MODERN MEDICINE AND PRACTICE
https://inovatus.es/index.php/ejmmp
EUROPEAN JOURNAL OF MODERN MEDICINE AND PRACTICE
Vol. 4 No. 6 (Jun - 2024) EJMMP ISSN: 2795-921X

SYNTHESIS, DIAGNOSIS, THERMAL AND SURFACE STUDY AND EVALUATION OF BACTERIAL EFFICACY OF SOME CADMIUM (II) COMPLEXES WITH A COMBINATION OF 4-METHOXYBENZALENE (HYDRAZINEYL AND PHOSPHINES) LIGANDS

Ziad J. Mutlag, Ahmed A. Irzoqi
Department of Chemistry, College of Education for Pure Science, University of Tikrit, Tikrit, 34001 Iraq

Abstract: Methoxybenzalene hydrazinayl benzothiazole was used as a ligand for the synthesis of complexes [Cd(L)(PPh3)2]Cl2 (1), [Cd2(L)2(dppm)Cl2]Cl2 (2), [Cd(L)2(dppe)]Cl2 (3), [Cd(L)(phosphine)]Cl2, where phosphines were dppp (4), dppb (5), dppf (6). The properties of molar conductivity, elemental analysis, infrared spectra and (1H NMR, 31P NMR) spectra proved that ligand (L) behaves as a bidentate ligand through N atom of the cyclic thiazole compound and the outer N atom, while phosphines have bi- and monodentate bonds through P atoms. The crystal structure of the compound was examined by using SEM. The results showed the presence of normal nanostructures.

Keywords: 4-methoxybenzalene, Diphosphines, SEM, Biological activity.

Introduction

Recently, the fused heterocyclic compounds have attracted great interest in the field of medicinal chemistry due to their significant contribution to the biological profile of drugs, such as anticancer drugs [2,1]. Benzothiazole substitutes have received great attention from researchers due to their wide use in pharmaceutical and agricultural chemistry. Hence, the study of benzothiazole derivatives is of great importance currently due to their important biological and biophysical properties, such as antimicrobials [4,3] and antifungal agents [5]. Several substituted benzothiazole compounds have been identified as potent anthelmintic drugs [6]. Amino benzothiazole compounds may be manifested on a wide range of biological activities, such as anti-Parkinson's (a disease of the nervous system) drug, dopamine antagonists, as well as antibacterial and antihistamines [7].

Benzothiazole hydrazine is a bicyclic structure related to the hydrazide group. Benzothiazole derivatives have been studied in general and received a lot of attention as they are considered the nucleus structure for the synthesis of new benzothiazole derivatives [8], due to their multi-reaction chemical composition. They have shown a wide range of chemotherapeutic properties including antimicrobials [9], anti-pain [10], antitumor agents [11]], anti-inflammatory [12], anti-cancer [13], antibacterial [14], antifungal [15] , anti-HIV [16] and effective animal growth stimulant [17]. In addition to several benzothiazole derivatives, their mineral complexes have shown antibacterial properties and antifungal activity [18]. It is found that the action of many drugs increases when the compound is considered a ligand fused with minerals [19].

Chemicals and Apparatuses

All chemicals, reagents and solvents used in the manufacture of compounds were supplied and used without purification. The following phosphines were used in this paper: Triphenylphosphine PPh3, (diphenylphosphine) Methane dppm, 1,2, (diphenylphospheno) ethane dppe,1,3 (diphenylphosphine) propane dppp,1,4 (diphenylphospheno) butane dppb and 1,1- ferrocene (diphenylphospheno) dppf.

The melting point of the prepared complexes was recorded on the automatic melting point device (SMP30). The molar conductivity of the prepared 10-3 M Freshly DMSO solution was recorded. The complexes were measured using the Starter 3100c digital conductivity scale device. The infrared spectra of the complexes were recorded as KBR tablets using the Shimadzu FTIR 8400S spectrophotometer (400-4000 cm 1). By using the nuclear magnetic resonance, spectra were obtained on the Bruker 400 MHz spectrometer in DMSO-d6 as a solvent.

Methods

1. The Synthesis of Methoxybenzalene Hydrazinayl Benzothiazole as a Ligand

The ligand was synthesized through using two steps:

a) The preparation of 2-hydrazonobenzobenzyothiazole

In this step, (0.011mol, 2ml) of hydrazine was added to (0.011mol, 2g) of benzothiazole compound directly in a flask. After that, the mixture was heated at a temperature of 120 ℃ for half an hour with stirring, and a thick foam was formed with the odor of H2S. Then, 3 ml of absolute ethanol was added to the mixture with heating for 4 hours, where a light-yellow precipitate was formed. The precipitate was filtered, washed with cold ethanol, and then dried at room temperature.

b) The preparation of methoxybenzalene hydrazinayl benzothiazole (L) ligand

In this step, (0.0030mol, 0.412g) of methoxybenzaldehyde was added to a hot solution (0.0030mol, 0.49g) of hydrazinothazole in 10ml methanol with drops of ice acetic acid. The mixture was heated for two hours where a yellow precipitate was formed. The precipitate was filtered, washed with cold methanol and then dried at room temperature.

