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COMPLEXATION OF ALKALINE EARTH METALS Mg^{2+}, Ca^{2+}, Sr^{2+} AND Ba^{2+} WITH ADRENALINE HORMONE: SYNTHESIS, SPECTROSCOPIC AND ANTIMICROBIAL ANALYSIS

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ABSTRACT. Adrenaline complexes with bivalent ions Mg^{2+}, Ca^{2+}, Sr^{2+} and Ba^{2+} in methanol at 60 ºC were prepared. The prepared complexes were isolated and characterized using elemental analyses, conductivity measurements, mid infrared, Raman laser, UV-Vis., ^{1}H–NMR spectra, X-ray powder diffraction, scanning electron microscopy and energy-dispersive X-ray spectroscopy (EDX). Upon the spectroscopic, conductivity and elemental analyses, the stoichiometric reactions indicated 1:2 (M:L) for Ca^{2+}, Sr^{2+} and Ba^{2+} complexes $[Ca(Adr)_2(H_2O)_2](H_2O)_4Cl_2$, $[Sr(Adr)_2(H_2O)_2]Cl_2$ and $[Ba(Adr)_2(H_2O)_6]Cl_2$ while the molar ratio of 1:1 (M:L) for Mg^{2+} with a formula $[Mg_2(Adr)_2(H_2O)_7]Cl_4$. The interpretation of Raman and infrared spectra confirmed the coordination mode, which was through the two-catechol moiety OH phenolic groups. The *in vitro* antibacterial activity of adrenaline chelates that have been tested against three gram-positive bacteria, two gram-negative bacteria, and two strains of fungus showed that antimicrobial activity of the metal chelates are more effective than the adrenaline free ligand.

KEY WORDS: Adrenaline, heavy metals, infrared, biological outcomes

INTRODUCTION

Adrenaline (Adr, Scheme 1) is neurotransmitter hormone (known as epinephrine) [1]. It makes increasing in the rate of heart, vessels of blood constrict, and passages of air dilate in the nervous sympathetic system that contributes to the fight-or-flight response. Based on chemical information, adrenaline is a monoamine catecholamine, formed adrenal glands from phenylalanine and tyrosine amino acids [2-5]. The information regarding the complexing behavior of catecholamines give an indication for adrenaline solid compounds referring to their antimicrobial properties, with ions of heavy of divalent meta-, such as Mg^{2+}, Ca^{2+}, Sr^{2+} and Ba^{2+}. A thermoanalytical study of different adrenaline coordination compounds with some divalent transition metal ions such as Co^{2+}, Ni^{2+} and Cu^{2+} has been reported. The combinatorial interactions of levodopa, dopamine, adrenaline, noradrenaline and tyramine with Ni^{2+}, Cu^{2+}, Zn^{2+}, Cd^{2+} and Pb^{2+} were studied by pH titration method at 20 °C. While levodopa has been found to act as a simple dimeric α-amino acid, dopamine, adrenaline, and norepinephrine coordinate with metal ions via catecholic OH groups. Composition and equilibrium constants of the complexes of Mg^{2+}, Co^{2+}, Ni^{2+}, Cu^{2+}, Cd^{2+}, and Cd^{2+} with two catechol double bonds: dopamine and adrenaline, in aqueous solution, using protomometric and spectrophotometric techniques. The degree of coordination of the metal ion is no more than two, with the stability order $Cu^{2+} > Pb^{2+} > Ni^{2+}$, Co^{2+}, $Cd^{2+} > Mg^{2+}$ [3, 4].

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The goal of this work is to study the chelation behavior and antimicrobial efficiency between Adr hormone as a vital biomolecule and bivalent metal ions Mg^{2+}, Ca^{2+}, Sr^{2+} and Ba^{2+}. The reason of the selection of alkaline earth metal ions, because Mg^{2+} and Ca^{2+} metal ions are some important and essential elements which already important to the human body. Also, the work aimed to compare and study the biological and spectroscopic properties of the Adr solid complexes produced from solutions of CH_3OH after precipitation via molar ratios of some divalent chloride/adrenaline (M/L). The interpretation of the solid complexes was carried out using elemental analysis, conductance measurements, mid infrared, Raman laser, UV-Vis., X-ray powder diffraction, scanning electron microscopy and energy-dispersive X-ray spectroscopy (EDX).

EXPERIMENTAL

Materials

From Aldrich Company $MgCl_2·6H_2O$, $CaCl_2·6H_2O$, $SrCl_2·2H_2O$, $BaCl_2·6H_2O$, and CH_3OH were obtained and from Fluka chemical company, adrenaline was obtained. In this paper high grade of purity chemicals were used.

Preparation of adrenaline complexity

The precipitated complexes were formed in CH_3OH solutions, with the (M^{II})/Adr ratios 1:1 or 1:2.

$[Mg_2(Adr)_2(H_2O)_7]Cl_4$. To an adrenaline solution (1 mmol; 0.183 g in 25 mL of absolute CH_3OH), with warming at (60 °C), $MgCl_2·6H_2O$ solution (1 mmol; 0.315 g) in 25 mL of absolute CH_3OH was added with stirring. The resulting precipitate was washed using absolute CH_3OH and dried *in vacuo* over anhydrous $CaCl_2$.

$[Ca(Adr)_2(H_2O)_2](H_2O)_4Cl_2$. To an adrenaline solution (2 mmol; 0.366 g in 25 mL of absolute CH_3OH), and warming at (60 °C), $CaCl_2·6H_2O$ solution (1 mmol; 0.110 g) in 25 mL of absolute CH_3OH was added with stirring. The resulting precipitate was washed using absolute CH_3OH and dried *in vacuo* over anhydrous $CaCl_2$.

