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Synthesis, characterization, and antimicrobial activity of a new pyrimidine Schiff base and its Cu(II), Ni(II), Co(II), Pt(II), and Pd(II) complexes

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A new Schiff base, {1-[(5-bromo-2-hydroxy-benzylidene)-amino]-4-phenyl-2-thioxo-1,2-dihyro-pyrimidin-5-yl}-phenyl-methanone, was synthesized from N-amino pyrimidine-2-thione and 5-bromsalicylaldehyde. Metal complexes of the Schiff base were prepared from acetate salts of Cu(II), Ni(II), Co(II), Pd(II), and $PtCl_2$ in methanol. The chemical structures of the Schiff base ligand and its metal complexes were confirmed by spectroscopic analysis. All of the compounds were evaluated for their antimicrobial against 4 gram-positive bacteria, 1 gram-negative bacterium, and 3 yeast strains. The Schiff base and the Cu(II) and Co(II) complexes showed good biological activity against all tested bacteria and yeast strains.

Key Words: N-aminopyrimidine-2-thione, 5-bromosalicylaldehyde Schiff base, metal complexes, antimicrobial activity

Introduction

Schiff bases, products of the reaction of primary amines and carbonyl compounds, are involved in many metabolic processes. Numerous products of further fragmentation and crosslinking are responsible for the color, flavor, and

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taste of foods and drinks.[1] Salicyliden- and 2-hydroxynaphthylideneamines have been the subject of particular interest because some of their complexes are found in nature and biological activities have been recorded for the synthesized ones.[2] Pyrimidine is the parent heterocycle of a very important group of compounds that have been extensively studied due to their occurrence in living systems.[3] Pyrimidines are reported to have a broad spectrum of biological activities. Some are endowed with antitumor,[4] antiviral,[5] antiinflammatory,[6] antipyretic,[7] antimicrobial,[8] and antifungal[9] properties. Considerable attention has been given to the metal(II) complexes of polydentate Schiff base ligands of the N-aminopyrimidine type, due to their structural richness and electrochemical properties as well as their potential as a model for a number of important biological systems.[10,11]

This paper describes the synthesis of a new Schiff base ligand (Figure 1) containing a ring of pyrimidine and its metal complexes. Spectral and magnetic studies were used to characterize the structure of the complexes. IR, ^{1}H-NMR, ^{13}C-NMR, and mass spectra were obtained to determine the structure of the ligand (HL). All of the synthesized compounds were evaluated for their antimicrobial activities against gram-positive and gram-negative bacteria and fungi using the microdilution procedure.

Experimental

Elemental analyses (C, H, N, S) were performed using a LECO CHNS model 932 elemental analyzer. The IR spectra were obtained using KBr disks (4000-400 cm^{-1}) on a Bio-Rad-Win-IR spectrophotometer. The electronic spectra, in the range of 200-900 nm, were obtained in DMF on a Unicam UV2-100 UV/Visible spectrophotometer. Magnetic measurements were carried out by the Gouy method using $Hg[Co(SCN)_4]$ as the calibrant. Molar conductance of the Schiff base ligand and the transition metal complexes were determined in DMF at room temperature using a Jenway model 4070 conductivity meter. The ^{1}H-NMR and ^{13}C-NMR spectra of the Schiff base were recorded with a Bruker 300 MHz UltraShield NMR instrument. LC/MS-API-ES mass spectra were recorded using an Agilent model 1100 MSD mass spectrophotometer. Thermogravimetric analysis (TGA) measurements were carried out with a Shimadzu-50 thermal analyzer. 1-Amino-5-benzoyl-4-phenyl-1*H*-pyrimidine-2-thione was prepared according to the literature method.[12] All other reagents and solvents were of reagent-grade quality and were obtained from commercial suppliers.

Chemistry

Synthesis of Schiff base (HL)

The Schiff base ligand was prepared by the condensation of 1-amino-5-benzoyl-4-phenyl-1-*H* pirimidine-2-thione (0.307 g, 1 mmol) with 5-bromosalicylaldehyde (0.201 g, 1 mmol) in *n*-butanol (40 mL), achieved by boiling the mixture under reflux for 3 h. The precipitated ligand was filtered off, recrystallized from ethanol, and dried in a vacuum desiccator. Yield was 295 mg (60%), mp 204 °C. Anal. Calc. for $C_{24}H_{16}BrN_3O_2S$ (490.37): C, 58.78; H, 3.29; N, 8.57; S, 6.54. Found: C, 58.84; H, 3.43; N, 8.70; S, 6.74%. Selected IR data, ν (cm^{-1}): 3200-3500 (O-H/H_2O-NH), 3059 (C-H), 1647 (C=O), 1616 (C=N), 1314 (C-O), 1180, 735 (C=S). UV-Vis [λ (nm)]: 257, 285, 334, 368, 374. ^{1}H-NMR (δ): 7.33-7.97 (m, aromatic H), 8.96 (s, C(6)pyrim.), 9.08 (s, HC=N-), 11.035 (bs, OH). ^{13}C-NMR (δ): 191.99 (-CO-Ph), 176.25 (C=S), 165.16 (Ph-C-pyrim.), 164.39 (-C-OH), 146.55 (-HC=N-), 137.50 (HC-pyrim.), 137.5-111.05 (aromatic C). API-ES: m/z 492.4 [M+H].

