

Synthesis, Spectral Characterization and Biological Evaluation of Cu(II) Complexes with Schiff Bases Derived from 2-Aminobenzoic Acid

S. AHALYA*, G. VALARMATHY and R. SUBBALAKSHMI

PG and Research Department of chemistry, Seethalakshmi Ramaswami College, Tiruchirappalli-620 002, India

*Corresponding author: E-mail: ahalchem2808@gmail.com

Received: 22 November 2017;

Accepted: 31 January 2018;

Published online: 28 February 2018;

AJC-18810

Schiff bases *i.e.*, 2-[(2-hydroxy-3-methoxybenzylidene)amino]benzoic acid (L^1) and 2-[(2-hydroxybenzylidene)amino]benzoic acid (L^2) have been synthesized by the reaction of *o*-vanillin and salicylaldehyde with 2-aminobenzoic acid, respectively. These chelating agents are having oxygen and nitrogen as the chelating positions. Complexes of Cu(II) with these ligands L^1 and L^2 have been synthesized and characterized by colorimetry, thin-layer chromatography, molar conductance, magnetic susceptibility, IR, UV-visible, ^1H NMR and CV. The metal chelates and their complexes with Cu(II) have been tested for the antimicrobial activity by disc diffusion method.

Keywords: Schiff bases, 2-Aminobenzoic acid, Metal complexes, IR, Antimicrobial activity.

INTRODUCTION

Schiff bases are the versatile ligands which are synthesized by the condensation of an amino compound with carbonyl compounds. These compounds and their metal complexes are very important as catalysts in various biological systems, polymers, dyes, medicinal and pharmaceutical fields [1,2]. Schiff bases have been widely explored for industrial applications. These have been used as corrosion inhibitor [3], in electrochemical sensors [4], in non-linear optical devices [5] and as an electroluminescent material [6], *etc.*, Especially, Schiff bases with nitrogen and oxygen donor atoms play important role in biological systems and represent interesting models for metalloenzymes, which efficiently catalyze the reduction of dinitrogen and dioxygen [7].

In this study, we have synthesized ligands 2-[(2-hydroxy-3-methoxybenzylidene)amino]benzoic acid (L^1) from *o*-vanillin and 2-aminobenzoic acid and 2-[(2-hydroxybenzylidene)amino]benzoic acid (L^2) from salicylaldehyde and 2-amino benzoic acid. Copper(II) complexes of these ligands were synthesized and characterized by colorimetry, thin-layer chromatography, IR, ^1H NMR, UV, molar conductance and magnetic susceptibility measurements. The *in vitro* antimicrobial activity of the free Schiff bases and its Cu(II) complexes were also investigated.

EXPERIMENTAL

The reagents such as *o*-vanillin, salicylaldehyde, 2-amino-benzoic acid, copper(II)chloride dihydrate and the solvents

like DMSO, DMF were purchased from commercial sources and were used as such. The commercially available ethanol was dried over anhydrous quicklime for 24 h, filtered and distilled before use. The molar conductivity of complexes isolated was measured in 10^{-3} M solutions of Cu(II) complexes in dimethyl formamide (DMF) using a elico conductivity bridge and a dip type conductivity cell.

Melting points of ligands and Cu(II) complexes were determined by using the finely powdered sample in a fused glass capillary using Elico melting point apparatus. The IR spectra of the free Schiff bases and its Cu(II) complexes were recorded using KBr pellets on Perkin Elmer RXI spectrometer in the region $4000\text{--}400\text{ cm}^{-1}$. The electronic spectra of ligands and complexes in UV-visible region of 190 to 1110 nm were taken using Perkin Elmer Lambda 35 spectrometer provided with quartz cells. The magnetic susceptibility of complex at room temperature was measured by Gouy method using PICO K11 GAUSS Gouy balance. Proton NMR spectra was taken for ligands and complexes using the instrument, Bruker 400 MHz FT-PMR spectrometer. Electrochemical cyclic voltammetry studies for ligands and complexes were carried out on Princeton applied Research-Multichannel Versa STAT-II. The room temperature EPR spectra of powdered samples were recorded at 9450 MHz. The antimicrobial studies of the Schiff bases and complexes were carried out by disc diffusion method in Periyar College of Pharmaceutical Sciences, Tiruchirappalli, India.

