Communication in Physical Sciences 2020, 5(3): 403-417

Synthesis, Characterization and Biological Studies of Trinuclear Ce(IV) Salen Capped Complex with 5-amino-2,4,6-tris(4-carboxybenzimino)-1,3-pyrimidine

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Received 19 May 2020/Accepted 04 July 2020/Published online: 07 July 2020

Abstract: *A novel tripodal Schiff base ligand, 5-amino-2,4,6-tris(4-carboxybenzimino)-1,3-pyrimidine (TTPS), was synthesized for the first time by the reaction of 2,4,5,6-tetraaminopyrimidine with 4-carboxybenzaldehyde. The prepared ligand was used to synthesize Ce(IV) salen capped complex, [{Ce(OH)$_2$(salen)}$_3$(TTPS)].3H$_2$O. Both compounds were characterized using UV-Visible, IR, ^{1}H and ^{13}C NMR spectroscopies, elemental analysis and molar conductivity measurements. The spectral studies indicate that the ligand is hexadentate and coordinates to Ce(IV) ions through the oxygen atoms of the carboxylic group. The trinuclear Ce(IV) salen capped complex was characterized as being bridged by carboxylate anions to the Ce(IV) salen centres and displays a coordination number of eight by involving two hydroxyl groups in the coordination sphere.. The in vitro antimicrobial activities of the ligand and its Ce(IV) salen capped complex were investigated against Gram-negative bacteria: Escherichia coli (ATCC 6749) and Pseudomonas aeruginosa (ATCC 9027), Gram-positive: Staphylococcus aureus (ATCC 6538P) and Bacillus cereus (ATCC 14579), and fungi: Candida albicans and Aspergillus bacteria niger by the agar well diffusion technique. The ligand was found to be more potent against the test micro-organisms relative to the trinuclear Ce(IV) salen capped complex. The MIC of the new tripodal Schiff base ligand, TTPS, against Staphylococcus aureus was comparable to that of tetracycline and gentamycin.*

Keywords: *Tripodal Schiff base; trinuclearCe(IV) salen capped complex; antimicrobial activity*

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1.0 Introduction

In recent years, the chemistry of lanthanide complexes has attracted much attention stimulated by a wide variety of applications in electroluminescent devices, diodes, lasers, cathode ray tubes, sensors, dosimeters, biological fluoro-immunoassays, imaging agent (MRI), organic light emitting diodes (OLEDS), display application, decoration purposes and telecommunication (Chen *et* al., 2015; Fei *et al.,* 2016; Liu *et al*., 2013; Mikhalyova *et al*., 2014; Taha *et al*., 2011). Consequently, lanthanide complexes with Schiff base ligands have been extensively investigated because of their interesting coordination behavior, wide range of biological applications and ability to form multidimensional architectures (Mohanan *et al*., 2014). Uniques properties of lanthanides are associated with their high coordination numbers and more flexible coordination geometry than transition metals. Although, lanthanide complexes with Schiff base ligands have been widely studied (Bashir and Abdulhadi, 2017; Chen *et al*., 2015; Chien *et al*., 2015; Cristovoa and Hnatejko, 2015;

Ghoush and Ghoush, 2016; Kanesato *et al.*, 2011; Lekha*et al*., 2014), those derived from tripodal Schiff base ligands have received comparatively less attention.

Tripodal- trinuclear [salen metal (III)] capped complexes of some main group and d-block metals have been synthesized and characterized, but no report exists of such complexes with the lanthanides and actinides. The work done by Koc and Ucan (Koc and Ucan, 2007) was the first reported synthesis of tripodal- trinuclear [salen metal (III)] capped complexes. They reported the synthesis of complexes of iron(III) salen and saloph Schiff bases with bridging 2,4,6-tris (2,5-dicarboxyphenylimino-4-formylphenoxy)-1,3,5-triazine and 2,4,6-tris(4-carboxyphenylimino-4[1]-formylphenoxy)-1,3,5-triazine and characterized them by means of elemental analysis, ^{1}H-NMR, IR spectroscopy, thermal analysis and magnetic susceptibility measurements. Moreover, work done on these complexes had concentrated on their synthesis and characterization. Not much has been reported on the application of this compound in areas such as catalysis, medicine, pharmacology, and as agrochemicals.

Our research group has reported the synthesis, characterization, antimicrobial and computational studies of a tripodal Schiff base containing pyrimidine unit(Oruma *et al*., 2018).This present work describes the synthesis, characterization and antimicrobial studies of Ce(IV) Salen Capped Complex of the novel tripodal Schiff base ligand.

2.0 Materials and methods

2.1 Materials and measurements

All the chemicals used were of analytical reagent grade, purchased from Zayo–Sigma and were used as supplied without further purification. The melting points of the compounds were determined using Fischer Jones melting point apparatus and were uncorrected. Molar conductance measurements were carried out by dissolving 10^{-4} mol/L solutions of the complex in methanol at room temperature and measured with WTW-LF 90 conductivity meter. Electronic spectra in dimethyl sulphoxide (DMSO) were recorded on UV-Vis 1800 SHIMADZU spectrophotometer. Infrared spectra of the compounds were performed using KBr discs on a Perkin–Elmer (Waltham, Massachusetts, USA) 100 series version 10.03.08 FTIR spectrophotometer. The ^{1}H and ^{13}C NMR spectra of the compounds were recorded on a Bruker (Billerica, Massachusetts, USA) DPX 300 spectrometer in DMSO- d_6 at 300.13MHz and 75.47MHz respectively. Elemental analysis for C, H and N were carried out using LECO – CHN – 932 analyzer.

2.2 Synthesis of 5-amino-2,4,6-tris(4-carboxybenzimino)-1,3-pyrimidine (TTPS)

Two molar solution of $BaCl_2$ (20 mL) was added to 2,4,5,6-tetraaminopyrimidine sulfate (4.2 mmol, 1.0 g), heated at 60 °C for 10 minutes, and filtered. The filtrate was tested for SO_4^{2-} and the test indicated the absence of SO_4^{2-}. Benzene (10 mL) was added to the filtrate and stirred for 1 hour before addition of 4-carboxybenzaldehyde (12.6 mmol, 1.89 g) and re-stirlling for 6 hours. A yellow precipitate was obtained. This was filtered and recrystallized using a 1:1 mixture of methanol and water. The crystals formed were dried over $CaCl_2$ (See Scheme 1).

2.3 Synthesis of the trinuclear CeIV) Salen capped complex of TTPS

This involves synthesis of:

1. salenH_2
2. Ce(IV) salen complex
3. Ce(IV) ligand complex
4. Ce(IV) Salen Capped Complex of TTPS

2.3.1 Synthesis of salenH_2

SalenH_2 was synthesized by modifying the method reported by Sathe *et al*., (Sathe *et al*., 2013). To a solution of ethylenediamine (3.35 mL, 0.05 mol) in 50 ml of methanol in a round bottom flask, salicylaldehyde (10.47 mL, 0.1 mol) was added. The yellow crystalline solid produced was filtered and recrystallized from absolute ethanol (50 mL) at 80 °C.

2.3.2 Synthesis of Ce(IV) salen complex

The method reported by Gembickỳ *et al.*, (Gembickỳ*et al.*, 2000) was modified and adopted for synthesis of salen complexes. To a hot methanolic solution (40 mL) of salenH_2 (1.34 g, 0.005 mol), a hot aqueous solution (50 mL) $Ce(SO_4)_2$ (1.65 g, 0.005 mol) was added. The mixture was stirred at 50 °C for 30 minutes. A light brown precipitate was formed, and then triethylamine (0.02 mol, 4 mL) was added. On adding triethylamine, the light brown precipitate turned reddish brown. The resulting solution was stirred at 50 °C for 2 hours and after cooling, a reddish brown precipitate was obtained. The

precipitate was washed with methanol and diethyl ether and dried over $CaCl_2$.

