

Preparation and Study of Mixed Ligand Complexes of Caffeine and Cyanate with Some Metal Ions

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Abstract: This work presents preparation and study of a new mixed ligand complexes of caffeine and cyanate ion with Co(II), Ni(II), Cu(II), Zn(II) and Cd(II). The prepared complexes were characterized on the bases of their elemental analysis (C, H, N), metal percentage determination, IR and UV-Vis spectroscopy. Conductivity measurements as well as their magnetic moments were carried out. From the obtained information the general formula has been given for the prepared complexes $[M(CA)_4Y_2]$ where CA=caffeine, Y=cyanate ion and M=Co(II), Ni(II), Cu(II), Zn(II) and Cd(II).

Key word: Caffeine complexes, Cyanate complexes, Mixed ligand complexes.

INTRODUCTION

Caffeine (1,3,7-trimethylxanthine) is one of purine alkaloids and it belongs to xanthine chemical groups and it plays an important role in pharmacological properties (Milan, 1981). Caffeine probably is the most popular drug in the world (Barone and Roberts, 1996), which includes antagonistic effect on adenosine receptors, inhibition of phosphodiesterase and stimulation of muscle contraction (Esimone, *et al*, 2008; DeGubareff and Sleator, 1965; Rall TW and Sutherland EW., 1958; Youn JH, *et al*, 1991). Thus, caffeine has the ability to form complexes with some drugs molecules like tetracycline and penicillin. It was shown to increase the inhibitory effect of tetracycline and penicillin G against *Staphylococcus aureus* (Esimone, *et al*, 2008; Charles and Rawal, 1973; Veselkov, *et al*, 2002). Moreover, caffeine-paracetamol analgesic is frequently taken concurrently with these drugs (Esimone, *et al*, 2008).

Caffeine could be used to examine the coordination ability on the N9 and (C6)=O positions as far as N7 which is blocked by methyl group (Bojidarka Ivanova, 2007). Therefore, the present paper deals with synthesis new mixed ligand complexes of caffeine and cyanate ion which was characterized using different methods such as elemental analysis C, H, N and UV-Vis and IR spectroscopy.

Experimental:

Material and Measurements:

All chemicals were obtained from commercial sources and were used without further purifications ($CoCl_2 \cdot 6H_2O$, $NiCl_2 \cdot 6H_2O$, $CuCl_2 \cdot 2H_2O$, $ZnCl_2$, $Cd(NO_3)_2 \cdot 4H_2O$ and KOCN) from Riedel-Dehaen and Fluka. Caffeine from BDH. Methanol, ethanol and dimethylsulfoxide from system.

The I.R spectra in the range of 4000-400 cm^{-1} were recorded as potassium bromide disc on Shimadzu FTIR-8300 Fourier transform infrared spectrophotometer. UV-Visible spectra were measured in DMSO using Shimadzu UV-Visible recorder spectrophotometer UV-160. Elemental analysis (C, H, N) were performed by the micro analytical unit on Berkin Elemer B-240 Elemental Analyzer. Determinations of metals were carried out using Laboratory methods. Conductivity measurements were carried out at 25°C in DMSO using Philips Pw-9526 digital conductivity meter. Melting point was determined using Stuart-Melting Point Apparatus and finally the magnetic susceptibility measurements were obtained using Balance Magnetic Susceptibility Model MsB-MK1.

General Procedure for Synthesis:

An ethanolic solution 12 ml of caffeine (CA) 1.25-2.84 g and 5 ml an aqueous solution of KOCN 0.26-0.59 g were added respectively to an aqueous solution of the metal salts. After constant stirring using appropriate amounts of materials needed as decided by the molar ratio (1:4:2) (M:CA:Y). The resulting precipitates were filtered off, washed several times with (1:1) water: ethanol and recrystallized from ethanol, Then dried in an oven at 65°C.

