Original Article

Int. J. New Chemistry, Vol. 1, No. 3, Autumn 2014, 126-133

ISSN: 2383-188X

International Journal of New Chemistry

Complexation of a Catecholamine with Zinc (II) in Media with Different Dielectric Constants

Azar Bagheri Gh[1*], Mahnaz Bagheri[2]

[1] Department of Chemistry, Center Tehran Branch, Islamic Azad University, Tehran, Iran

[2] Institutes of Standards and Industrial Research of Iran, Tehran, Iran

Received: 20 October 2014; Accepted: 15 November 2014

Abstract:

The complexation of zinc (II) with dopamine has been investigated by spectrophotometric measurements in mixed solvent system at an ionic strength of 0.2 mol*dm^{-3} sodium chloride, employed (25± 0.1° ^{C}) at *pH* ranges of ~6 to ~7 with a high ratio of ligand to metal.

Keywords: Zinc (II), Catecholamine, Complexation , Mixed solvent.

(*) Corresponding Author: e-mail: azar.bagheri@iauctb.ac.ir

1. INTRODUCTION

Dopamine can be supplied as a medication that acts on the sympathetic nervous system, producing effects such as increased heart rate and blood pressure [1-3]. However, since dopamine cannot cross the blood-brain barrier, dopamine given as a drug does not directly affect the central nervous system. To increase the amount of dopamine in the brains of patients with diseases such as Parkinson's disease [4-6] and Dopa-Responsive Dystonia, L-DOPA (levodopa), which is the precursor of dopamine, can be given because it can cross the blood-brain barrier.As a member of the catecholamine [7] family, dopamine is a precursor to epinephrine (adrenaline) and then norepinephrine in the biosynthetic pathways for these neurotransmitters.Neurotransmitters are frequently organic bases, which form adducts with systems of electron acceptors as metal ions, proteins and components of protein by direct or indirect interactions. For example operation of neurotransmitters are distorted if they react with heavy metals such as Pb, Hg or lanthanides that frequently act as hard acids.The coordination chemistry of these compounds is complicated by their ability to act as ambidentate or bridging ligands [8,9]

An important finding is the demonstration that alcohol can affect the function of specific neurotransmitter [10]. Specifically, alcohol can act as a depressant by increasing inhibitory neurotransmission, by decreasing excitatory neurotransmission or through a combination of both. Alcohol has been shown to activate dopamine systems in certain areas of the brain. Through an interaction with glutamate receptors [11]. Interestingly endogenous opitate systems could cause the decrease in the acting of dopamine systems that occurs during alcohol with drawal. In this paper we evaluate the stability constants and thermodynamic parameters for Zn^{2+} binding to dopamine in cosolvent systems of ethanol and water using a combination of potentiometric and spectrophotometric methods [12-14].

2. EXPERIMENTAL

Reagent: Dopamine, Zinc nitrats, ethanol, sodium dihydrogen phosphate, disodium hydrogen phosphate and sodium chloride were supplied from Merck Chemical Company.

Table 1. Average values of log $K_{Zn(HL)2}$ and log $^{K\,H}_{Zn(HL)_2}$ and protonation dopamine with standard deviations (0.01) , in (*x*) water + (1-*x*) ethanol at different temperatures and *I* =0.2 mol*dm^{-3}

x **(molar fraction)**	**log** $K_{Zn(HL)2}$	**log** $K^{H}Zn(HL)_2$	**log** k_{1a}	**log** k_{3a}
1.000	**52.14**	**8.96**	**8.89**	**13.10**
0.979	**52.65**	**9.37**	**8.94**	**13.10**
0.955	**52.89**	**9.49**	**8.99**	**13.11**
0.930	**53.57**	**10.07**	**9.03**	**13.12**

Measurements: All measurements were carried out at 25 ± 0.1° ^{C} and at an ionic strength of 0.2 mol*dm^{-3} which was controlled with sodium chloride. The ligand concentrations were 1.2 m mol*dm^{-3} and Zn^{2+} concentrations were 0.4,0.6,1.2 m mol*dm^{-3} with ligand to Zn^{2+} molar ratios of 3, 2 and 1. The pHs of the solutions were controlled with phosphate buffers.