2.3.3 Synthesis of Ce(IV) ligand complex

The ligand complexes were prepared by modifying the method reported by Kopel *et al.*, (Kopel *et al.*, 1998) and Uysal *et al.,* (Uysal and Koc, 2010; Uysal and Ucan, 2009). A solution of Ce(IV) salen complex (0.50g, 10^{-3} mol) in absolute ethanol (20 mL) was stirred at 50 °C for 15 minutes. Excess concentrated ammonia solution (1 mL at a time) was added and stirred. The pH of the solution was monitored with the aid of a pH meter until the pH of 12. A brown precipitate was formed, filtered and dried over $CaCl_2$.

2.3.4 Synthesis of Ce(IV) salen capped complex of TTPS, [{Ce(OH)$_2$(salen)}$_3$(TTPS)].3H$_2$O

Ce(IV)LC (0.65 g, 0.00075 mol) was suspended in hot absolute ethanol (25 mL) and a solution of TTPS tripod ligand (0.27 g, 0.00050 mol) in absolute ethanol was added while stirring. The reaction mixture was boiled under reflux for 4 hours. The red solid formed was dried over $CaCl_2$. See Scheme 2.

2.4 In vitro antimicrobial activity

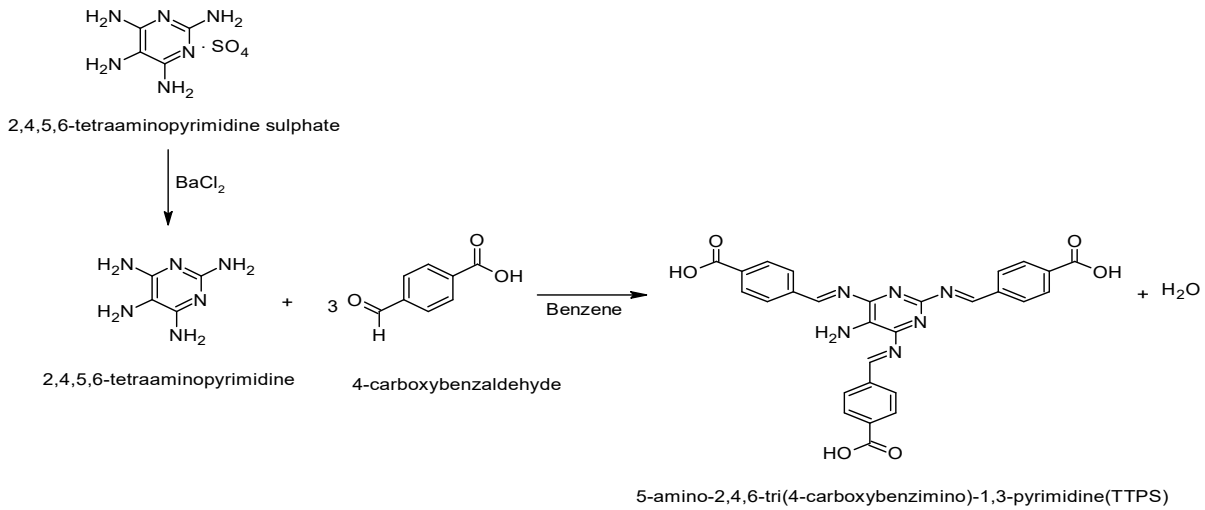
TTPS and its trinuclear Ce(IV) salen capped complex were tested *in vitro* for their antimicrobial activities against American Type Culture Collection (ATCC) bacteria strains obtained from Rockville, MD, USA, by the Department of Microbiology, University of Nigeria, Nsukka while the fungi strains were isolated under clinical conditions. The typed bacteria culture comprises Gram-positive bacteria: *Staphylococcus aureus* (ATCC 6538P) and *Bacillus cereus* (ATCC 14579); Gram-negative bacteria: *Escherichia coli* (ATCC 6749) and *Pseudomonas aeruginosa* (ATCC 9027). The fungi strains used were *Candida albicans* and *Aspergillus niger*. The bacteria strains were tested for sterility on nutrient agar and then grown in nutrient broth at 37 °C for 24 hours while the fungal strains were tested on Sabourand Dextrose Agar (SDA) and cultured in Sabourand Dextrose Liquid medium at 25 °C for 24 hours. The overnight cultures were subsequently diluted and suspensions were made in normal saline and adjusted to 0.5 McFarland standards (Cheesbrough, 2006).

2.5 Antimicrobial assay

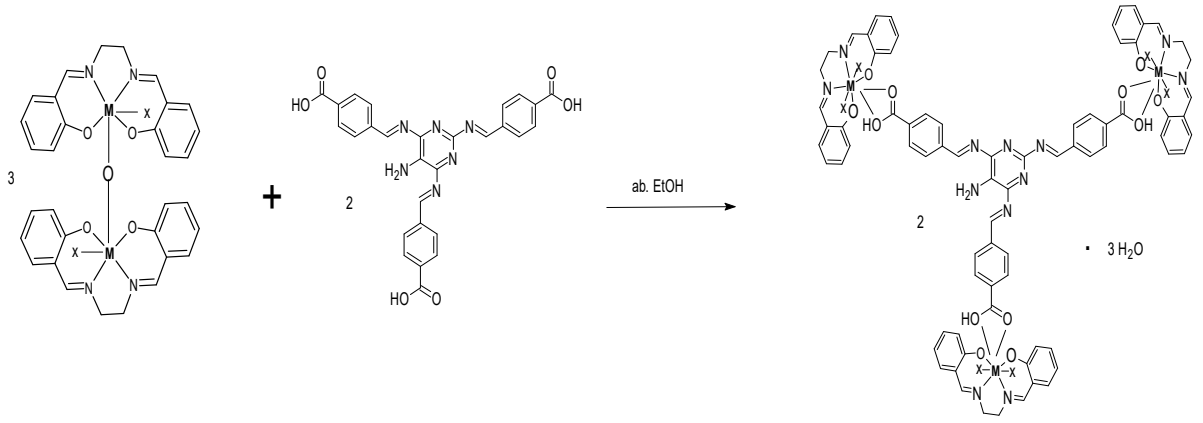
The antimicrobial activities of all the synthesized compounds were determined by the agar cup diffusion technique (Alli *et al*., 2011).The nutrient agar and SDA plates were inoculated with 0.1 mL broth culture of the test bacteria or fungi. Using a sterile cork borer, wells (5 mm in diameter and 2.5 mm deep) were bored into the inoculated agar. Fresh stock solutions (1000 µg/mL) of the synthesized compounds were prepared in DMSO. The stock solution was further diluted with sterilized distilled water to 12.5, 25, and 50 µg/mL for antimicrobial evaluation. The wells were filled with 100 µL of the test compounds by means of a sterile micropipette. Standard antibiotics namely: ciprofloxacin, tetracycline, gentamycin and fluconazole were used as positive control while sterile DMSO served as negative control. Subsequently, 12.5, 6.25, and 3.125 µg/mL of each positive control were prepared in DMSO. The bacteria plates were incubated at 37 ^{o}C for 24 hours while fungal plates were incubated at 25 ^{o}C for 24 hours. Inhibition zone diameter (IZD) around each well was measured in millimeter and recorded. The graph of IZD^2 against the log of concentration was plotted for each plate containing a specific compound and a microorganism. The anti-log of the intercept on *x*-axis is the MIC.