Synthesis of the complexes (1-5)

In 30 mL of methanol, 0.912 g (2.00 mmol) of the ligand was dissolved, and a solution of 1.00 mmol of the metal-salt [$Cu(AcO)_2{\cdot}H_2O$ (0.200 g), $Co(AcO)_2{\cdot}4H_2O$ (0.250 g), $Pd(AcO)_2$ (0.224 g), $Ni(AcO)_2{\cdot}4H_2O$ (0.248 g), and $PtCl_2$ (0.266 g)] methanol was added dropwise with continuous stirring. The mixture was stirred further for 1.5-2.5 h at 65 °C. The precipitated solid was then filtered off, washed with cold methanol followed by diethyl ether, and dried in vacuum desiccators.

$[Cu(L)_2]{\cdot}4H_2O$ (1): Yield was 445 mg (40%), mp 254 °C. Anal. Calc. for $C_{48}H_{38}Br_2CuN_6O_8S_2$ (1114.33 g mol^{-1}): C, 51.74; H, 3.44; N, 7.54; S, 5.76. Found: C, 51.43; H, 3.18; N, 7.69; S, 5.49%. Selected IR data, ν (cm^{-1}): 3356 (O-H/H_2O), 1657 (C=O), 1594 (C=N), 1350 (C-O), 1215 (C=S), 545 (M-O), 421 (M-N). UV-Vis [λ (nm)]: 241, 252, 283, 295, 312, 320, 338, 347, 355, 376, 462. μeff 1.92 BM, Λo (S cm^2 mol^{-1}) 12.95. API-ES: m/z 1043.0 [$^{63}Cu(L)_2+1$].

$[Ni(L)_2]{\cdot}3H_2O$ (2): Yield was 510 mg (46%), mp 238 °C. Anal. Calc. for $C_{48}H_{36}Br_2NiN_6O_7S_2$ (1091.47 g mol^{-1}): C, 52.82; H, 3.32; N, 7.70; S, 5.88. Found: C, 52.88; H, 3.22; N, 7.69; S, 5.75%. Selected IR data, ν (cm^{-1}): 3340 (O-H/H_2O), 1661 (C=O), 1600 (C=N), 1290 (C-O), 1224 (C=S), 522 (M-O), 434 (M-N). UV-Vis [λ (nm)]: 227, 251, 270, 296, 309, 321, 407, 560. μeff 2.88 BM, Λo (S cm^2 mol^{-1}) 3.95. API-ES: m/z 1041.0 [$^{58}Ni(L)_2+3$].

$[Co(L)_2]{\cdot}2H_2O$ (3): Yield was 450 mg (42%), mp 266 °C. Anal. Calc. for $C_{48}H_{34}Br_2CoN_6O_6S_2$ (1073.69 g mol^{-1}): C, 53.69; H, 3.19; N, 7.83; S, 5.97. Found: C, 53.78; H, 3.33; N, 8.32; S, 6.03%. Selected IR data, ν (cm^{-1}): 3200-3500 (O-H/H_2O-NH), 1651 (C=O), 1596 (C=N), 1340 (C-O), 1220 (C=S), 545 (M-O), 429 (M-N). UV-Vis [λ (nm)]: 238, 283, 299, 306, 314, 453, 790. μeff 2.36 BM, Λo (S cm^2 mol^{-1}) 10.75. API-ES: m/z 1019.8 [$^{59}Co(L)_2$-OH]$^+$.

$[Pd(L)_2]{\cdot}H_2O$ (4): Yield was 435 mg (39%), mp 198 °C. Anal. Calc. for $C_{48}H_{32}Br_2N_6O_5PdS_2$ (1103.16 g mol^{-1}): C, 52.26; H, 2.92; N, 7.62; S, 5.81. Found: C, 51.66; H, 3.15; N, 8.26; S, 6.56%. Selected IR data, ν (cm^{-1}): 3400 (O-H/H_2O), 1659 (C=O), 1596 (C=N), 1271 (C-O), 1175 (C=S), 538 (M-O), 432 (M-N). UV-Vis [λ (nm)]: 249, 307, 352, 376, 393, 407, 424, 442, 451, 463, 471, 481. μeff Dia, Λo (S cm^2 mol^{-1}) 5.19. API-ES: m/z 1083 [$^{106}Pd(L)_2+1$].