EUROPEAN JOURNAL OF MODERNMEDICINE AND PRACTICE
Vol. 4 No. 6 (Jun - 2024) ISSN: 2795-921X

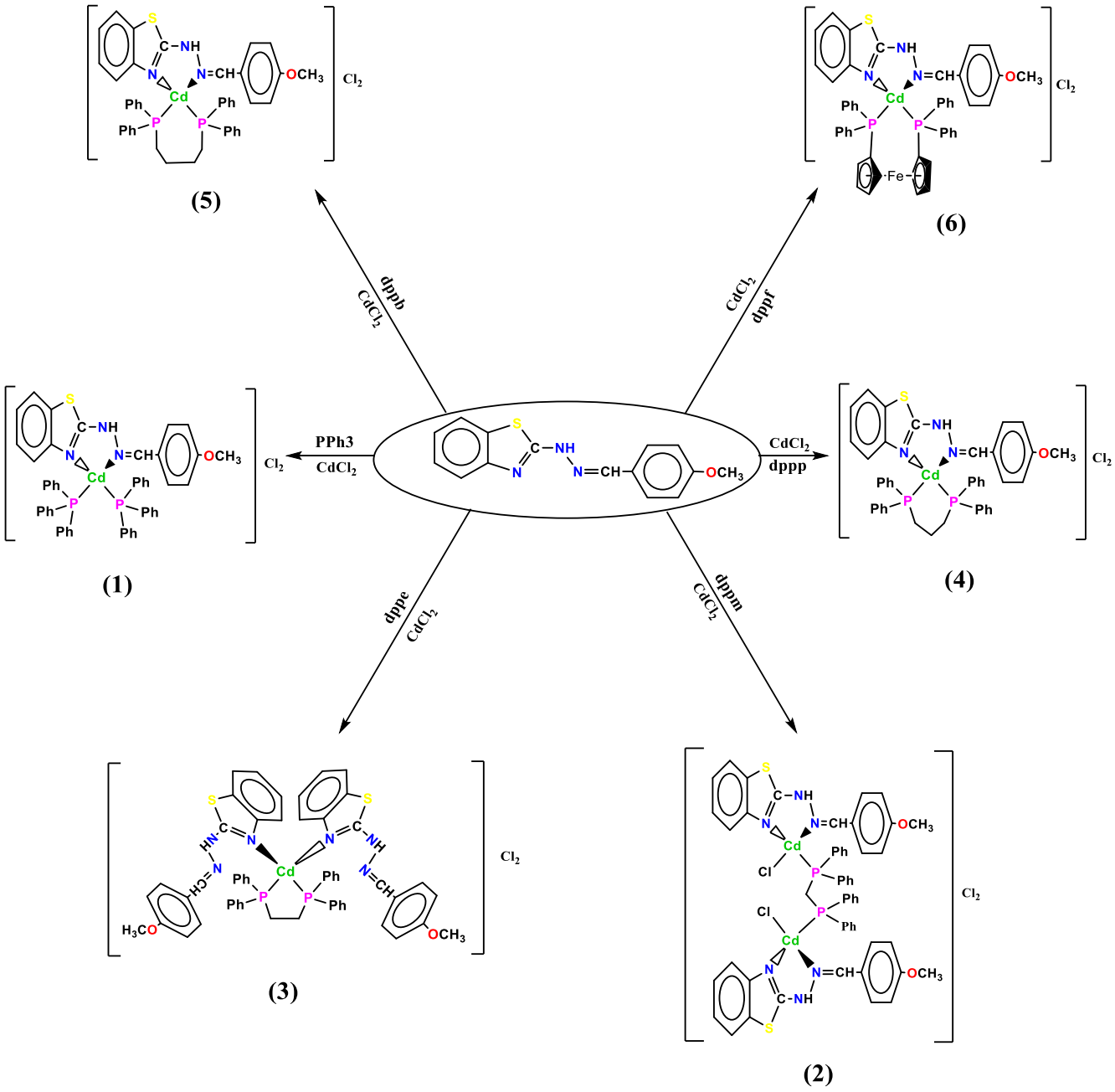


Figure 1: the structure of complexes [Cd(L)(PPh3)2]Cl2 (1), [Cd2(L)2(dppm)Cl2]Cl2 (2), [Cd(L)2(dppe)]Cl2 (3), [Cd(L)(dppp)]Cl2 (4), [Cd(L)(dppb)]Cl2 (5), [Cd(L)(dppf)]Cl2 (6)

L Yellow powder (0.682 g) yields 79%, m.p : 138-140 °C . FTIR(KBr): 3407w ν(N-H), 3078w ν(C-H)Arom, 2960w ν(C-H)aliph, 1618s ν(HC=N), 1569s ν(C=C), 1506s ν(C=N), 1251s ν(C-O-O), 1112m ν(C-N), 1022s ν(N-N), 750s ν(C-S) . ^{1}H NMR (DMSO-d6) δ(PPm) : 12.15 (s, 1H, NH), 8.12 (s, 1H, CH), 7.78 (d, ^{3}J = 7.75 Hz, 1H, H_a), 7.67 (d, ^{3}J = 8.78 Hz, 2H, H_e), 7.45 (d, ^{3}J = 7.99 Hz, 1H,H_d), 7.32 (t, ^{3}J = 1.30 Hz, 1H, H_c), 7.12 (t, ^{3}J = 1.20 Hz, ^{4}J = 7.43 Hz, 1H,H_b), 7.05 (d, ^{3}J = 8.78 Hz, 2H, H_f), 3.83 (s, 3H, CH_3) . The elemental analysis is calculated for $C_{15}H_{13}N_3OS$: C,63.58 ; H,4.62 ; N,14.83 . It is found that: C,63.64 ; H,4.81 ; N,14.86. Λ ($\Omega^{-1}.cm^2.mol^{-1}$) : 17.5

[Cd(L)(PPh3)2]Cl2 (1) Yellow powder, (0.279 g), yields 79% m.p : 122-124 °C . FTIR(KBr): 3377w ν(NH), 3062m ν(C-H)arom, 2943m ν(C-H)Aliph, 1614s ν(HC=N), 1569s ν(C=C), 1506s ν(C=N), 1419s

ν(P-Ph), 1251s ν(C-O-C), 1122m ν(C-N), 1095m ν(P-C), 1022s ν(N-N),748s ν(C-s), 694s δ(P-C), 424m ν(Cd-N) . ^{1}H NMR (DMSO-d_6) δ(PPm) : 12.12 (s, 1H, NH), 8.11 (s, 1H, CH), 7.76 (d, ^{3}J = 7.73 Hz, 1H, H_a), 7.66 (d, ^{3}J = 8.76 Hz, 2H, H_e), 7.48 (m, 22H,H_{d+ph}), 7.31 (d, ^{3}J = 8.51 Hz, 1H, H_d) , 7.26 (m, 11H ,H_{ph+c}), 7.1 (t, ^{3}J = 7.48 Hz, 1H, H_b), 7.04 (d, ^{3}J = 8.78 Hz, 2H, H_f), 3.38 (s, 3H, CH_3). ^{13}P{^{1}H}NMR(DMSO-d_6): δ25.60 ppm . The elemental analysis is calculated for $C_{51}H_{43}CdCl_2N_3OP_2S$: C,61.80 ; H,4.37 ; N,4.24. It is found that: C,61.95 ; H,4.43 ; N,4.27. ʌ (Ω^{-1}.cm^2.mol^{-1}): 74.9

[Cd_2(L)$_2$(dppm)Cl_2]Cl_2 (2) Yellow powder, (0.67 g), yields 72% m.p : 126-128 ^{o}C . FTIR(KBr): 3390w ν(NH), 3062m ν(C-H)$_{arom}$, 2948w ν(C-H)$_{Aliph}$, 1614s ν(HC=N), 1571s ν(C=C), 1506s ν(C=N), 1425s ν(P-Ph), 1251s ν(C-O-C), 1112m ν(C-N), 1097m ν(P-C), 1024s ν(N-N), 746s ν(C-S), 690s δ(P-C), 429m ν(Cd-N) . ^{1}H NMR (DMSO-d_6) δ(PPm) : 12.19 (s, 1H, NH) , 8.11 (s, 1H, CH) , 7.78 (d, ^{3}J= 7.78 Hz, 1H, H_a), 7.67 (d, ^{3}J= 8.78 Hz, 2H, H_e), 7.49 (m, 10H , H_{ph}), 7.44 (d, ^{3}J= 8.84 Hz, 1H,H_d), 7.36 (m, 10H, H_{ph}), 7.31 (t , ^{3}J= 1.32 Hz, ^{4}J= 7.69 Hz, 1H, H_c) 7.12 (t, ^{3}J= 1.23 Hz, ^{4}J= 7.53 Hz, 1H,H_b), 7.05(d, ^{3}J= 8.81 Hz, 2H, H_f), 3.83 (s, 3H, CH_3), 3.00 (t, ^{3}J= 1.77 Hz, 2H, CH_2). ^{13}P{^{1}H}NMR(DMSO-d_6): δ 27.47(d,^{3}J=50.79Hz), -28.16(d,^{3}J=50.90 Hz) , 23.61(s) ppm. The elemental analysis is calculated for $C_{55}H_{48}Cd_2Cl_4N_6O_2P_2S_2$: C,50.13 ; H,3.67 ; N,6.38 . It is found that: C, 49.89 ; H,3.76 ; N,6.04. ʌ (Ω-1.cm2.mol-1):78.8

