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Template synthesis of macrocyclic complexes of Co(II), Ni(II), Cu(II), Zn(II) and Cd(II): spectroscopic, antibacterial and antifungal studies

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Abstract: A new series of macrocyclic complexes of the type $[M(C_{17}H_{14}N_4O_2)X_2]$, where M = Co(II), Ni(II), Cu(II), Zn(II) or Cd(II) and X = Cl^-, NO_3^- or CH_3COO^-, was synthesized by the condensation reaction of malonyldihydrazide with benzil in the presence of divalent metal ions. The complexes were characterized with the aid of elemental analyses, conductance measurements, magnetic susceptibilities, electronic, NMR and infrared spectral studies. On the basis of these studies, a six-coordinate distorted octahedral geometry, in which two nitrogen and two carbonyl oxygen atoms are suitably placed for coordination towards metal ion, is proposed for all the complexes. The complexes were tested for their *in vitro* antibacterial activity and antifungal activities. The minimum inhibitory concentration shown by these complexes were compared with the minimum inhibitory concentration shown by standard drugs.

Keywords: macrocyclic complexes; MIC; antibacterial; antifungal.

INTRODUCTION

During recent years, macrocyclic chemistry has attracted much attention and has become a growing class of research. Macrocyclic complexes are of great importance due to their resemblance to many naturally occurring macrocycles, such as porphyrins and cobalamines. A number of nitrogen donor macrocyclic derivatives have long been used in analytical, industrial and medical applications.[1–3] Macrocyclic metal complexes of lanthanides, *e.g.*, Gd^{3+}, are used as MRI contrast agents.[4] Macrocyclic metal chelating agents are useful for detecting tumor lesions.[5] The chemistry of macrocyclic complexes is also important due to their use as dyes and pigments[6] as well as NMR shift reagents.[3] Furthermore, some macrocyclic complexes have been found to exhibit potential antibacterial activities.[7]

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Prompted by these facts, in the present paper, a series of macrocyclic complexes of Co(II), Ni(II), Cu(II), Zn(II) and Cd(II) obtained by template condensation reaction of malonyldihydrazide and benzil are reported. The complexes were characterized with the help of various physico-chemical techniques, such as elemental analyses, IR, NMR and electronic spectral studies and magnetic susceptibility and molar conductance measurements. These macrocyclic complexes were also screened for their *in vitro* antibacterial and antifungal activity.

EXPERIMENTAL

Synthesis of the complexes

All the reported macrocyclic complexes were prepared by the template method. To a stirring methanolic solution (≈50 cm^3) of malonyldihydrazide (10 mmol) was added divalent cobalt, nickel, copper, zinc and cadmium salts (Cl^-, NO_3^-, CH_3COO^-) (10 mmol) dissolved in a minimum quantity of methanol (20 cm^3). The resulting solution was refluxed for 0.5 h. Then benzil (10 mmol) dissolved in ≈20 cm^3 methanol was added to the refluxing mixture and the refluxing was continued for 6–8 h. On overnight cooling, light colored complexes formed, which were filtered, washed with methanol, acetone, and ether and dried *in vacuo* (yield: 55––60 %). The complexes were soluble in DMF and DMSO, but were insoluble in water. They were found to be thermally stable up to ≈250 °C and then decomposed.

In vitro *antibacterial assay*

Primary screening. The antibacterial activities of the newly synthesized compounds were evaluated by the agar well diffusion assay technique against two Gram-positive bacteria, *i.e.*, *Bacillus subtilis* (MTCC 8509) and *Bacillus stearothermophilus* (MTCC 8508), and two Gram--negative bacteria, *i.e.*, *E. coli* (MTCC 51) and *Pseudomonas putida* (MTCC 121). The bacterial cultures were maintained on the nutrient agar media by sub-culturing them on the fresh slants after every 4–6 weeks and incubating them at the appropriate temperature for 24 h. All stock cultures were stored at 4 °C. For the evaluation of antimicrobial activity of the synthetic compounds, suspension of each test microorganism was prepared. The turbidity of each suspension was adjusted to 0.5 McFarland units by suspending the cultures in sterile distilled water. The size of final inoculum was adjusted to 5×10^7 cfu/ml.

