**Original Research Article****DOI: 10.26479/2019.0502.62****SYNTHESIS, CHARACTERIZATION, CATALYTIC AND ANTIBACTERIAL ACTIVITIES OF SOME TRANSITION METAL CHELATES WITH TRIDENTATE SCHIFF BASE LIGAND****Pravin Prajapati^{1*}, Manish Brahmabhatt¹, Jabali vora², Kuntal Prajapati¹**

1. Sheth M. N. Science College, Hem. North Gujarat University, Patan, India.

2. Department of Chemistry, Hem. North Gujarat University, Patan, India.

ABSTRACT: Transition metal chelates of cobalt(II), nickel(II) and copper(II) perchlorate with schiff base (TSCS) derived from condensation of thiosemicarbazide and salicylaldehyde were synthesized. The transition metal chelates have been structurally characterized by elemental analysis, UV visible reflectance spectra, IR, molar conductance, magnetic moment and thermal analysis. All the chelates were studied for catalytic activity. Activation energy was also evaluated from the TGA data by Broido method. The Schiff base ligand and their transition metal chelates also were screened for their antibacterial activity against bacterial species, *Escherichia coli*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Bacillus cereus* using Ciprofloxacin as a standard. The activity data show that the metal chelates to be more potent/antibacterial than the parent schiff base ligand against one or more microbial species.

KEYWORDS: Transition metal chelates, Schiff base, Thiosemicarbazide, Antibacterial activity.

Corresponding Author: Dr. Pravin Prajapati* Ph.D.

Sheth M. N. Science College, Hem. North Gujarat University, Patan, India.

1. INTRODUCTION

Chelating agents which contain O, N and S donor atoms are of special interest to inorganic chemist because of these compounds show wide range of biological activity and have capability of bonding to metal ions in variety of ways. Schiff base which contains ONS donor atoms have widespread applications in many biological aspects and have been utilized in synthesis of biologically active metal chelates [1,2]. Transition metal chelates of schiff base are most studied due to their industrial, antitumour, antifungal, antibacterial, antiviral, antiamebic activity [3], carcinostatic and other biological applications [4,5]. Tridentate schiff base containing ONS donor atoms are well known

and form stable chelates. Furthermore, presence of these atoms in the chelates makes these compounds stereospecific catalyst for hydrolysis, oxidation [6], reduction [7] and other chemical reactions in inorganic and organic chemistry [8]. It is familiar that some medicines show greater activity in the form of metal chelates than as free ligands [9-11]. In the present work we reported, the synthesis of Co(II), Ni(II) and Cu(II) metal ions chelates with schiff base. The structural feature of metal chelates have been proposed on the basis of analytical, physical and spectral data. The Schiff base and their chelates were screened for antibacterial activities. The Schiff base ligand used in this study is as shown in Figure 1.

2. MATERIALS AND METHODS

A. R. grade chemicals were used throughout the experimental work. Spectroscopic grade solvents were used for recording the spectra. Stock solutions of metal perchlorates were prepared and standardized by complexometric titration method [12]. Elemental analysis was done with the help of Thermo Finnigan FLASH EA 1112 Series CHN Analyzer. Magnetic susceptibility was recorded by using Gouy's method at room temperature, using $\text{Hg}[\text{Co}(\text{CNS})_4]$ as calibrant. The Infrared spectra were recorded on a Shimadzu, IR Affinity 1 S spectrophotometer by using sample as KBr pellets. For additional confirmation by infrared spectroscopy, Far-IR were also recorded with the help of Bruker, 3000 Hyperion Microscope with Vertex 80 FTIR System spectrophotometer. The UV visible reflectance spectra were recorded on a Varian Cary 500, Shimadzu UV 3600 UV-VIS Spectrophotometer. Thermogravimetric analysis was recorded by using a Perkin-Elmer Diamond Thermogravimetric/Differential Thermal Analyzer.

2.1.Synthesis of Schiff base (TSCS)

A mixture of 1.823 gm thiosemicarbazide dissolved in deionized water and solution of 2.09 ml salicylaldehyde (0.02 mol) in sodium carbonate refluxed for 2 hours [13]. Then resulting mixture was filtered followed by acidifying with 50% hydrochloric acid which results in separation of schiff base. This is then filtered and recrystallized with hot ethanolic solution and dried. The melting point of this Schiff base was found to be 205°C.

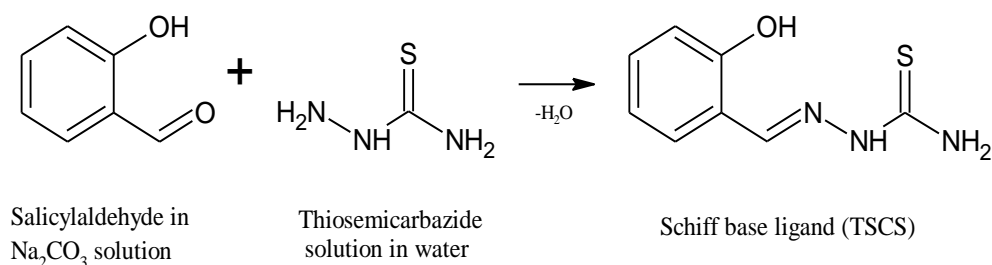


Figure 1: Synthesis scheme for thiosemicarbazide salicylaldehyde Schiff base (TSCS)

2.2. Synthesis of metal chelates

The metal chelates were prepared by mixing solution of the metal perchlorate (70 ml, 0.1 M) and the solution of the Schiff base (70 ml, 0.1 M) in the ethanol-water solvent in 1:1 molar ratio. The

resulting mixture was refluxed for about 3 hours and allowed to cool at room temperature. There was no instant precipitation. The pH of this solution was raised up to 5 pH by using alkali solution which resulted in precipitation. The product thus obtained was washed with a mixture of alcohol and water and then dried in oven at 50°C to 60°C temperature.