[Cd(L)$_2$(dppe)]Cl_2 (3) Yellow powder, (0.129 g), yields 81% m.p: 130-132 ^{o}C . FTIR(KBr): 3377w ν(NH) , 3055w ν(C-H)$_{arom}$, 2896w ν(C-H)$_{Aliph}$, 1625s ν(HC=N), 1568s ν(C=C) , 1506s ν(C=N), 1427s ν (P-Ph), , 1244s ν(C-O-C), 1112m ν(C-N), 1099m ν(P-C), 1022s ν(N-N), 748s ν(C-S), 682s δ(P-C), 422m ν(M-N) . ^{1}H NMR (DMSO-d_6) δ(PPm) : 12.14 (s, 1H, NH), 8.11 (s, 1H, CH), 7.77 (d, ^{3}J = 7.83 Hz, 1H, H_a), 7.67 (d, ^{3}J = 8.79 Hz, 2H, H_e), 7.44 (d, ^{3}J = 8.06 Hz, 1H ,H_d), 7.34 (m, 12H, H_{c+ph}), 7.12 (t, ^{3}J = 1.19 Hz, ^{4}J = 7.52 Hz, 1H,H_b), 7.05 (d, ^{3}J = 8.81 Hz, 2H, H_f), 3.83 (s, 3H, CH_3), 2.06 (t, ^{3}J = 4.46 Hz,2H, CH_2) . ^{13}P{^{1}H}NMR(DMSO-d_6): δ14.47 ppm . The elemental analysis is calculated for $C_{56}H_{50}CdCl_2N_6O_2P_2S_2$: C,58.57 ; H,4.39 ; N,7.32 . It is found that: C,58.25 ; H,3.98 ; N,7.80 . ʌ (Ω^{-1}.cm^2.mol^{-1}): 71.4

[Cd(L)(dppp)]Cl_2 (4) Yellow powder, (0.260 g), yields 83% m.p : 147-149 ^{o}C . FTIR(KBr): 3400w ν(NH) , 3068m ν(C-H)$_{arom}$, 2929m ν(C-H)$_{Aliph}$, 1614s ν(HC=N), 1569s ν(C=C), 1508s ν(C=N), 1425s ν(P-Ph), 1251s ν(C-O-C), 1124m ν(C-N), 1099m ν(P-C), 1022s ν(N-N), 750 ν(C-S), 692s δ(P-C), 424m ν(Cd-N). ^{1}H NMR (DMSO-d_6) δ(PPm) : 12.12 (s, 1H, NH), 8.12 (s, 1H, CH), 7.76 (d, ^{3}J = 7.57 Hz, 1H, H_a), 7.66 (d, ^{3}J = 8.44 Hz, 2H, H_e) , 7.45 (M, 8H, H_{Ph}) , 7.44 (d, ^{3}J = 8.00 Hz, 1H,H_d) , 7.37 (m, ^{3}J = 2.530 Hz, 12H, H_{ph}) , 7.30 (t, ^{3}J = 7.65 Hz, 1H,H_c) , 7.10 (t, ^{3}J = 7.48 Hz, 1H, H_b) , 7.04 (d, ^{3}J = 8.67 Hz, 2H, H_f), 3.83 (s, 3H, CH_3), 2.25 (m, 4H, CH_2), 1.46 (m, ^{3}J = 6.78 Hz, ^{4}J = 6.78 Hz, 2H, CH_2) . ^{13}P{^{1}H}NMR(DMSO-d_6): δ29.95 ppm . The elemental analysis is calculated for $C_{42}H_{39}CdCl_2N_3OP_2S$: C,57.38 ; H,4.47 ; N,4.78 . It is found that: C,56.97 ; H,4.62 ; N,4.36 .. ʌ (Ω^{-1}.cm^2.mol^{-1}): 75.7

[Cd(L)(dppb)]Cl_2 (5) Yellow powder, (0.271 g), yields 86% m.p : 143-145 ^{o}C . FTIR(KBr): 3402m ν(NH), 3055m ν (C-H)$_{arom}$, 2929m ν(C-H)$_{Aliph}$, 1612s ν(HC=N), 1573s ν(C=C), 1508s ν(C=N), 1431s ν(P-Ph), 1249s ν(C-O-C), 1122m ν(C-N), 1095m ν(P-C), 1022s ν(N-N), 746s ν(C-S), 692s δ(P-C), 435m ν(Cd-N) . ^{1}H NMR (DMSO-d_6) δ(PPm) : 12.10 (s, 1H, NH), 8.12 (s, 1H, CH), 7.77 (d, ^{3}J = 5.93 Hz, 1H, H_a), 7.68 (d, ^{3}J = 8.30 Hz, 2H, H_e), 7.40 (m, ^{3}J = 3.44 Hz, ^{4}J = 3.33 Hz, 21H,H_{d+ph}), 7.32 (t, 1H, H_c), 7.12 (t, ^{3}J = 6.78 Hz, 1H,H_b), 7.06 (d, ^{3}J = 8.24 Hz, 2H, H_f), 3.85 (s, 3H, CH_3), 2.10 (s, 4H, CH_2), 1.70 (s, 4H, CH_2) . ^{13}P{^{1}H}NMR(DMSO-d_6): δ30.11 ppm . The elemental analysis is calculated for $C_{43}H_{41}CdCl_2N_3OP_2S$: C,57.83 ; H,4.63 ; N,4.70. It is found that: C,57.56 ; H,4.54 ; N,4.37. ʌ (Ω^{-1}.cm^2.mol^{-1}) : 72.3

[Cd(L)(dppf)]Cl_2 (6) Yellow powder , (0.296 g), yields 82% m.p : 160-162 ^{o}C . FTIR(KBr): 3375w ν(NH), 3072m ν(C-H)$_{arom}$, 2941m ν(C-H)$_{Aliph}$, 1623s ν(HC=N) , 1573s ν(C=C), 1506s ν(C=N), 1417s ν (P-Ph), 1251s ν(C-O-C), 1122m ν(C-N), 1099m ν(P-C), 1022s ν(N-N),752 ν(C-S), 688s δ(P-C), 428 ν(Cd-N) . ^{1}H NMR (DMSO-d_6) δ(PPm) : 12.16 (s, 1H, NH), 8.11 (s, 1H, CH), 7.78 (d, ^{3}J = 7.81 Hz, 1H,

H_a), 7.67 (d, ^3J = 8.65 Hz, 2H, H_e), 7.45 (s, 1H,H_d), 7.37 (m, ^3J = 2.40 Hz,10H, H_{ph}), 7.32 (m, 1H,H_c), 7.26 (m, 12H,H_{ph}), 7.12 (t, ^3J = 7.56 Hz , 1H,H_b), 7.05 (d, ^3J = 8.71 Hz, 2H, H_f), 4.29 (m, 4H, CH_2), 3.97 (q, ^3J = 1.80 Hz, ^4J = 1.86 Hz, 4H, CH_2), 3.38(s, 3H,CH_3). $^{13}P\{^1H\}$NMR(DMSO-d_6): δ18.89 ppm. The elemental analysis is calculated for $C_{49}H_{41}CdCl_2FeN_3OP_2S$: C,57.64 ; H,4.05 ; N,4.12. It is found that: C,57.87 ; H,3.89 ; N,3.97. ʌ ($\Omega^{-1}.cm^2.mol^{-1}$): 80.3

Results and Discussion

1. Molar Conductivity

The data showed high conductivity values, reflecting the presence of free ions outside the coordination sphere. The values correspond to the formulas of the prepared complexes [20]. The data showed that the ligand solution (L) is nonelectrolyte, as its electrical conductivity is at (6.5 $ohm^{-1}.cm^{-2}.mol^{-1}$). As for the solutions of cadmium complexes, the electrical conductivity value of the complex $[Cd_2(L)_2(\mu\text{-}dppm)Cl_2]Cl_2$ is (43.8 $ohm^{-1}.cm^{-2}.mol^{-1}$), which is within the ratio 1:1, i.e. a positive ion to a negative ion. While other complexes are within the ratio of 1:2, giving conductivity values ranging between (36.2-58.1 $ohm^{-1}.cm^{-2}.mol^{-1}$).