Agar medium (20 ml) was poured into each Petri plate and plates were swabbed with broth cultures of the respective micro-organisms and kept for 15 min for adsorption to take place. Using a punch, ≈8 mm diameter wells were bored in the seeded agar plates and 100 µl of each test compound reconstituted in DMSO was added into the wells. DMSO was used as the control for all the test compounds. After holding the plates at room temperature for 2 h to allow diffusion of the compounds into the agar, the plates were incubated at 37 °C for 24 h. The antibacterial activity was determined by measuring the diameter of the inhibition zone. The entire tests were made in triplicates and the mean of the diameter of inhibition was calculated. The antimicrobial activities of the complexes were compared against the standard drugs.

Minimum inhibitory concentration. Nutrient broth adjusted to pH 7.0 was used for the determination of the *MIC* of synthesized complexes.[8] The *MIC* is the lowest concentration of the antimicrobial agents that prevents the development of visible growth of a micro-organism after overnight incubation. The inoculum of the test microorganisms were prepared using 16 h old cultures adjusted by reference to the 0.5 McFarland standards (10^8 cells/ml).[9] These cultures were further diluted up to 10-fold with nutrient broth to obtain an inoculum size of 1.2×10^7 CFU/ml. A positive control (containing inoculum but no compound) and a negative

control (containing compound but no inoculum) were also prepared. A stock solution of 4 mg/ml of each complex was prepared in DMSO and further appropriately diluted to obtain a final concentration ranging from 250 to 0.03 µg/ml.[10] The requisite quantity of the antifungal drug (cyclohexamide) was added to the broth to obtain its desirable final concentration of 100 µg/ml. Separate flasks was taken for each test dilution. To each flask was added the 100 µl of inoculum. Then an appropriately diluted test sample was added to each flask having broth and microbial inoculum. The contents of the flask were mixed and incubated for 24 to 48 h at 37 °C. The test bacterial cultures were spotted in a predefined pattern by aseptically transferring 5 µl of each bacterial culture onto the surface of the solidified agar-agar plates and incubated at 37 °C for 24 h for determining the *MIC* value.

In vitro *antifungal activity*

Potato dextrose medium (PDA) was prepared in a flask and sterilized. To check the growth of the bacterial culture in the medium, the requisite quantity of a standard antibiotic (ampicillin) was added, so as to obtain their desired final concentration of 100 µg/ml of the medium. Test samples were prepared in different concentrations (10, 50 and 100 µg/ml) in DMSO and 200 µl of each sample was spread on PDA medium contained in sterilized Petri plates. Mycelial discs taken from the standard cultures (*Aspergillus flavus* and *A. niger*) of fungi, were grown on PDA medium for 5–7 days. These cultures were used for aseptic inoculation in the sterilized Petri dish. Standard cultures, inoculated at 28±1 °C, were used as the control. The efficacy of each sample was determined by measuring the radial mycelial growth. The radial growth of the colony was measured in two directions at right angle to each other, and the average of two replicates was recorded in each case. Data were expressed as percent inhibition over the control from the size of the colonies. The percent inhibition was calculated using the formulae: %Inhibition = $((C–T)/C)\times100$, where C is the diameter of the fungus colony in the control plate after 96 h incubation and T is the diameter of the fungus colony in the tested plate after the same incubation period.

RESULTS AND DISCUSSION

The analytical data suggest the formula of the macrocyclic complexes as: $[M(C_{17}H_{14}N_4O_2)X_2]$, where M = Co(II), Ni(II), Cu(II) Zn(II) or Cd(II) and X = = $Cl^–$, $NO_3^–$ or $CH_3COO^–$. The test for the anions was positive after decomposition of the complexes, indicating their presence inside the coordination sphere (Fig. 1). The conductivity measurements (10–20 S cm^2 $mol^{–1}$) in DMSO indicate them to be non-electrolytic in nature.[11] All complexes give satisfactory elemental analyses results, as shown in Table I.

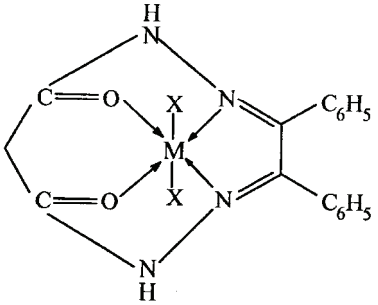

Fig. 1. Proposed structure of the synthesized complexes, where, M = Co(II), Ni(II), Cu(II), Zn(II) or Cd(II); X = Cl^-, NO_3^- or CH_3COO^-.

