Determination of stability constants of (e)-n-(2-ethoxyphenyl)-2-(mercapto-phenylamino- methylene)-3-oxo-butanamide (EPMPB) complexes with some transition metal ions.

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ABSTRACT

New transition metal [V(V), Co(II), Ni(II), Cu(II), Pd(II) and Cd(II)] complexes of (EPMPB) have been investigated in solution using Potentiometric and spectrophotometric methods. The composition of the complexes was determined to be 1:1 and/or 1:2 (M: L), the optimum conditions favouring the formation of the coloured complexes were studied extensively; protonation constants and their stability constants of the complexes were calculated. The stability constants of the formed complexes increase in the order Pd (II) > V (V) > Cu (II) > Co (II) > Ni (II) > Cd (II).Adherence to Beer's law was observed for the μgmL^{-1} concentration range form 0.31- 3.49 and 1.06 - 4.25(μgml^{-1}) for Cu(II) ion and Pd(II) ions, respectively, Molar absorptive was 6,899 and 10,788 L mol^{-1} cm^{-1} for Cu(II) and Pd(II) ions, respectively.

Introduction

(E)-N-(2-ethoxyphenyl)-2-(mercapto-phenylamino-methylene)-3-oxo-butanamide (EPMPB) as derivative of acetoacetanilide [1]. It is noticed that the preparation of metal complexes of various transition metals with different derivatives of β -ketoanilides compounds and their structural investigations have not been carried out much. It was therefore considered worthwhile to undertake this study systematically.
 It is of growing interest that the coordination compounds and metal chelates possessing nitrogen and oxygen donor atoms, show strong biological properties [2, 3].

Stability constants of some metal ion complexes have been studied by using different techniques, potentiometric [4-14], spectrophotometric [15-19] and paper electrophoretic [20]. Metals play a vital role in all living systems. Any malfunctioning of these metals can initiate a number of physiological abnormalities and symptoms of clinical disorders. Transition metal ions are responsible for proper functioning of different enzymes. Copper is one of the trace elements essential to the healthy life of humans and animals [21, 22]. Human diet usually includes 2 to 5 mg of copper per day. The adult body contains 100–150 mg, the muscle mass having 64 mg and the liver 18 mg of copper, [23]. Copper(II) usually forms stable complexes with N, O, and S donor ligands. For example, Cu(II) makes square planar complex with 4-methyl-imidazole [24].Metal coordination complexes have been extensively used in clinical applications as enzyme inhibitors [25], anti-bacterial [26, 27], antiviral [28–30] and as anti-cancerous [31–33]. Different kinds of metals have been employed in these complexes including platinum, gold, vanadium, iron, molybdenum, cobalt, tin, gallium, copper and many others [32]. Metal complexes of adenine (A) have been shown to possess anticancer activity [33–37]. The present study investigates the physico- chemical properties of the complexes of chelating agents with transition metals on solution.The potentiometric method has been used extensively in many branches of solution chemistry. It is by the most accurate and widely applicable technique currently available for the study of ionic equilibria [38]. The stability of (EPMPB) in aqueous buffer solutions has been studied as a function of pH. The rate of (EPMPB); loss and the mode of degradation are dependent upon the pH of solution. This work aims to study the complex formation of EPMPB with V(V), Co(II), Ni(II),Cu(II), Pd(II) and Cd(II) in mixed ethanol-water solutions using Potentiometrie and spectroscopic methods to throw some light on their compositions, structures, and analytical applications.

Experimental

Apparatus

All The pH measurements were carried out on VWR scientific model 2000 digital analyzer accurate total 0.01 pH unit. The absorption spectra of solutions were measured at room temperature with a Perkin-Elmer Lambda 3B recording spectrophotometer, using 1-cm matched quartz cells in the wavelength range 200-800 nm.