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RESULTS AND DISCUSSION

The prepared complexes were found to be solids, insoluble in water but they were soluble in some organic solvents like dimethylformamide and dimethylsulfoxide. The lower value observed of molar conductivities in DMSO indicates the non electrolyte behavior of the complexes (Kettle, 1975; Quaglian, *et al.*, 1961). Elemental analysis (C, H, N) and metal determination were in good agreement with general formula given for the complexes. Table 1 gives the physical properties of the complexes.

Magnetic Susceptibility:

The magnetic moment for the complex of cobalt ion should be around 4.195 B.M while the measured value was shown to be higher than the expected value, this could be related to orbital-spin coupling (David, 1984; Ehssan, 1988). However the, values of Ni²⁺ and Cu²⁺ complexes were found to be closer to that of spinning only (Clyde, 1983; David Nicholls, 1984). The complexes of Zn²⁺, Cd²⁺ were diamagnetic as expected from their electron configuration. All data are also included in Table 1.

Electronic Spectral Studies:

The electronic spectra for free ligands CA and OCN⁻ ion shows absorption bands in the UV- region expressed as $\pi \rightarrow \pi^*$ and $n \rightarrow \pi^*$ transitions. The Co(II) complex exhibited three bands at 280 nm due to ${}^4T_{1g(F)} \rightarrow {}^4A_{2g(F)}(v_2)$, another one at 505, 592 nm which is attributed to ${}^4T_{1g(F)} \rightarrow {}^4T_{1g(D)}(v_3)$ and at 644, 767, 774nm which is assigned to ${}^4T_{1g(F)} \rightarrow {}^4T_{2g(F)}(v_1)$. The ligand field splitting energy 10Dq was found to be 17285.688 and the inter electronic repulsion parameter B λ was found to be 838.371 cm⁻¹ according to the following relation:

$$\left(\beta \frac{B\lambda}{B}\right)$$

Where β was found to be equal to 0.863.

The electronic spectra of Ni(II) complex shows electronic transition ${}^3A_{2g(F)} \rightarrow {}^3T_{1g(P)}$ at 352, 366 nm and electronic transition ${}^3A_{2g(F)} \rightarrow {}^3T_{2g(F)}$ at 991 nm. The 10Dq value for the complex was equal to 10090.817 cm⁻¹ and B λ value found to be 957.9 cm⁻¹ while β was equal to 0.93. These assignments are corresponding to Ni(II) octahedral complexes.

The spectrum of Cu(II) complex shows band in the visible region at 402 nm which is attributed to ${}^2E_{g(D)} \rightarrow {}^2T_{2g(D)}$.

Finally the electronic configuration of Zn(II) and Cd(II) complexes was (d¹⁰) which confirms the absence of any (d-d) transitions, but the absorption bands in their spectra are suffered blue shift with Hypo or Hyper chromic effect (Lever, 1968; Monther, 1983). Thus, some absorptions have suffered red shifts or blue shifts, hyper or hypo chromic effects. These absorptions were fully assigned in Table 2.

Infrared Spectra Studies:

Further information about the coordination behavior of the free ligands with metal ions were carried out by the comparison of the infrared spectra of the free ligands and their complexes. The absorption band appeared at 1658 cm⁻¹ were caused by $\nu(-N=C)$ bond in the structures of CA (Cross and Alan, 1969; John, 1965; Socrates, 1980; William and Flemming, 1973). In the spectra of their complexes, these absorptions were lowered by 18-3 which and indicated the coordination of CA to the metal ions through the nitrogen atom N9 in their structures (Elizabeth and Elmer, 1979; Katsuyuki and Hiroshi, 1980; Milan, 1981; Roger, *et al.*, 1981).