TABLE I. Analytical data of divalent Co, Ni, Cu, Zn and Cd complexes derived from malonyldihydrazide and benzil

No.	Complex	Found (Calcd.), %				Color	MW
		M	C	H	N		
1	$[Co(C_{17}H_{14}N_4O_2)Cl_2]$	13.27 (13.53)	46.15 (46.78)	3.09 (3.21)	12.37 (12.84)	Reddish brown	436
2	$[Co(C_{17}H_{14}N_4O_2)(NO_3)_2]$	11.97 (12.06)	41.42 (41.71)	2.76 (2.86)	17.12 (17.17)	Reddish brown	489
3	$[Co(C_{17}H_{14}N_4O_2)(OAc)_2]$	12.03 (12.21)	52.06 (52.17)	4.11 (4.14)	11.28 (11.59)	Dark brown	483
4	$[Ni(C_{17}H_{14}N_4O_2)Cl_2]$	13.19 (13.33)	46.85 (46.89)	3.19 (3.21)	12.64 (12.87)	Dark brown	435
5	$[Ni(C_{17}H_{14}N_4O_2)(NO_3)_2]$	11.79 (11.88)	41.58 (41.80)	2.73 (2.86)	17.24 (17.21)	Green	488
6	$[Ni(C_{17}H_{14}N_4O_2)(OAc)_2]$	11.91 (12.03)	52.07 (52.28)	4.08 (4.14)	11.42 (11.61)	Green	482
7	$[Cu(C_{17}H_{14}N_4O_2)Cl_2]$	14.13 (14.31)	46.17 (46.36)	3.04 (3.18)	12.51 (12.72)	Brown	440
8	$[Cu(C_{17}H_{14}N_4O_2)(NO_3)_2]$	12.68 (12.77)	41.22 (41.37)	2.75 (2.83)	17.01 (17.03)	Yellow	493
9	$[Cu(C_{17}H_{14}N_4O_2)(OAc)_2]$	12.52 (12.93)	51.29 (51.74)	4.03 (4.10)	11.17 (11.49)	Dark green	487
10	$[Zn(C_{17}H_{14}N_4O_2)(OAc)_2]$	13.21 (13.29)	51.39 (51.53)	4.02 (4.08)	11.23 (11.45)	Dark green	489
11	$[Cd(C_{17}H_{14}N_4O_2)(OAc)_2]$	20.74 (20.89)	46.89 (47.01)	3.62 (3.73)	10.21 (10.44)	Reddish Orange	536

IR Spectra

In the IR spectrum of malonyldihydrazide, a pair of bands corresponding to $\nu(NH_2)$ was present at ≈3210 and ≈3270 cm^{-1} but was absent in the IR spectra of all the complexes.[12] However, a single broad medium band at ≈3360–3450 cm^{-1} was observed in the spectra of all the complexes, which may be assigned to ν(NH).[13,14] A strong peak at ≈1660cm^{-1} in the IR spectrum of malonyldihydrazide was assigned to the >C=O group of the CONH moiety. This peak was shifted to a lower frequency (≈1620–1640 cm^{-1})[15,16] in the spectra of all the complexes, suggesting the coordination of the oxygen of the carbonyl group with the metal. Furthermore, no strong absorption band was observed near 1700 cm^{-1} in the IR spectra of all complexes as was observed in spectrum of benzil. This indicates the absence of >C=O groups of the benzil moiety in the complexes. These facts confirm the condensation of carbonyl groups of benzil and the amino groups of malonyldihydrazide.[17,18] The IR spectra of the complexes showed a new strong absorption band in the region ≈1595–1610 cm^{-1}, which may be attributed due to ν(C=N).[19,20] These results provide strong evidence for the formation of the macrocyclic frame.[21] The lower value of ν(C=N) indicates coordination of

the nitrogens of azomethine to the metal.[22] The bands present at ≈1300–1000 cm^{-1} were assigned to ν(C–N) vibrations. The bands presents at ≈3080 cm^{-1} may be assigned to ν(C–H) vibrations of the benzil moiety.