A Horiba D-14 *pH* meter was employed for *pH* measurements.The hydrogen ion concentrations were measured using an Ingold UO3234 glass electrode and an Ingold UO3236 calomel electrode. It is essential that the system be calibrated routinely for various solvent mixtures of known hydrogen-ion concentration [15-19].

Spectrophotometric measurements were conducted using an UV-VIS Shimadzu 2101 spectrophotometer equipped with a Acermate 486 SX/25D computer and thermostatically matched 10-mm quartz cells.

3. RESULTS AND DISCUSSION

Protonation equilibria of the ligand. The protonation constants for a 1mmol*dm^{-3} concentration ligand in water and in mixed solvent systems of ethanol and water were obtained from potentiometric titrations with NaOH 0.1 mol*dm^{-3} and employing a

computer-programmed nonlinear least-squares method.Values of the constants obtained are listed in Table 1 and agree with those obtained from the literature (pK_{a1} = 8.89 , pK_{a2} = 10.41 , pK_{a3} = 13.1 in 25 °C) [20-22]. We assume that deprotonation occurs in the following order with increasing *pH*: the paraphenolic group, the ammonium group and then the second OH group for dopamine.

The following equilibria are considered:

$$H^+ + L^{-2} \overset{k_1a}{\rightleftharpoons} HL^- \quad (1)$$

$$H^+ + HL^- \overset{k_2a}{\rightleftharpoons} H_2L \quad (2)$$

$$H^+ + H_2L \overset{k_3a}{\rightleftharpoons} H_3L^+ \quad (3)$$

The protonation constants are K_1a, K_2a, K_3a.

Complexation Zn(II) with dopamine .Complexation equilibria of a Zn(II) ion with dopamine have been studied by employing a technique based on the relationship of

absorbance as a function of *pH* , $A = f(pH)$. Absorbance measurements were made for solutions containing Zn (II) and dopamine with different molar ratios in *pH* of ~6 and ~7 in different solvent systems.

Considering that absorbance is a function of *pH*, the values of the molar absorptivities of Zn (II), ε_0 , (and for dopamine, ε_1) at different wavelengths and various dielectric constants are obtained. In order to determine ε_1 and ε_0 , solutions was prepared by the similar method and conditions, but in the absence of metal and ligand ions as described, respectively.

In order to determine ε_2, the formation constant of complex can be expressed as follows:

$$Zn(HL)^+ + 2H^+ \rightleftharpoons Zn^{2+} + H_3L^+ \quad (4)$$

$$K^H_{Zn(HL)^+} = \left[Zn(HL)^+\right]\left[H^+\right]^2 / \left[Zn^{2+}\right]\left[H_3L^+\right] \quad (5)$$

The absorbance at a wavelength is given by:

$$A = \varepsilon_0 \left[Zn^{2+}\right] + \varepsilon_1 \left[H_3L^+\right] + \varepsilon_2 \left[Zn(HL)^+\right] \qquad (6)$$

Where ε_0, ε_1, ε_2 are the molar absorptivities of the Zn (II) ion and dopamine and complex , respectively.

Thus, considering material balance, the equilibrium constant for the formation reaction of complex can be expressed as follows:

$$A + \varepsilon_1 C_{Zn^{2+}} + \varepsilon_0 \left(C_{H_3L^+} / C_{Zn^{2+}} \right) = \varepsilon_2 + \frac{(\varepsilon_0 + \varepsilon_1 - \varepsilon_2)\left(-A + \varepsilon_1 C_{H_3L^+} + \varepsilon_0 C_{Zn^{2+}} \right)\left[H^+\right]^n}{C_{Zn^{2+}}\left(A - \varepsilon_0 C_{Zn^{2+}} - \varepsilon_2 C_{H_3L^+} + \varepsilon_0 C_{H_3L^+} \right) K^H_{Zn(HL)^+}} \qquad (7)$$