$[Sr(Adr)_2(H_2O)_2]Cl_2$. To an adrenaline solution (2 mmol; 0.366 g in 25 mL of absolute CH_3OH), and warming at (60 °C), $SrCl_2·2H_2O$ solution (1 mmol; 0.266 g) in 25 mL of absolute CH_3OH, was added with warming (60 °C) and stirring. The resulting precipitate was washed using absolute CH_3OH and dried *in vacuo* over anhydrous $CaCl_2$.

$[Ba(Adr)_2(H_2O)_6]Cl_2$. To solution of an adrenaline (2 mmol; 0.366 g in 25 mL of absolute CH_3OH), and warming at (60 °C), $BaCl_2·2H_2O$ solution (1 mmol; 0.244 g) in 25 mL of absolute CH_3OH, was added with warming (60 °C) and stirring. The resulting precipitate was washed using absolute CH_3OH and dried *in vacuo* over anhydrous $CaCl_2$.

Measurements

The C and H analyses were carried out at Cairo University, Egypt, in microanalysis unit, using a CHN 2400 instrument (Perkin Elmer, USA). For the soluble adrenaline complexity using conductivity meter Jenway 4010 $1.0×10^{-2}$ g/5 cm^3 the freshly prepared conductivities of solutions of dimethyl formamide (DMF) were detected. FT-IR spectra were recorded as potassium bromide discs on Bruker Spectrophotometer within range (4000–400 cm^{-1}), while Raman laser spectra of samples were recorded on Bruker FT-Raman with laser 50 mW. UV spectra of adrenaline

complexes in DMSO were measured on UV2 Unicam UV/Vis Spectrophotometer using a 1.0 cm path length quartz cell. The scanning electron microscopy (SEM) were recorded on Joel JSM-6390 equipment with an accelerating voltage of 20 KV images and energy dispersive X-ray detection (EDX) were measured. For adrenaline free ligand and its Ca^{2+} complexity on X 'Pert PRO PANanalytical X-ray powder diffraction, target copper with secondary monochromate the X-ray diffraction patterns was recorded.

Antibacterial and antifungal activities

The antimicrobial activity of the target compounds was measured using a modified Kirby-Bauer disc diffusion method [6]. Briefly, for fresh media in 10 mL, 100 µL of the best bacteria/fungi were grown till arriving 105 cells/mL count for fungi and approximately108 cells/mL for bacteria [7]. Onto agar plates 100 µL of suspension microbial corresponding to the broth was spread that were maintained. It should be selected isolated colonies of each organism that might be playing a pathogenic role from primary agar plates and then make a test by disc diffusion method for susceptibility [8-17]. Plates inoculated with filamentous fungi as *Aspergillus flavus* at 25 °C for 48 hours; Gram (+) bacteria, *Bacillus subtilis*, *Streptococcus pneumonia* and *Staphylococcus aureus*; *Escherichia coli* and *Pseudomonas aeruginosa* Gram (-) bacteria, were incubated at 35-37 °C for 1-2 days and *Candida albicans* as yeast incubated at 30 °C for 1-2 days, then measuring the inhabitation zones diameters in millimeters. Standard discs of tetracycline (antibacterial agent), amphotericin B (antifungal agent) served as positive controls for antimicrobial activity, but filter disc impregnated with 10 µL of solvent (distilled water, chloroform, DMSO) were used as a negative control.

RESULTS AND DISCUSSION

The measured molar conductivity, C and H analysis of adrenaline complexes with Mg^{2+}, Ca^{2+}, Ba^{2+}, and Sr^{2+} are given in Table 1. The C and H data for the synthesized complexes confirmed the molar ratio (M: Adr) 1:1 or 1:2 which are consisted with suggested structures $[Mg_2(Adr)_2(H_2O)_7]Cl_4$ and $[Ca(Adr)_2(H_2O)_2](H_2O)_4Cl_2$, $[Sr(Adr)_2(H_2O)_2]Cl_2$, and $[Ba(Adr)_2(H_2O)_6]Cl_2$. It is important to mention that adrenaline complexes were prepared at 60 °C, the reactions can be represented by the following stoichiometric equations:

$$2MgCl_2{\cdot}6H_2O + 2Adr \xrightarrow{60^oC} [Mg_2(Adr)_2(H_2O)_7]Cl_4 + 5H_2O \quad (1)$$

$$CaCl_2{\cdot}6H_2O + 2Adr \xrightarrow{60^oC} [Ca(Adr)_2(H_2O)_2](H_2O)_4Cl_2 \quad (2)$$

$$SrCl_2{\cdot}2H_2O + 2Adr \xrightarrow{60^oC} [Sr(Adr)_2(H_2O)_2]Cl_2 \quad (3)$$

$$BaCl_2{\cdot}6H_2O + 2Adr \xrightarrow{60^oC} [Ba(Adr)_2(H_2O)_6]Cl_2 \quad (4)$$

In DMF and dimethylsulfoxide, the complexes were soluble, have high melting points and air stable. Based on conductivity measurements in DMF using solutions of 10^{-2} g/5 mL, the complexes have variation data with an electrolytic nature (Table 1).