2.3.Determination metal content in chelates

Metal contents of chelates were determined by complexometric titration against standardized EDTA solution at proper pH value using appropriate indicator.

3. RESULTS AND DISCUSSION

3.1. Schiff base characterization

The schiff base, TSCS is characterized by elemental analysis. The result of the elemental analysis with molecular formula are shown in table 1. The results obtained are in accordance with those calculated for proposed formula of schiff base. The melting point and TLC (ethyl acetate: n-hexane in 3:7 ratio) were also recorded. Sharp melting point, single and separate spot in TLC indicating the purity of the synthesized schiff base. The Schiff base is also structurally characterized by IR and mass spectrum. The mass spectrum of the Schiff base ligand is shown in the Figure 2. The base peak obtained at m/z 196.1 corresponds to the molecular ion of the ligand. The IUPAC name of the schiff base is: (2E)-2-(2-hydroxybenzylidene) hydrazinecarbothioamide and it is abbreviated as TSCS.

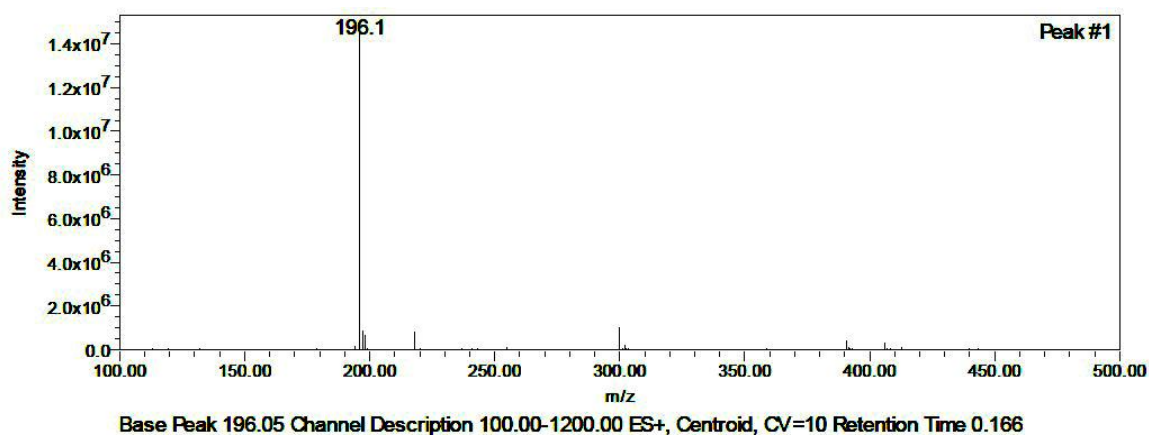


Figure 2: Mass spectra of Schiff base (TSCS)

3.2.Composition and structures of metal chelates

Metal chelates of Co(II), Ni(II) and Cu(II) ions with Schiff base ligand, TSCS are synthesized and subjected for structure elucidation by using elemental analysis (C, H, N, S and metal content), UV-vis, IR, molar conductance, magnetic moment and thermal analysis (TGA). On the basis of elemental analysis, the synthesized chelates have been proposed to have formula $[ML_2] \cdot nH_2O$ (M=Co(II) and Ni(II); n=0 and 1) and $[ML(H_2O)]$ (M= Cu(II)). The result of the elemental analysis is listed in table 1. All the synthesized chelates were insoluble in common organic solvents such as methanol, ethanol, acetone, chloroform or in water but soluble in DMSO.

3.3. Molar conductivity measurements

The molar conductance of metal chelates of 10^{-3} M solutions in DMSO were recorded which is listed in Table 1. The molar conductance of metal chelates was found in the range of 0.187 to $1.887 \Omega^{-1} \text{cm}^2 \text{mol}^{-1}$ indicating non-electrolytic nature of the chelates.

3.4. Infrared spectra

Important IR bands of ligand and its metal chelates are shown in table 2. The IR spectrum of free ligand shows peak at 3176.76 cm^{-1} due to -OH (phenolic) stretching which is absent in all the three chelates. Furthermore, $\nu(\text{C-O})$ stretching vibration observed at 1236.37 cm^{-1} in the free schiff base ligand. It is shifted to lower energy in the range 1203.58 cm^{-1} to 1211.30 cm^{-1} indicating coordination occur between metal and O atom [14]. This is further confirmed by the band observed in the chelates in the range of 482 cm^{-1} to 455 cm^{-1} , assigned to the $\nu(\text{M-O})$ frequency [15,16]. The band at 1616.35 cm^{-1} in schiff base ligand is due to $\nu(\text{C=N})$ stretching. In metal chelates this bands observed in 10 cm^{-1} to 15 cm^{-1} lower frequency suggesting the coordination of azomethine nitrogen to the central metal atom. The band observed in the range of 572 cm^{-1} to 566 cm^{-1} in metal chelates assigned to $\nu(\text{M-N})$ frequency [17-19], which also support the coordination between nitrogen to metal atom. IR spectrum of the ligand exhibits band at 1367.53 cm^{-1} and 831.32 cm^{-1} assigned for $\nu(\text{C=S})$ and $\delta(\text{C=S})$ [20,21], which is shifted to lower wavenumber in metal chelates by 25 cm^{-1} to 50 cm^{-1} , indicating coordination of sulfur to metal atom. Which is further confirmed by band observed at 354 cm^{-1} to 326 cm^{-1} assigned for $\nu(\text{M-S})$ frequency [22,23]. The single band observed in the range of 3000 cm^{-1} to 3200 cm^{-1} which correspond to assignment of $\nu(-\text{NH}-)$ stretch. Two bands observed in the range of 3150 cm^{-1} to 3500 cm^{-1} are assigned for $\nu(-\text{NH}_2)$ stretch. In Co-TSCS and Cu-TSCS, a broad single peak observed at 3570 cm^{-1} and 3458.37 cm^{-1} which corresponds to $\nu(\text{H}_2\text{O})$ stretch.