The asymmetrical and symmetrical vibrations in OCN⁻ were noticed at 2165 cm⁻¹ and 1207 cm⁻¹ respectively in the spectra of the free ligand. The asymmetrical stretching vibration was found to be at higher positions in the region of 2200-2260 cm⁻¹, were shifted to the higher frequencies by 35-95 cm⁻¹. The absorptions band in the case of symmetrical stretching vibration was shifted to higher frequencies by 28-48 cm⁻¹ which are indicated the coordination of cyanate ion with metal ions through its oxygen atom (Bailey and Kozak, 1969; Kazuo, 1997; Socrates, 1980). Thus, the spectra of the complexes exhibited lower frequency absorptions bands in the range of 585-650 cm⁻¹ were assigned as $\delta(M-OCN)$ and another between 420-460 cm⁻¹ are due to $\nu(M-N)$. Table 3 gives the diagnostic absorptions and their assignments.

Table 1: The physical properties of the metal complexes [M(CA)₄Y₂]

| Compound | Color | M.P °C | Elemental analysis: Calc. (Found)% | | | | Magnetic moment Calc. (Found)% | Molar conductivity Ohm ⁻¹ cm ² mol ⁻¹ |
|---------------------------------------|--------------|----------|------------------------------------|-----------------|-------------------|-----------------|-----------------------------------|---|
| | | | C | H | N | M | | |
| [Co(CA) ₄ Y ₂] | Light pink | 23 8-240 | 44.40 1 (45.44) | 4.379 (4.52) | 27.411 (28.31) | 6.33 (7) | 3.872 (4.195) | 13.04 |
| [Ni(CA) ₄ Y ₂] | Green yellow | 256-258 | 44.412 (44.29) | 4.38 (4.40) | 27.417 (26.51) | 6.36 (6.76) | 2.828 (2.798) | 15 |
| [Cu(CA) ₄ Y ₂] | Green blue | 214-215 | 44.180 (44.22) | 4.357 (5.11) | 27.274 (27.30) | 6.66 (7.66) | 1.732 (1.692) | 15 |
| [Zn(CA) ₄ Y ₂] | white | 224-226 | 44.092 (43.33) | 4.349 (4.13) | 27.220 (27.15) | 7.03 (7.4) | zero | 16.66 |
| [Cd(CA) ₄ Y ₂] | white | 260-262 | 41.962 (41.88) | 4.138 (4.18) | 25.905 (25.77) | 11.53 (12.3) | zero | 15.62 |

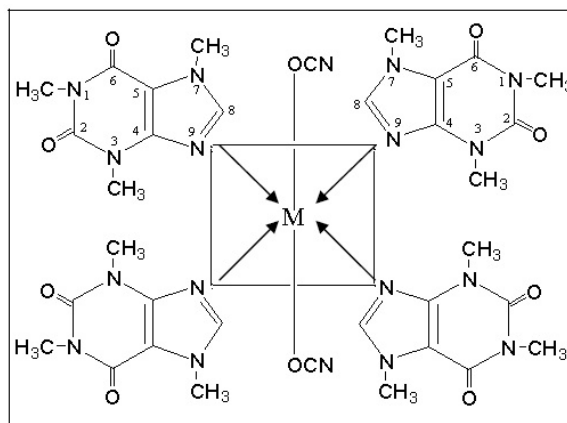
Table 2: U.V-visible spectra of free ligands and their complexes 10⁻³M in DMSO