3.0 Results and Discussion

The steps involved in the formations of the compounds are represented in Scheme 1 and 2. The uncoordinated water molecule in Ce(IV)TTPS was formed from oxidation of ethanol as shown in Scheme 3. The TTPS and its trinuclear Ce(IV) salen capped complex are stable at room temperature and have high melting point of 348–350 °C and decomposition temperature of 335 °C respectively. Synthesis of TTPS and its trinuclear Ce(IV) salen capped complex was achieved in high to moderate yield of 1.66 g (74 %) and 0.52 g (57.14 %) respectively. They are soluble in DMSO, DMF, ethylacetate, and methanol but insoluble in water. The analytical data of TTPS and its trinuclear Ce(IV) salen capped complex are in good agreement with the proposed molecular formula as shown in Table 1. Molar conductivity measurements in methanol at room temperature indicate that both compounds are neutral (Ali *et al*., 2013).



Scheme 1: Synthesis of TTPS



M =Ce, X = OH

Scheme 2: Synthesis of Ce(IV)TTPS

$CH_3CH_2OH + O^{2-} \rightarrow CH_3CHO + H_2O$

Scheme 3: Formation of uncoordinated water

Table 1: Elemental and physical data of TTPSand its Ce(IV) salen capped complex

Compound	Colour	Λ_m ($\Omega^{-1}cm^2mol^{-1}$)	Yield g (%)	M.p. (°C)	Elemental analysis % calc. and found					
					C		H		N	
					Calc.	Found	Calc.	Found	Calc.	Found
$C_{28}H_{20}O_6N_6$ (TTPS)	Yellow	-	(1.66)74	348-350[a]	62.69	62.25	3.73	4.10	15.67	15.30
Ce(IV)TTPS	Brick red	44	(0.52) 57.14	335[a]	48.69	48.70	3.84	3.70	8.97	8.85

**** [a] = decomposition temperature**

3.1 Synthesis of the precursors

SalenH$_2$ was synthesized in high yield. The UV, IR and elemental analysis data are presented below while the UV and IR spectra are presented in appendices1 and 6. Yield = 11.14 g (83 %); mp of 109– 110 °C; UV (λ nm) (DMSO) (ε):316 (1.91 × 10^4), 404 (0.41 × 10^4);IR (KBr): 3441 (br) ((O-H)

Phenolic), 1608 (s) (C═N), 1287(m) (C–O), 751 (m) (C–H) cm^{-1}; Anal. calcd for $C_{16}H_{16}O_2N_2$ (268): C, 71.64; H, 5.97; N, 10.45. Found: C, 71.60; H, 6.00; N, 10.30.

Synthesis of Ce(IV) salen complex was achieved in moderate yield. The UV, IR and elemental analysis data are presented below while the UV and IR spectra are presented in appendices 2 and 7. Yield = 1.48 g (49.33 %); mp of 102[a] °C(a = decomposition temperature); UV (λ nm) (DMSO) (ε): 232 (1.75×10^4), 269 (7.04×10^4); IR(KBr): 3419 (br) (O–H Phenolic), 1637 (s) (C═N), 1420 (m), 1121 (br) (SO_4^{2-}), 629 (m) (C–H), 494 (m) (Ln-O), 412 (w) (Ln-N) cm^{-1}; Anal. calcd for $[Ce(SO_4)_2salenH_2]$(600): C, 32.00; H, 2.67; N, 4.67. Found: C, 32.20; H, 2.70; N, 4.40.

Ce(IV) ligand complex was obtained in moderate yield. Ligand complex is one which acts as a ligand by being able to coordinate to another ligand. This is the first example of a ligand complex bearing Ce(IV) ion. The UV, IR and elemental analysis data are presented below while the UV and IR spectra are presented in appendices 3 and 8. Yield = 0.43 g (63.77 %); mp of 318– 320 °C; UV (λ nm) (DMSO) (ε): 260 (8.61×10^3), 307 (5.20×10^3); IR (KBr): 3250 (br) (O – H), 1631(s) (C═N), 1546(s) (C═C), 1199(m) (C–O), 907(s), 752(s) (C–H), 600 (s) (M-O-M), 580(m) (Ln-O), 455(m) (Ln-N) cm^{-1}; Anal. calcd for $[\{Ce(OH)(salen)\}_2O]$ (862): C, 44.55; H, 3.48; N, 6.50. Found: C, 44.65; H, 3.70; N, 6.60.

3.2 Electronic spectra

The UV/Vis absorption spectra of the TTPS and Ce(IV)TTPS (10^{-4} $moldm^{-3}$) were carried out in DMSO at room temperature. The spectral values of the absorption wavelength and the corresponding molar absorptivities (ε) are given in Table 2. The absorption spectra are displayed in appendices 4 and 5 respectively. The electronic absorption spectrum of TTPS showed three bands at 231, 263 and 404 nm, which are assigned to π – π* and n – π* transitions of the conjugated phenyl ring and azomethine group respectively. The absorption spectrum of Ce(IV)TTPS show only one peak, which is assigned to n – π* transition. The changes in the values of molar absorptivities (ε) also indicate the formation of the complex.

Table 2: Electronic absorption data of 5-amino-2,4,6 - tris(4-carboxybenzimino) -1,3- pyrimidine (TTPS) and its Ce(IV) salen capped complex

Compound	λ_{max}		ε $x10^3$($mol^{-1}dm^3cm^{-1}$)	Band assignment
	nm	cm^{-1}		
TTPS	231	43290	7.90	π– π*
	263	38022	49.35	π– π*
	404	24752	7.26	n– π*
Ce(IV)TTPS	340	29412	5.06	n– π*

3.3 Infrared spectra

The relevant stretching frequencies of TTPS and its Ce(IV) salen capped complex are shown in Table 3 while the spectra are presented in appendices 9 and 10 respectively. The infrared spectrum of TTPS displayed a broad band at 3391 cm^{-1} assigned to the free NH_2 stretch (Uysal and Koc, 2016; Uysal and Koc, 2018; Uysal*et al*., 2012). This indicates that not all the amino groups in 2,4,5,6- tetraaminopyrimidine is involved in formation of azomethine linkage with 4-carboxybenzaldehyde. However, this band did not appear in the spectrum of Ce(IV)TTPS. The broad band centered at 3220 cm^{-1} in the spectrum of TTPS due to carboxylate OH was shifted to 3200 cm^{-1} in the spectrum of Ce(IV)TTPS indicating that the carboxylate OH group was coordinated to the Ce(IV) ions without deprotonation (Koc and Ucan, 2007). The absorption band observed at 1719 cm^{-1} was assigned to ν (C=O) of carboxylic acid. In the spectrum of Ce(IV)TTPS, this band shifted to lower frequency of about 35 cm^{-1} indicating that the carboxylic acid C=O might have been involved in coordination to the metal ions (Koc and Ucan, 2007; Kocyigit and Guler, 2010). The vibration due to azomethine C=N was observed at 1686 cm^{-1} and 1660 cm^{-1} in the spectrum of TTPS. The spectrum of the complex show two chemically different vibrations due to C = N namely: **ν** (C = N) b and **ν** (C = N) c. The **ν** (C = N) b band shifted to lower wave number while the **ν** (C = N) c band was

absent in the ligand but present in the complex. This confirm that the ligand complex is capped to the COO^- group of the ligand and that the azomethine nitrogen of salen participated in coordination (Uysal and Koc, 2010; Uysal *et al*., 2012). The vibration due to the C=N of pyrimidine ring occurred at 1526 cm^{-1} in both compounds. This indicates that this group is not involved in bonding. Similar observation has been made in literature (Kumar *et al*., 2013). The carboxylic (COO^-) band was observed at 1420 cm^{-1} in TTPS but changed in intensity and also shifted to lower wavenumber in Ce(IV)TTPS, suggesting that the COO^- is involved in coordination (Uysal and Ucan, 2009; Uysal *et al*., 2012). Bands assignable to ν (Ln – O) and ν (Ln - N) were observed at 522 cm^{-1}, and 459 cm^{-1} respectively (Lekha *et al*., 2014; Taha *et al*., 2011; Karatas and Ucan, 2014).

