.67	29.17	--
0.20	8.10	0.698	^{r}32	2149.80	105.24	48.87	1.75
0.30	8.05	0.712	31	6435.76	213.02	68.50	1.81
0.40	7.80	0.722	31	14474.4	360.73	88.30	1.85

The concentration of $Citr^{3-}$ was varied from 0 to 0.40 M keeping (o-CBG] constant at 0.002M. The $E_{1/2}$ values were more negative than those obtained in the absence of [o-CBG] (Table 5) thereby showing the formation of mixed ligand complexes. The system was repeated at another concentration of $o\text{-}CBG^{-}$ (0.005M). Polarographic characteristics of F_{ij}[X, Y] function ($Citr^{3-}$, Y= o-CBG) of this system at fixed concentration of $o\text{-}CBG^{-}$(0.002M and 0.0005M) have been presented in the tables. From the plots of F_{ij} [X, Y] data vs $[Citr^{3-}]$ the following intercept values for constants A, B, C and D have been obtained for both the series:



Plots of F_{jj} [X, Y] Functions of Cd (II)- Citrate -o- Chloro Benzoyl Glycinate System

Series I: [o-CBG^{-}] = 0.002M (Fixed)

log A = 1.62; log B = 2.70; log C = 4.06; log D = 5.61

Series II: [o-CBG^{-}] = 0.005M (Fixed)

108 A = 1.65; log B = 2.87; log C = 4.15; log D = 5.24

The stability constant has been obtained from these constants. Two mixed complexes as noted below are formed.

(Cd(Citr)(o-CBG)$_2$]$^{3-}$ **log ß$_{12}$ = 9.22**

(Cd(Citr)$_2$ (o-CBG)]$^{5-}$ **log ß$_{21}$ = 7.0**

The numerical values shown are the logarithms of equilibrium constants for the reaction indicated. Two mixed complexes existing in the solution have the following equilibria. The equilibrium constant K(log value) is given in each case for equilibrium.

	Equilibria			**logK**
1.	Cd^{2-}+ Citr^{3-} + 2 o-CBG^{-}	⇌	[Cd(Citr)(o-CBG))$_2$]$^{3-}$	9.22
2.	Cd^{2-} + 2 Citr^{3-} + C-NBG^{-}	⇌	[Cd(Citr)$_2$(o-CBG)]$^{5-}$	7.00
3.	[Cd(Citr)$_3$]$^{-7}$ + o-CBG^{-}	⇌	[Cd(Citr)$_2$(o-CBG)]$^{5-}$ + Citr^{3-}	2.79
4.	[Cd(o-CBG)$_2$] + Citr^{3-}	⇌	[Cd(Citr)(o-CBG)$_2$]$^{3-}$	4.39
5.	[Cd(Citr) (o-CBG)$_2$]$^{3-}$ + Citr^{3-}	⇌	[Cd(Citr)$_2$(o-CBG)]$^{5-}$	2.22
6.	[Cd(Citr)$_2$ (o-CBG)]$^{5-}$ + o-CBG^{-}	⇌	[Cd(Citr)(o-CBG)2]$^{3-}$ + Citr^{3-}	2.22

The equilibrium constants for the above reactions show that the formation of mixed complexes $[(Cd(Citr)(o\text{-}CBG)_2]^{3-}$ and $[Cd(Citr)_2(o\text{-}CBG)]^{5-}$ is strongly favored.

Conclusion

Cadmium forms successive complexes with Malonate and Succinate but a single complex with Citrate. Cd(II) -o-CBG system shows that with addition of increasing amounts of Benzoyl glycine E1/2 of Cd(II) gets shifted to more negative potentials thereby indicating the formation of successive complexes.