Conductance measurements

In DMF, the values of molar conductance for the adrenaline complexes of (10^{-2} g/5 mL solution) were 245, 228, 220 and 321 Ω^{-1} cm^2 mol^{-1} for $[Ca(Adr)_2(H_2O)_2](H_2O)_4Cl_2$, $[Sr(Adr)_2(H_2O)_2]Cl_2$, $[Ba(Adr)_2(H_2O)_6]Cl_2$ and $[Mg_2(Adr)_2(H_2O)_7]Cl_4$ complexes, respectively, confirming that complexes have an be electrolytic nature (Table 1). The mode of chelation of adrenaline

complexes can be deduced from conductivity measurements within the lower limits of their solubility. The degree of ionization of the complexes can be tested, and the liberation of the ions of the complexes in solution (for external coordination anions), the more molar conductivity value can be used and vice versa. From the conductivity measurements, $[Mg_2(Adr)_2(H_2O)_7]Cl_4$ complex is more electrolyte than $[Ca(Adr)_2(H_2O)_2](H_2O)_4Cl_2$, $[Sr(Adr)_2(H_2O)_2]Cl_2$ and $[Ba(Adr)_2(H_2O)_6]Cl_2$ complexes. For all adrenaline complexes the values of molar conductance, referring that all Cl anions are outside the sphere of chelation. This result was detected from the data of analysis of Cl^- which precipitated on addition of $AgNO_3$ solution, this experimental test is in a good match with CH data. All adrenaline complexes will have an electrolytic character which refer to presence of Cl^-. The stoichiometry of the complexes based on these data was established, which are consisted with the suggested general formulas.

Table 1. Elemental analysis and conductivity measurements for Adr metal complexes.

Complexes	M.Wt.	Elemental analysis (%) found (calcd.)				Λm ($\Omega^{-1}cm^2mol^{-1}$)
		C	H	N	M	
$[Mg_2(Adr)_2(H_2O)_7]Cl_4$	612.043	(35.32) 35.78	(6.58) 6.40	(4.57) 4.53	(3.97) 3.94	321
$[Ca(Adr)_2(H_2O)_2](H_2O)_4Cl_2$	585.490	(36.89) 36.46	(6.49) 6.65	(4.78) 4.76	(6.85) 6.81	245
$[Sr(Adr)_2](H_2O)_2]Cl_2$	560.968	(38.54) 38.61	(5.39) 5.32	(4.99) 4.95	(15.62) 15.60	228
$[Ba(Adr)_2](H_2O)_6]Cl_2$	610.688	(37.29) 37.37	(4.52) 4.57	(4.58) 4.51	(22.49) 22.42	220

Infrared and Raman spectra

The C_s is a point group represented free ligand molecular structure of adrenaline [18]. The (CH_2NHCH_3) secondary N-methyl amino group of adrenalines, act as point mass. There are forty-eight active IR and Raman spectra represented the modes of vibration for adrenaline that can be divided as Γ_{vib} = 33A' + 15A" of C_s point group which are shown in Figures 1 and 2. The interpretation of the adrenaline spectrum is difficult, due to it has low symmetry and high degree of complexity where 29 modes of vibrations only determined that divided into vibrations of 19A' and 10 A". Based on value and relative intensities for observed bands in similar complexity, for adrenaline, the interpretation of the vibrational frequencies has been discussed [19] (Table 2) as follows: for benzene ring the C–C aromatic vibrations have bands at 1525, 1496 cm^{-1} and at 1504 cm^{-1}. The aromatic C–H of substituted benzene ring has infrared vibration motion at 3035 and 3023 cm^{-1}, and at 3024 and 3047 cm^{-1} in Raman spectrum. The C–O alcohol group has infrared vibrational motion at 1157, 1175 and 1278 cm^{-1} owing to its vibrational stretching at 1200–1000 cm^{-1}, while at 1177 and 1288 cm^{-1} appeared in Raman spectrum. At 3351, 3368 and 3386 cm^{-1} Infrared spectrum of hydroxyl O–H group appeared. At 3000 cm^{-1} for infrared spectrum and at 2995 cm^{-1} in Raman spectrum referring to vibrational stretching of the C–H aliphatic moiety appeared. The ν(C–C) stretching vibrations motion of aliphatic part and ($CH–CH_2–NH–CH_3$) are appeared, respectively at 1205 and 1141 cm^{-1}. There are some vibrational bending deformation motions in free ligand, adrenaline as: in infrared 689, 649, 633 and 612 cm^{-1}; in Raman 655 cm^{-1} assigned to (δ(C–C–C)). In infrared 1350 and 1256 cm^{-1}; in Raman 1346 cm^{-1}: assigned to (δ (C–O–H)). In infrared 1105, 1082, 1061 and 1029 cm^{-1}; in Raman 1109, 1087 and 1035 cm^{-1}: assigned to (δ(C–C–H)). In infrared 598, 583, 535, 512, 504 and 483 cm^{-1}; in Raman 605, 537 491 and cm^{-1}: assigned to (δ(C–C–O)).

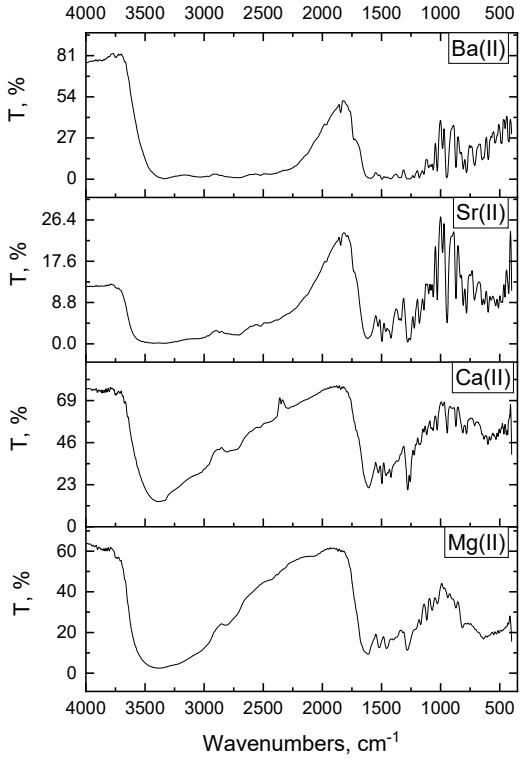
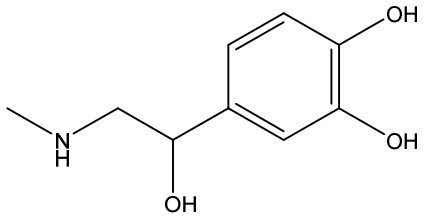


Figure 1. Infrared spectra of $[Mg_2(Adr)_2(H_2O)_7]Cl_4$, $[Ca(Adr)_2(H_2O)_2](H_2O)_4Cl_2$, $[Sr(Adr)_2(H_2O)_2]Cl_2$, and $[Ba(Adr)_2(H_2O)_6]Cl_2$ complexes.