Table 1. Analytical and physical data of Schiff base ligand and its metal chelates

Compound	Colour (Formula weight, gm/mole)	m.p. (°C)	% Found (calculated)					Λ_m $\Omega^{-1} \text{cm}^2$ mol^{-1}
			C	H	N	S	M	
TSCS ($\text{C}_8\text{H}_9\text{N}_3\text{OS}$)	Colourless (195.24)	205	49.47 (49.21)	3.55 (4.65)	21.47 (21.52)	15.86 (16.42)	-- --	--
Co-TSCS ($\text{C}_{16}\text{H}_{18}\text{CoN}_6\text{O}_3\text{S}_2$)	Black (465.42)	>300	41.58 (41.29)	3.76 (3.90)	17.67 (18.06)	12.26 (13.78)	11.78 (12.66)	1.887
Ni-TSCS ($\text{C}_{16}\text{H}_{16}\text{N}_6\text{NiO}_2\text{S}_2$)	Green (447.16)	>300	41.41 (42.98)	3.67 (3.61)	17.58 (18.79)	14.19 (14.34)	11.74 (13.13)	0.187
Cu-TSCS ($\text{C}_8\text{H}_9\text{CuN}_3\text{O}_2\text{S}$)	Dark Brown (274.79)	>300	36.50 (34.97)	2.98 (3.30)	15.23 (15.29)	13.04 (11.67)	23.83 (23.13)	1.027

Λ_m = Molar conductance

Table 2. Infrared spectral Data for TSCS and its transition metal chelates

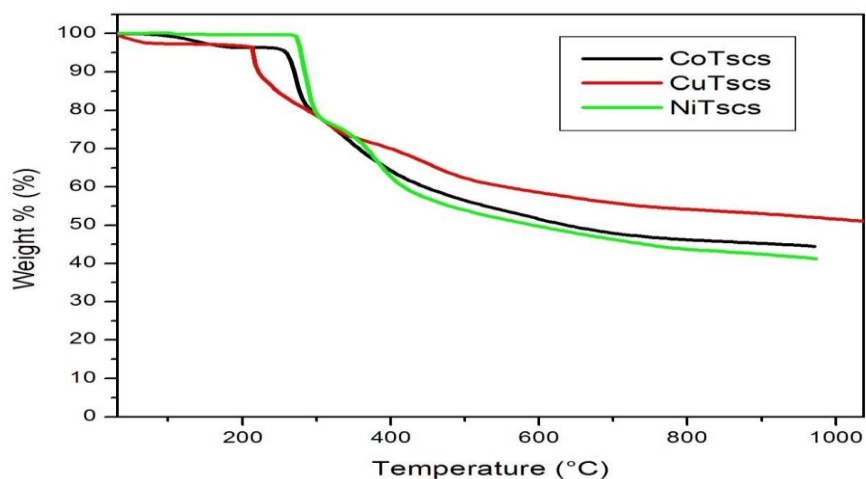
Compound	$\nu(\text{H}_2\text{O})$	$\nu(\text{OH})$ (phenolic)	$\nu(-\text{NH}_2)$	$\nu(-\text{NH}-)$	$\nu(\text{C}=\text{N})$	$\nu(\text{C}=\text{S})$	$\nu(\text{C}-\text{O})$	$\nu(\text{M}-\text{N})$	$\nu(\text{M}-\text{O})$	$\nu(\text{M}-\text{S})$
TSCS	--	3176.76	3444.87, 3321.42	3034.03	1616.35	1367.53, 831.32	1236.37	--	--	--
Co-TSCS	3570	--	3490, 3427.51	3111.18	1606.7	1344.38, 812.03	1205.51	571.54	481.40	353.29
Ni-TSCS	--	--	3408.22, 3298.28	3200	1604.77	1321.24, 808.17	1203.58	566.08	455.83	337.37
Cu-TSCS	3458.37	--	3153.61, 3284.77	--	1597.06 (coordinated), 1680 (uncoordinated)	1317.38, 810.10	1211.30	581.35	476.17	326.29

3.5. Thermal analysis

Thermogravimetric analysis of the metal chelates have been carried out in the range of room temperature to 1000°C in the air by controlling heating rates at 10°C/min using a Perkin-Elmer Diamond Thermogravimetric/Differential Thermal Analyzer. At initial phase of the experiment, weight loss is because of water molecule. In metal chelates, there are two types of water molecules associated, one of them lattice water and second of them coordinated water molecule. Nikolaev et al considered water eliminated below 150°C as lattice water and above 150°C as coordinated water to the metal ions [24]. Thermogravimetric data of metal chelates are presented in table 3. The thermal analysis data for Co, Ni and Cu chelates show weight loss of 2.537 % (11.8077 gm/mole), 0.258 % (1.1536 gm/mole) and 2.616 % (7.18 gm/mole) in the range of R.T. to 150°C suggesting that Co chelate is considered as having one lattice water molecule whereas Ni and Cu chelates have no lattice water molecules. TGA data of the three chelates Co, Ni and Cu show weight loss of 1.452 % (6.7578 gm/mole), 0.071 % (0.3174 gm/mole) and 12.956 % (35.60 gm/mole) in the range of 150°C to 250°C, which corresponds to Co and Ni chelates with no coordinated water molecule. In spite of weight loss of 35.60 gm/mole in the case of copper chelate, only one water molecule is considered to coordinate with Cu^{2+} . This is thought because of copper chelate having resemblance with elemental analysis and there is not thumb rules that at 150°C to 250°C, only water of coordination will be lost and it might be NH_3 in place of H_2O .