$[Pt(LH)_2]{\cdot}Cl_2$ (5): Yield was 470 mg (37%), mp 210 °C. Anal. Calc. for $C_{48}H_{32}Br_2CI_2N_6O_4PtS_2$ (1246.73 g mol^{-1}): C, 46.24; H, 2.59; N, 6.74; S, 5.14. Found: C, 45.40; H, 3.18; N, 7.47; S, 5.75%. Selected IR data, ν (cm^{-1}): 3400 (O-H/H_2O-NH), 1663 (C=O), 1595 (C=N), 1315 (C-O), 1217 (C=S), 533 (M-O), 410 (M-N). UV-Vis [λ (nm)]: 231, 278, 311, 335, 361, 386, 410, 438, 460. μeff Dia, Λo (S cm^2 mol^{-1}) 140.5. API-ES: m/z 1031.8 [$^{195}Pt(L)_2$-$(PhCO)_2$+$^{35}(Cl)_2$]$^+$.

Biological assay

Compounds and cells

Test compounds were dissolved in DMSO (12.5%) at an initial concentration of 1280 μg mL^{-1} and then serially diluted in culture medium. Bacterial strains were supplied by the American Type Culture Collection. *Candida* strains were obtained from Refik Saydam Hıfzıssıhha Research Institute, Ankara, Turkey.

Antibacterial assay

The newly synthesized compounds were screened for their antibacterial activity against 4 gram-positive (*S. aureus* ATCC 6538, *S. aureus* ATCC 25923, *B. cereus* ATCC 7064, and *M. luteus* ATCC 9345) and 1 gram-negative (*E. coli* ATCC 4230) bacteria, as described by the guidelines in NCCLS-approved standard document M7-A4, using the microdilution broth procedure.[13] Ampicillin trihydrate was used as the reference antibacterial agent. Solutions of the compounds and reference drug were dissolved in DMSO at a concentration of 2560 μg mL^{-1}. The 2-fold dilutions of the compounds and the reference drug were prepared (1280, 640, 320, 160, 80, 40, 20, 10, 5 μg mL^{-1}). Antibacterial activities of the newly synthesized chemical compounds were performed in Mueller-Hinton broth medium (Difco) at a pH of 7.2 with an inoculum of (1-2) $\times$ 10^3 cells mL^{-1} by the spectrophotometric method, and an aliquot of 100 μL was added to each tube of serial dilution. The chemical compounds-broth medium serial tube dilutions inoculated with each bacterium were incubated on a rotary shaker at 37 °C for 18 h at 150 rpm. The minimum inhibitory concentration (MIC) of each chemical compound was recorded as the lowest concentration of each chemical compound in the tubes with no growth (i.e., no turbidity) of inoculated bacteria.

Antifungal assay

The antifungal activities of the newly synthesized chemical compounds were tested against 3 yeast strains (*C. albicans* ATCC 14053, *C. krusei* ATCC 6258, and *C. parapsilosis* ATCC 22019) according to the guidelines in NCCLS-approved standard document M27-A2, using the microdilution broth procedure.[14] Fluconazole was used as the reference antifungal agent. Solutions of the test compounds and reference drug were dissolved in DMSO at a concentration of 2560 μg mL^{-1}. The 2-fold dilutions of the compounds and reference drug were prepared (1280, 640, 320, 160, 80, 40, 20, 10, 5 $>$ μg mL^{-1}). Antifungal activities of the yeast strains were performed in RPMI 1640 medium (Sigma), which had been buffered to a pH of 7.0 with 0.165 M morpholinopropanesulfonic acid (Sigma), as outlined in document M27-A. The stock yeast inoculum suspensions were adjusted to a concentration of (0.5-2.5) $\times$ 10^3 cells mL^{-1} by the spectrophotometric method, and an aliquot of 100 μL was added to each tube of the serial dilution. The chemical compound-broth medium serial tube dilutions inoculated with yeast were incubated on a rotary shaker at 37 °C for 18 h at 150 rpm. The MIC of each chemical compound was recorded as the lowest concentration of each chemical compound in the tubes with no growth (i.e., no turbidity) of inoculated yeast.