| Compounds | λ ^{max} n.m | ABS | Wave (cm ⁻¹) | ε ^{max} Lmol ⁻¹ cm ⁻¹ | assignment |
|---------------------------------------|-------------------------|-------|-----------------------------|---|---|
| CA | 275 | 1.774 | 36363.636 | 1774 | π → π* |
| | 316 | 0.006 | 31645.569 | 6 | n → π* |
| | 365 | 0.014 | 27397.26 | 14 | |
| KOCN | 246 | 0.057 | 40650.406 | 57 | n → π* |
| | 272 | 0.614 | 36764.705 | 614 | n → π* |
| [Co(CA) ₄ Y ₂] | 220 | 0.149 | 45454.545 | 149 | (C-T) |
| | 280 | 1.792 | 35714.285 | 1792 | ⁴ T _{1g(F)} → ⁴ A _{2g(F)} (v ₂) |
| | 312 | 0.014 | 3205.1282 | 14 | - |
| | 505 | 0.068 | 1901.98 | 68 | |
| | 592 | 0.061 | 1689.1891 | 61 | ⁴ T _{1g(F)} → ⁴ T _{1g(D)} (v ₃) |
| | 644 | 0.063 | 15527.95 | 63 | |
| | 767 | 0.042 | 13 03 7.809 | 42 | ⁴ T _{1g(F)} → ⁴ T _{2g(F)} (v ₁) |
| [Ni(CA) ₄ Y ₂] | 774 | 0.044 | 12919.896 | 44 | |
| | 278 | 1.938 | 35971.223 | 193 | (C-T) |
| | 352 | 0.397 | 28409.09 | 397 | |
| | 366 | 0.404 | 27322.404 | 404 | ³ A _{2g(F)} → ³ T _{1g(P)} |
| [Cu(CA) ₄ Y ₂] | 991 | 0.014 | 10090.8 17 | 14 | ³ A _{2g(F)} → ³ T _{2g(F)} |
| | 277 | 1.925 | 36101.083 | 1925 | Charge transfer |
| [Zn(CA) ₄ Y ₂] | 402 | 0.008 | 24875.621 | 8 | ² E _{g(D)} → ² T _{2g(D)} |
| | 281 | 1.781 | 35587.188 | 1781 | Charge transfer (M o L) |
| [Cd(CA) ₄ Y ₂] | 279 | 1.797 | 35842.293 | 1797 | Charge transfer (M o L) |

Table 3: The characteristic bands of infrared spectra of the ligands and their complexes.

| Compound | ν(OCN) _{asy} | ν(C=O) | ν(-N=C) | ν(OCN) _{sy} | δ(M.OCN) | ν(M- |
|---------------------------------------|-----------------------|----------|---------|----------------------|----------|-------|
| CA | - | 1720 s.b | 1658 | - | - | - |
| KOCN | 2165v.s | - | - | 1207 s | - | - |
| [Co(CA) ₄ Y ₂] | 2260 | 1710 | 1650 | 1250 | 585 s | 460 |
| [Ni(CA) ₄ Y ₂] | 2260 | 1715 | 1655 | 1235 | 650,590 | 420 |
| [Cu(CA) ₄ Y ₂] | 2240 | 1710 | 1645 | 1250 s | 585 s | 460 |
| [Zn(CA) ₄ Y ₂] | 2200 m | 1715 w | 1655 | 1240 s | 605, 590 | 460 |
| [Cd(CA) ₄ Y ₂] | 2220 m | 1715 w | 1650 | 1255 s | 590 s | 460 s |

s= strong, m= medium, w= weak, b= broad, sh= sharp, sho= shoulder, v= very, asy=asymmetry, sy=symmetry

**Fig. 1:**

Conclusions:

In this paper, new mixed ligand complexes containing caffeine and cyanate ion coordinated with Co(II), Ni(II), Cu(II), Zn(II) and Cd(II) were synthesized. The molar conductivity of complexes in DMSO solution were non electrolyte. The configuration was that the caffeine is coordinated with metal ions through the nitrogen atom and cyanate ion is coordinated with metal ions through oxygen atom. Therefore, from the results presented in this paper the metal complexes have octahedral configuration, as can seen in Fig 1.

