Baghdad Science Journal

Volume 22 | Issue 2 Article 2

2025

Palladium (II) Mixed Ligand Complexes of Benzoisothiazol-3(2H)-Dithiocarbamate (Bit-dtc) and Tertiary Diphosphines: Synthesis, Characterization, Biological and Anticancer Studies

Nazk Mohammed Aziz
Department of Chemistry, College of Science, University of Sulaimani, Sulaimaniyah, Iraq,
nazk.aziz@univsul.edu.iq

How to Cite this Article

Aziz, Nazk Mohammed (2025) "Palladium (II) Mixed Ligand Complexes of Benzoisothiazol-3(2H)-Dithiocarbamate (Bit-dtc) and Tertiary Diphosphines: Synthesis, Characterization, Biological and Anticancer Studies," *Baghdad Science Journal*: Vol. 22: Iss. 2, Article 2.
DOI: https://doi.org/10.21123/bsj.2024.9491

BAGHDAD SCIENCE JOURNAL 2025;22(2):371–378

RESEARCH ARTICLE

Palladium (II) Mixed Ligand Complexes of Benzoisothiazol-3(2*H*)-Dithiocarbamate (Bit-dtc) and Tertiary Diphosphines: Synthesis, Characterization, Biological and Anticancer Studies

Nazk Mohammed Aziz

Department of Chemistry, College of Science, University of Sulaimani, Sulaimaniyah, Iraq

ABSTRACT

[Pd(bit-dtc)$_2$] complex was prepared by the reaction of sodium benzoisothiazol-3(*2H*)-dithiocarbamate (Nabit-dtc) with sodium tetrachloropalladate(II). Treatment of [Pd(bit-dtc)$_2$] with one mole equivalent of $Ph_2P(CH)_nPPh_2$ afforded complexes of the type [Pd(bit-dtc)$_2$($Ph_2(CH_2)_n$ PPh_2)] in good yield: n = 1(dppm); n = 2 (dppe), n = 3 (dppp); n = 4 (dppb); n = $(C_5H_4)_2Fe$ (dppf). The prepared complexes were characterized by elemental analysis, I.R., ^{1}H-{^{31}P} and ^{31}P-{^{1}H} NMR spectroscopy the dithiocarbamate ligand bonded as mono dentate with Pd ion. The NMR spectroscopic data suggested that the prepared complexes have mononuclear coordination mode with diphosphines binding as chelating ligands, except dppm which behaves as bridging ligand, afforded binuclear complex. The antimicrobial activities of the newly synthesized Pd(II) complexes were evaluated against two types of bacteria, namely *Staphylococcus aureus* (*S. aureus*) and *Escherichia coli* (*E. coli*). Furthermore, the complexes where n = 2, 4 and 5 were screened against pancreatic adenocarcinoma (SNU-2469), human gastric-esophageal adenocarcinoma (SK-GT-5), and healthy cell(WRL68). The complex [Pd(bit-dtc)$_2$(dppe)] exhibited a significant activity against pancreatic adenocarcinoma of SNU-2469 cancer cells with IC_{50} value of 5.067 μM.

Keywords: Anticancer activity, Benzoisothiazol-3-dithiocarbamate, Mixed ligand complexes, Palladium, Phosphine

Introduction

Metal complexes of S, N-donor ligands have been the focus of many studies, due to their interesting biological properties.[1–3] For instance, palladium complexes with dithiocarbamate, thione or thiourea moiety showed high anti-bacterial, anti-fungal and anti-cancer activity values.[4–7] In addition, these ligands have contributed to many applications. Thus, palladium dithiocarbamate complexes were used as a sulfur precursor for PdS nanoparticles.[8] These ligands have the ability to interact with heavy metals and form stable complexes due to their unique system, which allow the ligands to share their electron density on S and N atoms with the central metal[9] Fig. 1.

Tertiary diphosphine (diphos) ligands can react with divalent square planar dithiocarbamate complexes in several ways. The reaction mechanism can be summarized as follows; as the diphosphine ligand approaches the [M(DTC)$_2$] complex, the metal-sulfur bond undergoes stepwise cleavage which result in either cationic [M(K^2-DTC)(diphos)] DTC or neutral complex [M(K^1-DTC)$_2$(diphos)],[10–13] Fig. 2. However, the cationic complex is believed to goes back to its stable neutral form via S_2^- nucleophilic attack on the central metal. In a previous publication, Al-jibori

Received 16 September 2023; revised 10 November 2023; accepted 12 November 2023.
Available online 20 February 2025

E-mail address: nazk.aziz@univsul.edu.iq (N. M. Aziz).

https://doi.org/10.21123/bsj.2024.9491

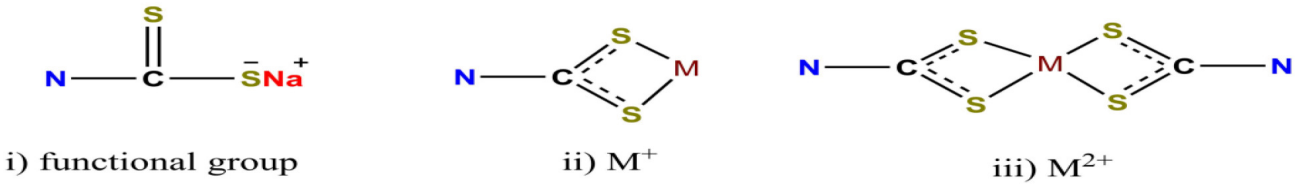


Fig. 1. The dithiocarbamate group attached to heavy metal M. i) functional group, ii) M^{+}, iii) M^{2+}.

