Available online at www.sciencedirect.com
ScienceDirect
Spectrochimica Acta Part A 67 (2007) 114–121
SPECTROCHIMICA ACTA PART A
www.elsevier.com/locate/saa

Synthesis, characterization and biological activity of some platinum(II) complexes with Schiff bases derived from salicylaldehyde, 2-furaldehyde and phenylenediamine

Akmal S. Gaballa [a,*], Mohsen S. Asker [b], Atiat S. Barakat [c], Said M. Teleb [c]

[a] *Faculty of Specific Education, Zagazig University, Zagazig, Egypt*
[b] *Microbial Biotechnology Department, National Research Center, P.O. 12622, Egypt*
[c] *Chemistry Department, Faculty of Science, Zagazig University, Zagazig, Egypt*

Received 12 June 2006; accepted 27 June 2006

Abstract

Four platinum(II) complexes of Schiff bases derived from salicylaldehyde and 2-furaldehyde with *o*- and *p*-phenylenediamine were reported and characterized based on their elemental analyses, IR and UV–vis spectroscopy and thermal analyses (TGA). The complexes were found to have the general formula $[Pt(L)(H_2O)_2]Cl_2{\cdot}nH_2O$ (where $n=0$ for complexes **1**, **3**, **4**; $n=1$ for complex **2**. The data obtained show that Schiff bases were interacted with Pt(II) ions in the neutral form as a bidentate ligand and the oxygens rather than the nitrogens are the most probable coordination sites. Square planar geometrical structure with two coordinated water molecules were proposed for all complexes The free ligands, and their metal complexes were screened for their antimicrobial activities against the following bacterial species: *E. coli*, *B. subtilis*, *P. aereuguinosa*, *S. aureus*; fungus *A. niger*, *A. fluves*; and the yeasts *C. albican*, *S. cervisiea*. The activity data show that the platinum(II) complexes are more potent antimicrobials than the parent Schiff base ligands against one or more microorganisms.

Keywords: Salicylaldehyde; 2-Furaldehyde; Phenylenediamine Schiff base; Platinum(II) complexes; IR; Thermal analysis; UV–vis; Biological activity; Antimicrobial activity

1. Introduction

Schiff bases are considered as a very important class of organic compounds which have wide applications in many biological aspects [1]. These wide applications of Schiff bases have generated a great deal of interest in metal complexes. Schiff base–transition metal complexes are one of the most adaptable and thoroughly studied systems [2,3]. These complexes have also applications in clinical [4] and analytical fields [5]. Some of Schiff base complexes are used as model molecules for biological oxygen carrier systems [6]. Tetradentate Schiff base complexes are well known to form stable complexes, where the coordination takes place through the N_2O_2 donor set [7–9].

The coordination chemistry of platinum(II) has attracted a considerable attention due to its biological applications and tumor treatment based on the early discovery of antitumer activity of *cis*-platin [10,11]. Although analogues platinum complexes with Schiff bases have been synthesized [12], the number, detailed vibrational and thermal studies of this class of compounds appear to be very limited in the literature.

In this paper, we report the synthesis of four new complexes of platinum(II) with Schiff bases, *N*,*N*′-*o*-phenylenebis (salicylideneimine) (sal-*o*-phdnH_2), *N*,*N*′-*p*-phenylene-bis (salicylideneimine) (sal-*p*-phdnH_2), N^1,N^2-bis((furan-2-yl) methylene)benzene-1,2-diamine (fur-*o*-phdn) and N^1,N^4-bis ((furan-2-yl)methylene)benzene-1,4-diamine (fur-*p*-phdn), Scheme 1. Their infrared and electronic spectra were recorded and fully assigned along with the complexes thermal properties as well as screening for their antimicrobial activities and mode of action.

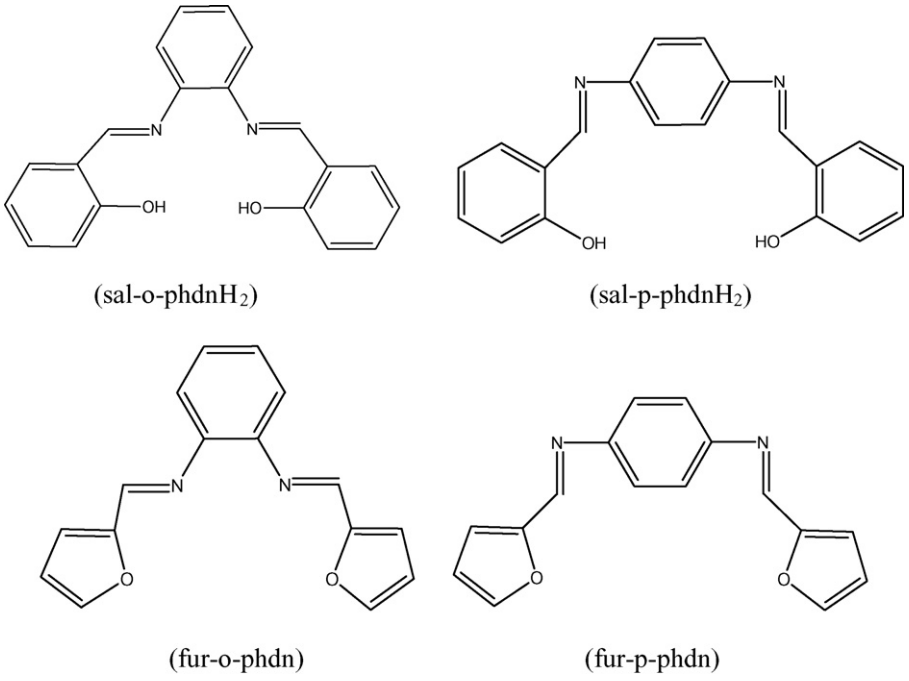
2. Experimental

2.1. Materials and spectral measurements

Analytical reagent grade chemicals were used throughout this investigation. K_2PtCl_4, *o*-phenylenediamine, *p*-phenylene-

* Corresponding author. Tel.: +20 55 2376777; fax: +20 55 2345452.
E-mail address: akmalsg@yahoo.com (A.S. Gaballa).