Synthesis of Schiff bases: The Schiff base ligand 2-[(2-hydroxy-3-methoxybenzylidene)amino]benzoic acid (L^1) was

synthesized by the condensation of *o*-vanillin (0.01 M, 1.52 g) with 2-amino benzoic acid (0.01 M, 1.367 g) in ethanol. The mixture was magnetically stirred for about 1 h. The resulting solution was evaporated to remove the solvent and cooled at room temperature. The product formed (yield = 75 %) was collected by filtration, washed several times with ether and recrystallized from hot ethanol. The melting point of the brick red coloured compound obtained was found to be 99 °C.

Similarly, ligand 2-[(2-hydroxybenzylidene)amino]benzoic acid (L^2) was synthesized by dissolving salicylaldehyde (0.01 M, 1.23 g) and 2-amino benzoic acid (0.01 M, 1.367 g) in ethanol. The above same procedure was followed for the synthesis of ligand L^2 . The orange coloured compound was obtained (yield = 70 %). Melting point of this compound was found to be 190 °C. Purity of both Schiff bases have been tested with thin-layer chromatography.

Synthesis of Schiff base copper(II) complexes: Copper complexes of ligands L^1 and L^2 were synthesized by mixing the warm ethanolic solution of the respective ligands (0.002 M) and the ethanolic solution of copper(II) chloride (0.3410 g). The resulting reaction mixture was refluxed for 6 h on a water bath. Copper(II) complex with ligand L^1 was obtained by leaving the mixture for evaporation of the solvent, the nut brown coloured solid (yield = 79 %) was then filtered and washed thoroughly with ether. The melting point of this complex was noted to be 122 °C. When ligand L^2 was refluxed with the ethanolic solution of copper(II) chloride, olive green coloured solid (yield = 71 %) was obtained with melting point 181 °C. These complexes were then dried in a desiccator over calcium chloride. Purity of both complexes have been tested with thin-layer chromatography.

RESULTS AND DISCUSSION

Both complexes are stable at room temperature and soluble in DMSO and DMF, whereas insoluble in ether. The summary of physical properties of the Schiff base ligands and their complexes are given in Table-1.

Molar conductance: The molar conductance of Cu(II) complexes were measured and the obtained values (Table-1) revealed the presence of a non-electrolytic and neutral nature. It is obvious from these data that complexes are non-ionic in nature.

Infrared analysis of Schiff base and its complexes: For ligand L^1 (Fig. 1), band at 1602 cm^{-1} overlap of $\nu(\text{C}=\text{O})$ and $\nu(>\text{C}=\text{N})$ stretching frequency; 1450 cm^{-1} $\nu(\text{C}-\text{O})$ phenolic stretching frequency; broad band at 3449 cm^{-1} hydrogen bonded $\nu(\text{O}-\text{H})$. In the IR spectrum of ligand L^2 (Fig. 2), the band at 1617 cm^{-1} overlap of $\nu(\text{C}=\text{O})$ and $\nu(>\text{C}=\text{N})$ stretching frequency; 1457 cm^{-1} $\nu(\text{C}-\text{O})$ phenolic stretching frequency; broad band at 3435 cm^{-1} hydrogen bonded $\nu(\text{O}-\text{H})$ [8].

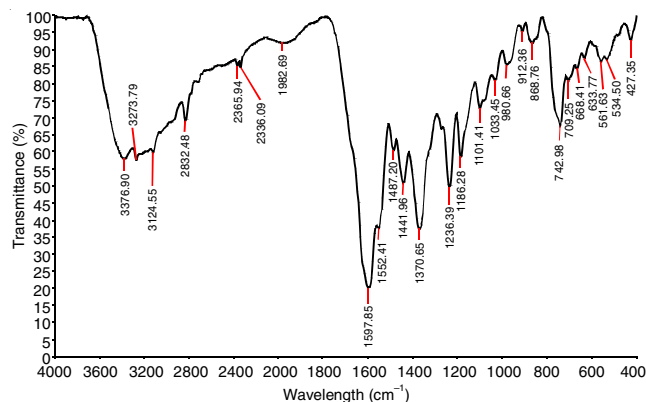


Fig. 1. IR spectrum of ligand L^1 2-[(2-hydroxy-3-methoxybenzylidene)-amino]benzoic acid