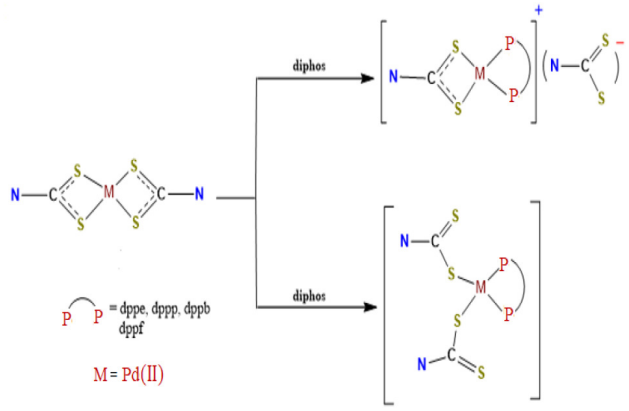


Fig. 2. The reaction pathways of square planar dithiocarbamate complexes with tertiary phosphine ligands.

demonstrated the reaction of Pd-dithiocarbamate moiety with tertiary phosphine ligands.[14]

In this study, palladium(II) mixed ligand complexes of dithiocarbamate derived from 1,2-benzisothiazol-3(*2H*)-one and diphosphine ligands were prepared. The antibacterial and anti-proliferative activities of the newly synthesized complexes were investigated.

Materials and methods

The chemicals and solvents used in this project were purchased from commercial sources and used as they were. Melting points were measured on a Gallenkamp melting point apparatus and were uncorrected. The IR spectra (as KBr disk) were recorded on a Shimadzu FT-IR 8400 spectrophotometer in the 400–4000 cm^{-1} range. NMR spectra were recorded (DMSO-d_6) on a Bruker (400 MHz) NMR spectrometer using TMS as an internal standard, sodium benzoisothiazol-3(*2H*)-dithiocarbamate (Nabit-dtc) was prepared by modified literature method.[15]

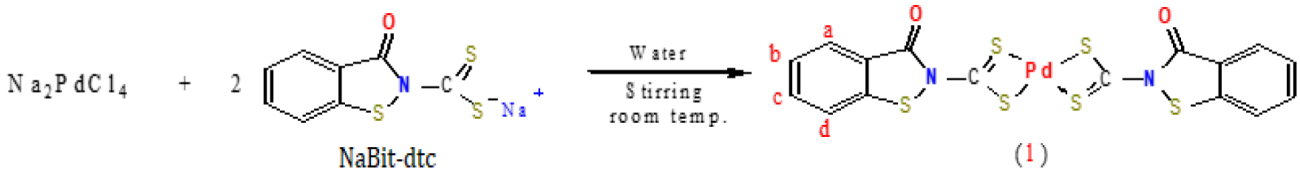
Preparation of [Pd(bit-dtc)$_2$] 1. To an aqueous solution of Na_2PdCl_4 (0.85 mmol, 0.250 g), was added an aqueous solution of Nabit-dtc (0.423 g, 1.7 mmol) resulted in the formation of red solution. The reaction mixture was stirred at room temperature for 24 hours furnished a red precipitate. The red precipitate was filtered-off, washed with cold EtOH and dried to give complex **1** (0.402 g, 85%) as a red powder, IR (KBr, cm^{-1}) 3063 υ(=C-H); 1631 υ(C=O); 1509 υ(C-N); 877 υ(C=S). ^{1}H NMR (DMSO-d_6, δ ppm): 7.62 (d, 1H, Ha); 7.58 (d, 1H, Hd); 7.31 (t, 1H, Hc); 7.15 (t, 1H, Hb). Anal. Calc. $C_{16}H_8N_2O_2PdS_6$: C, 34.38; H, 1.44; N, 5.01. Found: C, 34.44, H, 1.51, N, 5.13 %.

General Procedure for Preparation of Complexes 2–4. Complex **1** (0.200 g, 0.358 mmol) was suspended in $CHCl_3$ (10 mL) followed by addition of a solution of diphosphine ligand (0.358 mmol) in $CHCl_3$ (10 mL). The suspension immediately turned into clear yellow, orange or red solution. The reaction mixture was refluxed for 1.5 hours and allowed to cool to room temperature. Evaporation of the resulting solution yielded gummy product, which was washed with diethyl ether to give the desired complex.

[Pd(bit-dtc)$_2$(dppe)] **2**. From dppe (0.143 g, 0.358 mmol). Yield: 0.238 g (69%) as a yellow, orange or red powder, IR (KBr, cm^{-1}) 3053 υ(=C-H); 1662 υ(C=O); 1587 υ(C-N); 914 υ(C=S); 489 υ(P-C); 1099 υ(P-C); 1435 υ(P-Ph). ^{31}P{^{1}H}-NMR (DMSO-*d6*, δ ppm): δP 31.53. ^{1}H NMR (DMSO-*d6*, $_\delta$ ppm): 6.9-8.30 (m, 28H, 5Ph); 2.76 (s, 4H, 2CH_2). Anal. Calc. for $C_{42}H_{32}N_2P_2PdS_6$: C, 52.69; H, 3.37; N, 2.93. Found: C, 52.64; H, 3.55; N, 3.12 %.

[Pd(bit-dtc)$_2$(dppp)] **3**. From dppp (0.148 g, 0.358mmol). Yield: 221 mg (64%) as a yellow orange powder, IR (KBr, cm^{-1}) 3055 υ(=C-H); 1665 υ(C=O); 1589 υ(C-N); 999 υ(C=S); 505 υ(P-C); 1101 υ(P-C); 1437 υ(P-Ph). ^{31}P{^{1}H}-NMR (DMSO-*d6*, δ ppm): δP 31.14. ^{1}H NMR (DMSO-*d6*, δ ppm): 7.14–7.87 (m, 28H, 5Ph); 2.79 (m, 4H, 2CH_2); 1.85 (m, 2H, CH_2). Anal. Calc. for $C_{43}H_{34}N_2P_2PdS_6$: C, 53.16; H, 3.53; N, 2.88. Found: C, 53.04; H, 3.61; N, 2.91 %.