Table 3: IR band assignments (cm^{-1}) for 5-amino-2,4,6-tris(4-carboxybenzimino) -1,3- pyrimidine (TTPS) and its Ce(IV) salen capped complex

Compound	ν (NH_2)	ν O -H carboxylate	ν C = O	ν C = N	ν COO-	ν C –O	ν Ln –O	ν Ln- N
TTPS	3391(br)	3220(br)	1719(s)	1686(m)b 1660(s)b 1526(m)a	1420(m)	1200(s)	-	-
Ce(IV)TTPS	-	3200(br)	1684(m)	1659(s)b 1571(m)c 1526 (m)a	1403 (s) 1382(s)	1288(s) 1245(s)	522(m)	459(m)

where C = N(b) = from azomethine linkage, C = N(c) = from salen, C = N(a) = from pyrimidine ring.

3.4 ^1H and ^{13}C NMR spectra

The ^1H and 13C NMR spectra of TTPS and its Ce(IV) salen capped complex are presented in Tables 4 and 5 while the spectra are presented in appendices 11, 13 and 12, 14 respectively. The ^1H NMR of TTPS and its Ce(IV) salen capped complex reveal the presence of protons due to NH_2. This indicates that one of the amino groups was not involved in the formation of azomethine link. The signal due to carboxylate proton was observed at 13.23 ppm in TTPS but shifted downfield by 0.14 ppm in Ce(IV)TTPS. This indicates that the carboxylic OH coordinated to the Ce(IV) ion without deprotonation, which is consistent with the IR data. The signal due to azomethine proton shifted downfield in Ce(IV)TTPS. This shift confirms that the azomethine nitrogen is involved in coordination. The absence of peak due to ethylene protons in TTPS but present in Ce(IV)TTPS confirms that the ligand complex capped to carboxylate ends of the tripodal ligand. The ^1H NMR spectrum provided evidence for the presence of uncoordinated water in Ce(IV)TTPS (Silverstein *et al.*, 2005).

Table 4: ^1H NMR data of 5-amino-2,4,6-tris(4-carboxybenzimino) -1,3-pyrimidine (TTPS) and its Ce(IV) salen capped complex (ppm)

Compound	OH Carboxylic	CH = N	$H_{aromatic}$	CH_2 = CH_2	$H_2O_{uncoordinated}$	DMSO	NH_2
TTPS	13.23(1H,s)	10.07(1H,s), 8.65(1H,s)	8.12 -7.97(H,m) 7.41(H,d), 7.38(H,d)	-	-	-	2.47(2H,s)
Ce(IV)TTPS	13.37(1H,s)	10.09(1H,s), 8.68(1H,s)	7.97 – 6.03(H,m)	4.41(4H,s) 5.70(4H,s)	3.40	2.50	3.89(2H,s)

The ^{13}C NMR spectrum of TTPS gave signal at 193.44 ppm, which is attributed to carboxylate carbon. However this signal was not observed in Ce(IV)TTPS. In TTPS, only one signal was observed for azomethine at 166.99 ppm while two signals were observed in Ce(IV)TTPS at 166.14 and 164.10 ppm respectively. This confirms that the salen complex actually capped to the carboxylic end and the signal observed at 164.10 ppm is assigned to C =N of salen. Likewise the presence

of signal at 62.95 ppm in Ce(IV)TTPS due to ethylene carbons confirms the ligation mode (Ukoha and Oruma, 2014). The signal at 134.40 and 133.84 ppm in Ce(IV)TTPS were attributed to carbons on pyrimidine ring (Chattopadhyay *et al.*, 2010). These recorded ^{1}H and ^{13}C resonances are consistent with literature (Uysal and Koc, 2010; Uysal and Koc, 2016; İşçi and Uysal, 2018).

Table 5: ^{13}C NMR data of 5-amino-2,4,6-tris(4-carboxybenzimino) -1,3- pyrimidine (TTPS) and its Ce(IV) salen capped complex

Compound	Carboxylic carbon	Azomethine carbon	Aromatic carbons	DMSO peak	CH_2 carbons
TTPS	193.44	166.99	139.29, 136.05, 130.35, 129.66, 128.73	39.90	-
Ce(IV)TTPS	-	166.14, 164.10	134.40, 133.84, 123.66, 117.46, 116.68	39.91	62.95

3.5 In vitro antimicrobial activity

The results of the *in vitro* antimicrobial screening carried out on the compounds are recorded in Table 6. Ciprofloxacin, tetracycline, gentamicin and fluconazole were used as positive control while sterile DMSO served as negative control. These drugs have been chosen because they have same mechanism of action, which is by inhibiting nucleic acid synthesis (Oruma *et al*., 2018). The structures of these drugs are shown in appendix 15.Ciprofloxacin ($C_{17}H_{18}FN_3O_3$) belongs to fluoroquinolnes and inhibits bacteria growth by preventing deoxyribonucleic acid (DNA) synthesis before mitosis. Tetracycline ($C_{22}H_{24}N_2O_8$) inhibits the multiplication of bacteria by binding to a subunit of the ribosomes, thereby inhibiting protein and nucleic acid synthesis and consequent death of the bacterium (Obasi *et al.*, 2017; Wolters, 2009). Gentamycin ($C_{21}H_{43}N_5O_7$) belongs to the class of aminoglycosides and acts by preventing protein synthesis, thereby inhibiting the synthesis of nucleic acids (DNA replication or RNA synthesis) and causes death of the bacterium. Fluconazole is an antifungal drug ($C_{13}H_{12}F_2N_6O$) and belongs to synthetic triazoles. Fluconazole inhibits fungal cytochrome P –450, an enzyme responsible for fungal sterol synthesis, thereby causing fungal cell walls to weaken (Wolters, 2009).

Table 6: Inhibition zone diameter (IZD in mm) of the compounds against typed strains (ATCC culture) microorganisms

Compound	*B.c*(ATCC 14579)	*S.a*(ATCC 6538P)	*P.a*(ATCC 9027)	*E.c*(ATCC 6749)	*C.a*	*A.n*
			50 µg/mL			
TTPS	21	23	13	13	27	22
Ce(IV)TTPS	9	15	7	8	5	4
			25 µg/mL			
TTPS	-	9	8	5	19	-
Ce(IV)TTPS	-	4	-	-	-	-
			12.5 µg/mL			
TTPS	-	5	3	-	5	-
Ce(IV)TTPS	-	-	-	-	-	-

***B.c = Bacillus cereus*, *S.a = Staphylococcus aureus*, *P.a = Pseudomonas aeruginosa*, *E.c = Escherichia coli*, *C.a = Candida albicans*.*A.n = Aspergillus niger*, (-) = no zone of inhibition observed.**

The results obtained (Table 6) show that the activity of TTPS is higher than that of the trinuclear Ce(IV) complex. TTPS exhibits higher activity against fungi (*Candida albicans* and *Aspergillus niger*) relative to the bacteria strains used. Hence, it could be inferred that the activity of the trinuclear complex was not enhanced after anion coordination.