Results and discussion

Schiff base HL (Figure 1) was synthesized by the condensation of 1-amino-5-benzoyl-4-phenyl-1*H*-pirimidine-2-thione[12] with 5-bromosalicylaldehyde. The Schiff base ligand and its complexes are very stable at room temperature in the solid state. The ligand is soluble in common organic solvents, but its metal complexes are generally only soluble in DMF and DMSO. The elemental analytical data of the complexes reveal a metal:ligand stoichiometry of 1:2 corresponding to the octahedral geometry of $[M(L)_2]\cdot nH_2O$ (Figure 2), except for the square-planar $[Pd(L)_2]\cdot H_2O$ and $[Pt(LH)_2]\cdot CI_2$ complexes (Figure 3). These analytical data are in good agreement with the proposed stoichiometry of the complexes. The molar conductivities of compounds **1-4**

in DMF at 25 °C were in the range of 3.95-12.95 Ω^{-1} cm^2 mol^{-1}, indicating nonelectrolytes, except for $[Pt(LH)_2]\cdot CI_2$, which behaved as a polar compound due to the electrolytic behavior of its chloride anions (Λo = 40.5 Ω^{-1} cm^2 mol^{-1}).[15]

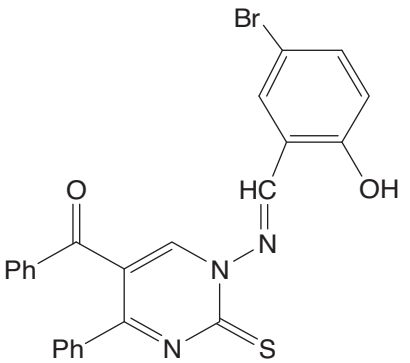

Figure 1. Structure of the Schiff base ligand.

IR spectra

The IR spectra of the Schiff base ligand showed characteristic broad bands at the 3200 cm^{-1} ν(O–H),[16–18] 3059 cm^{-1} ν(C–H pyrimidine ring), l647 cm^{-1} ν(C=O benzoyl), 1616 cm^{-1} ν(C=N azomethine), 1314 cm^{-1} ν(C–O phenolic),[16] and 1180 and 735 cm^{-1} ν(C=S) vibrations.[19,20]

The IR spectra of the complexes were compared with that of the free ligand to show changes during complexation. In the spectra of the Cu(II), Ni(II), Co(II), and Pd(II) complexes, the phenolic (C–O) band at 1271-1350 cm^{-1} shifted to ±25-43 cm^{-1}, the lower or higher frequency supporting bonding of the phenolic OH after deprotonation.[21,22] The azomethine vibration of the ligand at 1616 cm^{-1} shifted to 1594-1600 cm^{-1} after complexation, confirming the formation of a bond from the imine nitrogen to the metal.[16–18] The ν(C=S) at 1180 and 735 cm^{-1} in the free ligand shifted to a higher frequency after complexation, due to coordination with the nitrogen of azomethine, the oxygen of hydroxyl, and the sulfur of the thione group for the Cu(II), Co(II), and Ni(II) complexes (Figure 2). On the other hand, the ν(C=S) thione bands in the spectrum of the Pd(II) complex remained at almost 1175 and 736 cm^{-1}, suggesting that the C=S group does not take part in complexation[17] and indicating bidentate coordination for the Schiff base through the phenolic oxygen and nitrogen of the azomethine to the Pd(II) ion (Figure 3).

Bands observed at 410-435 and 520-545 cm^{-1} were due to ν(M–N) and ν(M–O), respectively.[16,20] Broad bands of the Cu(II), Ni(II), Co(II), and Zn(II) complexes from 3200-3500 cm^{-1} were assigned to the ν(OH) of water;[23] water content was also identified by thermal analyses.

NMR spectra

DMSO-d_6 was used as a solvent to measure the ^{1}H-NMR and ^{13}C-NMR spectra of HL (Figure 4 and 5). The ^{1}H-NMR spectra of the ligand did not show a signal corresponding to the primary amine, supporting the complete condensation and formation of the Schiff base. The signal due to the imine group at δ 9.08 ppm (s,

1H) provides evidence for the formation of the Schiff base.[24] Sharp singlets at δ 11.05 and 8.96 ppm were due to the phenolic proton and C6(H)-pyrimidine proton of the ligand. The phenyl proton multiplets were between δ 7.33 and 7.97 ppm.[11,24] The ^{13}C-NMR spectrum of the ligand had a cluster of peaks at δ 191.99 and 176.25 ppm due to benzoyl and thione carbons. The peak at δ 146.25 ppm may be attributed to CH=N. Peaks in the region of δ 111.05–137.5 ppm were due to aromatic carbons.