The far IR spectra showed bands in the region ≈420–450 cm^{-1} corresponding to ν(M–N) vibrations in all the complexes.[23] The presence of these bands support the fact concerning the coordination of the azomethine nitrogen with the metal.[24] The bands present at ≈310–315 cm^{-1} were due to ν(M–Cl)[23] and the bands present at ≈210–240 cm^{-1} in all nitrate complexes were due to ν(M–O).[23]

NMR Spectra

The ^{1}H-NMR spectrum of the Zn(II) complex showed a broad singlet at 8.45 ppm due to protons of the –CONH moiety.[13,25] A singlet peak at 2.43 ppm may be due to $–CH_2$ protons.[15] The multiplets in the region 6.9–7.5 ppm may be assigned to aromatic protons.[26]

Magnetic measurements and electronic spectra

Cobalt complexes. The magnetic moments of the cobalt complexes were measured at room temperature and lay in the range 4.85–4.90 μ_B which corresponds to 3 unpaired electrons. The solution spectra of the cobalt(II) complexes exhibited absorption in the region 8100–9160 (ν_1), 12500–15700 (ν_2) and 18600––20500 cm^{-1} (ν_3), respectively. The spectra resemble those reported for octahedral complexes.[27] Thus, the various bands can be assigned to: $^4T_{1g} \rightarrow {}^4T_{2g}(F)$, ($\nu_1$); $^4T_{1g} \rightarrow {}^4A_{2g}(F)$, ($\nu_2$) and $^4T_{1g} \rightarrow {}^4T_{1g}(P)$, ($\nu_3$), respectively. It appears that the symmetry of these complexes was not idealized O_h, but distorted octahedral. The assignment of the first spin-allowed band seems plausible since the first band appears at approximately half the energy of the visible band.[28]

Nickel complexes. The magnetic moments of the nickel complexes at room temperature lay in the range 2.91–2.95 μ_B, showing an octahedral environment around the Ni(II) ion in all complexes. The solution spectra of the Ni(II) complexes exhibited a well-discernable band with a shoulder on the low energy side. The other two bands, generally observed in the region at *ca*. 16,570–17,240 cm^{-1} (ν_2), and 26,860–28000 cm^{-1} (ν_3), were assigned to $^3A_{2g} \rightarrow {}^3T_{1g}(F)$ (ν_2) and $^3A_{2g} \rightarrow {}^3T_{1g}(P)$ (ν_3), respectively. The first two bands resulted from the splitting of one band, ν_1, and are in the range ≈9700–10000 and 11800–12440 cm^{-1}, which can be assigned to $^3B_{1g} \rightarrow {}^3E_g$ and $^3B_{1g} \rightarrow {}^3B_{2g}$, assuming the effective symmetry to be D_{4h} (component of $^3T_{2g}$ in O_h symmetry).[28] The intense higher energy band at *ca*. 34000 cm^{-1} may be due to a π–π* transition of the (C=N) group. Various bands do not follow any regular pattern and seem to be anion independent. The spectra are consistent with the distorted octahedral nature of these complexes.

Copper complexes. The magnetic moments of the copper complexes lay in the range 1.77–1.82 μ_B. The electronic spectra of the copper complexes exhibited

bands in the region ≈17780–19000 cm^{-1} with a shoulder on the low energy side at ≈14600–16000 cm^{-1}, which showed that these complexes were distorted octahedral.[27,28] Assuming tetragonal distortion in the molecule, the d-orbital energy level sequence for these complexes may be: $x^2 - y^2 > z^2 > xy > xz > yz$ and the shoulder can be assigned to $z^2 \rightarrow x^2 - y^2$ ($^2B_{1g} \rightarrow {}^2B_{2g}$) and the broad band contained both the $xy \rightarrow x^2 - y^2$ ($^2B_{1g} \rightarrow {}^2E_g$) and $xz, yz \rightarrow x^2 - y^2$ ($^2B_{1g} \rightarrow {}^2A_{2g}$) transitions.[29] The band separation of the spectra of the complexes was of the order 2500 cm^{-1}, which is consistent with the proposed geometry of the complexes.[29] Therefore, it may be concluded that all the complexes formed by the macrocycles with Cu(II) metals are distorted octahedral.

Biological results and discussion

In this study, all the chemically synthesized complexes were evaluated against Gram-positive and Gram-negative bacteria. The minimum inhibitory concentrations (*MIC*) of these synthetic complexes were determined by the method given by Andrews.[30] The standard antibiotic, namely streptomycin and chloramphenicol were used for comparison with the antibacterial activities shown by these complexes. All the complexes of the tested series possessed some antibacterial activity against Gram-positive bacteria and Gram-negative bacteria (Table II). Complexes **2**, **3** and **9** exhibited good activities against all the tested bacterial strains with a zone of inhibition ranging from 29 to 47 mm. Complex **6** showed the highest zone of inhibition (47 and 44) against *E. coli* and *P. putida* (Table II).