The current values for conductivity measurements showed that complexes (1-6) have two Cl ions outside the coordination. While complex 2 has two Cl ions inside the coordination sphere and two outside the sphere. This would probably lead to the formation of a tetrahedral planar for the central cadmium ion of the complexes and exclude the octahedral planar.

2. Infrared (IR) Spectrum

The FTIR spectrum of (L) ligand showed a strong range at (3407 cm^{-1}) related to υ(NH), a signal at (1618 cm^{-1}) belonging to the group υ(N=CH) outside the sphere [21], a band at the frequency (1569cm^{-1}) belonging to the ν(C=C) aromatic group. In addition, there was a signal appeared in (1506 cm^{-1}) belonging to the group υ(C = N) inside the five numbered ring [22], a band at the frequency of (1251cm^{-1}) belonging to the group ν(C-O-C), a band at the frequency of (1112cm^{-1}) belonging to ν(C-N) [23], band at the frequency of (1022cm^{-1}) belonging to ν(N-N) [24], and another band at the frequency of (750cm^{-1}) belonging to ν(C-S).

While the IR spectrum of the prepared complexes showed a new signal between (1417s-1431s cm-1) and (1095s-1099s cm-1) belonging to υ(P-Ph) and υ(P-C), respectively [25], a signal between (682s-694s cm-1) belonging to the curve of δ(P-C), a signal between (1612s-1625s cm-1) belonging to the group υ(CH=N) outside the ring [21], and a signal between (1506s-1508s cm-1) belonging to υ(C=N) within the five numbered ring [22]. These signals proved that the bonds are successfully bonded with the metal.

3. ^{1}H NMR Spectrum for (L) Ligand

The 1H NMR spectrum of the ligand measured in the DMSO-d^6 solvent showed a singlet signal at the shift (δH = 12.15 ppm) with a single proton belonging to the group (NH), and a singlet signal at (δH = 8.12 ppm) with a single proton belonging to (CH).

The spectrum also showed six signals: doublet, doublet, doublet, triplet, triplet and doublet at the shifts (7.78, 7.67, 7.45, 7.32, 7.12 and 7.05 ppm) due to the protons of H_a, H_e, H_d, H_c , H_b and H_f, respectively. Moreover, there was a singlet signal at the shift (δH = 3.83 ppm) with the integration of three protons belonging to (CH_3) as shown in Figure 2.

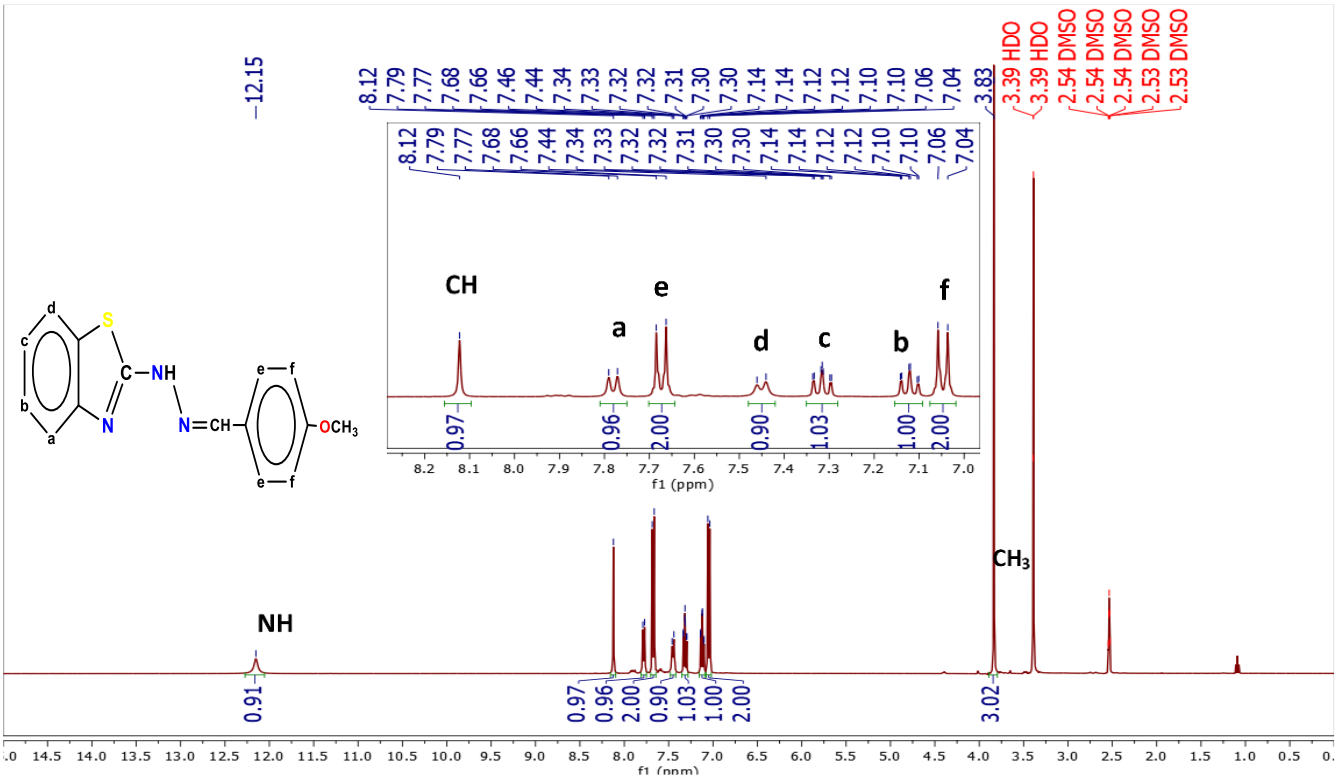


Figure 2: the ^{1}H NMR Spectrum of (L) Ligand

The NMR spectra of proton of the prepared complexes (1-6) showed multiple signals at the shifts (7.48,7.26), (7.49, 7.36), (7.34), (7.45, 7.37), (7.40) and (7.37, 7.26), respectively, belonging to the protons of phosphine rings. The ^{31}P-{^{1}H}NMR spectrum of complexes (1, 3-6) showed a positive singlet signal at 25.60, 14.47, 29.95, 30.11 and 18.89 ppm, respectively. The signal indicated the valence of the two phosphorus atoms and that the complex has one isomer. The phosphorus spectrum of complex (2) showed two isomers, where it showed a positive singlet signal at 23.61, indicating the valence of the two phosphorus atoms in dppm and its behavior as a bridge in a two nuclei complex. Additionally, there were two doublet signals, a positive signal at 27.47 and a negative one at -27.64, indicating the coordination of one of the phosphorus atoms in dppm.

4. The Results of SEM and EDX

The recent studies on the geometry of coordinate compounds have shown that most of them can be systematically produced nano-sized engineering structures [26]. In this paper, the morphological appearance of the microstructure of some complexes prepared by SEM technology was studied. The SEM image of $[Cd(L)_2(dppe)]Cl_2$ showed irregular protrusions with a nano size of 170-240 nm (as in Fig. 3a). The EDX result showed remarkable peaks representing the atoms found in the complex (Fig. 3b).