Reagents and Materials

The solutions of V(V), Co(II), Ni(II), Cu(II), Pd(II) and Cd(II) ions (Merck and BDH) as nitrates were prepared and titrated complexmetrically by EDTA [39]. Were obtained by dissolving the accurate weight of metal nitrate in the appropriate volume of bi-distilled water. More dilute solutions used for spectral measurements were obtained by accurate dilution. Stock standard solution of ($1x10^{-3}$ M) of (EPMPB) ligand was prepared by dissolving accurate weight of pure Ligand in ethanol and diluted with the same solvent to 10 mL volumetric flask (at 25 °C). (EPMPB) working solutions were

prepared daily by sequential dilution of the stock standard solution using bidistilled water.Sodium hydroxide (Merck) was prepared in bidstilled water as fresh solution.The universal buffer solution were prepared as recommended [40], and used to control the hydrogen ion concentration and ionic strength.

General Experimental procedure

Calvin-Bjerrum, technique as adopted by Irving and Rossoti [41] or Kather and Munshi [42], were used to determine the dissociation constants of the ligand (EPMPB) and the formation constants of their metal complexes with at 25 ± 0.1^0C in aqueous solutions. The solutions were titrated potentiometrically with 0.2 M standard free sodium hydroxide solution standardized against standard potassium hydrogen phthalate a = 0.001 M.HNO$_3$, b = a + 0.001 M (EPMPB) and c = b + 0.001 M metal nitrate solution. The total volume was adjusted to 50 cm^3 by adding doubly-distilled water in each case. The titration's were performed at 25 ± 0.1 ^{o}C and Ionic strength of I = 0.1M NaNO$_3$.

Preparation of (EPMPB) Ligand

(E)-N-(2-ethoxyphenyl)-2-(mercapto-phenylamino-methylene)-3-oxo-butanamide (EMPMB) was synthesized [1], as follow: a Cold suspension of potassium hydroxide 0.01 mole in DMF 30mL was added the acetoacetanilide 0.01mole, followed by phenyl isothiocyanate 0.01 mole. The mixture was stirred for 5 h at room temperature. The reaction mixture was poured into ice-cold water and acidified by dilute HCl 10% v/v. The solid product formed was filtered off, washed with water, dried and crystallized from ethanol to give a compound characterized by elemental analysis, IR, UV-Vis spectra and thermal analysis.

Results and Discussion

The titration curves are shown in Fig. 1, and the average number of proton attached per ligand,

$\bar{n} H$

was calculated [41].

$$\bar{n} H = Y + \frac{(V_1 - V_2)(N^0 + E^0)}{(V_0 - V_1)(Tcl^0)} \qquad \text{---------------------} \rightarrow 1)$$

Where Y= 3 (number of dissociable protons in the

ligand), V$_\circ$ is the initial volume, V$_1$ and V$_2$ are the volume of alkali required to reach the same pH in mineral acid (HNO$_3$) and (HNO$_3$ + EMPMB) respectively. T$_C$L$^\circ$ is the total concentration of ligand, N$^\circ$ is the normality of the alkali and E$^\circ$ is the initial concentration of free acid.

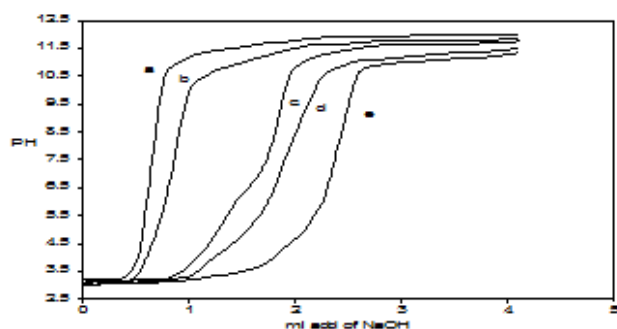**Figure 1. Titration curves of (EMPMB) L with different metal ions at I = 0.1M NaNO$_3$ (a): acid solution, (b): solution (a) +ligand (L), (c): solution (b) + Cu(II) ion, (d):b+ (V) ion and (e): b+ Ni(II) ion**