Table 3. Thermogravimetric analysis of metal chelates

Chelate	RT to 150°C			150°C to 250°		
	% weight loss	Gm/mole	No. of water molecule per chelate molecule (water of crystallization)	% weight loss	Gm/mole	No. of water molecule per chelate molecule (water of coordination)
Co-TSCS	2.537	11.8077	1	1.452	6.7578	0
Ni-TSCS	0.258	1.1536	0	0.071	0.3174	0
Cu-TSCS	2.616	7.18	0	12.956	35.60	1

**Figure 3: TGA of Chelates**

3.6. UV-visible reflectance spectra and magnetic susceptibility

The geometry of the chelates are also determined by electronic spectra and magnetic moment data as shown in the table 4. Magnetic moment value of Co(II) chelate is 1.79 B.M. and the two transition bands observed at 17094.02 cm^{-1} and 20876.83 cm^{-1} may be assigned as ${}^4T_{1(g)}(F) \rightarrow {}^4A_{2(g)}$ and ${}^4T_{1(g)}(F) \rightarrow {}^4T_{1(g)}(P)$ transitions respectively, assuming Co(II) chelate having octahedral geometry [25]. Ni(II) chelate has magnetic moment 3.14 B.M. and three transition bands are observed at 13947.00 cm^{-1} , 18691.59 cm^{-1} and 21231.42 cm^{-1} may be assigned as ${}^3A_{2(g)} \rightarrow {}^3T_{2(g)}$, ${}^3A_{2(g)} \rightarrow {}^3T_{1(g)}(F)$ and ${}^3A_{2(g)} \rightarrow {}^3T_{1(g)}(P)$ transitions respectively, assuming Ni(II) chelate to have octahedral geometry [26]. In case of Cu(II) chelate, the magnetic moment is 1.64 B.M. and transition bands are observed at 13774.10 cm^{-1} and 17152.66 cm^{-1} which may be assigned to ${}^2B_{1g} \rightarrow {}^2A_{1g}$ and ${}^2B_{1g} \rightarrow {}^2E_g$ transitions of square planar geometry of Cu(II) chelate and band observed at 23310.02 cm^{-1} is

probably due to ligand to metal charge transfer [27].

Table 4. UV visible reflectance Spectra and Magnetic moment Data of the Chelates

Chelate	Absorption λ_{\max} (cm ⁻¹)	Assignment	Magnetic moment μ (B.M.) (Geometry)
Co-TSCS	17094.02 cm ⁻¹ 20876.83 cm ⁻¹	$^4T_{1(g)}(F) \rightarrow ^4A_{2(g)}$ $^4T_{1(g)}(F) \rightarrow ^4T_{1(g)}(P)$	1.79 (Octahedral)
Ni-TSCS	13947.00 cm ⁻¹ 18691.59 cm ⁻¹ 21231.42 cm ⁻¹	$^3A_{2(g)} \rightarrow ^3T_{2(g)}$ $^3A_{2(g)} \rightarrow ^3T_{1(g)}(F)$ $^3A_{2(g)} \rightarrow ^3T_{1(g)}(P)$	3.14 (Octahedral)
Cu-TSCS	13774.10 cm ⁻¹ 17152.66 cm ⁻¹ 23310.02 cm ⁻¹	$^2B_{1g} \rightarrow ^2A_{1g}$ $^2B_{1g} \rightarrow ^2E_g$ Charge transfer	1.64 (Square planar)

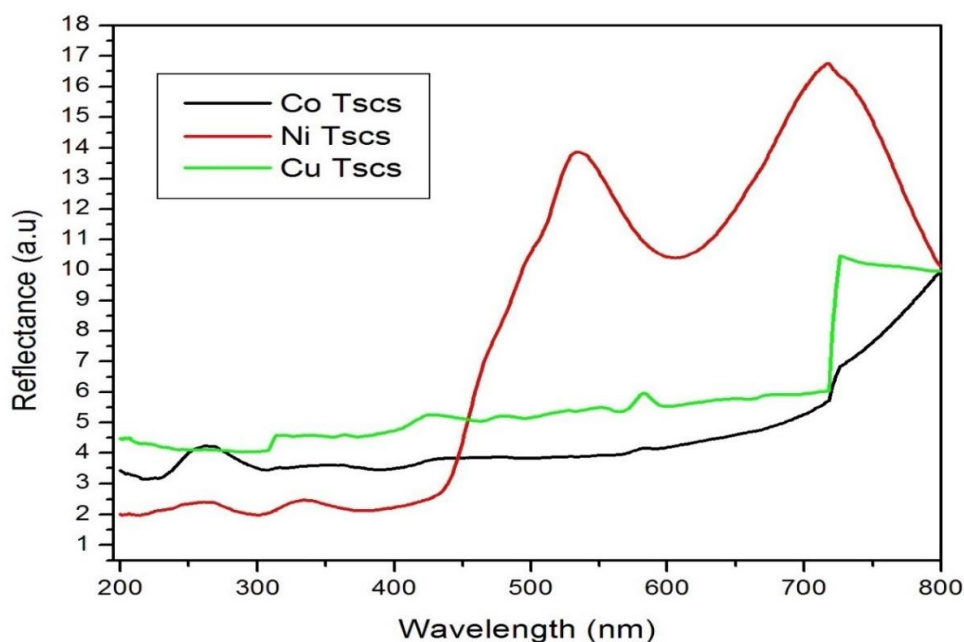
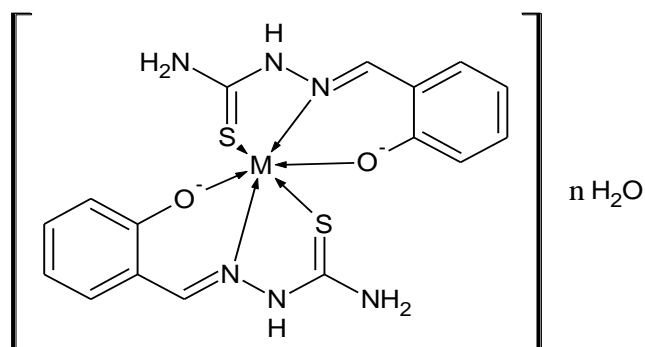