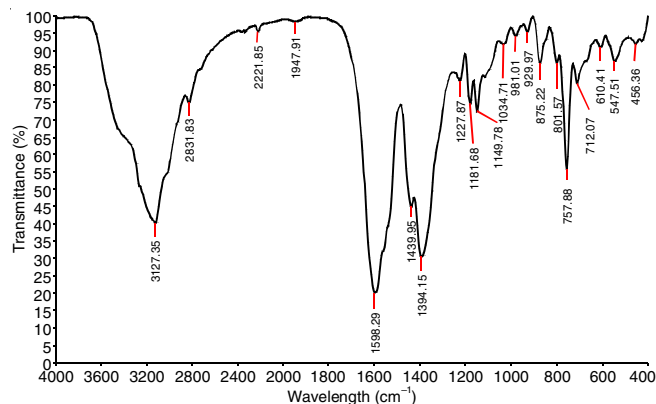


Fig. 2. IR spectrum of ligand L^2 2-[(2-hydroxybenzylidene)amino]benzoic acid

The IR spectrum of Cu(II) complex with ligand L^1 consist the following bands. The azomethine $\nu(>\text{C}=\text{N})$ band of ligand L^2 , shifted to lower frequency and obtained at 1597 cm^{-1} , suggests the coordination of N atom of azomethine group with the metal ion. The azomethine $\nu(>\text{C}=\text{O})$ band of ligand L^2 , shifted to lower frequency region and observed at 1487 cm^{-1} , it indicates the involvement of oxygen atom of carboxyl group of $-\text{COOH}$ in bonding with the metal ion after deprotonation. The phenolic $\nu(\text{C}-\text{O})$ stretching frequency shifted to lower frequency, seen at 1442 cm^{-1} and is indicative of bonding through phenolic oxygen. The non-ligand bands at 427 and 743 cm^{-1} have been assigned to $\nu(\text{Cu}-\text{N})$ and $\nu(\text{Cu}-\text{O})$ stretching frequencies, respectively. It supports the involvement of N and O atoms on complexation with Cu(II) metal ion. The coordination of water molecules is indicated by the presence of broad band in the region 3300-3000 cm^{-1} .

In the IR spectrum of complex of Cu(II) with ligand L^2 , the stretching frequency of $\nu(\text{C}=\text{O})$ and $\nu(>\text{C}=\text{N})$ of ligand L^1 shifts to lower frequency and observed at 1598 and 1440 cm^{-1} , respectively. It suggests the coordination of N atom of azomethine group and O atom of carbonyl group after deprotonation

TABLE-1
PHYSICAL CHARACTERISTICS AND ANALYTICAL DATA OF SCHIFF BASES AND COPPER(II) COMPLEXES

Compound	m.f.	Colour	m.p. (°C) (Decomposition temperature)	Molar conductance $\times 10^{-3}$ ($\text{Ohm}^{-1} \text{cm}^2 \text{mol}^{-1}$)
Ligand (L^1)	$\text{C}_{15}\text{H}_{13}\text{NO}_4$	Brick red	99	—
Ligand (L^2)	$\text{C}_{14}\text{H}_{11}\text{NO}_3$	Orange	190	—
$[\text{Cu}(\text{L}_1-2\text{H})(\text{H}_2\text{O})_3] \cdot \text{H}_2\text{O}$	$\text{C}_{15}\text{H}_{19}\text{NO}_8\text{Cu}$	Nut brown	122	6.0
$[\text{Cu}(\text{L}_2-2\text{H})(\text{H}_2\text{O})_3] \cdot \text{H}_2\text{O}$	$\text{C}_{14}\text{H}_{16}\text{NO}_7\text{Cu}$	Olive green	181	5.0

to the metal ion. The phenolic $\nu(\text{C-O})$ stretching frequency is seen at 1394 cm^{-1} . The new bands at 456 and 758 cm^{-1} which are not present in the L^1 spectrum corresponds to $\nu(\text{Cu-N})$ and $\nu(\text{Cu-O})$. A broad band is obtained at $3200\text{--}3000\text{ cm}^{-1}$ indicates the coordination of water molecules [9].

Electronic spectral and magnetic susceptibility: The electronic spectra of ligand (L^1) shows three bands at 276 nm (36323 cm^{-1}) corresponds to $\pi \rightarrow \pi^*$, while 315 nm (31746 cm^{-1}) and 356 nm (280901 cm^{-1}) corresponds to $n \rightarrow \pi^*$ transition. Likely, the electronic spectra of ligand (L^2) shows two bands at 275 nm (36364 cm^{-1}) may be assigned to $\pi \rightarrow \pi^*$ and another band at 331 nm (30211 cm^{-1}) attributed to $n \rightarrow \pi^*$ [10].