1386-1425/$ – see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.saa.2006.06.031



Scheme 1.

diamine, salicylaldehyde and 2-furaldehyde were BDH or Merck chemicals.

Infrared spectra of the reactants and the obtained complexes were recorded from KBr bellets (4000–400) using a Buck scientific 500-IR spectrophotometer. Microanalyses were performed using CHNS-932 (LECO) and vario-EL elemental analyzers. Chlorine was determined by burning the substance in oxygen with platinum contact and subsequent titration with mercuric nitrate towards diphenylcarbazide. Thermal analysis, TG was carried out using a Shimadzu TGA-50 H computerized thermal analysis system. The rate of heating of the samples was kept at 10 °C min^{-1}. Sample masses varied between 2.7 and 4.0 mg were analyzed under N_2 flow of 30 ml min^{-1}. Electronic spectra of solutions of ligands, and platinum(II) complexes in methanol were recorded on a UV–vis Recording Spectrophotometer, UV-2401PC Shimadzu at 25 °C.

2.2. Preparation of Schiff base ligands

Schiff base ligands were prepared according to the known method [13] from the condensation of the respective diamine with the corresponding aldehyde in a molar ratio of 1:2, respectively, using methanol as a solvent at *ca.* 45 °C. The reaction mixture was stirred for 3 h. The precipitate were filtered off, washed several times with methanol and finally dried in a desiccator over phosphorous pentoxide. The Schiff bases were obtained in good yields (above 90.0%). The infrared and elemental analysis measured for the obtained products are consistent very well with the corresponding Schiff base formula.

2.3. Preparation of platinum complexes

2.3.1. *[Pt(sal-o-phdnH$_2$)(H$_2$O)$_2$]Cl$_2$ (**1**), [Pt(sal-p-phdnH$_2$)(H$_2$O)$_2$] Cl$_2$·H$_2$O (**2**) [Pt(fur-o-phdn)(H$_2$O)$_2$]Cl$_2$ (**3**), [Pt(fur-p-phdn)(H$_2$O)$_2$]Cl$_2$ (**4**)*

To a solution of K_2PtCl_4 (124.5 mg, 0.30 mmol) in methanol (10 ml), a methanolic solution (10 ml) of the respective Schiff base (0.30 mmol) was added. The reaction mixtures were stirred several hours at *ca.* 40 °C. The formed powdery precipitates of complexes **1**–**4** were left to cool to room temperature, filtered off, washed several times with methanol and dried in vacuo. The analysis results came in good consistence with the proposed formulas as follows.

[Pt(sal-o-phdnH$_2$)(H$_2$O)$_2$]Cl$_2$ (***1***): ($C_{20}H_{20}Cl_2N_2O_4Pt$, 618.37); yield = 91.6%; C, 39.44 (38.85); H, 3.66(3.26); N, 4.58(4.53); Cl, 11.49(11.47).

[Pt(sal-p-phdnH$_2$)(H$_2$O)$_2$]Cl$_2$·H$_2$O (***2***): ($C_{20}H_{22}Cl_2N_2O_5Pt$, 636.38); yield = 83.8%; C, 38.56(37.75); H, 3.59(3.48); N, 4.54(4.40); Cl, 11.38(11.14).

[Pt(fur-o-phdn)(H$_2$O)$_2$]Cl$_2$ (***3***): ($C_{16}H_{16}Cl_2N_2O_4Pt$, 566.29); yield = 76.5%; C, 34.43 (33.93); H, 3.01(2.85); N, 5.19(4.95); Cl, 12.77(12.52).

[Pt(fur-p-phdn)(H$_2$O)$_2$]Cl$_2$ (***4***): ($C_{16}H_{16}Cl_2N_2O_4Pt$ (566.29); yield = 83.8%; C, 34.52(33.93); H, 3.11(2.85); N, 5.22(4.95); Cl, 12.79(12.52).

2.4. Antimicrobial activity

The antimicrobial activities were carried out according to the conventional agar diffusion test [14] using cultures of *Bacillus*

subtilis NRRL B-94, *E. coli* NRRL B-3703, *Pseudomonas aereuguinosa* NRRL B-32, *Staphylococcus aureus* NRRL B-313, *Aspergillus niger* NRRL 599, *A. fluves* NRC, *Saccharomyces cervisiea* NRC and *Candida albicans* NRRL 477. The bacterial strains were cultured on nutrient medium, while the fungi and yeast strains were cultured on malt medium and yeast medium, respectively. Broth media included the same contents except for agar. For bacteria and yeast, the broth media were incubated for 24 h. As for fungus, the broth media were incubated for approximately 48 h, with subsequent filtering of the culture through a thin layer of sterile Sintered Glass G2 to remove mycelia fragments before the solution containing the spores was used for inoculation. For preparation of plates and inoculation, 1.0 ml of inocula were added to 50 ml of agar media (50 °C) and mixed. The agar was poured into 120 mm petri dishes and allowed to cool to room temperature. Wells (6 mm in diameter) were cut in the agar plates using a proper sterile tubes. Then, fill wells were filled up to the surface of agar with 0.1 ml of the test compounds dissolved in DMSO (200 μmol/ml). The plates were left, on a leveled surface, incubated for 24 h at 30 °C for bacteria and yeast and 48 h for fungi and the diameter of the inhibition zones were read. DMSO (0.1 ml) alone was used as control under the same conditions for each organism. By subtracting the diameter of inhibition zone resulting with DMSO from that obtained in each case. The results were compared with a similar run of Tetraceycline as an antibacterial and Fluconazol as an antifungal. Both antimicrobial activities could be calculated as a mean of three replicates.