Figure 4: UV visible reflectance spectra of chelates



Where, M = Co²⁺ (n=1) and Ni²⁺ (n=0)

Figure 5: Octahedral Geometry for Co(II) and Ni(II) Chelates

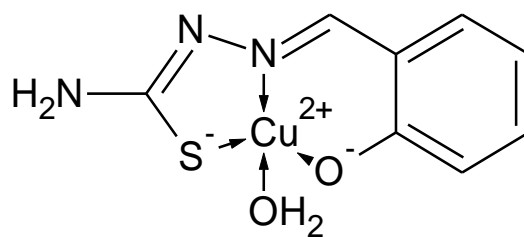
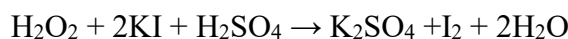
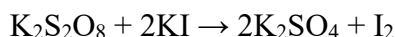


Figure 6: Square Planar Geometry for Cu(II) Chelate

3.7. Kinetic study

In order to study the catalytic effect of chelates, three, second order redox reactions, potassium persulphate with potassium iodide, potassium bromate with potassium iodide and hydrogen peroxide with potassium iodide were selected [28].



These three second order reactions were carried out with and without addition of Co, Ni and Cu chelates. Out of three chelates, cobalt and copper chelates were able to increase the rate of reaction between potassium persulphate and potassium iodide significantly and nickel chelate increased reaction rate to smaller extent. Copper chelate is also able to increase rate of reaction, the rate of which is between that of potassium bromate and potassium iodide in acidic medium. In other cases, rate of reaction decreases on the addition of chelates.

Table 5. Reaction rates with and without chelates

Reactions	$\text{K}_2\text{S}_2\text{O}_8 + \text{KI}$	$\text{KBrO}_3 + \text{KI} + \text{HCl}$	$\text{H}_2\text{O}_2 + \text{KI} + \text{H}_2\text{SO}_4$
k without chelates	3.30786×10^{-5}	7.39218×10^{-4}	2.34078×10^{-4}
k with Co-TSCS	7.57254×10^{-5}	6.24433×10^{-4}	1.73588×10^{-4}
k with Ni-TSCS	3.41044×10^{-5}	6.48246×10^{-4}	2.16243×10^{-4}
k with Cu-TSCS	5.45753×10^{-5}	8.81473×10^{-4}	1.9039×10^{-4}
% Increase in reaction rate at 306 K Co-TSCS	128.93 %	-15.53 %	-25.84 %
% Increase in reaction rate at 306 K Ni-TSCS	3.10 %	-12.31 %	-7.62 %
% Increase in reaction rate at 306 K Cu-TSCS	64.99 %	19.24 %	-18.66 %

Where, k denotes rate constant

3.8. Catalytic study

Diphenylhydantoin is used as antiepileptic drug and it is pharmaceutically important compound, hence its synthesis is selected for catalytic study. An ethanolic solution of benzil (5.3 gm), urea (3.0

gm) and 30 % sodium hydroxide solution (15ml) was refluxed for 2 hours and allowed to cool to room temperature. The reaction mixture was filtered off to remove insoluble by-product and filtrate was acidified with concentrated hydrochloric acid, cooled in ice water bath and immediately the precipitated product was filtered. The product was recrystallized [29, 30]. This was the standard organic reaction selected to study the catalytic effect of chelates.

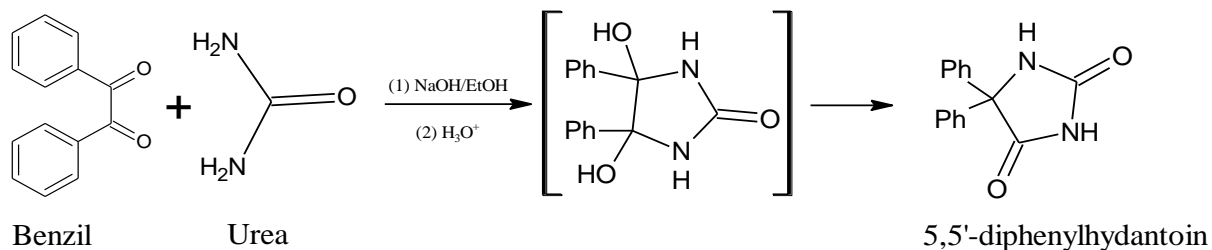


Figure 7: Synthesis scheme for 5,5'-diphenylhydantoin

The yield was about 1.391 gm (44.16 %). The same reaction was also carried out for 1 hour and the yield was 1.268 gm (40.25 %) obtained without catalyst. The same reaction was carried out in the presence of 1 % catalytic amount of chelates. The % yield and % increase in the yield for catalyzed reaction are shown in table 6. In comparison to uncatalyzed reaction, about 14 % increase was observed in case of cobalt and copper chelates catalyzed reaction and 7.97 % increase in yield was observed in case of Ni chelate-catalyzed reaction.