The inhibition zone diameter (IZD in mm) of the controls is displayed in appendix 16. From appendix 16, the inhibition zone diameters (IZD) of the controls are higher than that of the compounds.
The minimum inhibitory concentration (MIC) of the compounds and controls against *Bacillus cereus*, *Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli, Candida albicans,* and *Aspergillus niger* are displayed in Table 7. From Table 7, the MIC of the new tripodal Schiff base ligand, TTPS, against *Staphylococcus aureus* was found to be 3.6 mg/ml while that of tetracycline and gentamycin were 1.80 and 2.70 mg/ml respectively.

Table 7: Minimum inhibitory concentration (MIC) of the compounds and controls against test bacteria and fungi

	MIC (µg/mL)					
Compound	***B.c*(ATCC 14579)**	***S.a*(ATCC 6538P)**	***P.a*(ATCC 9027)**	***E.c*(ATCC 6749)**	***C.a***	***A.n***
TTPS	50	3.6	6.4	25	2.9	50
Ce(IV)TTPS	50	25	50	50	50	50
			Controls			
T	1.90	1.80	0.63	2.15	2.10	0.58
F	6.25	6.25	6.25	2.80	0.64	0.74
CP	1.50	0.70	0.92	0.65	2.00	6.25
G	1.40	2.70	0.71	2.60	2.50	0.64

****T** = Tetracycline, **F** = Fluconazole, **CP** = Ciprofloxacin, **G** = Gentamycin

.4.0 Conclusion

A tripodal Schiff base ligand derived from 5-amino-2,4,6-tris(4-carboxybenzimino)-1,3-pyrimidine (TTPS), and its novel trinuclear Ce(IV) Salen Capped Complex were synthesized and characterized. Based on analytical and spectral data, the ligand was found to be hexadentate and coordinate to Ce(IV) ions through the oxygen atoms of the carboxylic group. The trinuclear Ce(IV) salen capped complex was characterized as being bridged by carboxylate anions to the Ce(IV) salen centres and displays a coordination number of eight by involving two hydroxyl groups in the coordination sphere. *In vitro* antimicrobial test indicate that the tripodal ligand, TTPS is more potent against the test micro-organisms relative to Ce(IV) Salen Capped Complex. The MIC of the new tripodal Schiff base ligand, TTPS, against *Staphylococcus aureus* was comparable to that of tetracycline and gentamycin.

5.0 Acknowledgements

The authors are grateful to Prof. Klaus Jurkschat of Technische Universität, Fakultät für Chemie und Chemische Biologie, D-44221 Dortmund, Germany for helping with the spectral analyses. We also acknowledge the support received from the African-German Network of Excellence in Science (AGNES), the Federal Ministry of Education and Research (BMBF) and the Alexander von Humboldt Foundation (AvH).

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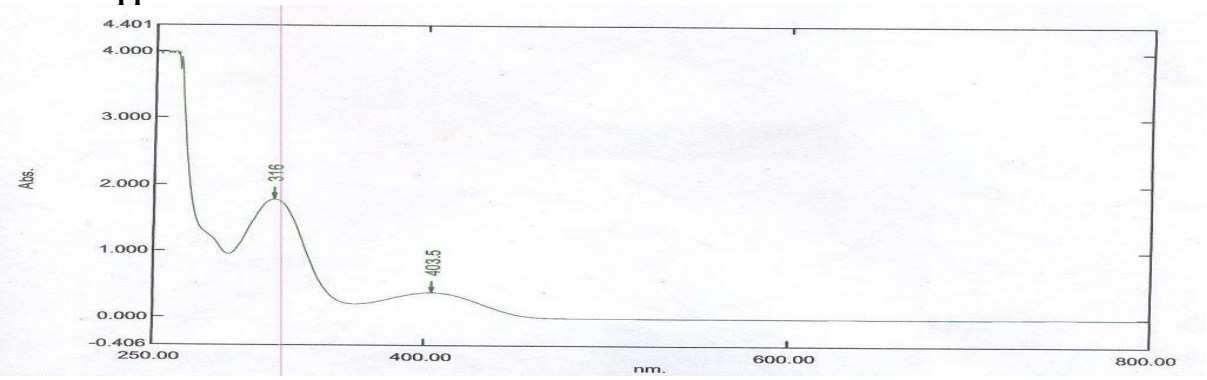
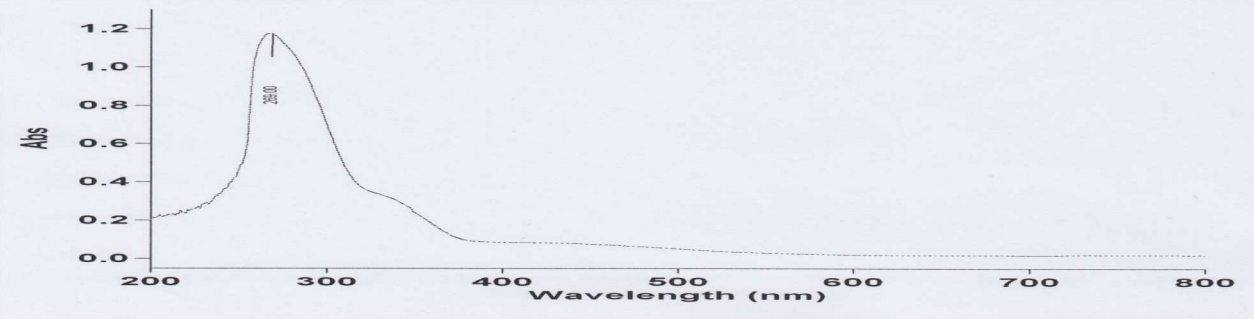
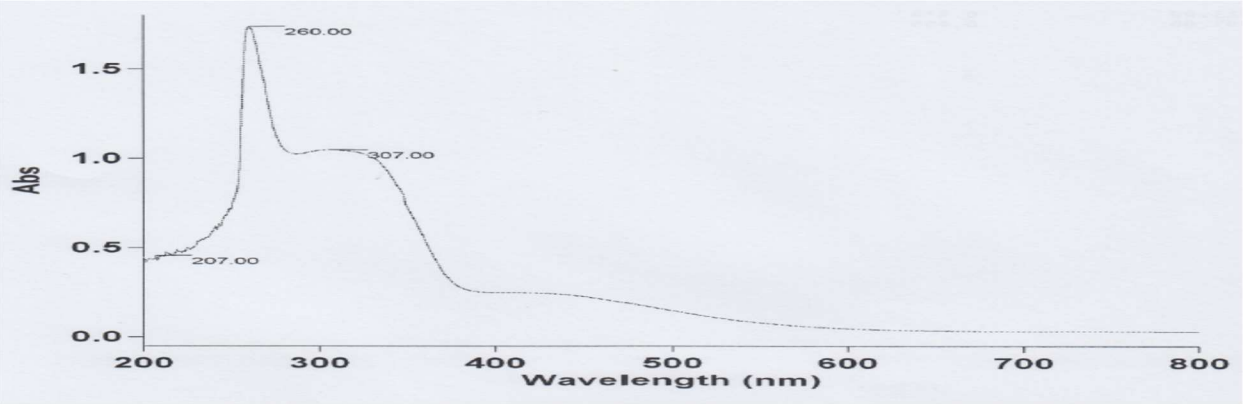
7.0 Appendices