[Pd(bit-dtc)$_2$(dppb)] **4**. From dppb (0.153 g, 0.358mmol). Yield: 0.249 g (71%) as an orange red powder, IR (KBr, cm^{-1}) 3035 υ(=C-H); 1665 υ(C=O); 1577 υ(C-N); 997 υ(C=S); 499 υ(P-C); 1101 υ(P-C); 1437 υ(P-Ph). ^{31}P{^{1}H}-NMR (DMSO-*d6*, δ ppm): δP 31.24. ^{1}H NMR (DMSO-*d6*, δ ppm): 6.99-7.99 (m, 28H, 5Ph); 2.39 (s, 4H, 2CH_2); 1.47 (s, 4H, 2CH_2). Anal. Calc. for $C_{44}H_{36}N_2P_2PdS_6$: C, 53.63; H, 3.68; N, 2.84. Found: C, 53.61; H, 3.57; N, 2.89 %.



Scheme 1. The reaction pathway for preparing palladium 1,2-benzisothiazol-3-one dithiocarbamate complex.

[Pd(bit-dtc)$_2$(dppf)] **5**. From dppf (0.198 g, 0.358mmol). Yield: 0.246 g (66%) as a red powder, IR (KBr, cm^{-1}) 3053 υ(=C-H); 1579 υ(C=O); 1560 υ(C-N); 916 υ(C=S); 520 υ(P-C); 1095 υ(P-C); 1435 υ(P-Ph). ^{31}P{^{1}H}-NMR (DMSO-*d6*, δ ppm): δP 28.38. ^{1}H NMR (DMSO-*d6*, δ ppm): 7.09–8.53 (m, 28H, 5Ph); 4.48 (s, 4H, Cp); 4.39 (s, 4H, Cp). Anal. Calc. for $C_{50}H_{36}FeN_2O_2P_2PdS_6$: C, 53.94; H, 3.26; N, 2.52. Found: C, 53.99; H, 3.31; N, 2.63 %.

[Pd(bit-dtc)$_2$(μ-dppm)]$_2$ 6. From dppm (0.138 g, 0.358mmol). Yield: 0.240 g (71%) as a red powder, IR (KBr, cm^{-1}) 3053 υ(=C-H); 1662 υ(C=O); 1587 υ(C-N); 914 υ(C=S); 489 υ(P-C); 1099 υ(P-C); 1435 υ(P-Ph). ^{31}P{^{1}H}-NMR (DMSO-*d6*, δ ppm): δP 25.14. ^{1}H NMR (DMSO-*d6*, δ ppm): 6.86–7.93 (m, 28H, 5Ph); 4.06 (t, 2H, CH_2). Anal. Calc. for $C_{82}H_{60}N_4O_4P_4Pd_2S_{12}$: C, 52.2; H, 3.21; N, 2.97. Found: C, 52.31; H, 3.31; N, 3.13 %.

Antimicrobial activity study

The synthesized complexes were evaluated for their biological activity using agar disc diffusion method, on following the Luria-Bertani Agar (LBA) medium.[16] The palladium complexes were tested against *Staphylococcus aureus* (*S. aureus*) as a Gram positive bacteria and *Escherichia coli* (*E. coli*) as a Gram negative bacteria. The obtained results were compared with Tetracycline as a standard antibiotic at 0.001 M concentration. The standard error for the experiments was ± 0.03%. The inhibition zones were determined using Luria-Bertani plates, after being incubated[17] for 24 hours at 37°C.

Results and discussion

Synthesis and characterization

Complex 1 was synthesized with an 85% yield through the reaction of an aqueous solution of NaBit-dtc with an equimolar aqueous solution of palladium (II) salt at room temperature, as depicted in Scheme 1 Subsequently, the obtained palladium (II) complex was further reacted with diphosphine ligands in equimolar ratios Scheme 2 to yield complexes 2–6 with yields ranging from 64% to 71%. Similarly, complex 6 was prepared in $CHCl_3$ with a yield of 71%.

The structures of ligand and the complexes 1–6 were assigned by IR, ^{1}H and ^{31}P{^{1}H}-NMR spectra.