TABLE II. *In vitro* antibacterial activity of the complexes obtained by the agar well diffusion method for a concentration of 100 μg/ml

No.	Complex	Diameter of the zone of growth inhibition[a], mm			
		B. subtilis (MTCC 8509)	*B. stearothermophilus* (MTCC 8508)	*E. coli* (MTCC 51)	*P. putida* (MTCC 121)
1	$[Co(C_{17}H_{14}N_4O_2)Cl_2]$	17	13	16	12
2	$[Co(C_{17}H_{14}N_4O_2)(NO_3)_2]$	37	29	37	40
3	$[Co(C_{17}H_{14}N_4O_2)(OAc)_2]$	40	37	32	36
4	$[Ni(C_{17}H_{14}N_4O_2)Cl_2]$	14	17	14	20
5	$[Ni(C_{17}H_{14}N_4O_2)(NO_3)_2]$	14	18	21	14
6	$[Ni(C_{17}H_{14}N_4O_2)(OAc)_2]$	36	36	47	44
7	$[Cu(C_{17}H_{14}N_4O_2)Cl_2]$	27	26	25	28
8	$[Cu(C_{17}H_{14}N_4O_2)(NO_3)_2]$	10	17	17	17
9	$[Cu(C_{17}H_{14}N_4O_2)(OAc)_2]$	32	36	37	33
10	$[Zn(C_{17}H_{14}N_4O_2)(OAc)_2]$	29	27	27	24
11	$[Cd(C_{17}H_{14}N_4O_2)(OAc)_2]$	11	10	12	11
Chloramphenicol		64	77	65	71
Streptomycin		63	77	79	82

[a]Mean of three replicates

Based on the *MIC* values shown by these complexes against bacteria, complexes **2**, **3** and **6** were found to be the most effective by showing an *MIC* of 8 μg/ml for *P. putida*, *B. subtilis* and *E. coli*, respectively (Table III). In the whole series, the *MIC* of complexes **3**, **6** and **9** was found to be 32 μg/ml for *B. stearothermophilus*, whereas the *MIC* of complexes **2** and **6** was found to be 32 μg/ml for *B. subtilis.* The complexes **2** and **9** also showed an *MIC* of 32 μg/ml for *E. coli* (Table III).

TABLE III. Minimum inhibitory concentration (*MIC*, μg/ml) shown by the complexes against the test bacteria obtained by the agar dilution assay

No.	Complex	*B. subtilis* (MTCC 8509)	*B. stearothermophilus* (MTCC 8508)	*E. coli* (MTCC 51)	*P. putida* (MTCC 121)
1	$[Co(C_{17}H_{14}N_4O_2)Cl_2]$	>250	>250	>250	>250
2	$[Co(C_{17}H_{14}N_4O_2)(NO_3)_2]$	32	64	32	08
3	$[Co(C_{17}H_{14}N_4O_2)(OAc)_2]$	8	32	64	32
4	$[Ni(C_{17}H_{14}N_4O_2)Cl_2]$	>250	>250	>250	>250
5	$[Ni(C_{17}H_{14}N_4O_2)(NO_3)_2]$	>250	>250	>250	>250
6	$[Ni(C_{17}H_{14}N_4O_2)(OAc)_2]$	32	32	8	16
7	$[Cu(C_{17}H_{14}N_4O_2)Cl_2]$	>128	>128	>128	>128
8	$[Cu(C_{17}H_{14}N_4O_2)(NO_3)_2]$	>250	>250	>250	>250
9	$[Cu(C_{17}H_{14}N_4O_2)(OAc)_2]$	64	32	32	64
10	$[Zn(C_{17}H_{14}N_4O_2)(OAc)_2]$	>128	>128	>128	>128
11	$[Cd(C_{17}H_{14}N_4O_2)(OAc)_2]$	>250	>250	>250	>250
Chloramphenicol		64.20	2	2	4
Streptomycin		63.24	2	2	4

The antifungal activities of all the complexes were determined against two fungal strains, *i.e.*, *Aspergillus niger* and *A. flavus*, and then compared with the standard antifungal drug cyclohexamide (Table IV). In the whole series, complex **3** showed the highest percentage inhibition (34–35 %) against both fungal strains, but none of the tested complexes restricted the fungal growth excellently. However, of all the tested complexes, complex **6** showed nearly 33–34 % inhibition of mycelial growth against both fungal strains *A. flavus* and *A. niger*, whereas complexes **7**, **9** and **10** showed nearly 25–27 % inhibition of mycelial growth against *A. flavus* and *A. niger* (Table IV).