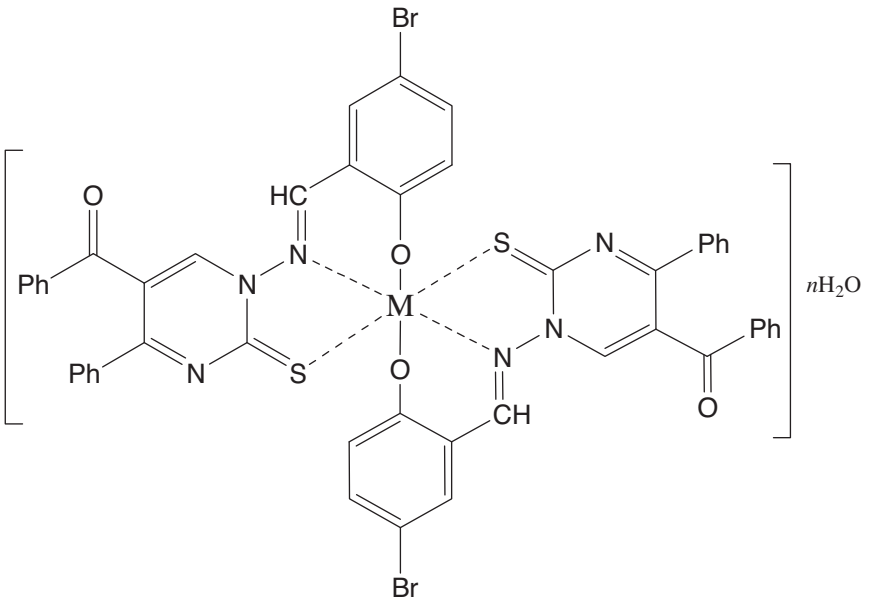

Figure 2. Proposed structure of the Cu(II), Co(II), and Ni(II) complexes.

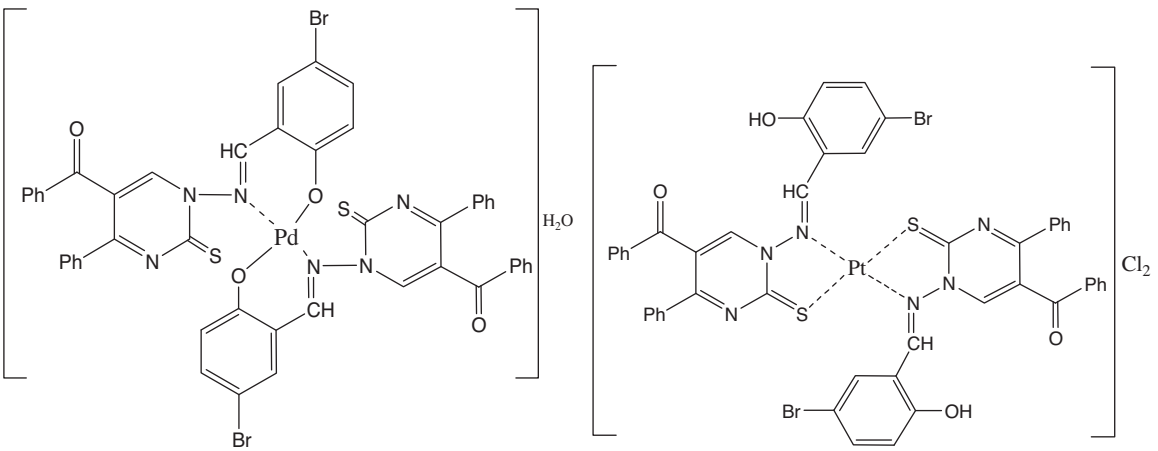

Figure 3. Proposed structures of the $[Pd(L)_2]\cdot H_2O$ and $[Pt(LH)_2]Cl_2$ complexes.