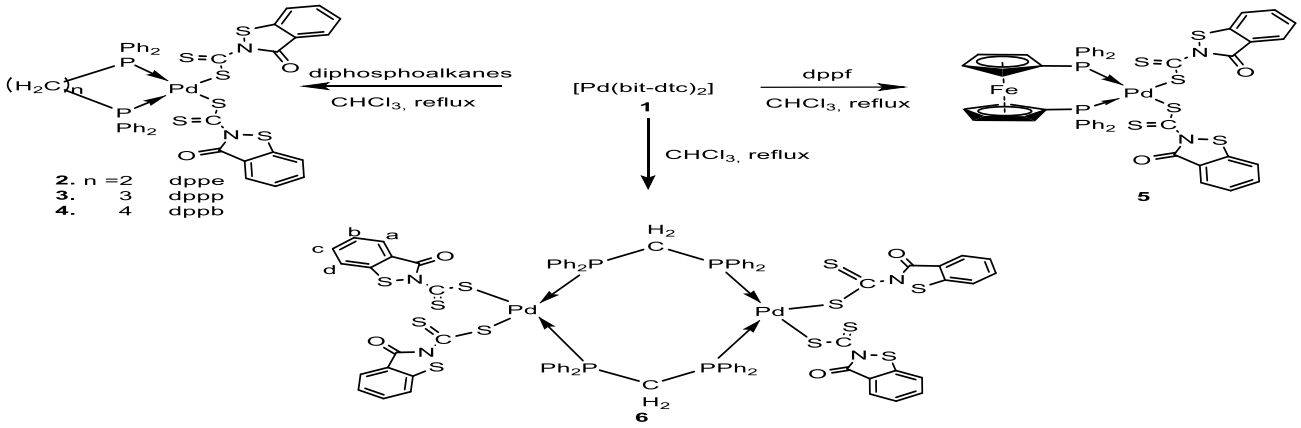
Infrared spectra

In the IR spectrum of the Nabit-dtc ligand, no absorption band corresponding to υ(N-H) was observed in the distinctive region around 3200 cm^{-1}. The band at 1631 cm^{-1} was attributed to the stretching of the carbonyl group, while the strong absorption band at 1508 cm^{-1} indicated the presence of υ(C-N).[18] The newly introduced CSS group exhibited an absorption at 877 cm^{-1}. In contrast, complex 1 displayed absorption bands similar to those of the bit-dtc ligand. Specifically, the absorption band at 1631 cm^{-1} was attributed to the carbonyl group, while the adjacent strong absorption was assigned to the υ(C-N) band. The υ(C=S) group was observed at 914 cm^{-1}. The addition of tertiary phosphine ligands to the palladium complexes was clearly discerned in the IR spectra, as the phosphine bands appeared in three distinctive regions of the spectrum.[19–22] The first phosphine band appeared within the range of 532–489 cm^{-1}. The second phosphine band was observed within 1103–1099 cm^{-1}, while the third phosphine band was noted within 1437–1433 cm^{-1}. A summary of all the results is provided in Table 1.

^{1}H and ^{31}P{^{1}H}-NMR Spectra

In the ^{1}H NMR spectrum of Nabit-dtc, the amide proton (N-H) signal disappeared, while the benzene ring protons appeared as four distinct signals corresponding to the four protons of the benzene ring. The most deshielded proton manifested as a doublet at 7.84 ppm (Ha, d, 1H), while another doublet appeared at 7.68 ppm, attributed to the Hd proton (Hd, d, 1H). The remaining protons, namely Hc and Hb, appeared as a triplet at 7.36 and 7.19 ppm, respectively. In the ^{1}H NMR spectrum of complex 1, the Ha and Hd protons were observed as two doublets adjacent to each other at 7.62 ppm and 7.58 ppm, respectively. Hc and Hb protons displayed as distinctive triplets at 7.31 ppm and 7.15 ppm, respectively.

The ^{1}H-NMR spectra of Pd(II) dithiocarbamate and tertiary phosphine moieties revealed the following:



Scheme 2. The reaction pathway for reacting [Pd(bit-dtc)$_2$] with diphosphine ligands.

Table 1. Selected absorption bands for IR spectra of the Bit-dtcNa ligand and its complexes 1–6.

Compd. No.	υ(C-H)cm^{-1} Arom.	υ(C-H) cm^{-1} aliphatic	υ(C=O) cm^{-1}	υ(C-N) cm^{-1}	υ(C=S) cm^{-1}	Phosphine bands cm^{-1} υ**P-C**	υ**P-C**	υ**Ph-P**
NaBit-dtc	3050	–	1639	1509	877	–	–	–
1	3063	–	1631	1585	914	–	–	–
2	3053	2850–2920	1662	1587	918	489	1099	1435
3	3055	2850–2920	1665	1589	999	505	1101	1437
4	3035	2850–2960	1665	1577	997	499	1101	1437
5	3053	–	1579	1560	916	520	1095	1435
6	3055	2908	1626	1570	995	532	1103	1433

complex 2 displayed the phenyl protons of both the dppe ligand and the bit-dtc ligand as a multiplet at 7.7 ppm, corresponding to 28 protons. The alkyl protons of the dppe ligand appeared as a singlet at 2.76 ppm (CH_2CH_2, s, 4H).

Complex **3** exhibited the 5 benzene protons, similar to complex 1, which appeared as a multiplet at 7.5 ppm (5Ph, m, 28H). The propyl moiety of dppp showed two signals at 2.79 and 1.85 ppm, respectively. Meanwhile, the dppb derived complex displayed the phenyl protons at 7.5 ppm (5Ph, m, 28H). Two signals appeared at 2.39 and 1.47 ppm, respectively, corresponding to the alkyl group (4CH_2), Fig. 3.

Complex **5** presented the 28 protons of the phenyl groups as a multiplet at 7.77 ppm, while the two Cps