The SEM image of $[Cd(L)(dppp)]Cl_2$ showed the formation of irregular cubes, some of them were fused with a nano size of 66 −130 nm (as in Fig. 4a), and the EDX result showed remarkable peaks representing the atoms found in the complex (Fig. 4b).

While the SEM image of $[Cd(L)(dppb)]Cl_2$ showed the formation of irregular clusters with a nano size of 70-118 nm (as in Fig. 5a), and the EDX result showed remarkable peaks representing the atoms found in the complex (Fig. 5b).

These results are good results in the field of coordination chemistry, as they open up prospects for the usability of complexes in a wide range of applications. Regarding the results obtained, the measurements

proved the existence of regular nanostructures with high porosity, which means that these compounds are able to be used in applications requiring a high porosity surface area, such as those required in hydrogen storage applications [27,28]. Although the compositions of nanocomplexes were addressed infrequently, the SEM results in this study are consistent with the previously published results [29,30], indication the possibility to synthesize complexes containing nanostructures. It was also revealed that the particle sizes in this study were somewhat larger than those previously reported.

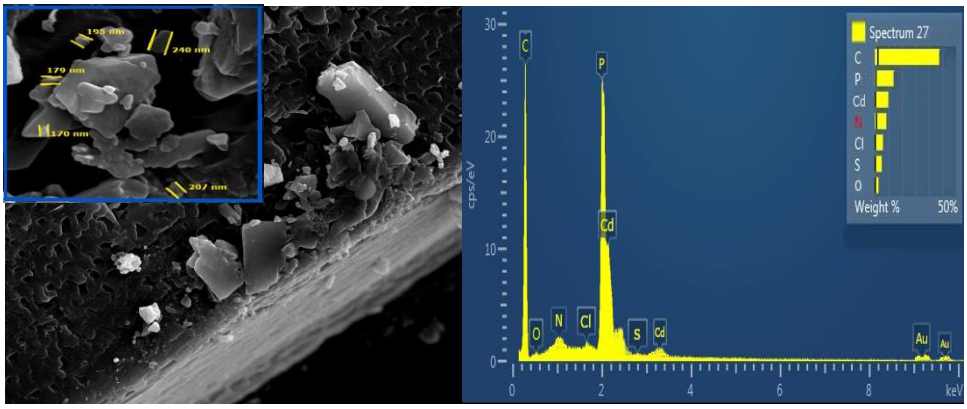


Figure 3a: The SEM measurements of $[Cd(L)_2(dppe)]Cl_2$/ 3b: The EDX measurements of $[Cd(L)_2(dppe)]Cl_2$

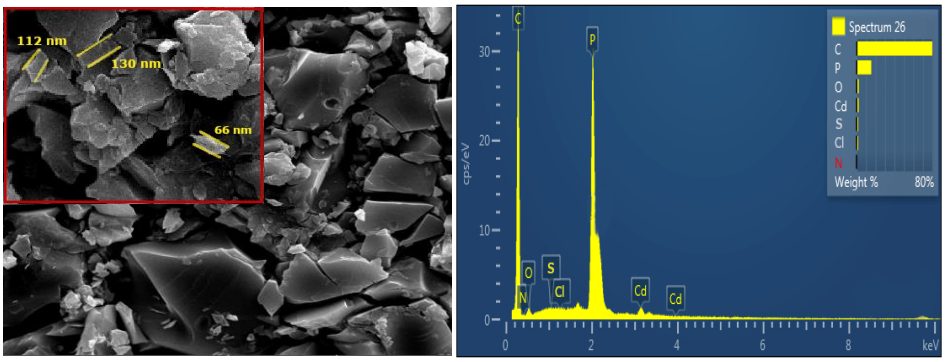


Figure 4a: The SEM measurements of $[Cd(L)(dppp)]Cl_2$/ 4b: The EDX measurements of $[Cd(L)(dppp)]Cl_2$

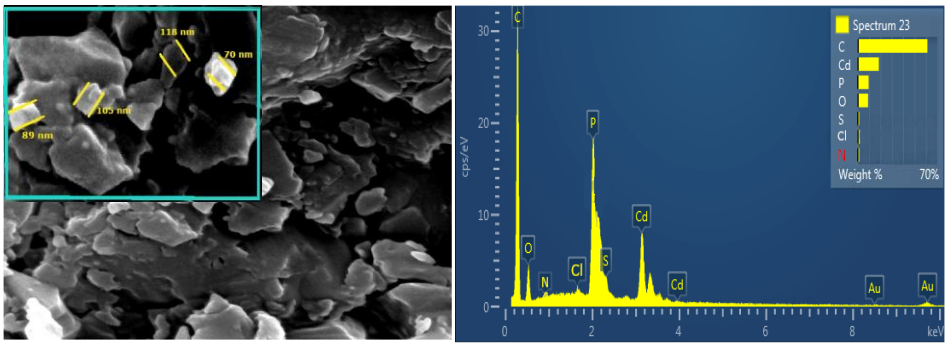
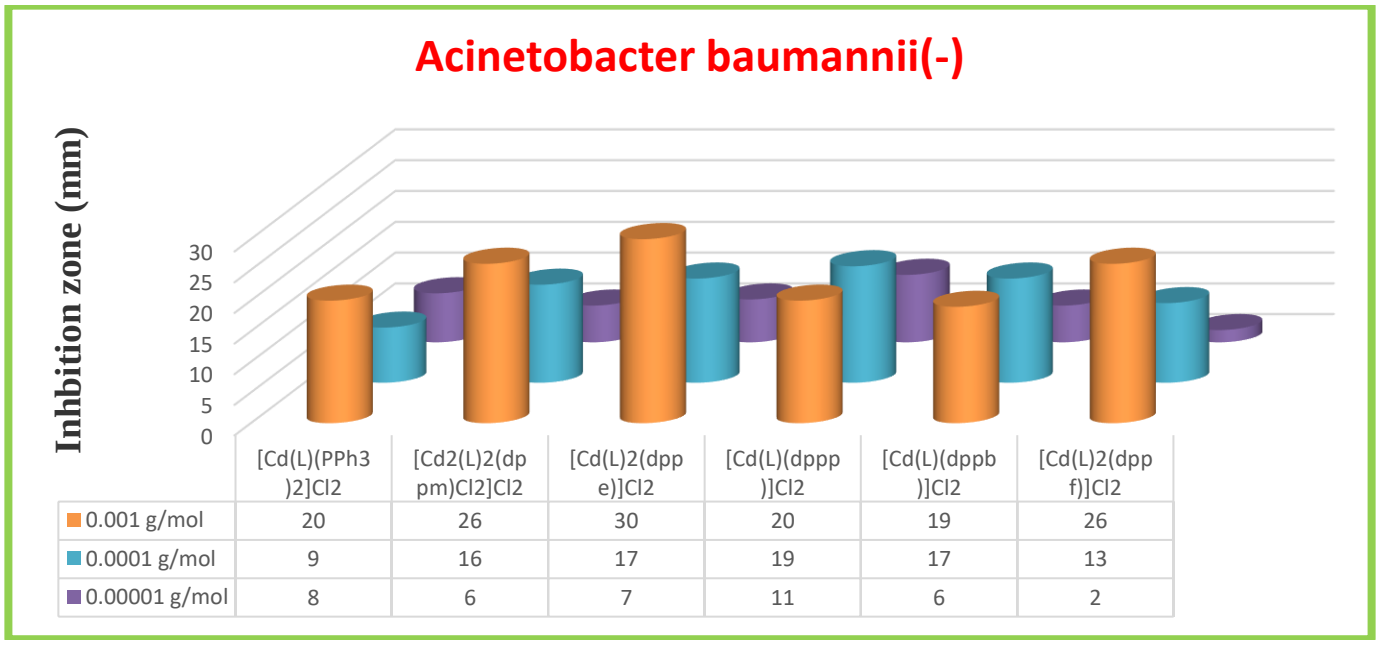