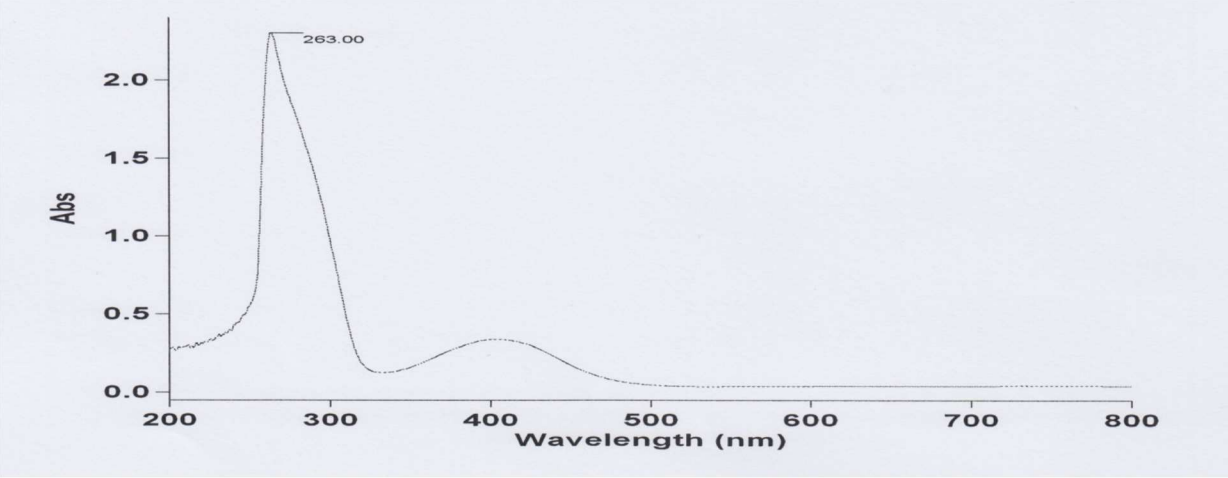
Appendix 1: Electronic absorption spectrum of salen H_2



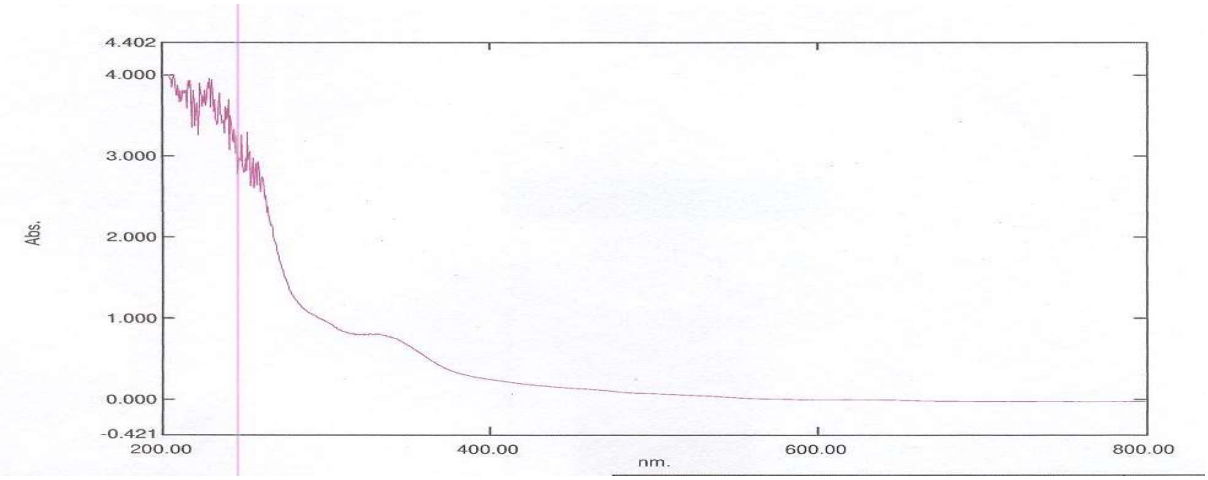
Appendix 2: Electronic absorption spectrum of Ce(IV)salen



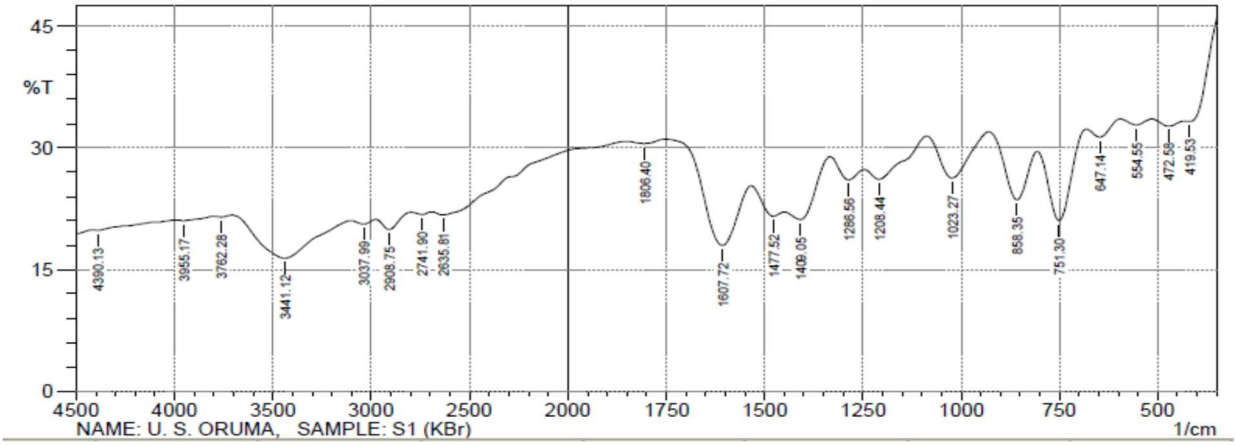
Appendix 3: Electronic absorption spectrum of Ce(IV)LC



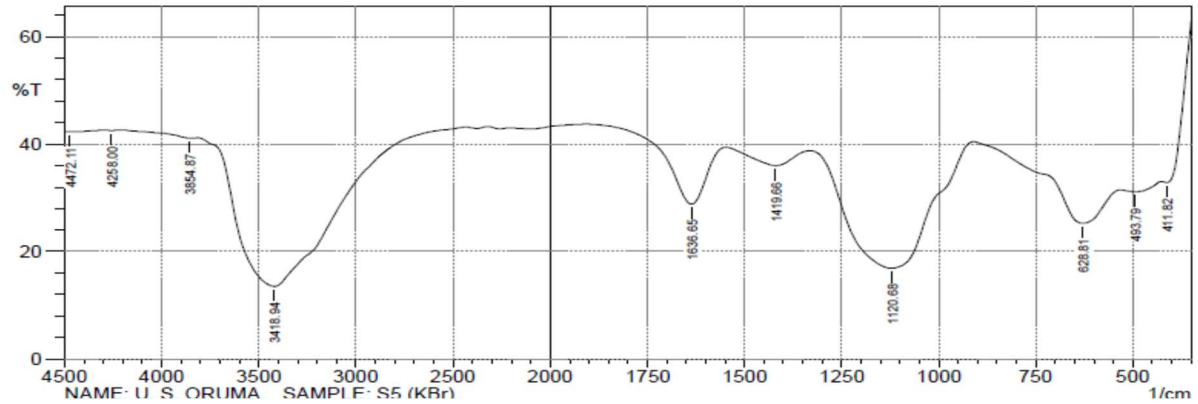
Appendix 4: Electronic absorption spectrum of TTPS