The proton - ligand formation curve obtained by plotting $\bar{n} H$ against pH at the ionic strength I = 0.1 M NaNO$_3$ as shown in Fig. 2.The values of logK$_1^H$, log K$_2$ ^{H} and log K$_3$ ^{H} (the first, second and third proton dissociation constants of (EPMPB) ligand are the pH values corresponding to half $\bar{n} H$ values such as $\bar{n} H$ = 0.5, 1.5 and 2.5, respectively.
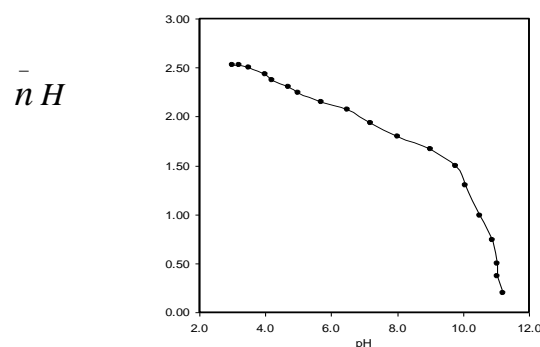

Figure 2. Protonation constants curve of (EPMPB) at 0.1 M (aqueous - ethanolic) solution at 25 ºC

It is worth mentioning that the ligand do not hydrolysis under the experimental conditions .This is indicated by the rapid attainment of equilibrium during the titration time. The titration curves of the metal - ligand solutions (C) are well separated from the ligand solution (b) in Fig. 1. Thus replacement of H$^+$ ion is due to complexation. From these titration curves, $\bar{n}$ (average number of ligand molecules attached per metal ion) and pL (free ligand exponent) values were calculated using Irving and Rossoti equations [41].

$$\bar{n} = \frac{(V_3 - V_2)(N^0 + E^0)}{(V_0 + V_2)\bar{n} H TcM^o} \qquad \text{--------------} \rightarrow (2)$$

$$pL = Log\left[\frac{(1 + K_1^H[H^+] + K_2^H[H^+]^2 + K_3^H[H^+]^3 + ----)}{(Tcl^0 - \bar{n}TcM^0)} \times \frac{V_0 + V_3}{V_0}\right]$$

$$\text{-----} \rightarrow (3)$$

Where V$_1$, V$_2$, V3 are the amounts of alkali reach the same pH in the free acid, free acid + ligand and free acid + ligand + metal, respectively. T$_c$M$^\circ$denotes the total concentration of metal present in the solution. The $\bar{n}$ values were plotted against the corresponding pL values to get the formation curves of the metal complexation equilibria. The formation curves are shown in Fig.3.
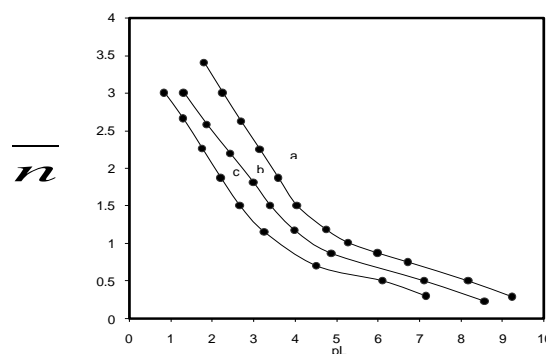

Figure 3. Formation curves of binary metal ion complexes with (EPMPB) ligand at I = 0.1 M NaNO$_3$ (a): Pd(II) ion, (b): V(V) ion and(C):Co(II)ion

From these formation curves, the values of stability constants at the ionic strength I = 0.1M listed in Table 1, were determined using the half - integral method [41].
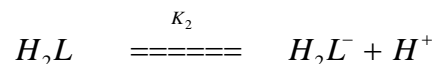
Table 1. Protonation constants and stability constants of metal ions with (EPMPB) ligand at ionic strength = 0.1M NaNO₃ at 25°C

| No	metal ion	LogK$_1$ (1:1) M:L	LogK$_2$ (1:2) M:L	LogK$_3$ (1:3) M:L
1	H$^+$ (ion)	3.42	9.66	10.56
2	Pd(II)	8.18	4.05	------
3	Cu(II)	6.24	3.74	------
4	Co(II)	6.12	2.67	------
5	Ni(II)	5.78	------	------
6	Cd(II)	4.14	------	------
7	V(V)	7.12	3.41	------

The three proton- ligand dissociation constants for (EPMPB) are 3.42, 9.66 and 10.56, listed in Table 1. These were assigned as follows: 3.42 belong to the protonation in imines (NH) group of 2-mercapto-phenylamino, 9.66 due to the deprotonation of thiol or mercapto (SH) group and 10.56 attributed to deprotonation (NH) group of N-P-tolybutamide. However ionization (EPMPB) takes place in three steps that can be represented by the following equilibria.