Table 6. % yield of organic reaction at 306 k and 1hour reaction time.

% yield without chelate (1 hour)	% yield with Co-TSCS (1 hour)	% yield with Ni-TSCS (1 hour)	% yield with Cu-TSCS (1 hour)	% Increase of yield in presence of Co-TSCS	% Increase of yield in presence of Ni-TSCS	%Increase of yield in presence of Cu-TSCS
40.25	48.03	44.54	47.59	14.47	7.97	13.64

3.9. Activation energy by Broido method

The Broido method was used to evaluate activation energy (E_a) as well as other kinetic parameters from the TGA curves [31]. The equation used to evaluate activation energy of degradation reaction is given below:

$$\ln \ln \left(\frac{1}{y} \right) = - \left(\frac{E_a}{R} \right) \left(\frac{1}{T} \right) + \text{constant}$$

Where, $y = (W_t - W_\infty) / (W_0 - W_\infty)$,

Where, y = Fraction of the number of initial molecules not yet decomposed.

W_0 = initial weight of sample.

W_t = residual weight of sample at any time t

W_∞ = weight of sample at infinite time

R = gas constant

From the slope of the plot $\ln(\ln 1/y)$ versus $1000/T$, activation energy (E_a) can be calculated as,

$$E_a = -2.303 \times R \times \text{slope}.$$

The calculated activation energy of thermal degradation of chelates and temperature range are shown in table 7.

Table 7. Activation energy of chelates

Chelates	Temperature range (°C)	Activation energy (E_a) in kJmol^{-1}
Co-TSCS	60°C to 160°C	101.69
Ni-TSCS	127°C to 197°C	26.03
Cu-TSCS	37°C to 77°C	93.54

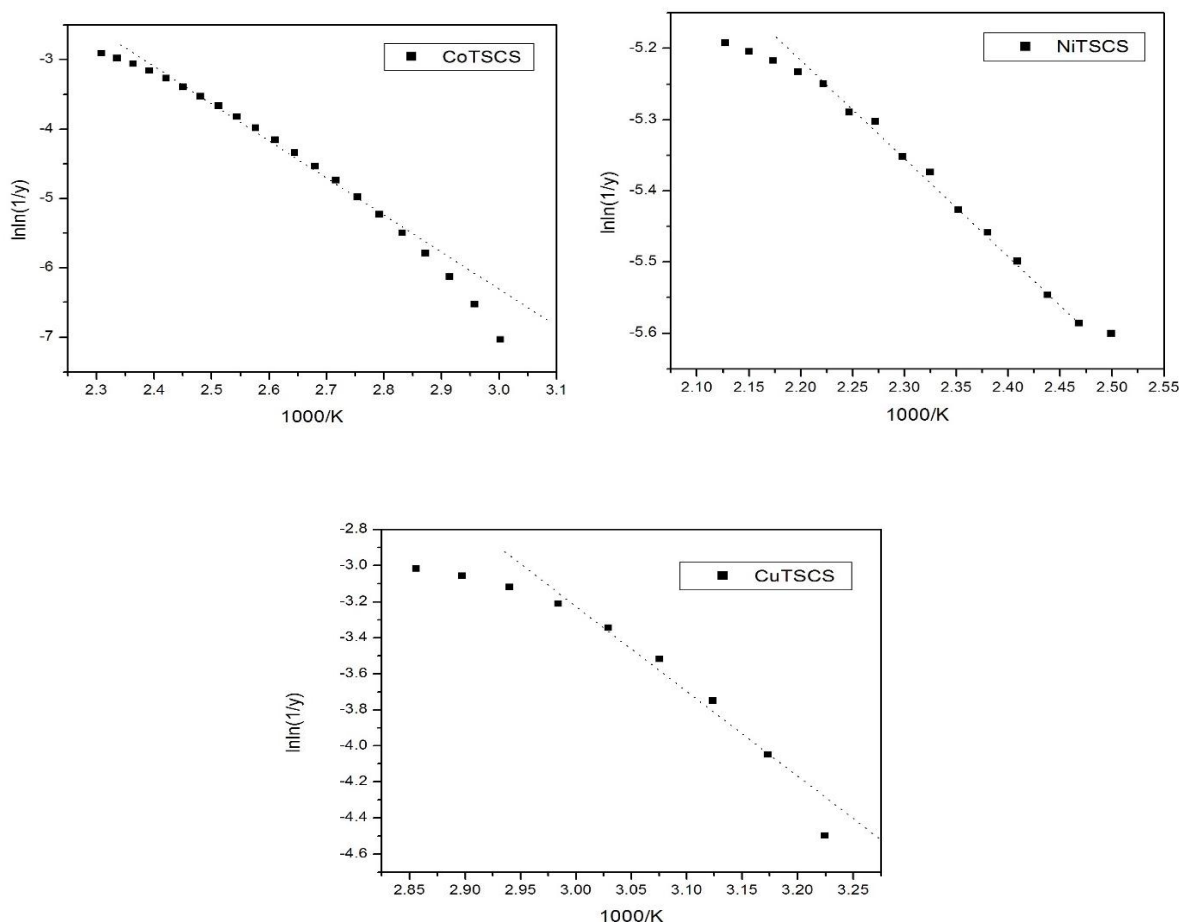


Figure 8: Plot of $\ln[\ln(1/y)]$ vs $1000/T$ for chelates

The activation energy of thermal degradation of cobalt, nickel and copper chelates were found to be $101.69 \text{ kJmol}^{-1}$, 26.03 kJmol^{-1} and 93.54 kJmol^{-1} . The higher value of activation energy reflects the thermal stability of the chelates [32].