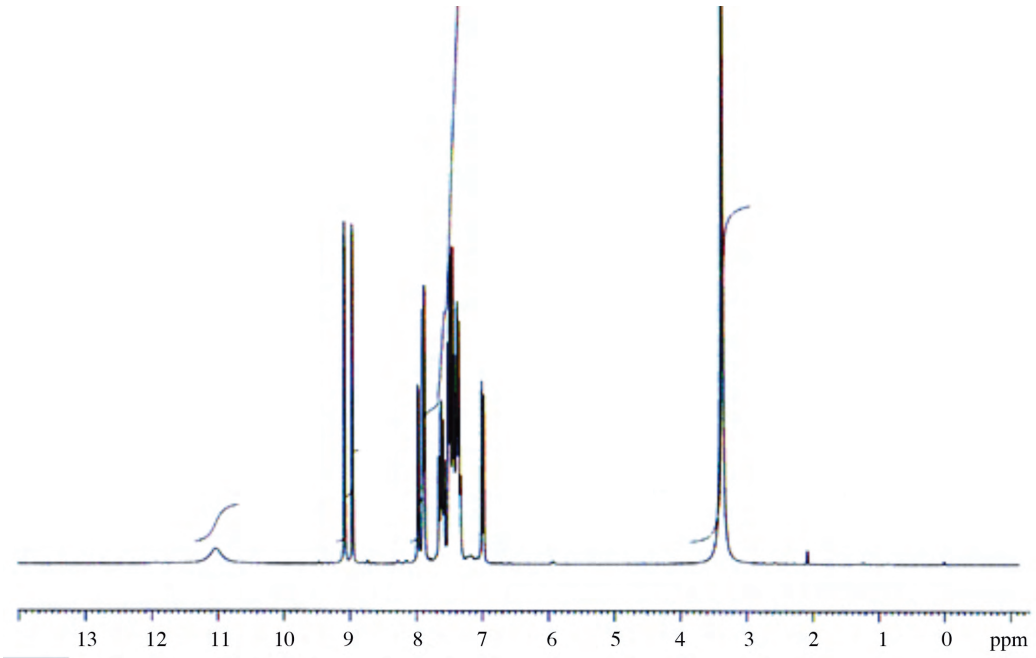

Figure 4. The ^{1}H-NMR spectrum of the ligand (in DMSO-d$_6$).

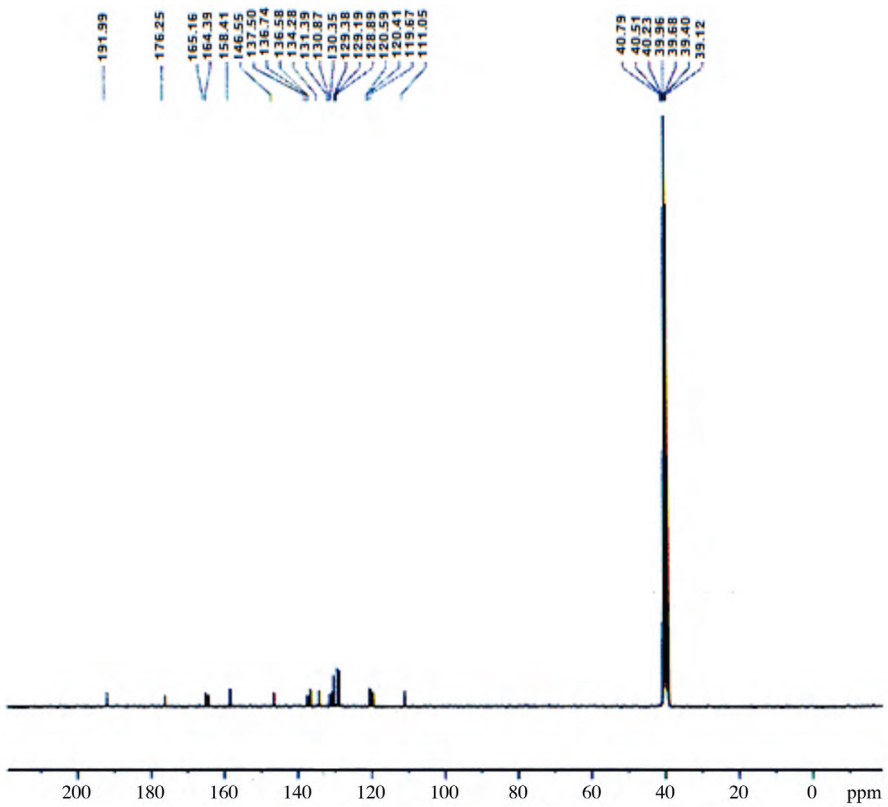

Figure 5. The ^{13}C-NMR spectrum of the ligand (in DMSO-d$_6$).

Magnetic and electronic spectral studies

Electronic spectra were recorded in DMF. In the Schiff base, the band at 368 nm was attributed to the $\pi - \pi^*$ of the azomethine. Bands between 334 and 257 nm are associated with phenyl and pyrimidine $\pi - \pi^*$ transitions. In the spectra of the complexes, the $\pi - \pi^*$ of the azomethine shifted to 374 nm, indicating that the imino nitrogen was involved in coordination. The electronic spectra of the Pd(II) and Pt(II) complexes had bands in the range of 311-231 nm due to the n-π^* and $\pi - \pi^*$ transitions of phenyl, pyrimidine, and azomethine. In the spectra of the complexes, the less intense and broad bands in the range of 311-481 nm resulted from the overlap of the low energy $\pi \rightarrow \pi^*$ transitions, mainly localized within the azomethine group, and the LMCT transitions from the lone pairs of the phenolate oxygen donor to Pd(II) and Pt(II).[3]