Scheme 1. Structure of adrenaline.

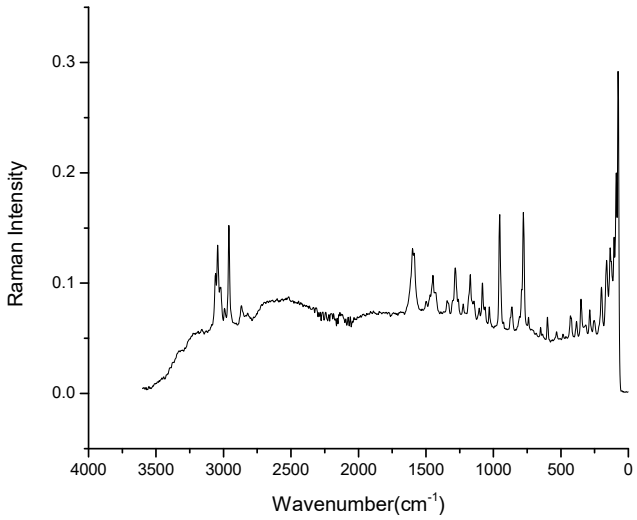


Figure 2. Raman spectra of free adrenaline ligand.

Table 2a. Assignments of infrared frequencies (cm^{-1}) for adrenaline and its complexes.

Assignments	Compounds				
	Adr	Mg(II)	Ca(II)	Sr(II)	Ba(II)
ν(O–H)	3368 3368 3351	3377 3018	3377 3059	3444 3035	3336 3100
ν(C–H); Ar ν(N–H)	3035 3023	2813	2813	3035	3019
ν(C–H); Alip	3000	2813	2813	2707	2701
ν(C–C); Ar δ(N–H)	1525 1496	1604 1522 1461	1604 1522 1461	1611 1491 1422	1779 1593 1491
δ(C–OH)	1350 1256	1276 1244	1276	1331	1348 1266
ν(C–O)	1278 1157 1175	--	--	--	--
ν(C–C); CH_2NHCH_3 ν(C–O)	1205 1141	1276 1163	1225 1122	1165 1117	1165
δ(C–C–H)	1105 1082 1061 1029	1112 1070 1021 938 866 815	1061 948 876 815 784 712	1062 1023 983 943 814 784	1030 979 948 866 815 744
δ(C–C–C)	689 649 633 612	640	631	644	651

δ(C–C–O)	598 583 535 512 483	548	518 467	594 515	599

Table 2b. Assignments of Raman frequencies (cm^{-1}) for adrenaline.

Frequencies (cm^{-1})	Tentative assignments
--	ν(O–H)
3047 3024	ν(C–H); Ar ν(N–H)
2995	ν(C–H); Alip
1504	ν(C–C); Ar δ(N–H)
1346	δ(C–OH)
1288 1177	ν(C–O)
--	ν(C–C); CH_2NHCH_3 ν(C–O)
1109 1087 1035	δ(C–C–H)
655	δ(C–C–C)
605 537 491	δ(C–C–O)

By comparing between free adrenaline ligand and its Mg^{2+}, Ca^{2+}, Sr^{2+} and Ba^{2+}complexes using IR and Raman laser spectra, we conclude that, there are a shift to lower wavenumbers for bands due to ν(O–H), ν(C–O) and δ(C–O–H) as decreasing the intensities, confirming that the coordination of heavy metal ions towards adrenaline carried out through two OH catechol moiety of phenolic groups. For adrenaline complexity, there are a sharp broadening with a distorted in the vibrational stretching bands in Raman spectra for Mg^{2+}, Ca^{2+}, Sr^{2+}, and Ba^{2+} (Figure 2), which can be explained based on the overlap of fluorescence which, even when very weak, can overwhelm the inherently weak Raman scattering signal where Raman analysis of fluorescent materials and compounds is a challenging task experimentally [20, 21]. Based on the above discussion we can conclude that adrenaline act as a bidentate ligand and can form a stable chelating structure through coordination of the phenolic oxygen's groups.

UV spectra

There are two essential UV bands observed for free ligand hormone adrenaline (Adr) appeared at 299 and 376 nm (Figure 3a) due to π→π*, n→π* transitions, r, for aromatic ring, Ar-OH, OH, –NH secondary amine and CH_3, with wavenumbers more or less shifting in the adrenaline complexes spectra (Figure 3b); $[Sr(Adr)_2(H_2O)_2]Cl_2$ and $[Ba(Adr)_2(H_2O)_6]Cl_2$ (298 and 318 nm), $[Mg_2(Adr)_2(H_2O)_7]Cl_4$ (291 and 337 nm), $[Ca(Adr)_2(H_2O)_2](H_2O)_4Cl_2$ (294 and 453 nm), confirming the coordination of ions of divalent heavy metal with adrenaline ligand. There are an observed band at 299 nm assigned to free ligand adrenaline π→π* transitions, which hypochromic shift in according to the coordination with metal, confirming metal adrenaline complexes formation. Above 501 nm, peaks appear for $[Mg_2(Adr)_2(H_2O)_7]2Cl_2$ complex is due to metal-ligand charge–transfer complex MLCT.