Figure 5a: The SEM measurements of $[Cd(L)(dppb)]Cl_2$/ 5b: The EDX measurements of $[Cd(L)(dppb)]Cl_2$

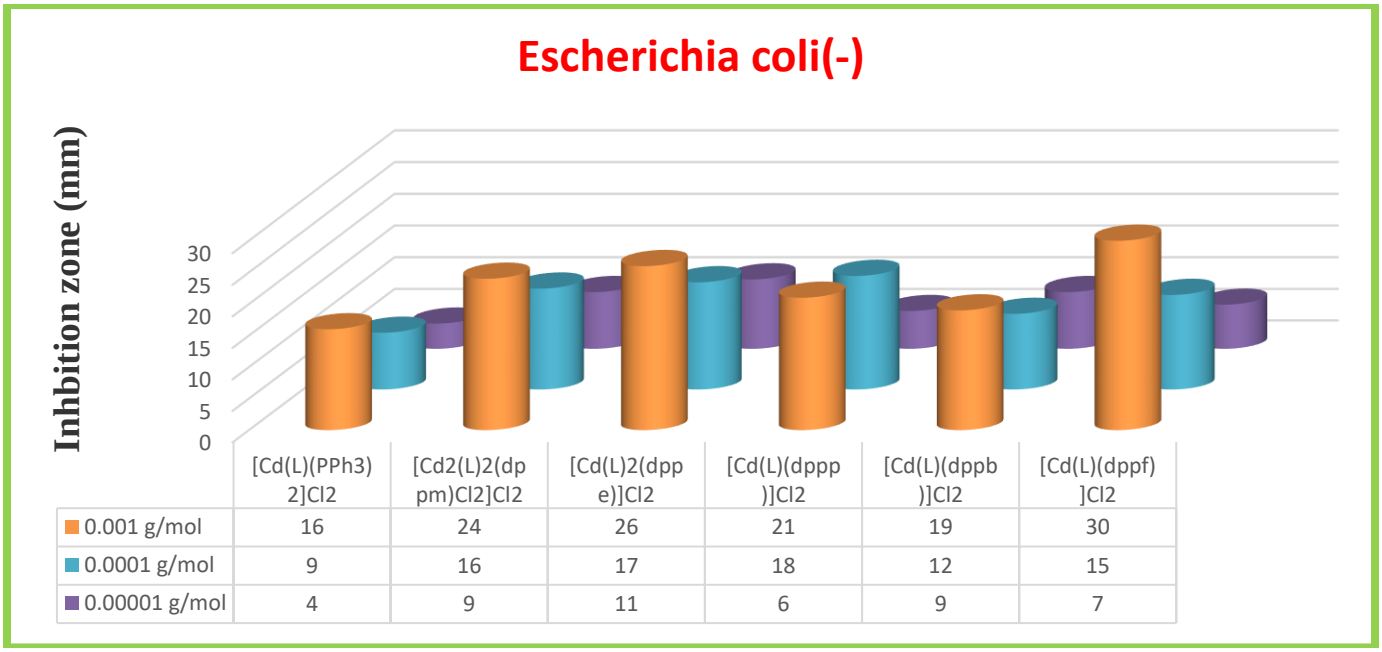
5. The Biological Activity of the Prepared Complexes

The biological activity of the complexes (0.01, 0.001, 0.0001 mg/ml) was tested against four species of bacteria: Acinetobacter baumannii(-), Escherichia coli(-), Enterococcus faecalis(+), and Staphylococcus aureus(+)[31,32]. Using the antibiotic amikacin as a standard, all complexes showed activity against these bacteria species (as in Figure 6). The concentration 10^{-4} gave a weak activity against the bacteria species, while the complex (4) showed the highest inhibition ratio at the concentration of 10^{-3} for Acinetobacter baumannii(-) and Escherichia coli(-)[33]. The complex (5) showed the highest inhibition ratio at the concentration of 10^{-3} for Staphylococcus aureus(+) and Enterococcus faecalis(+). The complex (6) showed the highest efficacy at the concentration 10^{-2} for Escherichia coli(-), while the complex (3) showed the highest efficacy at the same concentration for other species[34].



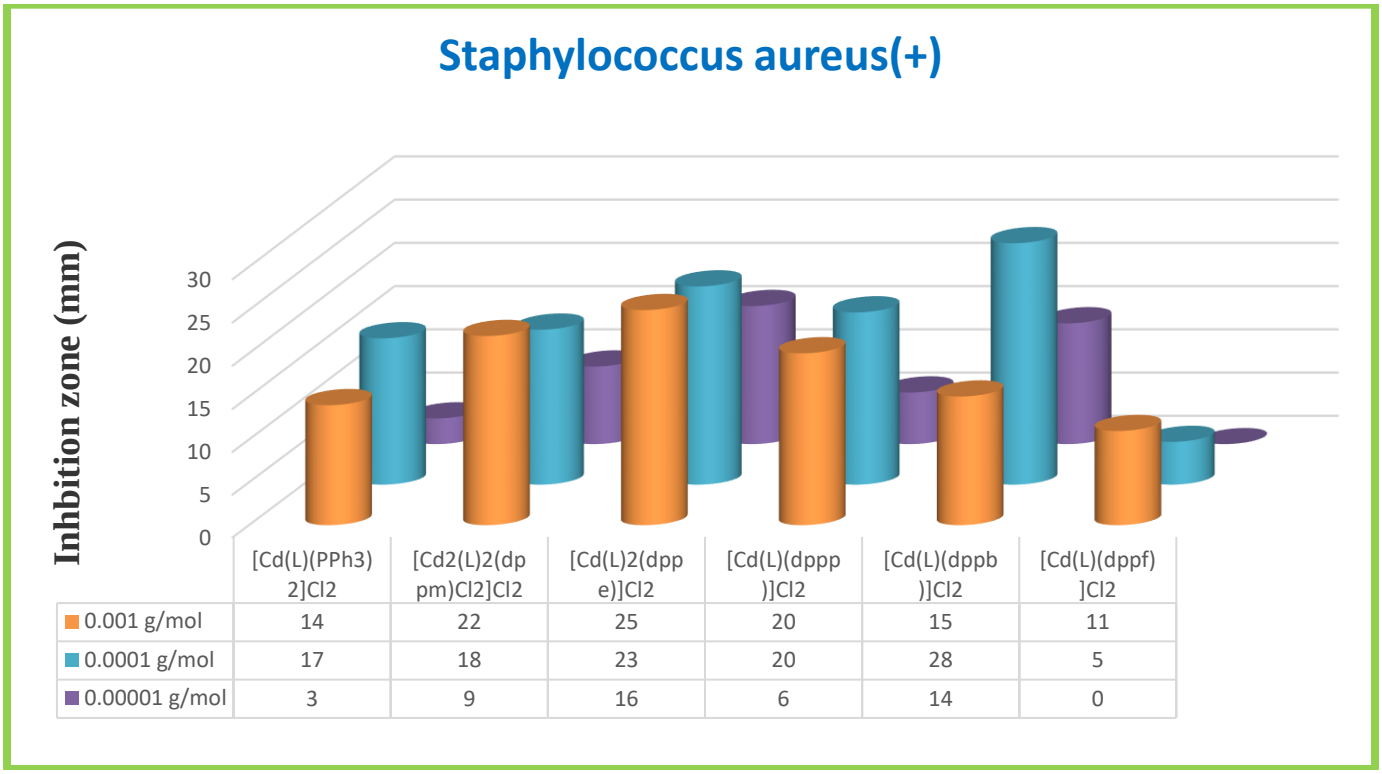
	[Cd(L)(PPh3)2]Cl2	[Cd2(L)2(dppm)Cl2]Cl2	[Cd(L)2(dppe)]Cl2	[Cd(L)(dpppp)]Cl2	[Cd(L)(dppb)]Cl2	[Cd(L)2(dppf)]Cl2
0.001 g/mol	20	26	30	20	19	26
0.0001 g/mol	9	16	17	19	17	13
0.00001 g/mol	8	6	7	11	6	2