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REFERENCES

- Barone, J.J., H.R. Roberts, 1996. Caffeine Consumption" Food Chemistry and Toxicology, 34, and National coffee Association, National soft drink Association, Teacouncil of the USA and information provided by food beverage and pharmaceutical companies.
- Bailey, R.A. and S.L. Kozak, 1969. Complex Hexacyanates of Rhenium and Molybdenum, *J. Inorg. Nucl. Chem.*, 3(1): 689-693.
- Bojidarka Ivanova, 2007. Gold(III) Complex of Caffeine, Synthesis, Isolation and Spectroscopic Characterization, *Turk J Chem*, 31: 97-103.
- Esimone, C.O., FBC, Okoye, CS Nworu and Agubata, 2008. In Vitro Interaction between Caffeine and some Penicillin Antibiotics Against *Staphylococcus Aureus*", *Tropical Journal of Pharmaceutical Research*, June, 7: 969-974.
- Charles, B.G., B.D. Rawal, 1973. Synergistic Effect of Methyl Substituted Xanthines and Neomycin sulfate on *Staphylococcus Aureus* and *Pseudomonas Aeruginosa* in vitro. *Lancet*, 1: 971-973.
- Clyde, M., J.R. Day and Joel Selbin, 1983. Theoretical Inorganic Chemistry.
- Cross, A.D., Alan Jones, 1969. An Introduction to Partical Infrared Spectroscopy.
- David Nicholls, 1984. Complexes and First. Row Transition Elements.
- Ehssan, A., 1988. "Inorganic and Coordination Chemistry", Mousel university, Iraq.
- Elizabeth, H., Griffith and L. Elmer Amma, 1979. Reaction of PtC14 with Therophylline, *J.C.S. Chem. Comm*, 322.
- John Dyer, 1965. Application of Absorption Spectroscopy of Organic Compounds.
- Kettle, S.F.A., 1975. Coordination Compounds, Thomas Nelson and Sons, London, 165.
- Katsuyuki Aoki and Hiroshi Yamazaki, 1980. Interactions of Terakis(carboxylato) dirhodium(II), an Antiumour Agent with Nucleic Acid Bases, 186.
- Kazuo Nakamoto, 1997. Infrared and Raman Spectra of Inorganic and Coordination Compounds" fifth edition.
- Lever, A.B.P., 1968. Inorganic Electronic Spectroscopy.
- Milan Melnik, 1981. Binuclear Caffeine Adducts of Cu(II)acetate and Cu(II)chloracetates with Unusually High Antiferromagnetic Interaction, 43: 3035-3038.
- Monther, Y., 1983. The physical Methods in Inorganic Chemistry.
- Quaglian, J.V., J. Fujita, G. Franz, 1961. *J. Am. Chem. Soc.*, 81: 3770.
- Roger, E., Cramer, Douglas M. Ho, William Van Doorn, James A., Ibers, Ted Norton and Midori Kashiwagi, 1981. Triphenylmethylphosphoniumtrichloro(caffeine) platinum(II), *Inorg. Chem*, 20: 2457-2461.
- Rall, T.W., E.W. Sutherland, 1958. Formation of a Cyclic Adenine Nucleotide by Tissue Particles. *J Biol. Chem.*, 232: 1065-1076.
- Socrates, G., 1980. Infrared Characteristic Group Frequencies, New Yourk, John Wiley and Sons.
- Sutherland, E.W., T.W. Rall, 1958. Fractionation and Characterization of a Cyclic Adenine Ribonucleoside formed by tissue particles. *J Biol. Chem.*, 232: 1077-1091.
- Veselkov, D.A., V.V. Kodintsev, V.I. Pakomor, L.N. Djimant, D.B. Davies, A.N. Veselkov, 2002. NMR analysis of Hetero-association of Caffeine with Antibiotic Actinomycin D in Aqueous Solutions. *Biophys*, 45: 193-202.
- William and Fleming, 1973. "Spectroscopic Methods in Organic Chemistry" 2nd edn.
- Youn, J.H., E.A. Gulve, J.O. Holloszy, 1991. Calcium Stimulates Glucose Transport in Skeletal Muscles by a Partway Independent of Contraction. *Am J Physiol*, 260: C555-561.