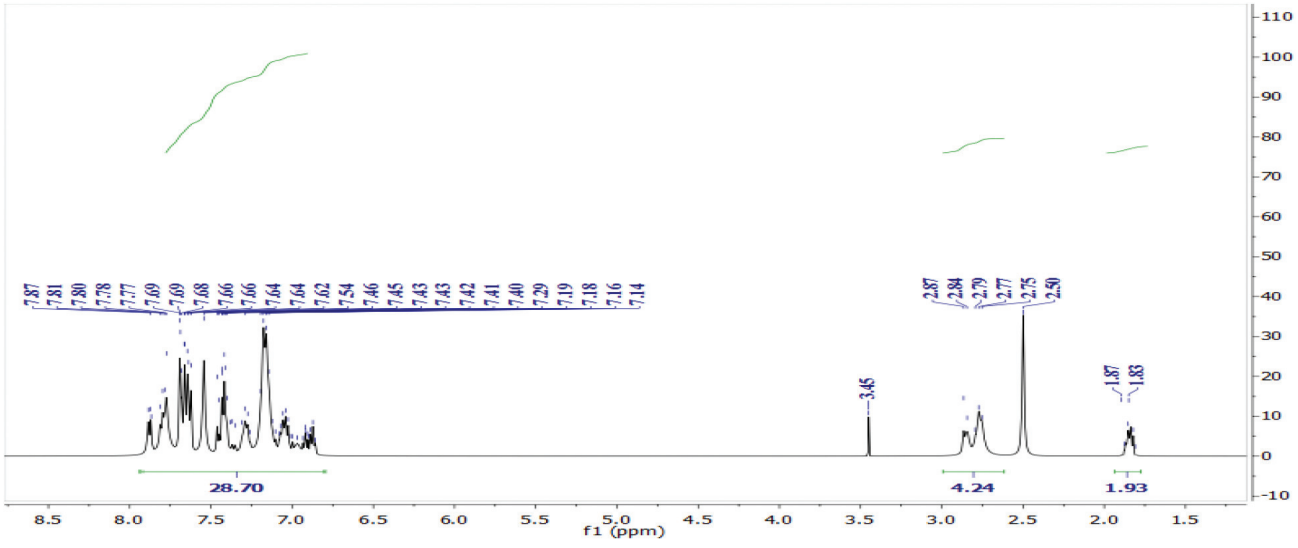


Fig. 3. ^{1}H-NMR spectrum of the complex [Pd(bit-dtc)$_2$(dppp)] **3**.

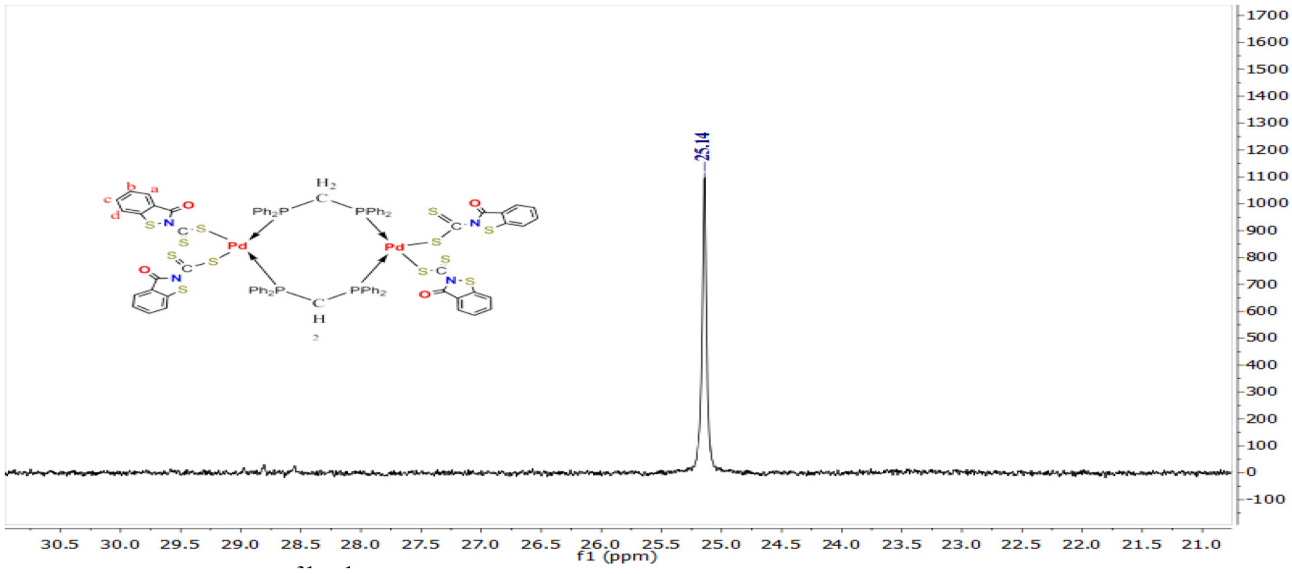


Fig. 4. $^{31}P\{^{1}H\}$-NMR spectrum of the complex $[Pd(bit\text{-}dtc)_2(\mu\text{-}dppm)]_2$ **6**.

of the dppf moiety appeared as two singlets at 4.58 and 4.39 ppm, respectively, corresponding to four protons each.

Finally, complex **6** exhibited binuclear characteristics (A-Frame), evident in both the ^{1}H-NMR and $^{31}P\{^{1}H\}$-NMR spectra.[23–25] The methylene protons appeared as a triplet at 4.06 ppm, indicating bridging behavior, as it displayed a deshielded signal. This behavior is anticipated from the dppm ligand due to the highly strained structure of its analogous mononuclear chelating compound. The protons of the 5 benzene rings appeared as expected at 7.5 ppm (5Ph, m, 28H).

The $^{31}P\{^{1}H\}$-NMR spectra of the complexes (**2-6**) showed one signal which clearly indicates that the trans atoms to the P ligand are the same. Therefore, the final structure is a square planar complex with two (bit-dtc) ligands, S-bonded to the Pd(II) central metal. However, complex **6** showed bridging characteristic. Even though, the $^{31}P\{^{1}H\}$-NMR spectrum of 6 showed one signal only, the positive value indicates that the ligand is attached to two Pd(II) ion in a bridging mode Fig. 4. If the dppm were to be bonded to a central metal in a chelating fashion, it would show highly negative values in the $^{31}P\{^{1}H\}$-NMR, which could appear around –40 or –50 ppm.[26]

Biological activity

Antibacterial activity

The newly synthesized Pd(II) complexes 1-5 were tested against two types of bacteria; *Staphylococcus aureus (S. aureus) and Escherichia coli (E. coli)*. and the results are presented in Table 2.