The UV-Vis spectrum of the Cu(II) complex had a strong band at 462 nm assigned to the $^2E_g \rightarrow {}^2T_{2g}$ transition and tailing to a higher wavelength, which is well-known behavior for octahedral Cu(II) complexes.[25,26] The Co(II) complex had 2 bands, 1 at 790 nm and the other at 453 nm, which were assigned to $^4T_{1g} \rightarrow {}^4T_{2g}$ (F) and $^4T_{1g} \rightarrow {}^4T_{1g}$ (P) transitions, respectively.[26,27] The Co(II) complex showed a magnetic moment of 2.36 BM.[28,29]

The observed magnetic moment of the Ni(II) complex (2.88 BM) indicates Oh geometry.[26] The spectrum of the $Ni(L_2]\cdot 3H_2O$ complex was characteristic of octahedral geometry, and the bands at 560 and 407 nm can be assigned to $^3A_{2g} \rightarrow {}^3T_{1g}$ (F) and $^3A_{2g} \rightarrow {}^3T_{2g}$ (F) transitions.

Mass spectra

The LC-API-ES mass spectrum of the Schiff base showed a molecular ion peak m/z at 491.4, which is equivalent to its molecular ion weight. The fragmentation peaks, at m/z 245, 199, and 173, were ascribed to the cleavage of $C_{11}H_8N_3O_2S$, $C_{10}H_6N_3S$, and C_6H_6OBr, respectively, and are well observed in the mass spectrum. The spectra of $[^{63}Cu(L)_2+1]^+$, $[^{58}Ni(L)_2+3H]$, $[^{59}Co(L)_2\text{-}O]^+$, $[^{106}Pd(L)_2+1]$, and $[^{195}Pt(L)_2\text{-}(PhCO)_2+^{35}(Cl)_2]^+$ showed a molecular ion peak M+ at m/z 1043.9, 1041.0, 1019.8, 1083.0, and 1031.8, respectively, equivalent to the molecular weight. All of the compounds were consistent with the molecular ion fragment and support the proposed structure of the complexes. The spectrum of the Pd(II) complex is shown in Figure 6.

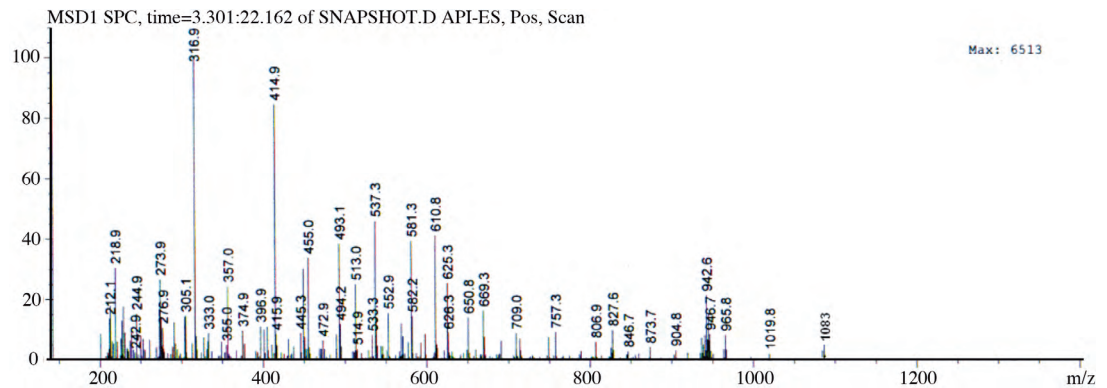

Figure 6. API-ES spectrum of the Pd(II) complex.

Thermogravimetric analysis

The TGA data agree with the formula suggested from elemental analyses. The thermal stabilities were investigated using TGA at a heating rate of 10 °C min^{-1} in N_2 from 20 to 850 °C. Mass losses corresponded to H_2O, Ph–CO–, and the other organic moieties in the first, second, third, fourth, and fifth stages of decomposition. The Cu(II), Ni(II), Co(II), and Pd(II) complexes suffered loss of H_2O in the first stage, 65-130 °C, and the ligands gradually decomposed from 220 to 580 °C. The complexes contained 4, 3, 2, and 1 moles of water of crystallization per complex molecule, respectively. The complexes decomposed to CuO, CoO, NiO, PdS, and Pt at higher temperatures.[30–32]