$$H_3L \xrightarrow{\;\;K_1\;\;} H_2L^- + H^+$$
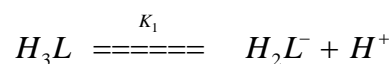
K_{BH^+} (protonation of (NH) group of 2 mercapto − phenyl a min o pK_{a1}

$$H_2L \xrightarrow{\;\;K_2\;\;} H_2L^- + H^+$$

(deprotonation of (SH) thiol or mercapto group pK_{a2}

$$HL \xrightarrow{\;\;K_3\;\;} L^- + H^+$$
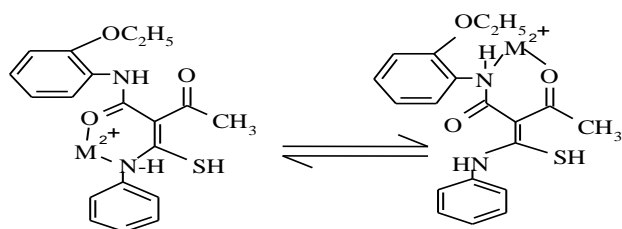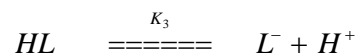
(EPMPB) - Metal ion complex

Where M = V(V), Co(II), Ni(II), Cu(II), Pd(II) and Cd(II)
The order of stability constants of the different binary complexes formed between (EPMPB) ligand and transition metal ions investigated in this study is in the expected Irving - Williams order [43] for (1:1) metal to ligand at I = 0.1 M NaNO₃ + 50 % alcoholic solution:

Pd (II) > V (V) > Cu (II) > Co (II) > Ni (II) > Cd (II).
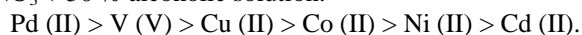
Spectrophotometric studies:
Determination of the Metal Complexes.

The stoichiometry of the Cu (II) and Pd (II) complexes was studied by applying the molar ratio [44], continuous variation [45] methods. Figures, (4, 5) shown the absorption spectra of molar ratio and continuous variation methods. The results proved the 1:1 or/and 1:2 (M: L) complexes were formed are shown in figs.(6, 7). The formation and stability

constants of the complexes of these metal ions are listed in table (2).The results concise to in potentiometeric method.

Table2. Formation constant, at 25°C of Cu(II) and Pd(II)-(EPMPB) chalets

Metal ion	Method	Ratio	K$_f$ (formation constant)	Log K$_f$ (stability constant)
Cu(II)-(EPMPB) complex	M.R.	1:1	1.5× 10^6	6.17
		1:2	4.52 × 10^6	6.65
	C.V.	1:2	1.70 × 10^6	6.23
Pd(II)-(EPMPB) complex	M.R.	1:1	2.0 × 10^6	6.30
		1:2	4.3 × 10^6	6.64
	C.V.	1:1	1.5 × 10^7	6.18

Where =*M.R: molar ratio.   =*C.V: continuous variation.
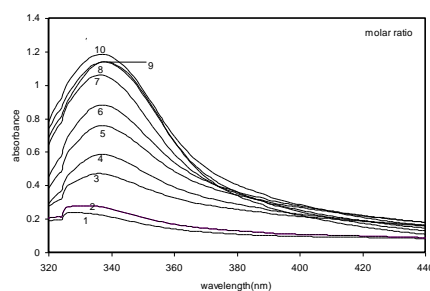

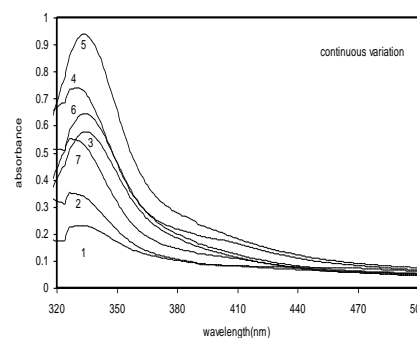**Figure 4. Absorption spectra of molar ratio for Pd(II)-(EPMPB) complex at 25°C and and λ$_{max}$ =336 nm**