Table 2. Dimeter inhibition zone (mm) of the tested complexes against *S. aureus* and *E. Coli* bacteria.

Complexes No.	Conc. (M)	Diameter inhibition zone (mm) *S. aureus*	*E. coli*
1	10^{-3}	20	22
2	10^{-3}	17	18
3	10^{-3}	12	16
4	10^{-3}	14	19
5	10^{-3}	20	18
Tetracycline	10^{-3}	29	26

The antibacterial activities of these complexes demonstrated moderate biological properties against both targeted bacteria. The inhibition diameter zone for Staphylococcus aureus ranged from 12 to 20 mm, while for Escherichia coli, it ranged from 16 to 22 mm. Notably, complexes 1 and 5 exhibited greater activity against both selected bacteria than the other complexes. These results are consistent with findings from previously reported papers on dithiocarbamate complexes.[19,27,28]

Anticancer activity

Complexes **2**, **4**, and **5** were subjected to *in vitro* evaluation for their anticancer activity against pancreatic adenocarcinoma (SNU-2469), cervical carcinoma (SK-GT-5) and human gastric-esophageal adenocarcinoma (SK-GT-5) by using MTT assay.[25,28,29] The results are summarized in Table 3.

Notably, among the tested complexes, $[Pd(bit\text{-}dtc)_2(dppe)]$ 2 exhibited significant activity against the pancreatic adenocarcinoma cell lines of SNU-2469 with an IC_{50} value of 5.067 μM.

Table 3. Anticancer activities of different Pd(II) complexes against three cancer cells in vitro.

	IC_{50} (μM)		
Complex No.	SNU-2469	SK-GT-5	WRL-68
2	5.067	30.42	30.96
4	26.17	37.14	101.6
5	23.11	62.50	62.50

The enhanced anticancer activity of complex 2 may be attributed to the favorable fitting of its five-membered ring (dppe) within the amino acid pocket of SNU-2469, leading to greater stability compared to the other two complexes, 4 and 5, which contain the seven-membered ring (dppb) and ferrocene ligand, respectively.

Conclusion

A new series of Pd(II) mixed ligand complexes derived from Benzoisothiazol-3(*2H*)-dithiocarbamate and tertiary diphisphine ligands have been synthesized and characterized by elemental analysis, IR and NMR spectroscopy. The IR spectra were effectively used to determine the formation of CSS group as well as showing the distinctive phosphine bands. In NMR, more specifically, $^{31}P\{^{1}H\}$- NMR techniques the complexes showed that diphosphine ligands attach as chelating mode except for dppm which showed as bridging ligand. The biological evaluation of the synthesized complexes **1-6** showed moderate activities against various cancer cells except complex **2** which exhibited significant activity against pancreatic adenocarcinoma. Complex **2** is considered as a new lead for treatment of pancreatic cancer.

Acknowledgments

The author is much indebted to the Department of Chemistry, College of Science, at University of Sulaimani. Appreciations are due to the lab staff at Al-Hashmiyah University, Amman, Jordan for doing NMR analyses. Gratitude and appreciations are also extended to the staff of the Pharmacology Lab. at Malaya University, Kuala Lumpur, Malaysia.

Authors' declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images, that are not ours, have been included with the necessary permission for re-publication, which is attached to the manuscript.
- Authors sign on ethical consideration's approval.
- No animal studies are present in the manuscript.
- No potentially identified images or data are present in the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee at University of Sulaimani.

References

1. Bobinihi FF, Onwudiwe DC, Ekennia AC, Okpareke OC, Aderne C, Lane JR. Group 10 metal complexes of dithiocarbamates derived from primary anilines: Synthesis, characterization, computational and antimicrobial studies. Polyhedron. 2019 Jan;158:296–310. https://doi.org/10.1016/j.poly.2018.10.073.
2. Muhammed RA, Abdullah BH, Rahman HS. Synthesis, cytotoxic, antibacterial, antioxidant activities, DFT, and docking of novel complexes of Palladium (II) containing a thiourea derivative and diphosphines. J. Mol. Struct. 2023 Jan 5;1295:136519. https://doi.org/10.1016/j.molstruc.2023.136519.
3. Khan SZ, Rehman Z, Amir MK, Ullah I, Akhter MS, Gariepy FB. Heteroleptic Palladium(II) dithiocarbamates: Synthesis, characterization and in vitro biological screening. J Mol. Struct. 2018 Mar 15;1156:564–570. https://doi.org/10.1016/j.molstruc.2017.11.068.
4. Faihan AS, Hatshan MR, Alqahtani AS, Nasr FA, Al-Jibori SA, Al-Janabi AS. New divalent metal ion complexes with 1, 8-diaminonapthalene-2-thione: Synthesis, Spectroscopic, anti-bacterial and anticancer activity studies. J Mol Struct. 2022 Jan 5;1247:131291. https://doi.org/10.1016/j.molstruc.2021.131291.
5. Faihan AS, Hatshan MR, Kadhim MM, Alqahtani AS, Nasr FA, Saleh AM, *et al.* Promising bio-active complexes of platinum (II) and palladium (II) derived from heterocyclic thiourea: Synthesis, characterization, DFT, molecular docking, and anticancer studies. J Mol Struct. 2022 Mar 15;1252:132198. https://doi.org/10.1016/j.molstruc.2021.132198.
6. Faihan AS, Al-Jibori SA, Al-Janabi AS. Novel base-free dianion complexes of Pt (II) and Pd (II) derived from heterocyclic thiourea and tertiary phosphine ligands. J Mol Struct. 2022 Mar 5;1251:131966. https://doi.org/10.1016/j.molstruc.2021.131966.
7. Zvarych V, Stasevych M, Lunin V, Deniz NG, Sayil C, Ozyurek M, *et al.* Synthesis and investigation of antioxidant activity of the dithiocarbamate derivatives of 9, 10-anthracenedione. Monatsh Chem. 2016 Dec;147:2093–101. https://doi.org/10.1007/s00706-016-1839-y.
8. Onwudiwe DC, Ekennia AC. Synthesis, characterization, thermal, antimicrobial and antioxidant studies of some transition metal dithiocarbamates. Res Chem Intermed. 2017 Mar;43:1465–85. https://doi.org/10.1007/s11164-016-2709-2.
9. Choudhary A, Sharma R, Nagar M, Mohsin M, Meena HS. Synthesis, characterization and antioxidant activity of some transition metal complexes with terpenoid derivatives. J Chil Chem Soc. 2011 Dec;56(4):911–7. http://dx.doi.org/10.4067/S0717-97072011000400019.
10. Amir MK, Rehman Z, Hayat F, Khan SZ, Hogarth G, Kondratyuk T, *et al.* Monofunctional platinum(II) dithiocarbamate complexes:Synthesis, characterization and anticancer activity.