(A)

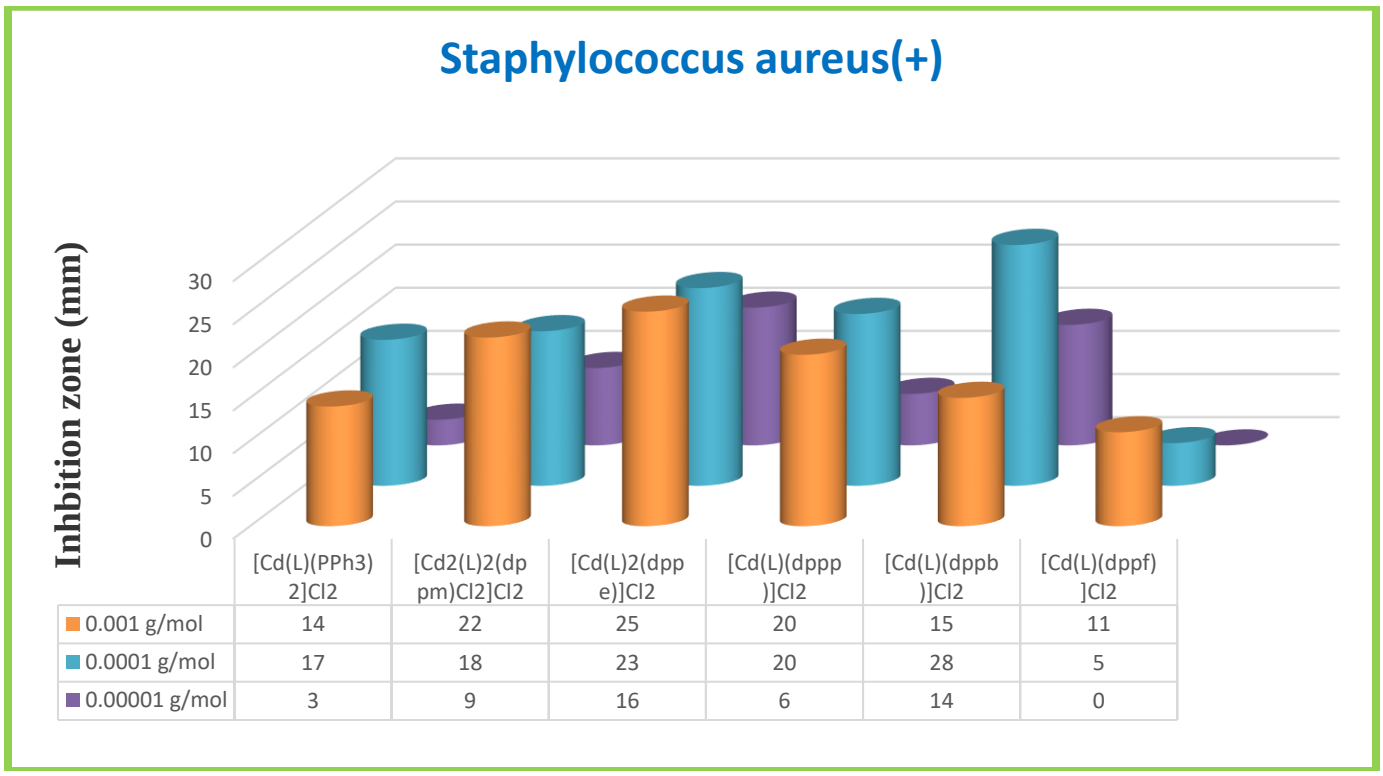


	[Cd(L)(PPh3)2]Cl2	[Cd2(L)2(dppm)Cl2]Cl2	[Cd(L)2(dppe)]Cl2	[Cd(L)(dpppp)]Cl2	[Cd(L)(dppb)]Cl2	[Cd(L)(dppf)]Cl2
0.001 g/mol	16	24	26	21	19	30
0.0001 g/mol	9	16	17	18	12	15
0.00001 g/mol	4	9	11	6	9	7

(B)



(C)



(D)

Figure 6: Inhibitory activity of prepared compounds in the growth of a number of negative bacteria (A), (B) and positive bacteria (C), (D)

Conclusions

In this paper, we concluded that 4-methoxybenzalene has the ability to coordinate to the cadmium ion in bidentate chelating fashion through the endo-cyclic nitrogen and nitrogen atoms in all complexes containing diamines or phosphines . The structural study using SEM proved that the complexes (3,4) and (5) have irregular protrusions - (170–240nm), showed the formation of irregular cubes - (66–130nm) and irregular clusters 70–118 nm, therefore the synthetic study will open horizons for researchers to investigate more about the nano structures of their complexes and search for suitable applications for them. Moreover, we concluded from the applied studies that some of the complexes have the ability to inhibit bacteria effectively compared to the positive reagent.

References

1. N. Pathak, E. Rathi, N. Kumar, S. G. Kini, and C. M. Rao, “A review on anticancer potentials of benzothiazole derivatives,” Mini Rev. Med. Chem., vol. 20, no. 1, pp. 12–23, 2020.
2. S.-T. Huang, I.-J. Hsei, and C. Chen, “Synthesis and anticancer evaluation of bis (benzimidazoles), bis (benzoxazoles), and benzothiazoles,” Bioorg. Med. Chem., vol. 14, no. 17, pp. 6106–6119, 2006.
3. M. A. Morsy et al., “Screening and molecular docking of novel benzothiazole derivatives as potential antimicrobial agents,” Antibiotics, vol. 9, no. 5, p. 221, 2020.
4. M. K. Singh, R. Tilak, G. Nath, S. K. Awasthi, and A. Agarwal, “Design, synthesis and antimicrobial activity of novel benzothiazole analogs,” Eur. J. Med. Chem., vol. 63, pp. 635–644, 2013.
5. B. Luo, D. Li, A.-L. Zhang, and J.-M. Gao, “Synthesis, antifungal activities and molecular docking studies of benzoxazole and benzothiazole derivatives,” Molecules, vol. 23, no. 10, p. 2457, 2018.
6. C. H. Suresh, J. V. Rao, K. N. Jayaveera, and S. K. Subudhi, “Synthesis and anthelminitc activity of 3 (2-hydrazino benzothiazoles)-substituted indole-2-one,” IJPR, vol. 2, pp. 257–261, 2011.
7. J. Apelt et al., “Search for histamine H3 receptor antagonists with combined inhibitory potency at N τ-methyltransferase: ether derivatives,” Die Pharm. Int. J. Pharm. Sci., vol. 60, no. 2, pp. 97–106, 2005.
8. M. I. Khalil and Q. Z. Khalal, “Synthesis and characterization of new compounds derived from 2-hydrazinobenzothiazole and evaluated their antibacterial activity,” in Journal of Physics: Conference Series, IOP Publishing, 2021, p. 12007.
9. S. R. Gurram and M. A. Azam, “Design, synthesis, antibacterial evaluation and molecular docking studies of some newer baenzothiazole containing aryl and alkaryl hydrazides,” Chem. Biodivers., vol. 18, no. 7, p. e2100117, 2021.
10. E. M. H. Abbas, K. M. Amin, W. S. El-Hamouly, D. H. Dawood, and M. M. Abdalla, “Synthesis, anti-inflammatory and antinociceptive activity of some novel benzothiazole derivatives,” Res. Chem. Intermed., vol. 41, pp. 2537–2555, 2015.
11. G. Huang, T. Cierpicki, and J. Grembecka, “2-Aminobenzothiazoles in anticancer drug design and discovery,” Bioorg. Chem., p. 106477, 2023.
12. S. S. Alazzawi and Y. K. Alasadi, “Synthesis and study of the biological activity and molecular Docking of 2-hydrazinobenzothiazole derivatives.,” Multi-Knowledge Electron. Compr. J. Educ. Sci. Publ., no. 62, 2023.
13. A. N. M. Zaki, S. S. Husain, and B. H. Obaid, “Effect of some derivatives quinoline prepared on some pathogenic bacteria species compared with the 2-hydrazinobenzothiazole,” AGERC, p. 805, 2016.