Figure 5. Absorption spectra of continuous variation for Pd(II) - (EPMPB) complex at 25°C and λ =336 nm
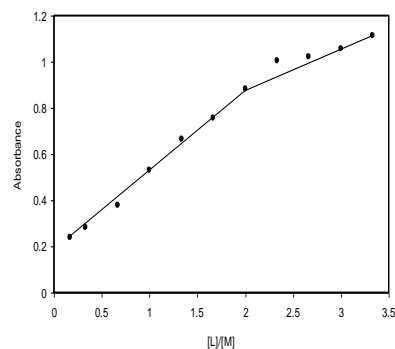

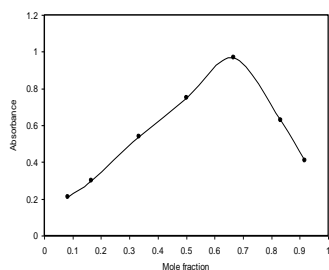**Figure 6. Absorbance molar ratio relationship for Pd(II)-(EPMPB) complex at 25°C and 25°C.and λ$_{max}$ =336 nm**

Figure 7. Absorbance mole fraction relationship for Pd(II) - (EPMPB) Complex at 25ºC and λ $_{max}$ = 336 nm. Calibration Curve

In order to use the complexes of the metal ions Cu(II), Pd(II), with (EPMPB) for microdetermination of metal ions. Solutions were prepared in which the concentration of the ligand was kept constant at $1x10^{-3}$ M and that of the metal ion was regularly varied. Absorbance of the obtained mixture is measured at the corresponding λ$_{max}$ of the formed chelate is shown in Fig (8). A graph of absorbance versus the concentration (μg/ml) of the tested metal ion is plotted in Fig.9.The curves indicate that, the absorbance is a linear function of the concentration of the metal ions studied. The linearity range obeyed beer's low form 0.31- 3.49 and 1.06 - 4.25(μgml^{-1}) for Cu(II) ion and Pd(II) ion, respectively. Molar absorptive was 6,899 and 10,788 L mol^{-1} cm^{-1} for Cu(II) and Pd(II), respectively. The curves pass through the origin, denoting a perfect validity of beer's law. Deviation is observed at high concentrations of metal ions. This behaviour clearly indicates that at such metal ion concentrations, the amount of lignad is not sufficient to transform the metal ions to complexes of the adequate stoichiometry.
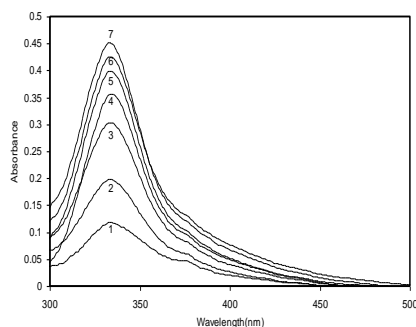

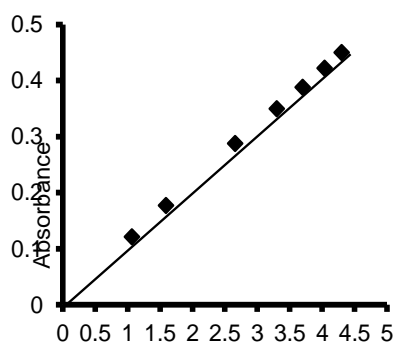**Figure 8. Absorption spectra of (EPMPB) with different concentrations of Pd(II) ion (μg mL^{-1}).**

Figure 9. plot of absorbance versus different concentrations of Pd(II) ion (μg mL^{-1})

Conclusion

Potentiometric and Spectrophotometric methods have been developed for determination of investigated metal ions based on chelating reaction with (EPMPB) reagent in aqueous solution. New binary complexes with (EPMPB) in aqueous solution and solid state were studied in this work.According to the results presented in the article, one can be noticed that potentiometric investigation of complexation in water solvent, more information about pH dependency of complexation could be obtained. Using the obtained data, selection of proper choice of parameter to predict selective and sensitive method.Potentiometric method is excellent method for calculation of stability constants of metal ligand complexes. (EPMPB) forms 1:1 and/or 1:2 metals to ligand complexes.

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