2.5. MIC determination

The minimum inhibitory concentration (MIC) was determination by the serial dilution method [15]. About 200 μmol of the active compounds were dissolved in 1.0 ml DMSO. Serial dilutions of the compounds were prepared to obtain concentrations rang from 37.5 to 200 μmol. The inocula of *B. subtilis* NRRL B-94, *E. coli* NRRL B-3703, *P. aeueuguinosa* NRRL B-32, *S. aureus* NRRL B-313, *A. niger* NRRL 599, *A. fluves* NRC, *S. cervisiea* NRC and *C. albicans* NRRL 477, were obtained from 24 h old cultures. The plates were finally incubated at 30 °C for 24 h.

2.6. The mode of action

The effect of different concentrations of complex **3** on the growth rate and some biochemical activities was studied. Immediately after incubating the flasks with *B. Subtilis* NRRL B-94, cells were harvested during the middle logarithmic phase; the active compound was applied in a concentration of the MIC and its folds (2 and 3) in three replicates. Subsequently, the flasks were shaken using a rotary shaker of 120 rpm at 30 °C. Samples were withdrawn at the onset of the experiment and after incubation periods of 10, 30, 50, 70, 90, 120, 150 and 180 min. The bacterial cells were subjected to the following determinations: acid soluble phosphorus compounds [16], total lipids [17] and total protein [18].

3. Results and discussion

Schiff bases sal-*o*-phdnH_2, sal-*p*-phdnH_2, fur-*o*-phdn and fur-*p*-phdn interact as neutral ligands with potassium tetrachloroplatinum(II) in methanol to form the corresponding platinum(II) complexes, [Pt(sal-*o*-phdnH_2)$(H_2O)_2$]Cl_2 (**1**), [Pt(sal-*p*-phdnH_2)$(H_2O)_2$] $Cl_2{\cdot}H_2O$ (**2**), [Pt(fur-*o*-phdn)$(H_2O)_2$]Cl_2 (**3**), [Pt(fur-*p*-phdn)$(H_2O)_2$]Cl_2 (**4**), respectively. The formulation of these complexes were based on the elemental analysis which agrees quite well with 1:1 (Pt(II):Schiff base) stoichiometry, as well as on qualitative chemical analysis (test of the ionic chloride by $AgNO_3$ solution), vibrational, and electronic spectra and thermal analysis. Tables 1 and 2 give assignments of the characteristic infrared bands of Schiff bases together with their corresponding Pt(II) complexes **1**–**4**, respectively. The results enable us to characterize the complexes and make an assessment of the bonding and structures inherent in them. The C=N in an open chain system characterizes by a sharp band definitely assigned in the region of 1690–1640 cm^{-1}. Aryl conjugation causes a shift towards longer wavelengths regardless of the substituent is located on N or C. The strong interaction between C=C and C=N stretching vibrations in olefin-substituted azomethine systems makes the assignment of a band due to ν(C=N) is rather tentatively. Furthermore, the C=N band of Schiff bases is mostly overlapped from the aromatic bands ν(C=C) and therefore difficult to assign [19].

The infrared spectra of sal-*o*-phdnH_2 and sal-*p*-phdnH_2 (Table 1) show two well resolved bands around 1632(s) and 1592(m) cm^{-1}, in addition to two weak bands lying in the region around 3253 and 3182 cm^{-1} which may be attributed to N^+–H bond vibration. Such situation could be explained on the basis of a partial protonation on the nitrogen atom of azomethine groups and the formation of Zwitter ion (form (II), as shown in Scheme 2, which is the more stable during complexation with Pt(II).