The values of $K^H_{Zn(HL)^+}$ were determined from the intercept of the straight line plots of $A + \varepsilon_1 C_{Zn^{2+}} + \varepsilon_0 \left(C_{H_3L^+} / C_{Zn^{2+}} \right)$ (Y) against $\left(-A + \varepsilon_1 C_{H_3L^+} + \varepsilon_0 C_{Zn^{2+}} \right)\left[H^+\right]^n / C_{Zn^{2+}}$ (X) .The intercept of linear fit yields ε_2.

In the equilibrium reaction of complex formation is:

$$Zn(HL)_2 + 2H^+ \rightleftharpoons Zn(HL)^+ + H_3L^+ \qquad (8)$$

The formation constant of the complex can be expressed as follows:

$$K^H_{Zn(HL)_2} = \left[Zn(HL)_2\right]\left[H^+\right]^2 / \left[Zn(HL)^+\right]\left[H_3L^+\right] \qquad (9)$$

The absorbance at a wavelength is given by:

$$A = \varepsilon_0 \left[Zn^{2+}\right] + \varepsilon_1 \left[H_3L^+\right] + \varepsilon_2 \left[Zn(HL)^+\right] + \varepsilon_3 \left[Zn(HL)_2\right] \quad (10)$$

$$Zn^{2+} \approx 0 \quad (11)$$

$$A = \varepsilon_1 \left[H_3L^+\right] + \varepsilon_2 \left[Zn(HL)^+\right] + \varepsilon_3 \left[Zn(HL)_2\right] \quad (12)$$

Where ε_0 , ε_1 , ε_2 and ε_3 are the molar absorptivities of the Zn(II) ion , dopamine and their complexes.

For the molar balance of zinc and dopamine:

$$\left[Zn^{2+}\right] = \left[Zn(HL)^+\right] + \left[Zn(HL)_2\right] \quad (13)$$

$$\left[H_3L^+\right] = C_{H_3L^+} + \left[Zn(HL)^+\right] + 2\left[Zn(HL)_2\right] \quad (14)$$

Where C_{Zn2+} and $C_{H3L}{}^{+}$ are the total concentrations of Zn^{2+} and dopamine. Thus, the equilibrium constant for formation the complex can be expressed as follows:

$$\left(-A + \varepsilon_1 C_{H_3L}{}^{+} - 2\varepsilon_1 C_{Zn^{2+}}\right) \Big/ C_{Zn^{2+}} = -\varepsilon_3 + \frac{(\varepsilon_3 - \varepsilon_2 - \varepsilon_1)\left(A - \varepsilon_1 C_{H_3L^+} + \varepsilon_1 C_{Zn^{2+}} - \varepsilon_2 C_{Zn^{2+}}\right)\left[H^+\right]^2}{K^{H}_{Zn(HL)_2}\left(\varepsilon_3 C_{H_3L^+} - \varepsilon_2 C_{H_3L^+} - A - \varepsilon_3 C_{Zn^{2+}} + 2\varepsilon_2 C_{Zn^{2+}}\right) C_{Zn^{2+}}} \quad (15)$$

Considering that A is a function of pH , the values of molar absorptivities, are obtained. The values of $K^{H}_{Zn(HL)_2}$ were determined from the intercept of the straight line plots of $-A + \varepsilon_1 C_{H_3L^+} - 2\varepsilon_1 C_{Zn^{2+}}$ (Y) against $\left(A - \varepsilon_1 C_{H_3L^+} + \varepsilon_1 C_{Zn^{2+}} - \varepsilon_2 C_{Zn^{2+}}\right)\left[H^+\right]^2 / C_{Zn^{2+}}$ (X) and are shown in Table 1. The intercept of the lines yields ε_3.