- $(Cd(Citr)(o\text{-}CBG)_2]^{3-}$(log $ß_{12}$ 9.22) and $[Cd(Citr)_2 (o\text{-}CBG)]^{5-}$ (log $ß_{21}$7.0) are the two complexes formed in Cadmium -citrate-o-CBG system.
- The mixed complex $[Cd(Mal)(o\text{-}CBG)]^-$ is more stable than the simple complexes $Cd(Mal)_2]^{2-}$ and $[Cd(o\text{-}CBG)_2]^-$ in Cd(II)-malonate-o-CBG system.
- The two complexes formed in Cd(II)- Succinate -o-CBG system are $[Cd(Succ)(o\text{-}CBG)]^-$ (log$ß_{11}$ 5.42) and $[Cd(Succ)2(o\text{-}CBG)]^{3-}$(log$ß_{21}$ 5.51).

References

1. Polarographic study of mixed ligand complexes: cadmium-oxalate-salicylate system, D.G. Dhuley, D.V. Jahagirdar and D.D. Khanolkar, J. Inorg. Nucl. Chem. 37, 2135 (1975).
2. Ionization constants of some N-aryl-hydroxamic acids in dioxane-water mixtures, G. Sharma and J.P. Tandon, Talanta., 18, 1163 (1971).
3. Mixed ligand complex formation by cadmium ion, S.C. Khurana, D.N. Chaturvedi and C.M. Gupta, J. Inorg, Nucl. Chem., 35, 1645 (1973).
4. Stability of Binary and Ternary Complexes of Cadmium with some Amino Acids and Propionic Acid. A Polarographic Study, Farid Khan and Krishna Nema, J. Indian Chem. Soc., 66, 17 (1989).
5. Mixed ligand complex formation by cadmium ion, S.C. Khurana and C.M. Gupta, J. Inorg. Nucl. Chem., 35, 209 (1973).
6. Mixed ligand chelates of Cd^{2+} with thiosulphate as primary ligand and adipic, itaconic and phthalic acids as secondary ligands, P.D. Jadhav and R.A. Bhobe, J. Inorg, Nucl. Chem., 39, 2290 (1977).
7. P.D. Jadhav and R.A. Bhobe, Gurr. Sci., 47, 339 (1977).
8. Reduction of cadmium-oxalate-malate complexes at the DME, S.C. Khurana, J.K. Gupta and C.M. Gupta, Electrochim. Acta., 18, 59 (1973).
9. Farid Khan, J. Indian Chem. Soc., 65, 464 (1988).
10. Mahmoud Ghandour, Nagva Aboul Maali, J. Indian Chem. Soc., 62, 156 (1980).
11. Hu, N. Tian, F. Fenxi Shiyanshi, 7(12), 17 (1988).
12. Sohn Sc. Chul, Eom. Tae Voon and Jung Key Suck., Tachan Hwahakhoe Chi., 33(6), 596 (1989).
13. Direct-current, normal-pulse and reverse-pulse polarography of some heavy metal -polycarboxylate complexes, M. Eslenbam, E. Casassas, H.G., De Jong and H.P. Vanlecurven., Anal. Chim. Acta., 229(1), 93 (1990).
14. Potentiometric investigations on the cadmium(II)-amino acid-imidazole systems (amino acid = glycine, DL-α-alanine or DL-valine), Zubida Khatoon and Kabir-Ud-Din ,J. Indian Chem. Soc. , 67, 344 (1990).
15. Polarographic Studies on Mixed Ligand Complexes of Cadmium(II) with some Amino Acids (L Leucine, DL-Serine or DL-Methionine) as Primary Ligands and 2,2'-Bipyridyl as Secondary Ligand, Zubida Khatoon and Kabir-Ud-Din, J. Indian Chem. Soc., 69, 677 (1992).
16. Polarographic Study of Mixed-Ligand Complexes of Cadmium(II) with Ascorbic Acid & Some Amino Acids, Rajni Kumari , C.P.S. Chandel and C.M. Gupta, J. Electro Chem. Soc. India, 35, 61 (1986).