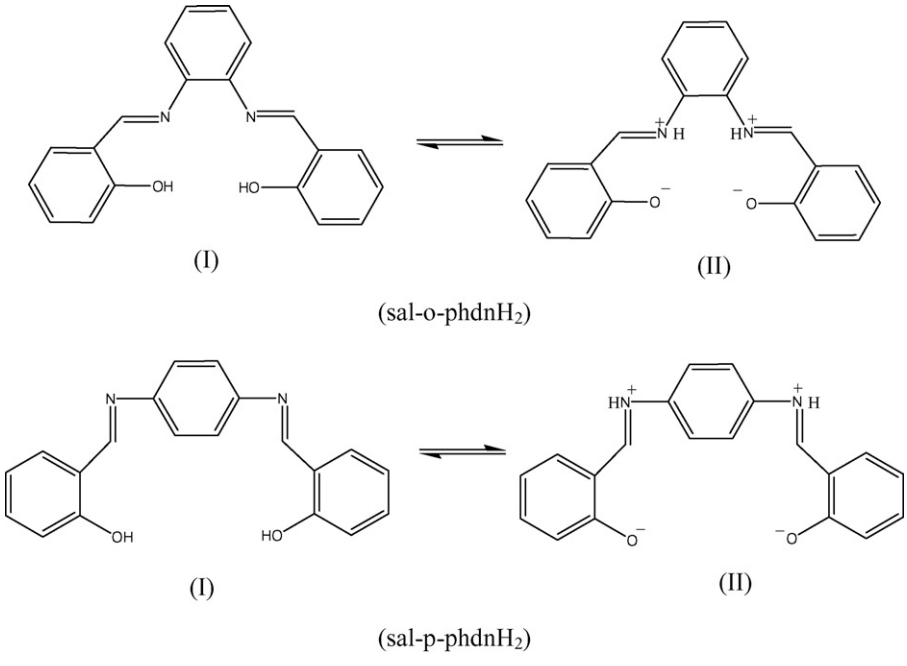
The infrared spectra of the two complexes reveal in comparison with the free ligands spectra the following observations. (i) The band around 1632 cm^{-1} in the free ligands is observed at almost the same region around 1620 cm^{-1} in complexes spectra. This band can be attributed to the ν(C=C) and the slight change in wavenumbers may be understood as a result of changing the electron density of the aromatic system due to complexation. (ii) The medium–strong band around 1592 cm^{-1} of the free ligands which may be assigned due to the partially protonated azomethine (C=N^+–H) is shifted (50–60 cm^{-1}) to lower wavenumber, around 1540 cm^{-1} in the complexes spectra as expected for fully protonated form of the azomethine group (form II, Scheme 2). (iii) The two bands around 3253 and 3182 cm^{-1} assigned to $\nu(N^+–H)$ are observed at almost the same frequencies but their intensity were changed from weak to strong. It should be mentioned here that protonation at the nitrogen of azomethine groups of Schiff bases was previously reported in literature [19,20]. (iv) The free Schiff bases spectra show two strong sharp bands in the region 3386–3365 cm^{-1}. Taking into consideration an expected intramolecular hydrogen bonding, these two bands can be quietly assigned due to ν(O–H)

Table 1
Characteristic infrared frequencies[a] (cm^{-1}) and tentative assignments for the Schiff bases, sal-*o*-phdnH_2 and sal-*p*-phdnH_2 together with their complexes, **1** and **2**

sal-*o*-phdnH_2	sal-*p*-phdnH_2	**1**	**2**	Assignments[b]
		3401 m	3446 vs	ν(O–H); H_2O
3386 s	3375 s			
3365 s	3366 s			
3295 s		3253 s	3255 m	$\nu(N^+–H)$
		3182 m	3185 sh	
3045 sh	3052 sh	3065 m	3060 w	ν(C–H); aromatic
2926 w	2927 w	2927 m	2926 w	ν(C–H); aliphatic
–	–	1686 w	1650 m	$\delta(H_2O)$; coordinated H_2O
1632 s	1631 s	1623 m	1615 s	ν(C=C)
1592 m	1588 m	1531 vs	1547 s	$\nu(C=N^+)$
1501 s	1515 s		1502 s	Phenyl breathing modes (quadrant vibrations) and C–H deformation
1456 vs	1438 vs	1442 m	1401 w	
1401 s	1389 vs	1353 s	1323 w	
1273 s	1262 m	1237 w	1260 w	ν(C–O), ν(C–C) and ν(C–O) chelating ring
1249 sh	1127 w	1150 m	1236 m	
1154 w			1124 w	
1151 vw				
1059 vw	1062 w	1020 w	1079 w	In plane CH-deformation
927 w	883 w		1011 vw	
875 sh	830 m			
		841 w	828 m	δ_r (H_2O)
750 s	707 m	762 m	735 vw	In plane CH-quadrant deformations; phenyl
	673 w	574 w	673 vw	
	515 m			
		539 w	535 w	ν(Pt–O); O of Schiff base
		455 w	467 vw	ν(Pt–O); O of coord. Water

[a] s, strong; m, medium; v, very; w, weak; br, broad.
[b] ν, stretching; δ, deformation.

even so they are observed at lower wavenumbers than expected. The corresponding complexes spectra **1** and **2** reveal no bands in this region, but instead a new broad band characteristic for H_2O molecules is observed in the region above 3400 cm^{-1}. This indicate that oxygen atoms are involved in coordination with Pt(II). Furthermore, two additional new bands are observed around 1650 and 850 cm^{-1} due to the bending and rocking motions of H_2O [21]. The latter band is characteristic for coordinated water molecules. The stretching vibrations ν(Pt(O) (oxygen of the Schiff base) in complexes **1** and **2**



Scheme 2.

Table 2
Characteristic infrared frequencies[a] (cm^{-1}) and tentative assignments for the Schiff bases, fur-*o*-phdn and fur-*p*-phdn along with their complexes **3** and **4**

fur-*o*-phdn	fur-*p*-phdn	**3**	**4**	Assignments[b]
		3425 s, br	3445 s, br	ν(O–H); H_2O
		3200 w	3205 s	
		3190 w	3196 s	
3122 w	3109 m	3111 m	3113 m	ν(C–H); aromatic
3059 w	3022 w	3058 sh	3025 sh	
2928 w	2973 w		2970 m	ν(C–H); aliphatic
	2879 w	2927 vw	2925 m	
		1641 m	1650 m	$\delta(H_2O)$
1618 m	1620 vs	1614 s	1618 s	ν_{as}(C=N); ν(C=C)
		1608 s	1610 m	
1509 s	1554 m	1509 s	1508 vs	Phenyl breathing modes
1457 m	1469 vs	1458 vs	1460 w	(quadrant vibrations) and
1422 m			1418 s	C–H deformation
1377 m	1392 m		1397 vw	
1339 m	1337 m	1340 vw	1337 vw	
1284 w	1280 m	1284 w	1280 vw	ν(C–O), ν(C–C) and
				ν(C–O) chelating ring
1258 m	1200 m	1227 m	1198 vw	
1225 w				
1148 m	1147 m	1147 m	1155 m	
1070 w	1109 w	1072 w	1102 w	In plane CH-deformation
1011 s	1069 w	1011 s	1017 m	
925 w	1013 s	923 w	935 vw	
907 w	957 w			
	933 s			
886 w	865 s	884 w	882 vw	
		826 w	835 m	$\delta_r(H_2O)$
820 w	819 s			In plane CH-quadrant
742 vs	762 vs	745 vs	760 w	deformations; phenyl
593 w	733 sh	591 m	576 w	
	590 m	559 w	509 w	ν(Pt–O); O of Schiff base
	552 m	442 w	462 w	ν(Pt–O); O of Coord.
			421 vw	water