14. A. Catalano et al., “2-Aminobenzothiazole derivatives: search for new antifungal agents,” Eur. J. Med. Chem., vol. 64, pp. 357–364, 2013.
15. S. R. Nagarajan et al., “Discovery of novel benzothiazolesulfonamides as potent inhibitors of HIV-1 protease,” Bioorg. Med. Chem., vol. 11, no. 22, pp. 4769–4777, 2003.
16. E. Holobova and A. Peijessy, “synthesis and properties of 2-hydrazinobenzothiazole derivatives,” Chem. Pap., vol. 40, no. 6, pp. 791–796, 1986.
17. D. C. Dash, A. Mahapatra, R. K. Mohapatra, S. Ghosh, and P. Naik, “Synthesis and characterization of dioxouranium (VI), thorium (IV), oxozirconium (IV) and oxovanadium (IV) complexes with 1, 11-dihydroxy-1, 4, 5, 7, 8, 11-hexaaza-2, 3, 9, 10-tetramethyl-1, 3, 8, 10-decatetraene-6-thione and their derivatives with chloroacetic acid,” 2008.
18. Y. A. AL SOUD et al., “Synthesis and in vitro antiproliferative activity of new benzothiazole derivatives,” Arkivoc, vol. 2008, no. 15, pp. 225–238, 2008.
19. V. V Shcherbakov, Y. M. Artemkina, I. A. Akimova, and I. M. Artemkina, “Dielectric characteristics, electrical conductivity and solvation of ions in electrolyte solutions,” Materials (Basel)., vol. 14, no. 19, p. 5617, 2021.
20. M. Sunjuk et al., “Transition metal complexes of Schiff base ligands prepared from reaction of aminobenzothiazole with benzaldehydes,” Inorganics, vol. 10, no. 4, p. 43, 2022.
21. R. K. Mohapatra et al., “Synthesis, structural investigations, DFT, molecular docking and antifungal studies of transition metal complexes with benzothiazole based Schiff base ligands,” J. Mol. Struct., vol. 1179, pp. 65–75, 2019.
22. H. L. Yale and K. Losee, “2-Amino-5-substituted 1, 3, 4-oxadiazoles and 5-imino-2-substituted Δ2-1, 3, 4-oxadiazolines. A group of novel muscle relaxants,” J. Med. Chem., vol. 9, no. 4, pp. 478–483, 1966.
23. L. A. Al-Doori, A. A. Irzoqi, H. M. Jirjes, A. H. AL-Obaidi, and M. A. Alheety, “Zn (II)-isatin-3-thiosemicarbazone complexes with phosphines or diamines for hydrogen storage and anticancer studies,” Inorg. Chem. Commun., vol. 140, p. 109454, 2022.
24. M. A. Alheety, M. Y. Mohammed, and I. K. Jebour, “Synthesis and characterization of novel nano dithiocarbamate complexes derived from GO-benzimidazole,” 2016.
25. A. S. M. Al-Janabi, A. Y. Osama’a, and M. A. Alheety, “Novel Mercury (II) 1-Phenyl-1H-tetrazol-5-thiol and carbon nanotube complexes: synthesis, characterization and H2 storage capacities,” Chem. Data Collect., vol. 28, p. 100399, 2020.
26. A. A. Irzoqi, M. M. Salih, H. M. Jirjes, and M. K. Mensoor, “Synthesis, Characterization, and Antibacterial Activity of Complexes of Hg (II) with Mixtures of 3-Hydrazonoindolin-2-one and Diphosphine, or Diimine Ligands,” Russ. J. Gen. Chem., vol. 90, pp. 1069–1073, 2020.
27. M. M. Salman, A. A. Al-Dulaimi, A. S. M. Al-Janabi, and M. A. Alheety, “Novel dithiocabamate nano Zn (II), Cd (II) and Hg (II) complexes with pyrrolidinedithiocarbamate and N, N-diethyldithiocarbamate,” Mater. Today Proc., vol. 43, pp. 863–868, 2021.
28. A. H. Ismail, H. K. Al-Bairmani, Z. S. Abbas, and A. M. Rheima, “Nano metal-complexes of theophylline derivative: synthesis, characterization, molecular structure studies, and antibacterial activity,” in IOP Conference Series: Materials Science and Engineering, IOP Publishing, 2020, p. 52028.

29. J. N. Saleh and A. Khalid, “Synthesis, Characterization and Biological Activity Evaluation of Some New Pyrimidine Derivatives by Solid Base Catalyst AL2O3-OBa,” Cent. Asian J. Med. Nat. Sci., vol. 4, no. 4, pp. 231–239, 2023.
30. M. J. Saleh and K. A. Al-Badrany, “Preparation, Characterization of New 2-Oxo Pyran Derivatives by AL2O3-OK Solid Base Catalyst and Biological Activity Evaluation,” Cent. Asian J. Med. Nat. Sci., vol. 4, no. 4, pp. 222–230, 2023.
31. A. W. A. S. Talluh, “Preparation, Characterization, Evaluation of Biological Activity, and Study of Molecular Docking of Azetidine Derivatives,” Cent. Asian J. Med. Nat. Sci., vol. 5, no. 1, pp. 608–616, 2024.
32. A. Talluh, J. N. Saleh, and M. J. Saleh, “Preparation, Characterization and Evaluation of Biological Activity and Study of Molecular Docking of Some New Thiazoli-dine Derivatives,” 2024.
33. A. W. A. S. Talluh, M. J. Saleh, J. N. Saleh, K. Al-Badrany, and H. mohammed saleh Al-Jubori, “Preparation, characterization, and evaluation of the biological activity of new 2, 3-dihydroquinazoline-4-one derivatives,” Eur. J. Mod. Med. Pract., vol. 4, no. 4, pp. 326–332, 2024.
34. O. A. F. Al-Hadidi, K. A. Al-Badrany, and S. A. Al-Bajari, “Synthesis some of thiazepine compounds from 2-carbboxyaldehyde-5-methyl thiophene and study their biological activity on infected male rats epileptic,” J. Educ. Sci. Stud., vol. 2, no. 20, 2022.