RSC Adv. 2016 Nov 6:110517–110524. https://doi.org/10.1039/C6RA19469A.
11. Al-Jibori SA, Gergees HM, Al-Rubaye MS, Modi SB, Ghosh S, Schmidt H, *et al.* Synthesis and molecular structures of palladium(II) metalated 2-phenylpyridine complexes [PdCl(pyC6H4)L] containing amino- or acetylamino-pyridine co-ligands. Inorg Chim Acta. 2016 Aug;450:50–56. https://doi.org/10.1016/j.ica.2016.04.046.
12. Khan MR, Zaib S, Khan A, Badshah A, Rauf MK, Din I, *et al.* Pd(II)-based heteroleptic complexes with N-(acyl)-N0, N0-(disubstituted)thioureas and phosphine ligands: Synthesis, characterization andcytotoxic studies against lung squamous, breast adenocarcinoma and Leishmania tropica. Inorg Chim Acta. 2018 Jul;479:189–196. https://doi.org/10.1016/j.ica.2018.04.060.
13. Mohamed DS, Al-Jibori SA, Ardakani RB, Faihan AS, Yousef TA, Alhamzani AG, *et al.* Spectroscopic, Anti-Cancer Activity, and DFT Computational Studies of Pt(II) Complexes with 1-Benzyl-3-phenylthiourea and Phosphine/Diamine Ligands. Inorganics. 2023 Mar;11(3):125. https://doi.org/10.3390/inorganics11030125.
14. Al-Jibori SA, Al-Janabi AS, Al-Sahan SW, Wagner C. Pd (II)-pyrrolidine dithiocarbamate complexes: Synthesis, spectroscopic studies and molecular structure of [Pd (PyDT)(ppy)]. J Mol Struct. 2021 Mar 5;1227:129524. https://doi.org/10.1016/j.molstruc.2020.129524.
15. Siddiqi KS, Nishat N. Synthesis and characterization of succinimide and phthalevhde dithiocarbamates and their complexes with some transition metal ions. Synth React Inorg met.-Org Chem. 2000 Sep 1;30(8):1505–18. https://doi.org/10.1080/00945710009351849.
16. Frei A, Zuegg J, Elliott AG, Baker M, Braese S, Brown C, *et al.* Metal complexes as a promising source for new antibiotics. Chem Sci. 2020 Feb;11:2637–2639. https://doi.org/10.1039/C9SC06460E.
17. Shaalan N. Preparation, Spectroscopy, biological activities and thermodynamic studies of new complexes of some metal ions with 2-[5-(2-Hydroxy-Phenyl)-1, 3, 4-Thiadiazol-2-Ylimino]-Methyl-Naphthalen-1-Ol]. Baghdad Sci J. 2022 Aug 1;19(4):0829–0837. http://dx.doi.org/10.21123/bsj.2022.19.4.0829.
18. Mahmood WA, Aldabbagh AK, Mahmoud MA. Synthesis and characterization of new benzothiazole-derived schiff bases metal complexes. Baghdad Sci J. 2022 Apr 1;19(2):0378. http://dx.doi.org/10.21123/bsj.2022.19.2.0378.
19. Al-Janabi EMA, Hatshan MR, Adil SF, Kadhum WR, Al-Jibori SA, Faihan AS, *et al.* Spectroscopic, antibacterial and anticancer studies of new platinum(II)-diethyldithiocarbamate mixed ligand complexes with phosphine or amine ligands. J Mol Struct. 2022 Mar;1252:132227. https://doi.org/10.1016/j.molstruc.2021.132227.
20. Faihan AS, Al-Jibori SA, Hatshan MR, Al-Janabi AS. Antibacterial, spectroscopic and X-ray crystallography of newly prepared heterocyclic thiourea dianion platinum (II) complexes with tertiary phosphine ligands. Polyhedron. 2022 Jan 15;212:115602. https://doi.org/10.1016/j.poly.2021.115602.
21. Al-Janabi AS, Al-Samrai OA, Yousef TA. New palladium (II) complexes with 1-phenyl-1H-tetrazole-5-thiol and diphosphine Synthesis, characterization, biological, theoretical calculations and molecular docking studies. Appl Organomet Chem. 2020 Dec;34(12):e5967. https://doi.org/10.1002/aoc.5967.
22. Lobana TS. Heterocyclic-2-thione derivatives of group 10–12 metals: Coordination versatility, activation of C=S (thione) bonds and biochemical potential. Coord Chem Rev. 2021 Aug;441:213884. https://doi.org/10.1016/j.ccr.2021.213884.
23. Lobana TS, Kaur P, Hundal G, Butcher RJ, Liu CW. 1, 9-Dihydro-purine-6-thione Derivatives of the d^8–d^{10} Metal Ions (PdII, PtII, and CuI): Synthesis, Spectroscopy, and Structures. Z Anorg Allg Chem. 2012 Sep;638:2340. https://doi.org/10.1002/zaac.201200278.
24. Nakamoto K. Infrared and Raman spectra of inorganic and coordination compounds, part B: applications in coordination, organometallic, and bioinorganic chemistry. John Wiley & Sons; 6^{th}. Ed. 2009 Jan 16: 1–221. https://doi.org/10.1002/9780470405840.
25. Al-Jibori SA, Ulghafoor MA, Karadag A, Aydin A, Akbas H, Ruiz SG, Synthesis, characterization and anti-tumor activity of Pd(II) complexes with 4,5-benzo-3H-1,2-dithiole-3-thione. Transit Met Chem. 2019 Mar;44:575–583. https://doi.org/10.1007/s11243-019-00314-6.
26. Aziz NM, Abdullah BH. Synthesis, cytotoxicity, antibacterial activity and molecular modeling study of new mono, homo and heterobimetallic complexes of palladium (II) with some transition metal ions containing the ligands N-phenyl-N'-(2-thiazolyl) thiourea and Diphosphines $Ph_2P(CH_2)nPPh_2$ (where n = 1–3). Indian J Chem. 2019;58A: 772–782.
27. Al-Janabi AS, Kadhim MM, Al-Nassiry AI, Yousef TA. Antimicrobial, computational, and molecular docking studies of Zn (II) and Pd (II) complexes derived from piperidine dithiocarbamate. Appl. Organomet. Chem. 2021 Feb;35(2):e 6108. https://doi.org/10.1002/aoc.6108.
28. Faihan AS, Aziz NM, Ashfaq M, Hassan WM, Al-Jibori SA, Al-Janabi AS. Synthesis, characterization, and x-ray crystallography of unexpected chloro-substitution on 1-(4-chlorophenyl)-3-phenylthiourea platinum (II) complex with tertiary phosphine ligand. J Mol Struct. 2022 Dec 15;1270:133985. https://doi.org/10.1016/j.molstruc.2022.133985
29. Rahman HS, Rasedee A, How CW, Abdul AB, Zeenathul NA, Othman HH, *et al.* Zerumbone-loaded nanostructured lipid carriers: Preparation, characterization, and antileukemic effect. Int J Nanomed. 2013 Aug 2:2769–2781. https://doi.org/10.2147/IJN.S45313.