[a] s, strong; m, medium; v, very; w, weak; br, broad.
[b] ν, stretching; δ, deformation.

are in the region 539(498 cm^{-1} while the ν(Pt(O) (oxygen of coordinated water) assigned at 455 and 467 cm^{-1}, respectively [19,21].

Schiff bases fur-*o*-phdn and fur-*p*-phdn in contrary lack such acidic protons, Scheme 1, and therefore, protonation in such a way is not expected in this case. The infrared spectra of the free ligands and their correspondence complexes **3** and **4** (Table 2) show the same pattern with some shift in bands frequencies as a result of coordination with Pt(II). The strong and relatively broad band around 1618 cm^{-1} in the spectra of the free ligands which is assigned due to ν(C=N) + ν(C=C) [19,20] and is observed at nearly the same frequencies in their Pt(II) complexes. This observation indicate at once that nitrogen atoms are not the binding sites and oxygen atoms should be the most probable sites to coordinate with the Pt(II) atom. In addition to the ligands bands, complexes spectra show a set of new bands at 3425, 1640 and 800 cm^{-1} (Table 2) due to stretching, bending and rocking motions of the coordinating water molecules [21]. Furthermore, two new bands are observed in complexes spectra above 500 cm^{-1} and around 450 cm^{-1} and can be assigned due to ν(Pt(O) (oxygen of the Schiff base) and ν(Pt(O) (oxygen of coordinated water), respectively [21].

The infrared spectra of the four ligands and their complexes show the stretching vibrations, ν(C–H) of the phenyl groups are in the region 3113–3025 cm^{-1}, while, ν(C–H) vibrations of the =CH– groups are observed as expected in the region 2970–2860 cm^{-1} [22,23]. A group of strong to week bands falling in the region 1554–1337 cm^{-1} should be associated as expected with the phenyl, quadrant, semicircular and sextant vibrations [24,25]. The ν(C–O), ν(C–C) and ν(C–O) stretching vibrations in both complexes are observed as a number of bands lying in the region 1280–1147 cm^{-1}. The C–H bends of the phenyl groups in the three complexes are assigned to a number of bands lying in the range 1072–576 cm^{-1}. These assignments agree quit well with those known for related systems [24–32].

Table 3
The maximum temperature values for the decomposition along with the species lost in each step of the decomposition reactions of complexes **1**, **2** and **4**

Complex	Decomposition	T_{max} (°C)	Lost species	% Weight loss	
				Found	Calculated
[Pt(sal-*o*-phdnH_2)(H_2O)$_2$]Cl_2 (**1**)	First step	201	$2H_2O$	6.20	5.82
	Second step	347	sal-*o*-phdnH_2	52.00	51.16
	Total loss			58.20	56.98
	Residue			41.80	43.03
[Pt(sal-*p*-phdnH_2)(H_2O)$_2$]Cl_2·H_2O (**2**)	First step	111	H_2O	2.90	2.83
	Second step	240	$2H_2O$	5.80	5.66
	Third step	384	sal-*p*-phdnH_2	47.5	49.71
	Total loss			56.20	58.2
	Residue			43.80	41.80
[Pt(fur-*p*-phdn)(H_2O)$_2$]Cl_2 (**4**)	First step	279	$2H_2O$	6.80	6.36
	Second step	442	fur-*p*-phdn	47.50	46.67
	Total loss			54.30	53.03
	Residue			45.70	46.97

According to the above discussion, Schiff bases interact with Pt(II) as a neutral bidentate ligand and oxygen rather than nitrogen atoms are the most probable coordination sites. With two water molecules inside the coordination sphere of the Pt(II) ion a square planar geometry is proposed in the four complexes.

The presence of coordinated and uncoordinated water was further investigated by thermal analysis. Table 3 gives the maximum temperature values for the decomposition along with the species lost in each step of the decomposition reactions of the complexes [Pt(sal-*o*-phdnH$_2$)(H$_2$O)$_2$]Cl$_2$ (**1**), [Pt(sal-*p*-phdnH$_2$)(H$_2$O)$_2$]Cl$_2$·H$_2$O (**2**) and [Pt(fur-*p*-phdn)(H$_2$O)$_2$]Cl$_2$ (**4**). The data obtained support the proposed structures and indicate that complexes **1**and **4** undergo two steps degradation reaction, while complex **2** undergoes three steps in good agreement with their structures, see Table 3. The first step in complexes **1** and **4**, and the second step in complex **2** occur at a maximum lying in the region above 200 °C. The weight loss associated with this step agrees quite well with the loss two coordinated water molecules. The first step in the decomposition reaction of complex **2** was observed at relatively lower temperature 111 °C with weight loss consistent with the loss of the uncoordinated water molecules. The last step in the degradation of the three complexes occurs in the region around 400 °C and should be associated with the loss of the ligand as the found and calculated weight loss are in good agreement (Table 3). The weight of the residue is found to be in consistent with the formation of PtCl$_2$ as final thermal decomposition product.