3.10. Antibacterial activity

The schiff base ligand and their transition metal chelates were evaluated for their antibacterial activity against bacterial species such as gram-positive bacteria (*B. subtilis*, *B. cereus*) and gram-negative bacteria (*E. coli*, *P. aeruginosa*) to compare their antibacterial activity using Ciprofloxacin

as standard by agar well diffusion method. Antibacterial activity was observed to increase with concentration of samples. It was observed that schiff base ligand was biologically active. It was also observed that on chelation antibacterial activity of ligand increased as compared to free ligand. Cu(II) chelate was found to have enhanced antibacterial activity than free schiff base ligand against all the bacterial stains. Co(II) chelate showed higher antibacterial activity against *B. subtilis*, *E. coli* and *P. aeruginosa*. Ni(II) chelate showed lower antibacterial activity than schiff base ligand and also compared to Co(II) and Cu(II) chelates.

Table 8. Antibacterial activity of Tscs schiff base ligand and its chelates

Sr. no	Bacterial species	µg/ml	TSCS	Co-TSCS	Ni-TSCS	Cu-TSCS	Ciprofloxacin
1	<i>B. subtilis</i> (G ⁺)	100 µg/ml	-	-	-	+	+++
		200 µg/ml	+	+	-	+	+++
		300 µg/ml	+	++	+	+++	+++
		400 µg/ml	++	+++	++	+++	+++
2	<i>B. cereus</i> (G ⁺)	100 µg/ml	-	-	-	+	+++
		200 µg/ml	+	-	-	+	+++
		300 µg/ml	++	+	-	++	+++
		400 µg/ml	++	+	+	+++	+++
3	<i>E. coli</i> (G ⁻)	100 µg/ml	-	-	-	+	+++
		200 µg/ml	+	+	-	+	+++
		300 µg/ml	+	++	+	++	+++
		400 µg/ml	++	++	+	++	+++
4	<i>P. aeruginosa</i> (G ⁻)	100 µg/ml	-	+	+	+	+++
		200 µg/ml	+	+	+	++	+++
		300 µg/ml	+	++	+	++	+++
		400 µg/ml	++	++	++	+++	+++

Highly active = +++ (inhibition zone >14 mm); Moderately active = ++ (inhibition zone 11-14 mm); Slightly active = + (inhibition zone 6-10 mm); Inactive = - (inhibition zone <6 mm).

4. CONCLUSION

Transition metal chelates of Co(II), Ni(II) and Cu(II) with schiff base derived from thiosemicarbazide and salicylaldehyde have been synthesized using corresponding metal perchlorate and characterized. The structure of the schiff base and metal chelates have been determined with the help of elemental analysis, IR, UV-visible spectra, Mass spectra, molar conductance, magnetic susceptibility and TGA. Catalytic effect of chelates on three well known redox reactions have been also studied. Cobalt and copper chelates significantly increased rate of

redox reaction between potassium persulphate and potassium iodide. The three chelates were effective as catalyst in the synthesis of diphenylhydantoin and were successful to increase the percentage yield by 7 % to 14 %. Activation energy for thermal degradation was also evaluated using Broido method, this indicates good thermal stability. Schiff base and all the chelates were screened for antibacterial activity against *Escherichia coli*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Bacillus cereus* using Ciprofloxacin as the standard. It was observed that cobalt and copper chelates showed enhanced antibacterial activity than schiff base ligand.

CONFLICT OF INTEREST

Authors have no any conflict of interest.

REFERENCES

1. Thangadurai TD, Natarajan K. Tridentate Schiff base complexes of ruthenium (III) containing ONS/ONO donor atoms and their biocidal activities. *Transition Metal Chemistry*. 2001 Dec 1;26(6):717-22.
2. Ali MA, Tarafdar MT. Metal complexes of sulphur and nitrogen-containing ligands: complexes of s-benzylthiocarbamate and a Schiff base formed by its condensation with pyridine-2-carboxaldehyde. *Journal of Inorganic and Nuclear Chemistry*. 1977 Jan 1;39(10):1785-91.
3. Maurya MR, Kumar A, Abid M, Azam A. Dioxovanadium (V) and μ -oxo bis [oxovanadium (V)] complexes containing thiosemicarbazone based ONS donor set and their antiamoebic activity. *Inorganica Chimica Acta*. 2006 May 15;359(8):2439-47.
4. Abu-Dief AM, Mohamed IM. A review on versatile applications of transition metal complexes incorporating Schiff bases. *Beni-suef university journal of basic and applied sciences*. 2015 Jun 1;4(2):119-33.
5. Mazlan NA, Ravoof TB, Tiekink ER, Tahir MI, Veerakumarasivam A, Crouse KA. Mixed-ligand metal complexes containing an ONS Schiff base and imidazole/benzimidazole ligands: synthesis, characterization, crystallography and biological activity. *Transition Metal Chemistry*. 2014 Sep 1;39(6):633-9.
6. Tamizh MM, Mereiter K, Kirchner K, Karvembu R. Ruthenium (II) carbonyl complexes containing 'pincer like' ONS donor Schiff base and triphenylphosphine as catalyst for selective oxidation of alcohols at room temperature. *Journal of Organometallic Chemistry*. 2012 Mar 1;700:194-201.
7. Aoyama Y, Fujisawa T, Toi H, Ogoshi H. Catalytic reactions of metalloporphyrins. 1. Catalytic modification of borane reduction of ketone with rhodium (III) porphyrin as catalyst. *Journal of the American Chemical Society*. 1986 Mar;108(5):943-7.
8. Gupta IK, Sutar AK. Catalytic activities of Schiff base transition metal complexes. *Coordination Chemistry Reviews*. 2008 Jul 1;252(12-14):1420-50.
9. Williams DR. Metals, ligands, and cancer. *Chemical reviews*. 1972 Jun;72(3):203-13.