4. REFERENCES

1. Pfaus, J.; Phillips, A.: Role of dopamine in anticipatory and consummatory aspects of sexual behavior in the male rat. *Behav Neurosci* **1991,** *105 (5*), 727-43

2. Schultz, W.: Getting formal with dopamine and reward. *Neuron* **2002**, *36 (2)*, 241-263.

3. Flaherty, A.W.: Frontotemporal and dopaminergic control of idea generation and creative drive. *Journal of Comparative Neurology* **2005**, *493 (1)* , 147-153.

4. Fiskum, G..; Starkov, A.; Polster, B. M.; Chinopoulos, C.: Mitochondrial Mechanisms of Neural Cell Death and Neuroprotective Interventions in Parkinson's Disease. *Acad. Sci***. 2003** ,*991***,** 111–119

5. Kaur, D.; Andersen, J. K.: Ironing out Parkinson's disease: is therapeutic treatment with iron chelators a real possibility? *Aging Cell*. **2002** ,*1***,** 17–21

6. Smigrodzki, R.; Parks, J.; Parker, W. D.: High frequency of mitochondrial complex I mutations in Parkinson's disease and aging. *Neurobiol. Aging*. **2004**, *25***,** 1273–1281

7. Nicholls, G..: *Proteins, transmitter& synapses*, Scotland, Blackwell Scientific Publications, **1994**

8. Gorton, J. E.; Jameson, R. F.: Complexes of Doubly Chelating Ligands.Proton and Copper (II) Complexes of L-DOPA. *J. Chem. Soc. (A)* **1968**, 2615-2618

9. Kiss, T. ; Gergely, A. : Copper (II) and nickel (II) ternary complexes of L-dopa and related compounds. *J.Inorg.Biochem*. **1985**, *25(4)* , 247-59

10. Lovinger, D.M.; White, G.; and weight, F.F. : Ethanol inhibits NMDA-activated ion current in hippocampal neurons. *Science* **1989**, 243,1721–1724,

11. Koob, G.F. Drug addiction: The yin and yang of hedonic homeostasis. *Neuron* ,**1996 ,**16, 893–896.

12. Gharib,F.; Zare,K.; Khorrami,S.A., J.Chem.Eng.Data**1993**, 38, 602-604

13. Monajjemi,M.; Azizi, Z.; Ghavami,M., Russ. J. Inorg. Chem. **2003**,48,1551

14. Monajjemi,M.; Moniri, E.; J. Chem. Eng. Data **2001**,46,1249

15. "*Manual of Symbols and Terminology for Physicochemical Quantities and Units*".2nd rev. *Pure Appl.Chem*. **1979**, *51*, 1-20

16. Beck, M.T.; Nagipal, I.: Chemistry of Complexation Equlibria, New York: Ellis Horwood, **1990**

17. Bates, R.G.: *Determination of pH*. 2nd edn.,Wiley, New York ,**1973**

18. British Standards Institution, *Specification for pH Scale* BS1647 , **1961**

19. Wu, Y. C.; Koch, W. F., and Durst, R. A., Standard Reference Materials: Standardization of *pH* Measurements, NBS Special Publication **1988**, 260-53

20. Kiss,T.; Gergely, A.: Complexes of 3,4-dhydroxyphnyl derivatives, III. Equilibrium study of parent and some mixed ligand complexes of dopamine, alanine and pyrocatechol with nickel (II), copper (II) and zinc (II) ions. *Inorg.chim. Acta*. **1979**,*36* , 31-36

21. Kiss, T.; Gergely,A.: Complexes of 3, 4-dihydroxyphenyl derivatives. II. Complex formation processes in the nickel (II)-L-DOPA and zinc (II)-L-DOPA systems. *Inorg. Chim. Acta* . **1979**, *36*, 113-120

22. Kiss, T.; Gergely A., Complexes of 3, 4-dihydroxyphenyl derivatives IV. Equilibrium studies on some transition metal complexes formed with adrenaline and noradrenaline. *Inorg. Chim.Acta.* **1981** , *56*, 35-40