Electronic absorption spectra of the Schiff bases and their Pt(II) complexes, 1–4 were recorded in methanol as a solvent. Table 4 show the observed absorption bands and their assignments. The complexes spectra generally show the characteristic bands of the free ligands with some changes both in frequencies (λ_{max}) and intensity together with appearances of new bands at longer wavelengths. This could be taken as an evidence for the complexation of Schiff bases with Pt(II) [33,34].

Table 4
Electronic spectral data of the Schiff bases and their Pt(II) complexes

Compound	λ_{max} (nm)		
	$\pi \rightarrow \pi^*$	$n \rightarrow \pi^*$	d → d transition
(sal-*o*-phdnH$_2$)	249	295	
1	249	285	432
(sal-*p*-phdnH$_2$)	222		
2	251	333	448
(fur-*o*-phdn)	216	308	
3	244	308	354
(fur-*p*-phdn)	222		
4	222	273	359

3.1. Antimicrobial activity

The results revealed that complexes are more microbial toxic than the ligands. Complexes **1** and **3** are much more microbial active than the other two. Moreover, complex 3 shows the highest antibacterial activity against all bacteria tests. The highest inhibition of growth occurred on complex **3** against the bacterium *B. subtilis* NRRL B-94 (as gram positive bacteria), Table 5. It may conclude that most of complexes have antibacterial effect except complex **4**, which have less antibacterial effect. On the other hand, complex **3** showed the best activity towards fungi against *A. fluves* NRC (27.00 ± 0.19 mm) and the lowest against *S. cervisiea* NRC (6.7.00 ± 0.094 mm). All complexes showed antifungal activities against *A. niger* NRRL 599 and *A. fluves* NRC. Therefore, the inhibition zone diameter results were mostly found to be dependant on both the type of Schiff bases and/or position of Pt(II) (*o*- or *p*-). The activities of complexes **1** and **3** may be explained on the basis of chelation theory; chelation reduces the polarity of the metal atom mainly because of partial sharing of its positive charge with the donor groups and possible π electron delocalization within the whole chalete ring. Also, chelation increases the lipophelic nature of the central atom which subsequently favors its permeation through the lipid layer of the cell membrane [35].

The results of minimum inhibitory concentration (MIC) of some active complexes against *B. subtilis* NRRL B-94, *S. aureus* NRRL B-313, *P. aereuguinosa* NRRL B-32, *A. niger* NRRL 599 and *A. fluves* NRC are shown in Table 6. The concentration (75.00 μmol/ml) was major in about all microorganisms tested except the complex 3 for which the MIC against *S. aureus* NRRL

Table 5
Antimicrobial activity of Schiff bases and their platinum(II) complexes

	Diameter of inhibition zone (mm)							
	Bacteria				Fungus		Yeast	
	B. subtils	*S. aureus*	*E. coli*	*P. aereuguinosa*	*A. niger*	*A. fluves*	*C. albicans*	*S. cervisiea*
1	14.3 ± 0.094	19.0 ± 0.094	19.0 ± 0.169	18.0 ± 0.160	18.6 ± 0.120	25.0 ± 0.094	06.0 ± 0.094	04.6 ± 0.120
2	11.6 ± 0.120	14.0 ± 0.250	11.6 ± 0.094	13.6 ± 0.047	16.3 ± 0.047	09.6 ± 0.094	00.0 ± 0.000	00.0 ± 0.000
3	27.0 ± 0.091	26.0 ± 0.120	19.0 ± 0.047	22.0 ± 0.170	25.0 ± 0.140	27.0 ± 0.190	11.0 ± 0.081	06.7 ± 0.094
4	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000	15.0 ± 0.047	13.0 ± 0.020	04.7 ± 0.047	05.3 ± 0.047
L1	04.6 ± 0.047	04.3 ± 0.047	00.0 ± 0.000	00.0 ± 0.000	04.6 ± 0.094	04.3 ± 0.047	00.0 ± 0.000	00.0 ± 0.000
L2	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000
L3	04.6 ± 0.047	08.0 ± 0.140	00.0 ± 0.000	00.0 ± 0.000	04.3 ± 0.047	04.7 ± 0.094	00.0 ± 0.000	00.0 ± 0.000
L4	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000
R1	32.3 ± 0.205	30.6 ± 0.047	29.6 ± 0.094	30.3 ± 0.170	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000
R2	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000	00.0 ± 0.000	27.6 ± 0.094	29.3 ± 0.094	25.6 ± 0.047	28.0 ± 0.124

Each value represents mean of sample ± S.D., L1, L2, L3 and L4 represent the Schiff base ligands, respectively. R1 and R2 represent tetraceycline and fluconazol, respectively.

Table 6
Minimum concentration inhibitory (MIC, μmol/ml) of active complexes (**1**–**3**) against some microorganisms

Complex	Bacteria		Fungus		
	B. subtils	*S. aureus*	*P. aeroeuguinosa*	*A. niger*	*A. fluves*
1	75.0	75.0	75.0	100.0	100.0
2	75.0	75.0	100.0	100.0	100.0
3	75.0	50.0	50.0	50.0	75.0

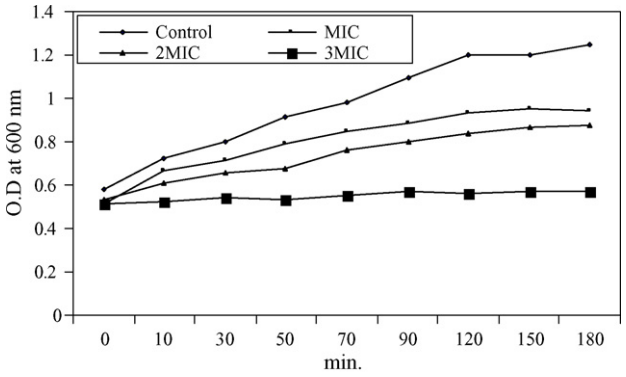


Fig. 1. Effect of different concentrations of complex **3** on growth rate of *B. subtilis* NRRL B-94.