10. Campbell MJ. Transition metal complexes of thiosemicarbazide and thiosemicarbazones. *Coordination Chemistry Reviews*. 1975 Mar 1;15(2-3):279-319.
11. Furst A, Haro RT. A Survey of Metal Carcinogenesis1, 2. In *Progress in experimental tumor research* 1969 (Vol. 12, pp. 102-133). Karger Publishers.
12. Vogel AI. *Quantitative inorganic analysis, theory and practice*. London: Longmann, Green and Co. 1961:783, p-412.
13. Joseph J, Mary NL, Sidambaram R. Synthesis, characterization, and antibacterial activity of the Schiff bases derived from thiosemicarbazide, Salicylaldehyde, 5-bromosalicylaldehyde and their copper (II) and nickel (II) complexes. *Synthesis and Reactivity in Inorganic, Metal-Organic, and Nano-Metal Chemistry*. 2010 Nov 30;40(10):930-3.
14. Çukurovali A, Yilmaz I, Özmen H, Ahmedzade M. Cobalt (II), copper (II), nickel (II) and zinc (II) complexes of two novel Schiff base ligands and their antimicrobial activity. *Transition metal chemistry*. 2002 Mar 1;27(2):171-6.
15. El-Wahab ZA, El-Sarrag MR. Derivatives of phosphate Schiff base transition metal complexes: synthesis, studies and biological activity. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*. 2004 Jan 1;60(1-2):271-7.
16. Temel H, İlhan S, Şekerci M, Ziyadanoğullari R. The synthesis and spectral characterization of new Cu (II), Ni (II), Co (III), and Zn (II) complexes with Schiff base. *Spectroscopy letters*. 2002 Jun 5;35(2):219-28.
17. Etaiw SE, El-Aziz DM, El-Zaher EH, Ali EA. Synthesis, spectral, antimicrobial and antitumor assessment of Schiff base derived from 2-aminobenzothiazole and its transition metal complexes. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*. 2011 Sep 1;79(5):1331-7.
18. Aziz AA, Salem AN, Sayed MA, Aboaly MM. Synthesis, structural characterization, thermal studies, catalytic efficiency and antimicrobial activity of some M (II) complexes with ONO tridentate Schiff base N-salicylidene-o-aminophenol (saphH₂). *Journal of Molecular Structure*. 2012 Feb 29;1010:130-8.
19. Mounika K, Pragathi A, Gyanakumari C. Synthesis characterization and biological activity of a Schiff base derived from 3-ethoxy salicylaldehyde and 2-amino benzoic acid and its transition metal complexes. *Journal of Scientific Research*. 2010 Aug 24;2(3):513.
20. Bindu P, Kurup MR. ESR and electrochemical studies of four- and five-coordinate copper (II) complexes containing mixed ligands. *Transition metal chemistry*. 1997 Dec 1;22(6):578-82.
21. Tada R, Chavda N, Shah MK. Synthesis and characterization of some new thiosemicarbazide derivatives and their transition metal complexes. *Journal of Chemical and Pharmaceutical Research*. 2011;3(2):290-7.

22. Melha KS. In-vitro antibacterial, antifungal activity of some transition metal complexes of thiosemicarbazone Schiff base (HL) derived from N4-(7'-chloroquinolin-4'-ylamino) thiosemicarbazide. *Journal of enzyme inhibition and medicinal chemistry*. 2008 Jan 1;23(4):493-503.
23. Raman N, Selvan A, Manisankar P. Spectral, magnetic, biocidal screening, DNA binding and photocleavage studies of mononuclear Cu (II) and Zn (II) metal complexes of tricoordinate heterocyclic Schiff base ligands of pyrazolone and semicarbazide/thiosemicarbazide based derivatives. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*. 2010 Jul 1;76(2):161-73.
24. Nikolaev, A.V.; Logvinenko, V.A.; Myachina, L.T. *Thermal Analysis*; Academic Press: New York, 1969; 779.
25. Natarajan C, Sheela CD, Athappan PR. Synthesis and study of cobalt (II), nickel (II), copper (II) and zinc (II) complexes of 2-formyl- and 2-acetyl-cyclohexanones. *Indian J of Chemistry*. 1990;29(June):569–72.
26. Lever ABP. *Inorganic electronic spectroscopy*. 1st ed. Amsterdam : Elsevier; 1968. 334 p.
27. El-Baradie KY. Preparation and characterization of sulfadiazine Schiff base complexes of Co (II), Ni (II), Cu (II), and Mn (II). *Monatshefte für Chemie/Chemical Monthly*. 2005 Jul 1;136(7):1139-55.
28. Yadav JB. *Advanced Practical Physical Chemistry*. Krishna Prakashan Media; 2006, p-63,85.
29. Furniss BS. *Vogel's textbook of practical organic chemistry*. Pearson Education India; 1989, p-1153.
30. Pankaskie MC, Small L. The synthesis of 5, 5'-diphenylhydantoin: A novel benzil-benzilic acid rearrangement. *Journal of Chemical Education*. 1986 Jul;63(7):650.
31. Broido A. A simple, sensitive graphical method of treating thermogravimetric analysis data. *Journal of Polymer Science Part A-2: Polymer Physics*. 1969 Oct;7(10):1761-73.
32. K. R. Patel, Dhara Patel and V D Patel. Characterization, Activation Energy and Thermodynamic Parameter of Crystals Synthesized from Solvent Evaporation Method. *Int J Res Biosci Agric Technol*. 2018;2(2):746–53.