Biological activity

The biological activities of the ligand and its series of metal complexes [Cu(II), Ni(II), Co(II), Pd(II), and Pt(II)] were screened for antibacterial activity against *S. aureus* ATCC 6538, *S. aureus* ATCC 25923, *B. cereus* ATCC 7064, *M. luteus* ATCC 9345, and *E. coli* ATCC 4230 and for antifungal activity against *C. albicans* ATCC 14053, *C. krusei* ATCC 6258, and *C. parapsilosis* ATCC 22019 by using broth microdilution procedures. Ampicillin trihydrate for bacteria and fluconazole for yeast were used as reference drugs. The results of the antimicrobial activity of the ligand and its metal complexes against all tested bacterial and fungal strains are shown in Tables 1 and 2. All compounds inhibited the growth of bacteria (gram-negative and gram-positive), with MIC values in the range of 20-320 μg mL^{-1}, and exhibited antifungal activity with MICs between 20 and 160 μg mL^{-1}.

According to the results of the antibacterial activity screening, the Co(II) and Cu(II) complexes possess effective and selective antibacterial activity against 1 gram-positive spore-forming bacterium (*B. cereus* ATCC 7064), 1 gram-negative bacterium (*E. coli* ATCC 4230), and other gram-positive bacteria (*S. aureus* ATCC 6538, *S. aureus* ATCC 25923, and *M. luteus* ATCC 9345) with MIC values in range of 20-40 μg mL^{-1}. On the other hand, other complexes had moderate antibacterial activity against all gram-positive and gram-negative bacteria, with MICs between 80 and 160 μg mL^{-1}. Moreover, our findings indicate that all prepared compounds had similar antibacterial efficacy against gram-positive and gram-negative bacteria.

Table 2 summarizes the antifungal activities of the free ligand and the complexes of compounds against 3 yeast strains (*C. albicans* ATCC 14053, *C. krusei* ATCC 6258, and *C. parapsilosis* ATCC 22019). According to antifungal studies, the ligand and the Cu(II) and Co(II) complexes compounds displayed good antiyeast efficacy against the tested fungal species (MICs: 20-40 μg mL^{-1}). Other complexes exhibited weak antifungal activities (MICs: 80-160 μg mL^{-1}).

The results of this investigation revealed that the Co(II) and Cu(II) complexes possess higher antimicrobial activity; it is generally reported that free ligands show lower activity than complexes.[13,14,33,34] Additionally, when all of the antimicrobial MIC values are compared, the ligand and Co(II) complex displayed the highest antimicrobial efficacy, with MIC values ranging between 20 and 40 μg mL^{-1}. Finally, it is suggested that the reason for this higher antimicrobial efficacy could be related to the inhibition of several structural enzymes that play a key role in vital metabolic pathways of the microorganisms.

Table 1. MICs of the ligand (HL) and its metal complexes [Cu(II), Ni(II), Co(II), Pd(II), Pt(II)] against gram-negative and gram-positive bacterial strains.

	Bacillus cereus ATCC 7064	Staphylococcus aureus ATCC 6538	Staphylococcus aureus ATCC 25923	Escherichia coli ATCC 4230	Micrococcus luteus ATCC 9345
HL	160	160	160	160	160
1	40	40	40	80	20
2	160	80	80	160	80
3	40	20	20	40	20
4	80	80	80	160	80
5	80	80	80	160	80
Ampicillin	5	5	10	20	10

The MIC values were determined as μg mL^{-1} of active compound in medium.

Table 2. MICs of the ligand (HL) and its metal complexes [Cu(II), Ni(II), Co(II), Pd(II), Pt(II)] against fungal strains.

	Candida albicans ATCC 14053	Candida parapsilosis ATCC 22019	Candida krusei ATCC 6258
HL	160	160	160
1	40	40	40
2	160	80	80
3	40	20	20
4	160	80	80
5	80	80	80
Fluconazole	5	5	10

The MIC values were determined as μg mL^{-1} of active compound in medium.

Conclusions

We have described the synthesis and structure of a new heterocyclic Schiff base and its metal complexes in a metal-to-ligand ratio of 1:2. The ligand is a bidentate or tridentate chelating agent coordinating through the deprotonated phenolic group, azomethine nitrogen, and sulfur of the pyrimidine thione group. The analytical data, electronic spectra, magnetic susceptibility, and IR, NMR, and API-ES mass spectral data revealed the mononuclear octahedral configuration of the Cu(II), Co(II), and Ni(II) complexes, while Pd(II) and Pt(II) are mononuclear and square-planar in configuration. The antibacterial activity results showed that all of the complexes have moderate activity against gram-positive bacteria. They have weak activity against gram-negative bacteria, except the Co(II) complex, which has moderate activity against *E. coli*. Generally, the antibacterial activities of all of the complexes are greater than those of the free Schiff base ligand.

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