B-313, *P. aereuguinosa* NRRL B-32 and *A. niger* NRRL 599 was 50.00 μmol/ml. The aforementioned results indicate that complex **3** exhibited antimicrobial activities higher than that of other complexes. The variation in the effectiveness of different complexes against different organisms depend either on differences in the permeability of the cells of the microbes or on difference in ribosome's of the microbes [36].

From the results illustrated in Figs. 1–4, it could be concluded that complex **3** reduced the growth rate, acid soluble phosphorus content, intracellular lipids and proteins content of *B. subtilis* NRRL B-94. The mode of action may involve the formation of a hydrogen bonds through the nitrogen atom in interference with the active contents of the cell constituents, resulting in interference with the normal cell process [37]. The inhibition growth may be due to the effect on the biosynthesis of phospholipids in cell membrane and proteins.

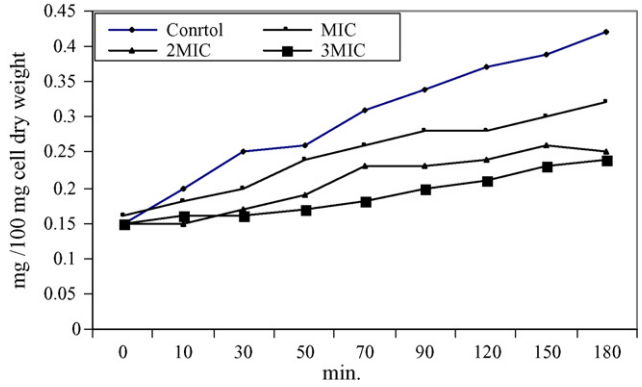


Fig. 2. Effect of different concentrations of complex **3** on acid soluble phosphorus content of *B. subtilis* NRRL B-94.

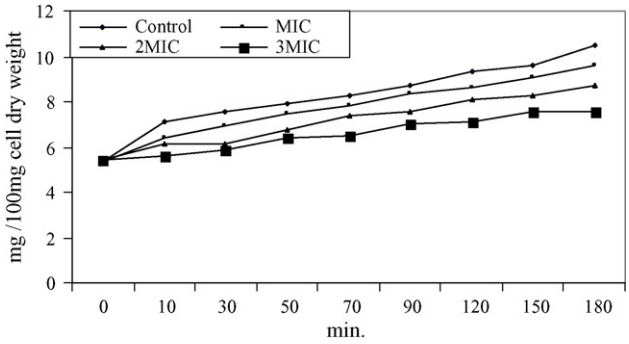


Fig. 3. Effect of different concentrations of complex **3** on total lipids content of *B. subtilis* NRRL B-94.

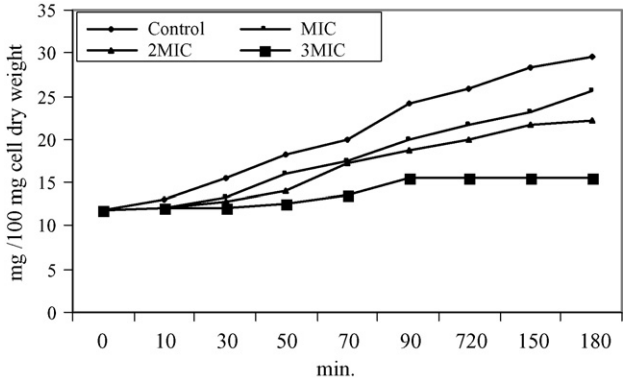


Fig. 4. Effect of different concentrations of complex **3** on total protein content content of *B. subtilis* NRRL B-94.

References

[1] (a) B. Witkop, L.K. Ramachandran, Metabolism 13 (1964) 1016;
(b) R.A. Morton, G.A.J. Pitt, J. Biochem. 59 (1955) 128;
(c) E. Grazi, R.T. Rowley, T. Cheng, O. Tchola, B.L. Horecker, Biochem. Biophys. Res. Commun. 9 (1962) 38;
(d) I. Fridovitch, F.H. Westheimer, J. Am. Chem. Soc. 84 (1962) 3208;
(e) G.G. Hammes, P. Fasella, J. Am. Chem. Soc. 84 (1962) 4644;
(f) B.S. Tovrog, D.J. Kitko, R.S. Drago, J. Am. Chem. Soc. 98 (1976) 5144.
[2] I.M.I. Fakhr, N.A. Hamdy, M.A. Radwan, Y.M. Ahmed, Egypt. J. Chem. (2004) 201.
[3] (a) P.S. Dixit, K. Srinivasan, Inorg. Chem. 27 (1988) 4507;
(b) A. Nishinaga, T. Tojo, T. Matsuura, J. Chem. Soc., Chem. Commun. (1974) 896.
[4] A.M. Mahindra, J.M. Fisher, Rabinovitz, Nature (London) 303 (1983) 64.
[5] P.R. Palet, B.T. Thaker, S. Zele, Indian J. Chem. A38 (1999) 563.
[6] R.E. Hester, E.M. Nour, J. Raman Spectrosc. 11 (1981) 49.
[7] E.M. Nour, A.A. Taha, I.S. Alnaimi, Inorg. Chim. Acta 141 (1988) 139.
[8] E.M. Nour, A.M. Al-Kority, S.A. Sadeek, S.M. Teleb, Synth. React. Inorg. Met. -Org. Chem. 23 (1993) 39.
[9] W. Wang, F.-L. Zeng, X. Wang, M.-Y. Tan, Polyhedron 15 (1996) 1699.
[10] B. Rosenberg, L. van Camp, J.E. Trosko, V.H. Mansour, Nature 222 (1969) 385.
[11] B. Lippert (Ed.), Cisplat and Chemistry of a Leading Anticancer Drug, Wiley–VCH, Weinheim, Germany, 1999.
[12] A.A. Bekhit, O.A. El-Sayed, T.A.K. Al-Allaf, H.Y. Aboul-Enein, M. Kunhi, S.M. Pulicat, K. Al-Hussain, F. Al-Khodairy, J. Arif, Eur. J. Med. Chem. 39 (2004) 499.
[13] P. Pefeiffer, E. Breith, E. Lubbe, T. Tsumaki, L. Justus, Ann. Chem. 503 (1933) 84.
[14] D. Greenwood, Antimicrobial Chemotherapy, Bailliere, Tindall, London. Part II. Laboratory Aspects of Antimicrobial Therapy, 1983, p. 71.