17. Mixed Ligand Complexes of Cadmium(II) with Reactive Methylene Compounds of Malonamic Acid Series and Tartaric Acid : A Polarographic Study, Ajay Taneja, Yadvendra Singh Yadav, Ashit Asthana , D.S. Seth and Ashok Kumar, J. Indian Chem. Soc., 68, 559 (1991).
18. Ajay Taneja, P.N. Han Sharma, D.S. Seth and Ashok Kumar, J. Indian Chem. Soc., 69, 226 (1992).
19. P.N. Gupta, Anju Raina, Asian J. Chem., 4(1), 15, 21 (1992).
20. Synthesis and Characterisation of Xanthate Anions as Salts of Bis (Cyclopentadienyl) zirconium (IV) Chelates formed with 2,3-Dihydroxypyridine and 2-amino-3-hydroxypyridine, Tikku and Sashi Kumar Bansal, J. Indian Chem. Soc., 68, 289 (1991).
21. Agrawal R.S., Kumar Ashok, J, Electro. Chem, Soc., 40(1), 63 (1991) (Eng.).
22. Polarographic study of complexes of metal ions and dibasic acids-II Complexes of lead with malonic, succinic, glutaric and adipic acids, J. N. Gaur and M.M. Palrecha, J. Polarog. Soc., 19(1), 31 (1968).
23. J N. Gaur, S.C. Baghel and R S. Sherma, J. Indian Chem. Soc., 27, 249 (1979).
24. K.D. Gupta, S.C. Baghel and J.N Gaur, Monatsch Chem.,110, 657 (1979).
25. Abdul Hamid, Refat, El-Haty Mohamad, T. Can. J Chem., 70(3), 877 (1992) (Eng.).
26. Polarographic Studies of Mixed Ligand Complexes of Europium(III) with α-, β- and γ-Picolines & Carboxylate Ions, Renu Kulshrestha, Nirupama Sengar and Mukhtayar Singh, J. Indian Chem . Soc., 64, 696 (1987).
27. Polarographic Studies on Mixed Ligand Complexes of Cadmium with DL-3-(3,4-Dihydroxyphenyl) alanine and Some Dicarboxylic Acids, N. Gupta C.P.S. Chandel, P.C. Gupta and C.M. Gupta, Bull. Chem. Soc. Japan, 56(10), 3138 (1983).
28. Studies on mixed-ligand complexes of cadmium with 2,2'-bipyridyl and some dicarboxylic acids in dioxane medium, R. Kumari, C.P.S. Chandel, and C.M. Gupta, Bull. Chem. Soc. Japan, 58, 271 (1985).
29. Takuzo Kurotu and Atsushi Asano, Memoirs of National Defence Academy, 38, 1925, (1998).
30. Helix-Coil Transition of Metal Ion-Poly(α-L-glutamic acid) Complex (Ⅱ), Takuzo Kurotu and Atsushi Asano, C.S.J., 1995.
31. The Helix-Coil Transition of Poly(Aspartic Acid)-Metal Ion Complex, Takuzo Kurotu, A. Yangisawa and Atsushi Asano, 33th S.P.S.J., 50 (1999).
32. Branica M., Pi et al. Mar. Chem., 28, 227-239 (1989).

33. Precise polarographic determination of the stability constants of cadmium and lead with oxalate and sulphate, Leif Nyholm and Gunnar Wikmark, Anal. Chim. Acta. 223, 429-440 (1989).
34. Sherry Ratna, Polarographic Studies of Mixed Ligand Complexes of Pb(II) with o-Chloro Benzoyl Glycine and Malonate Ions using $NaNO_3$ as Supporting Electrolyte, RESEARCH HUB – International Multidisciplinary Research Journal, Volume-5, Issue-01, pp 1-6 (2018).
35. Sherry Ratna, Polarographic Studies of Mixed Complexes of Pb(II) with o-Chloro Benzoyl Glycine and Citrate Ions using $NaNO_3$ as Supporting Electrolyte, RESEARCH HUB – International Multidisciplinary Research Journal, Volume-5, Issue-04, pp 1-7 (2018).