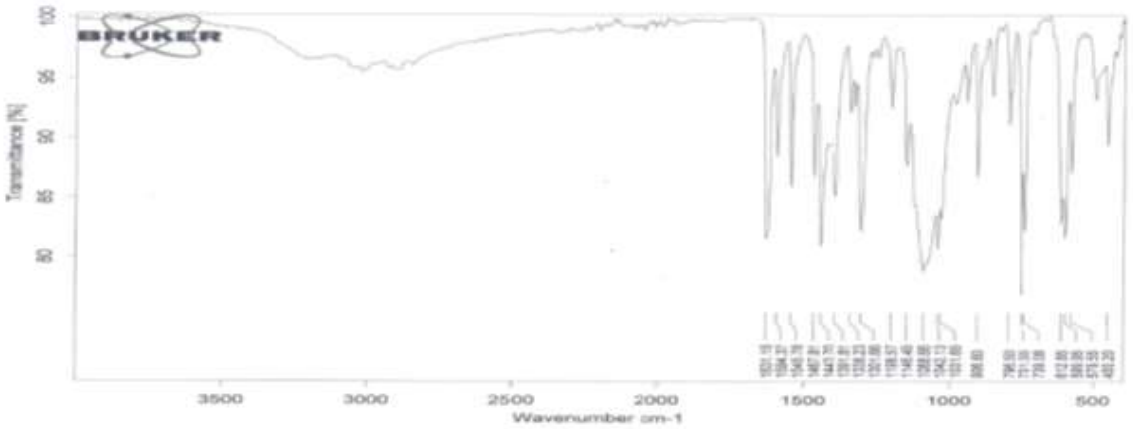
Appendix 5: Electronic absorption spectrum of Ce(IV)TTPS



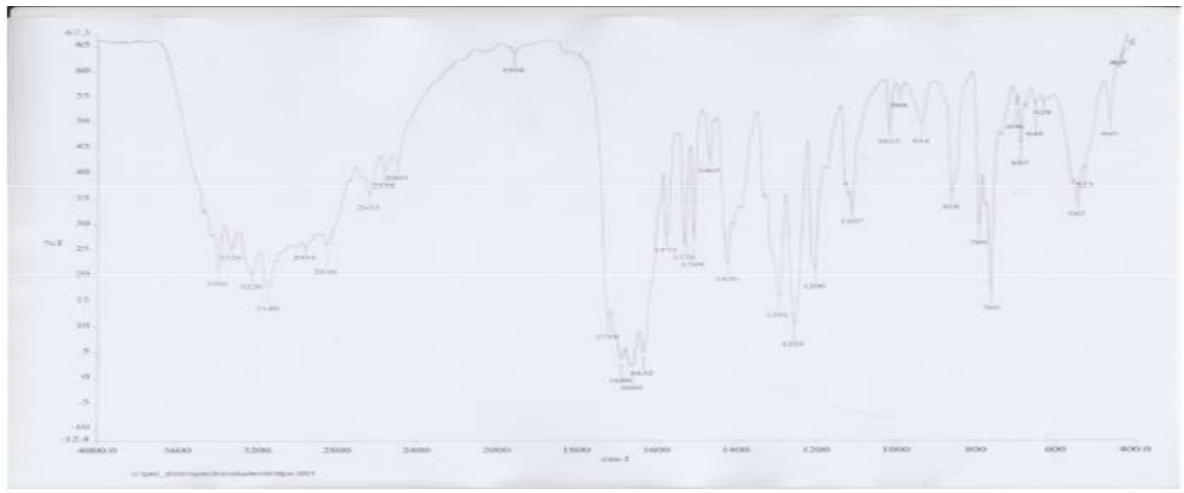
Appendix 6: Infrared spectrum of salenH_2



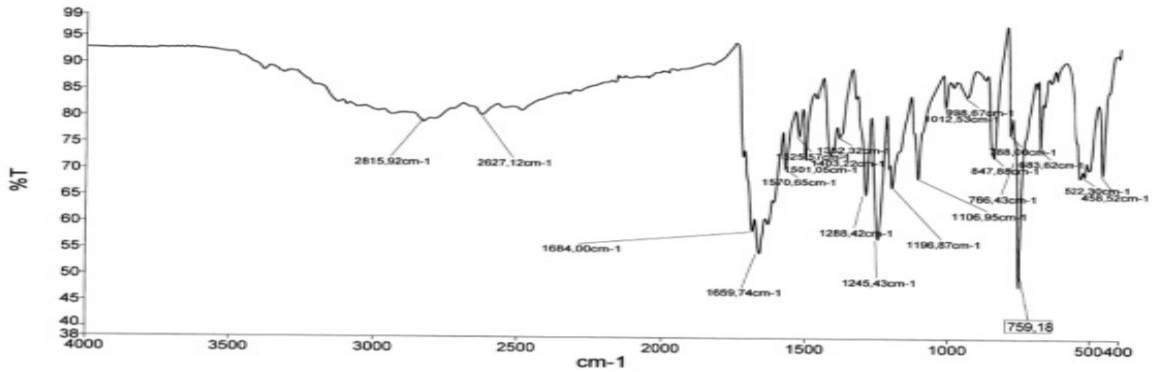
Appendix 7: Infrared spectrum of Ce(IV)salen



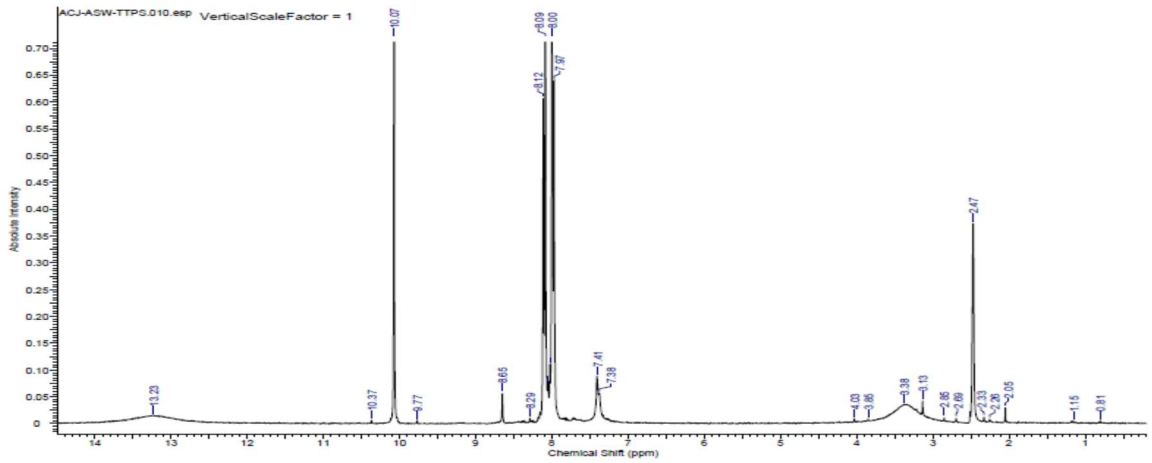
Appendix 8: Infrared spectrum of Ce)IV)LC