[15] K.E. Copper, in: F. Cavanaugh (Ed.), Analytical Microbiology, vol. 2, Academic press, New york, 1972, p. 13.
[16] (a) J.R. Toribara, P.S. Chen, H. Warner, Anal. Chem. 28 (1956) 1756;
(b) W.C. Scheinder, H.G. Hogebom, H.E. Ross, J. Biol. Chem. 186 (1950) 417.
[17] (a) E.G. Bligh, W.J. Dyer, Can. J. Biochem. Physiol. 37 (1959) 911;
(b) J.A. Kinght, S. Anderson, J.M. Ramle, Clin. Chem. 18 (1972) 199.
[18] W.H. Daughaday, O.H. Lowry, N.J. Rosebrough, W.S. Fields, Can. J. Biochem. Physiol. 37 (1952) 911.
[19] (a) H. Günzler, H. Germlich, IR Spectroscopy: An Introduction, Wiley–VCH Verlag GmbH, Weinheim (F.R.G.), 2002, p. 69469;
(b) E. Pretsch, P. Bühlmann, C. Affolter, Structure Determination of Organic Compounds, Springer-Verlag, Berlin, 2000.
[20] C. Sandorfy, in: S. Patal (Ed.), The Chemistry of Carbon–Nitrogen Double Bond, vol. 42, 1970.
[21] (a) L.J. Bellamy, The Infrared Spectra of Complex Molecules, Chapman & Hall, London, 1975;
(b) K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, 4th ed., Wiley, New York, 1986.
[22] J.A. Faniran, K.S. Patal, J.C. Bailar, J. Inorg. Nucl. Chem. 36 (1974) 1547.
[23] E.J. Olszwski, D.F. Martin, J. Inorg. Nucl. Chem. 26 (1964) 1577.
[24] M. Data, D.H. Brown, W.E. Smith, Spectrochim. Acta 39A (1983) 37.
[25] (a) E.M. Nour, I.S. Alnaaimi, N.A. Alem, J. Phys. Solids 53 (1992) 197;
(b) E.M. Nour, A.A. Taha, I.S. Alnaimi, Inorg. Chim. Acta 141 (1988) 139;
(c) E.M. Nour, A.M. Al-Kority, S.A. Sadeek, S.M. Teleb, Synth. React. Inorg. Met. -Org. Chem. 23 (1993) 39.
[26] H.A. Tajmir-Riahi, Polyhedron 2 (1983) 723.
[27] M.N. Patel, B.N. Jani, J. Indian Chem. Soc. LXIII (1986) 278.
[28] M. Consiglio, M. Magio, T. Pizzino, V. Romano, Inorg. Nucl. Chem. Lett. 35 (1978) 14.
[29] N.A. Al-Hashimi, K.A. Hassan, E.M. Nour, Polish J. Chem. 78 (2004) 919.
[30] G. Bandoli, D.A. Celemente, U. Croatto, M. Vidali, P.A. Vigato, J. Chem. Soc., Dalton Trans. (1973) 2331.
[31] G. Bandoli, D.A. Celemente, U. Croatto, M. Vidali, P.A. Vigato, J. Chem. Soc., Chem. Commun. (1971) 1330.
[32] N.B. Colthup, L.H. Daly, S.E. Wiberley, Introduction to Infrared and Raman Spectroscopy, Academic Press, New York, 1975.
[33] (a) M. Shakir, Y. Azim, H. Chishti, S. Parveen, Spectrochim. Acta A 65 (2006) 490;
(b) A. Golcu, M. Tumer, H. Demirelli, R.A. Wheatley, Inorg. Chim. Acta 358 (2005) 1785.
[34] (a) G.G. Mohameda, Z.H. Abd El-Wahab, Spectrochim. Acta A 61 (2005) 1059;
(b) Z.H. Abd El-Wahab, M.M. Mashaly, A.A. Salam, Spectrochim. Acta A 60 (2004) 2861.
[35] (a) N. Fahmi, I.J. Gupta, R.V. Singh, Phosphorus Sulfur Slicon 132 (1998) 1;
(b) A. Chaudhary, R.V. Singh, Phosphorus Sulfur Slicon 178 (2003) 603.
[36] (a) N. Sarin, S. Arslan, E. Logolu, L. Sakiyan, J. Sci. 16 (2003) 283;
(b) C. Jayabalakrishnan, K. Natarajan, Transit. Met. Chem. 27 (2002) 75.
[37] N. Raman, A. Kulandaisamy, C. Thangaraja, Transit. Met. Chem. 28 (2003) 29.