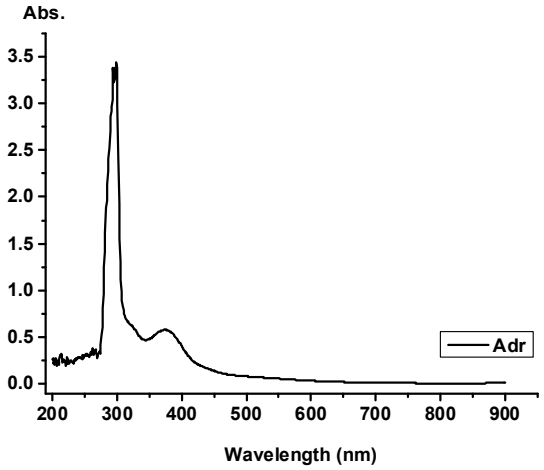


Figure 3a. Electronic spectrum of adrenaline free ligand.

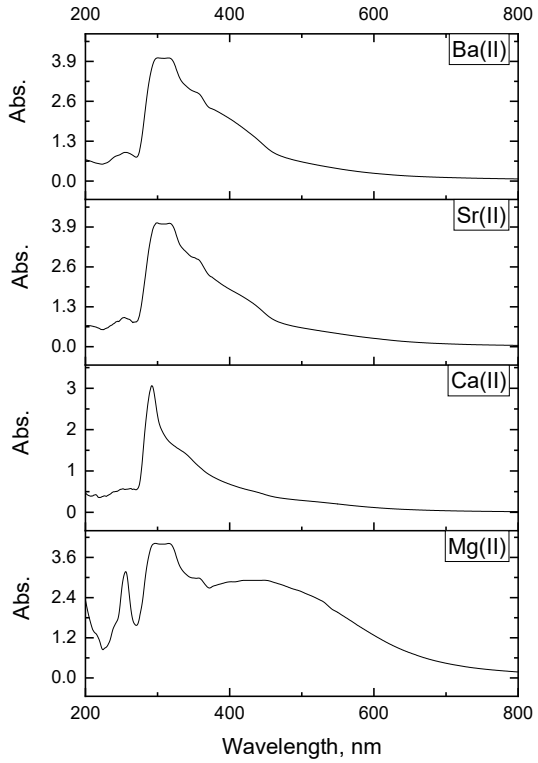


Figure 3b. Electronic spectra of $[Mg_2(Adr)_2(H_2O)_7]Cl_4$, $[Ca(Adr)_2(H_2O)_2](H_2O)_4Cl_2$, $[Sr(Adr)_2(H_2O)_2]Cl_2$ and $[Ba(Adr)_2(H_2O)_6]Cl_2$ complexes.

X–ray

For free adrenaline ligand and $[Ca(Adr)_2(H_2O)_2](H_2O)_4Cl_2$,the X–ray powder diffraction patterns are in Figures 4a and 4b, respectively. Based on these patterns, we can conclude that there are semi crystalline systems that are well. From XRD patterns by applying FWHM of the peak's characteristic through Deby-Scherrer equation, the size of the crystallite of complexity could be calculated. Where, size of particle of the crystal gain is symbol D, the value 0.94 for Cu grid is a constant K, 1.5406 Å is the X-ray wavelength λ, Bragg diffraction angle is θ and the peak integral width is β. The size particle was calculated based on to the value highest intensity of comparing to other peaks. These information data gave an amorphous structure (Figure 4b).

$$D = K\lambda/\beta Cos\theta \quad (5)$$

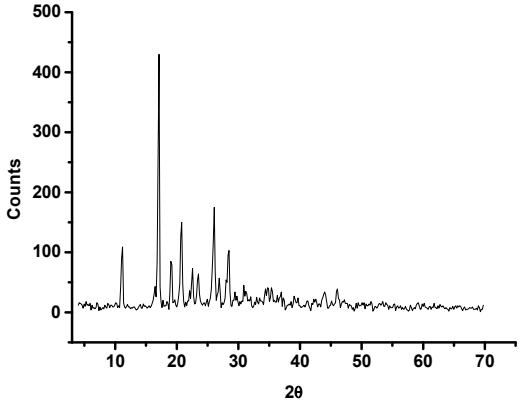


Figure 4a. X-ray spectrum of adrenaline powder diffraction.

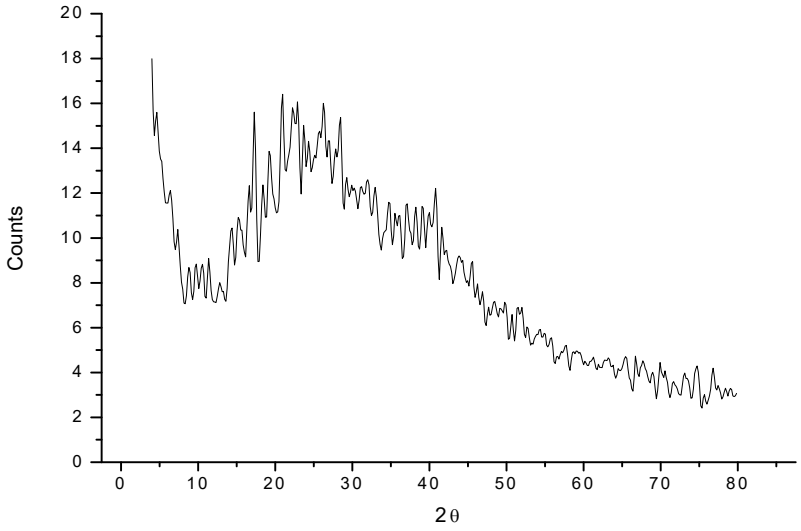


Figure 4b. Spectrum of X-ray powder diffraction $[Ca(Adr)_2(H_2O)_2](H_2O)_4Cl_2$ complex.