معقدات البلاديوم الثنائي لليكاندات المختلطة بنزوايزوثيازول -(2H) 3 ثنائي ثايوكربراميت و الفوسفينات الثالثية : تحضيرها وتشخيصها و دراسة فعاليتها الحيوية والمضادة للسرطان

نازك محمد عزيز

قسم الكيمياء، كلية العلوم، جامعة السليمانية، السليمانية، العراق.

الخلاصة

تم تحضير المعقد $[Pd(bit\text{-}dtc)_2]$ من تفاعل بنزوايزوثيازول -(H2) 3 ثنائي ثايوكربامات الصوديوم (Nabit-dtc) مع ملح الصوديوم رابع كلوريد البلاديوم (II). وبمعاملة معقد $[Pd(bit\text{-}dtc)_2]$ مع ثنائي الفوسفينات $Ph_2P(CH)_nPPh_2$ بنسب مولية متساوية ادت للحصول على معقدات بنسب جيدة من نوع $[Pd(bit\text{-}dtc)_2(Ph_2(CH_2)_nPPh_2)]$ حيث ان n تمثل؛ n = 1 (dppm) n = 2 (dppe); n = 3 (dppp); n = 4 (dppb); n = $(C_5H_4)_2Fe$ (dppf). وقد تم تشخيص المعقدات المحضرة باستخدام التحليل الدقيق للعناصر والتحليل الطيفي للأشعة تحت الحمراء علاوة على ذلك نتائج تحليل للطيف الرنين المغناطيسي للبروتون ^1H- NMR و-$^{31}P\{^1H\}$ NMR حيث اتضح بان ليكند الثايوكاربامات يسلك سلوك احادي السن مع ايون البلاديوم. ومن خلال نتائج طيف الرنين المغناطيسي تم اقترح معقدات الليكندات المختلطة لها صيغ تناسقية أحادي النواة يسلك فيها ثنائي فوسفين كلكيند كيلتي (ثنائي المخلب) ماعدا اللكيند dppm حيث يسلك كليكند جسري وتكوين معقدات ثنائي النواة. تم تقييم الأنشطة المضادة للميكروبات لمعقدات البلاديوم الثنائية المحضرة حديثا ضد نوعين من البكتيريا، وهما ستافيلوكوكوس اوريس (S. aureus) وأشريشيا كولاي (E. coli). وتم فحص المعقدات 2 و 4 و 5 ضد سرطان البنكرياس (SNU-2469) وسرطان المعدة والمريء البشري (SK-GT-5) وخلايا البشرية الصحية (WRL68) , أظهر المركب 2 $[Pd(bit\text{-}dtc)_2]$ نشاطًا ملحوظا ضد سرطان البنكرياس الغدي للخلايا السرطانية SNU-2469 بقيمة IC_{50} حيث تبلغ 5.067 مايكرومولر.

الكلمات المفتاحية: الفعالية ضد السرطان، بنزوايزثايزول3-ثايوكابامات، معقدات للكيندات المختلطة، البلاديوم، الفوسفين.