TABLE IV. Antifungal (inhibition, %) activities of the complexes against the tested fungal strains (for a concentration of 100 μg/ml)

No.	Complex	*A. flavus*	*A. niger*
1	$[Co(C_{17}H_{14}N_4O_2)Cl_2]$	17.7	12.8
2	$[Co(C_{17}H_{14}N_4O_2)(NO_3)_2]$	27.8	22.4
3	$[Co(C_{17}H_{14}N_4O_2)(OAc)_2]$	34.2	35.3
4	$[Ni(C_{17}H_{14}N_4O_2)Cl_2]$	18.5	19.8
5	$[Ni(C_{17}H_{14}N_4O_2)(NO_3)_2]$	13.7	17.2

TABLE IV. Continued

No.	Complex	*A. flavus*	*A. niger*
6	$[Ni(C_{17}H_{14}N_4O_2)(OAc)_2]$	33.8	34.5
7	$[Cu(C_{17}H_{14}N_4O_2)Cl_2]$	24.5	22.5
8	$[Cu(C_{17}H_{14}N_4O_2)(NO_3)_2]$	10.5	16.5
9	$[Cu(C_{17}H_{14}N_4O_2)(OAc)_2]$	26.1	21.5
10	$[Zn(C_{17}H_{14}N_4O_2)(OAc)_2]$	27.5	23.9
11	$[Cd(C_{17}H_{14}N_4O_2)(OAc)_2]$	10.7	09.8
Cyclohexamide		87.3	89.9

CONCLUSIONS

Based on elemental analyses, conductivity and magnetic measurements, and electronic, IR, far IR and NMR spectral studies, the structure as shown in Fig. 1 may be proposed for all the prepared complexes.

However, none of the synthesized macrocyclic metal complexes showed good antibacterial activities against the tested bacterial strains, but some of the cobalt, nickel and copper complexes were reported to show some antibacterial activities against various bacterial strains. It has been suggested that chelation/coordination reduces the polarity of the metal ion mainly because of the partial sharing of its positive charge with the donor group within the whole chelate ring system.[31] This process of chelation thus increases the lipophilic nature of the central metal atom, which in turn, favors its permeation through the lipoid layer of membranes, thus causing the metal complex to cross the bacterial membrane more effectively thus increasing the activity of the complexes. In addition to this, many other factors such as solubility, dipole moment and conductivity influenced by the metal ion may be the possible reasons for the antibacterial activities of these metal complexes.[32] It was also observed that some moieties, such as an azomethine linkage or a heteroaromatic nucleus, introduced into such compounds exhibit extensive biological activities that may be responsible for the increase in hydrophobic character and liposolubility of the molecules in crossing the cell membrane of the microorganism and thus enhance the biological utilization ratio and activity of complexes.[33]

Abbreviations. *MIC* – Minimum inhibitory concentration; MTCC – microbial type culture collection; CFU – colony forming unit; DMF – *N*,*N*-dimethylformamide; DMSO – dimethylsulphoxide; PDA – potato dextrose medium.

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ИЗВОД

ТЕМПЛАТНА СИНТЕЗА МАКРОЦИКЛИЧНИХ КОМПЛЕКСА Co(II), Ni(II), Cu(II), Zn(II) И Cd(II): СПЕКТРОСКОПСКО, АНТИБАКТЕРИЈСКО И АНТИФУГАЛНО ПРОУЧАВАЊЕ

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Кондензационом реакцијом малонилдихидразида са бензилом у присуству двовалентних металних јона синтетисана је нова серија макроцикличних комплекса типа $[M(C_{17}H_{14}N_4O_2)X_2]$, где је M = Co(II), Ni(II), Cu(II), Zn(II) или Cd(II) и X = Cl^-, NO_3^- или CH_3COO^-. Комплекси су окарактерисани помоћу елементалне анализе, мерења проводљивости, магнетних сусцептибилности, електронских, NMR и IR спектралних проучавања. На основу овога предложена је дисторгована октаедарска геометрија за све комплексе у којима су два азотова атома и два карбонилна кисеоникова атома у повољном положају за координацију са металним јонима. Комплекси су тестирани на *in vitro* антибактеријске и антифугалне активности. Минимале инхибиторне концентрације ових комплекса су упоређене са онима које дају стандардни лекови.

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