SEM and EDX studies

The simple tool of scanning electron microscopy explains aspects of microscopic of physical behavior of adrenaline complexes (Figure 5). This technique is not considered a basic method to elucidate formation of complex, but it can be taken as a guide for the presence of a single component in the prepared complexity. The SEM for $[Sr(Adr)_2(H_2O)_2]Cl_2$ and $[Ba(Adr)_2(H_2O)_6]Cl_2$ complexes gave a homogenous feature products with irregular structures. The elemental analysis data collected by EDX analysis for the prepared complexes between adrenaline and metal ions are listed in Table 3. The peaks of EDX profile of complexes (Figure 5b-e) confirmed the presence of all elements which present in adrenaline complexes $[Mg_2(Adr)_2(H_2O)_7]Cl_4$, $[Ca(Adr)_2(H_2O)_2](H_2O)_4Cl_2$, $[Sr(Adr)_2(H_2O)_2]Cl_2$ and $[Ba(Adr)_2(H_2O)_6]Cl_2$ that proving the suggested formulas.

Table 3. Percentage composition of elements of the synthesized complexes observed by the EDX analysis.

Complex	Element percentage %			
	M	C	O	Cl
$[Mg_2(Adr)_2(H_2O)_7]Cl_4$	3.90	36.00	39.41	11.55
$[Ca(Adr)_2(H_2O)_2](H_2O)_4Cl_2$	6.75	36.38	32.73	12.16
$[Sr(Adr)_2](H_2O)_2]Cl_2$	15.49	38.65	22.80	12.58
$[Ba(Adr)_2](H_2O)_6]Cl_2$	22.46	37.30	21.00	11.67

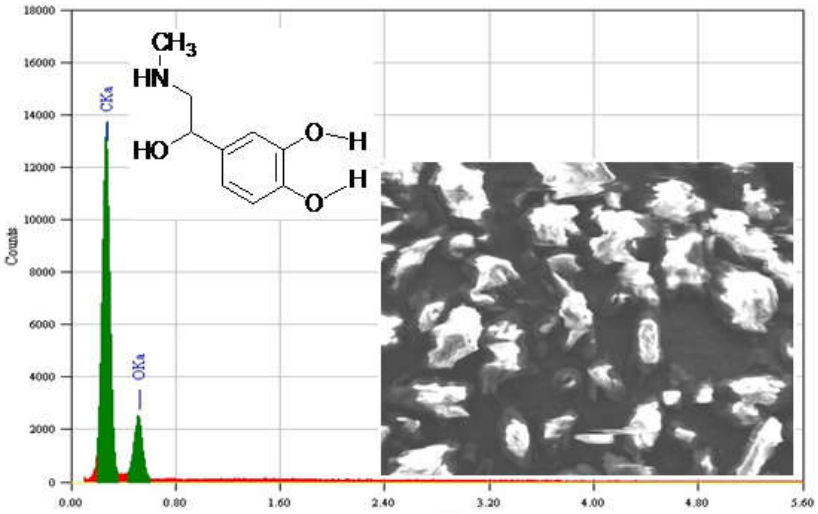


Figure 5a. EDX spectrum, SEM photo and structure of adrenaline free ligand.

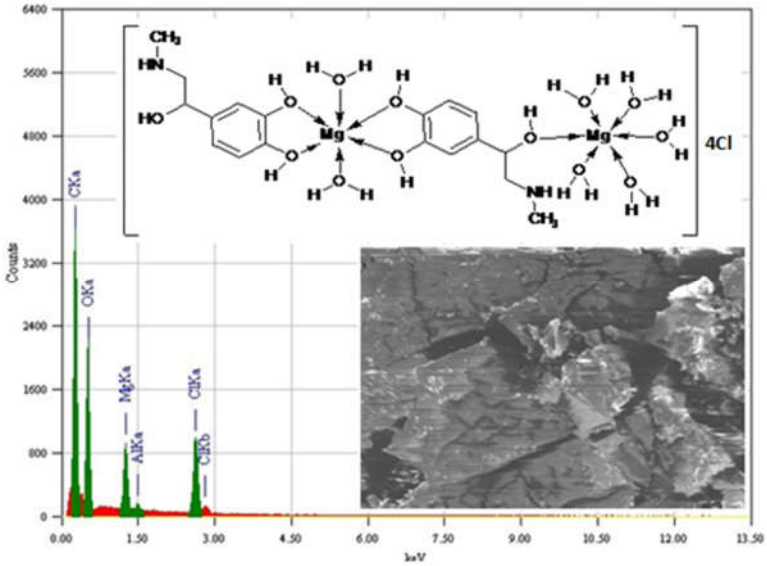


Figure 5b. EDX spectrum, SEM photo and structure of $[Mg_2(Adr)_2(H_2O)_7]Cl_4$ complex.