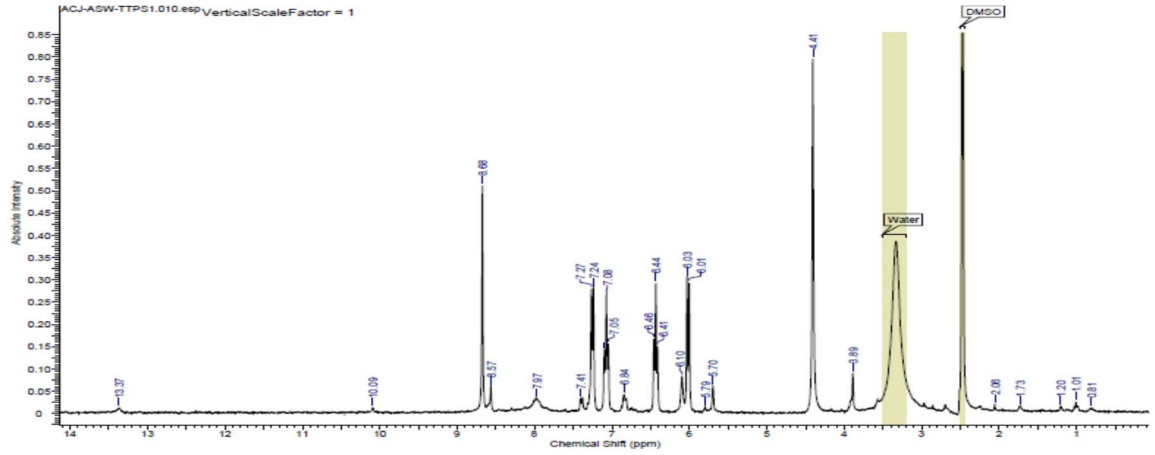
Appendix 9: Infrared spectrum of TTPS



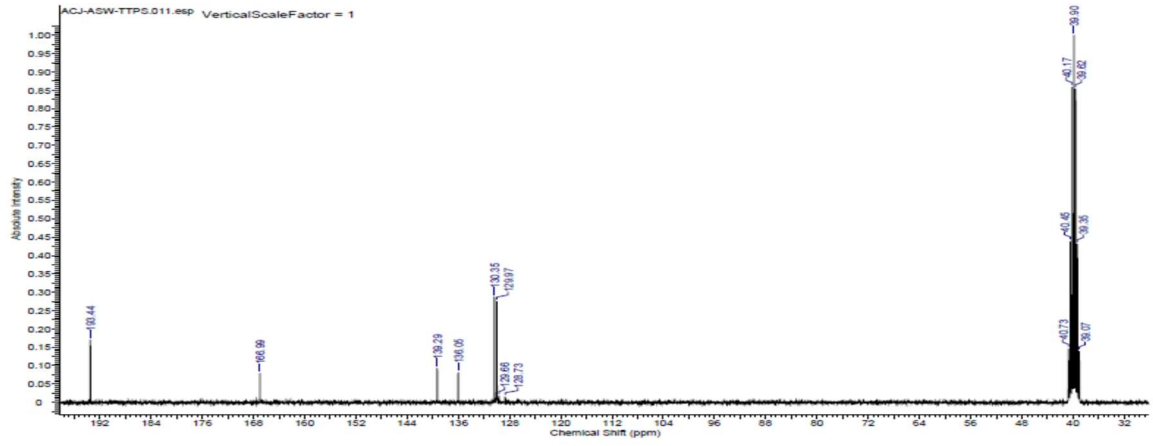
Appendix 10: Infrared spectrum of Ce(IV) TTPS



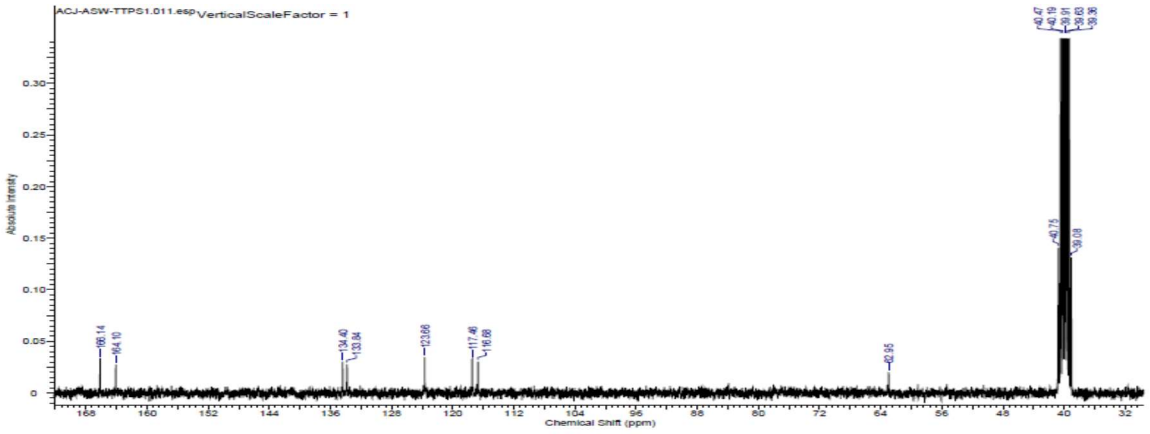
Appendix 11 :^{1}H NMR Spectrum of TTPS



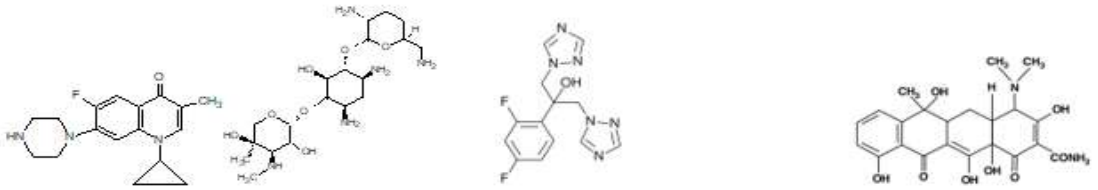
Appendix 12: ^{1}H NMR Spectrum of Ce(IV)TTPS



Appendix 13: ^{13}C NMR Spectrum of TTPS



Appendix 14: ^{13}C NMR Spectrum of Ce(IV)TTPS



Ciprofloxacin Gentamicin Fluconazole Tetracycline

Appendix 15: Structures of the drugs used as standard.

Appendix 16: Inhibition Zone Diameter (IZD in mm) of the Controls

Conc. (µg/mL)	Code	*B.c*(ATCC 14579)	*S.a*(ATCC 6538P)	*P.a*(ATCC 9027)	*E.c*(ATCC 6749)	*C.a*	*A.n*
12.5	T1	11	13	20	14	15	20
6.25	T2	7	9	16	8	9	15
3.125	T3	3	5	11	3	4	14
12.5	F1	6	8	5	8	20	21
6.25	F2	3	5	3	5	15	17
3.125	F3	-	-	-	2	12	10
12.5	CP1	17	20	16	18	15	11
6.25	CP2	11	14	12	14	11	5
3.125	CP3	5	8	3	9	4	-
12.5	G1	19	12	20	14	16	21
6.25	G2	12	5	11	11	13	14
3.125	G3	5	2	8	2	9	10
12.5	DMSO	0	0	0	0	0	0
6.25	DMSO	0	0	0	0	0	0
3.125	DMSO	0	0	0	0	0	0

****T = Tetracycline, F = Fluconazole, CP = Ciprofloxacin, G = Gentamycin**.