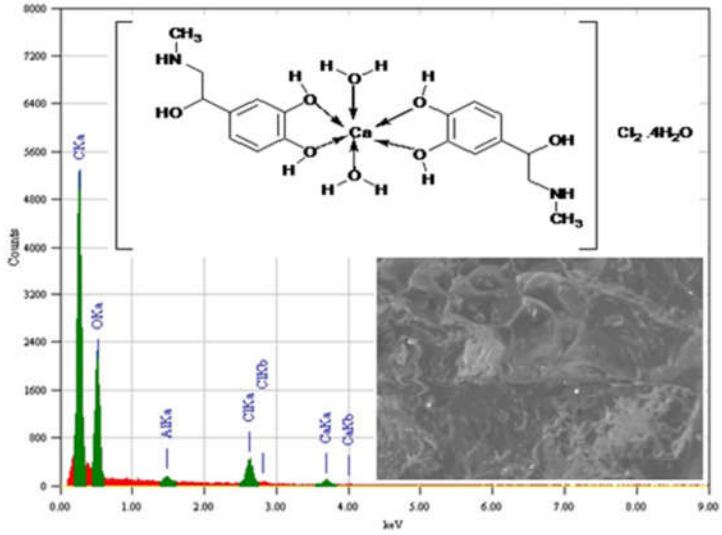


Figure 5c. EDX spectrum, SEM photo and structure of $[Ca(Adr)_2(H_2O)_2](H_2O)_4Cl_2$ complex.

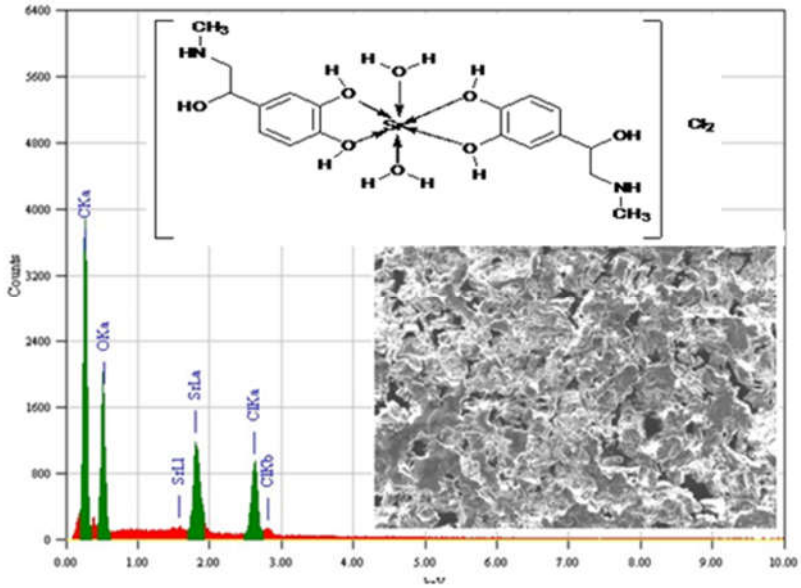


Figure 5d. EDX spectrum, SEM photo and structure of $[Sr(Adr)_2(H_2O)_2]Cl_2$ complex.

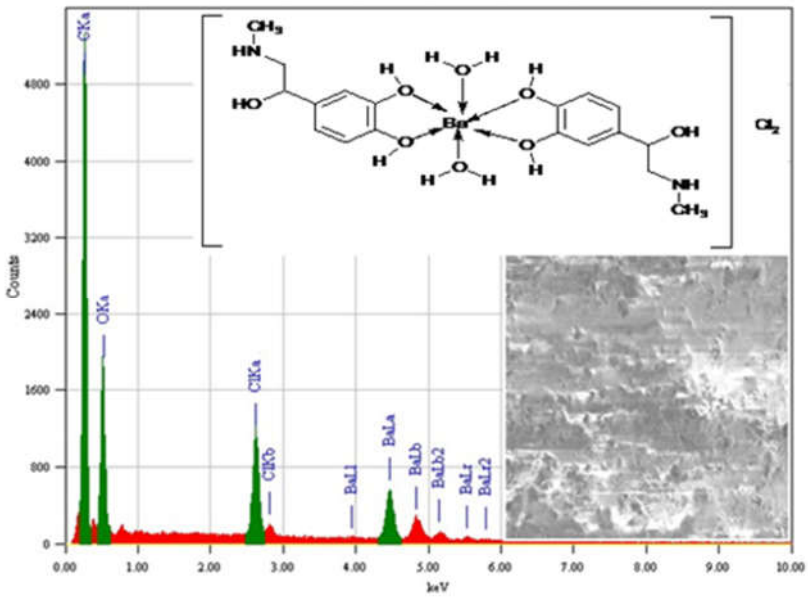


Figure 5e. EDX spectrum, SEM photo and structure of $[Ba(Adr)_2(H_2O)_6]Cl_2$ complex.

Biological evaluation

For adrenaline complexity, the antibacterial and anti-fungal activities against (*Bacillus subtilis, Streptococcus pneumonia* and *Staphylococcus aureus*) gram-positive and (*Escherichia coli* and *Pseudomonas aeruginosa*) gram-negative and two fungus strains of (*Aspergillus flavus* and *Penicillium*). From the diffusion tests agar disc, result of adrenaline complexes for antimicrobial activities are presented in Table 4, and illustrated in Figure 6a and b. The inhibition zone diameters

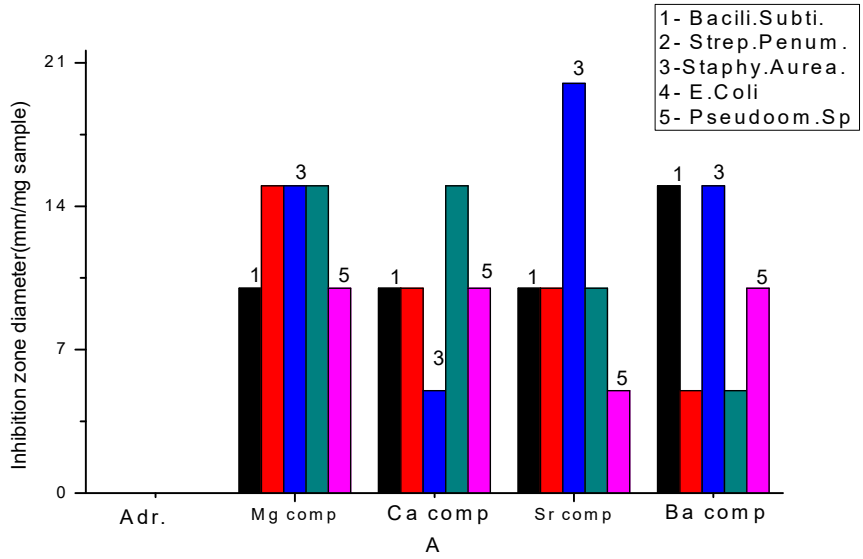


Figure 6a. Adrenaline and their complexity inhibition zone diameter against gram (+) and gram (-) bacteria.

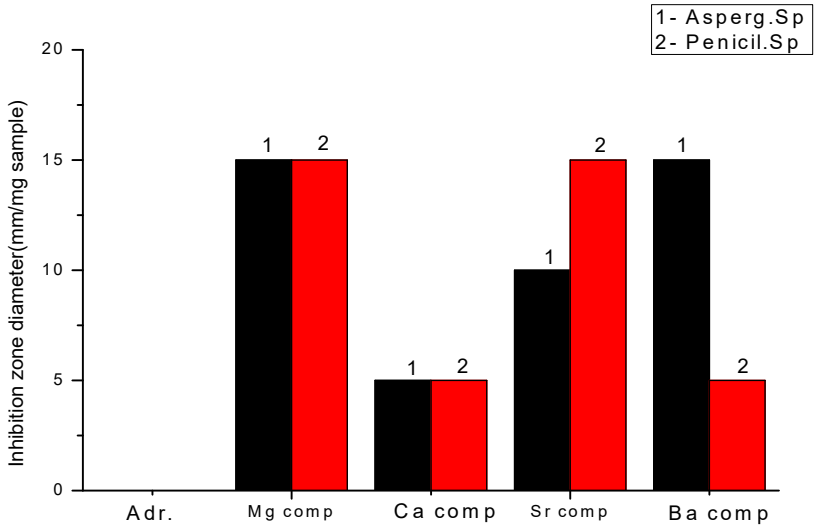


Figure 6b. Adrenaline and their complexity inhibition zone diameter against *Aspergillus niger* and *Penicillium sp.* fungi.

(in mm) for the target compounds against gram-positive bacteria (*B. subtilis* and *S. aureus*) and gram negative bacteria (*E. coli* and *P. aeruginosa*) give 36, 30, 31 and 35 mm, respectively, but the amphotericin drug B standard against *Aspergillus flavus* and *Candida albicans* gave 18 and 19, respectively. Table 4 explained, free ligand adrenaline $[Mg_2(Adr)_2(H_2O)_7]Cl_4$, $[Ca(Adr)_2(H_2O)_2](H_2O)_4Cl_2$, $[Sr(Adr)_2(H_2O)_2]Cl_2$ and $[Ba(Adr)_2(H_2O)_6]Cl_2$ complexes (10, 15, 15, 15,10,15, and 15), (10, 10, 5, 15, 10, 5, and 5), (10, 10, 20, 10, 5,10, and 15), (15, 5, 15, 5, 10,15, and 5), respectively, for *Bacillus subtilis*, *Streptococcus penumonia, Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Aspergillus niger* and *Penicillium sp*. All complexes were found to be efficient antimicrobial agents.

Table 4. Adrenaline and its complexity inhibition zone diameter (mm/mg sample).

Sample		Inhibition zone diameter (mm / mg sample)						
		B.subtilis (G^+)	*S. penumonia* (G^+)	*S. aureas* (G^+)	*E. coli* (G^-)	*P. aeruginosa* (G^-)	*niger* (Fungus)	*P. sp.* (Fungus)
Control: DMSO		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Standard	Tetracycline antibacterial agent	36	31	35	30	-	--	--
	Amphotericin B antifungal agent	--	--	--	--	-	18	19
Adr		0	0	0	0	0	0	0
Mg(II)		10	15	15	15	10	15	15
Ca(II)		10	10	5	15	10	5	5
Sr(II)		10	10	20	10	5	10	15
Ba(II)		15	5	15	5	10	15	5

CONCLUSION

Adrenaline (Adr) react with chlorides of Mg^{2+}, Ca^{2+}, Sr^{2+}, and Ba^{2+} to yield metal ion complexes of definite composition. These compounds were characterized by elemental analyses, molar conductivity, magnetic susceptibility measurements, mid infrared, Raman laser, UV-Vis., ^1H–NMR spectra, X-ray powder diffraction, scanning electron microscopy and energy-dispersive X-ray spectroscopy (EDX) investigations. The complexes are found to have the formulae $[Ca(Adr)_2(H_2O)_2](H_2O)_4Cl_2$, $[Sr(Adr)_2(H_2O)_2]Cl_2$, $[Ba(Adr)_2(H_2O)_6]Cl_2$ and $[Mg_2(Adr)_2(H_2O)_7]Cl_4$, respectively with the molar ratio of 1:1 (M:L). *In vitro* antibacterial activity of adrenaline chelates was tested against gram-positive (*Bacillus subtilis*, *Streptococcus pneumonia* and *Staphylococcus aureus*) and gram-negative (*Escherichia coli* and *Pseudomonas aeruginosa*) bacteria, and two strains of fungus (*Aspergillus niger* and *Penicillium*). The antimicrobial data revealed that the metal chelates are more effective than the adrenaline free ligand.

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