The electronic spectrum of hexa-coordinate complex of Cu(II) with ligand L^1 , gives three absorption bands at 267.40 nm (37453 cm^{-1}), 326.69 nm (30581 cm^{-1}) and 419.20 nm (23866 cm^{-1}). The bands observed may be assigned to intra ligand charge transfer, $\text{Cu} \rightarrow \text{L}$ charge transfer [11] and ${}^2E_g \rightarrow {}^2T_{2g}$ transitions [12], respectively. The magnetic susceptibility value lie at 1.48 BM , which is attributed to distorted octahedral geometry of complex.

The magnetic susceptibility measurement of complex of Cu(II) with L^2 lie at 1.35 BM indicating a distorted octahedral geometry. The electronic spectrum of this complex displays three bands at 261.18 nm (38314 cm^{-1}), 294.69 nm (33898 cm^{-1}) and 411.80 nm (24272 cm^{-1}). These bands are assigned intra ligand charge transfer, $\text{Cu} \rightarrow \text{L}$ charge transfer and ${}^2E_g \rightarrow {}^2T_{2g}$ transitions [13], respectively.

${}^1\text{H}$ NMR spectra: The ${}^1\text{H}$ NMR spectrum of ligand (L^1) (Fig. 3), shows a signal at $\delta 3.95\text{ ppm}$ and a strong signal is observed at $\delta 11.13\text{ ppm}$ corresponding to $-\text{OCH}_3$ and hydroxyl group of $-\text{COOH}$ group [14], respectively, the peak at $\delta 9.92\text{ ppm}$ is attributed to phenolic $-\text{OH}$ group present in ligand [15], the signal at $\delta 8.85\text{ ppm}$ is assigned to $(-\text{CH}=\text{N}-)$ proton and the signals for the protons of the phenyl group attached to ligand is observed are observed the range $\delta = 7.00\text{--}8.25$ corresponds to seven protons [16]. Likely, in the ${}^1\text{H}$ NMR spectrum of ligand (L^2) (Fig. 4), a strong signal is observed at $\delta 11.13$

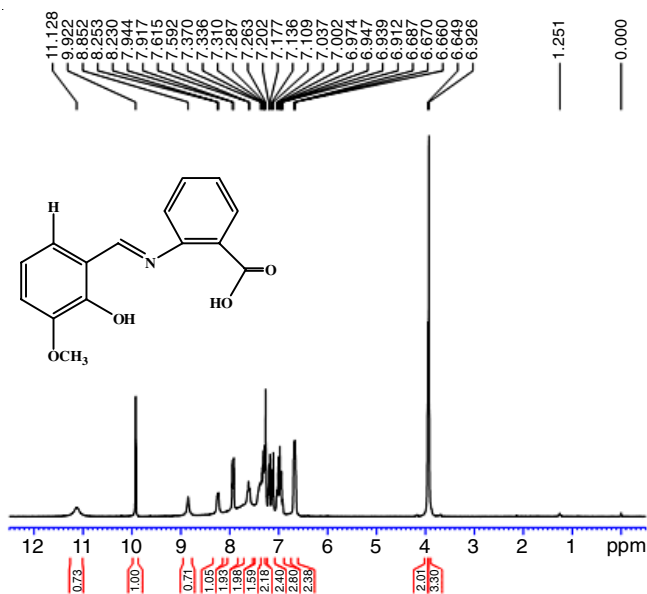


Fig. 3. ${}^1\text{H}$ NMR spectrum of ligand (L^1) 2-[(2-hydroxy-3-methoxybenzylidene)amino]benzoic acid

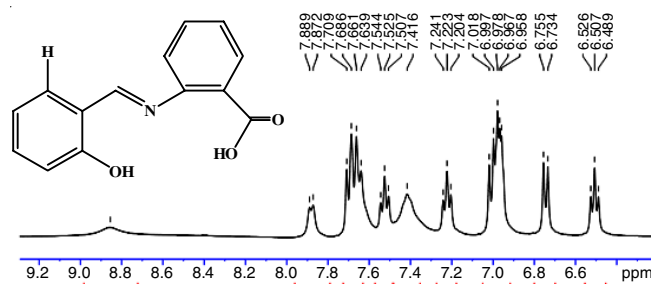


Fig. 4. ${}^1\text{H}$ NMR spectrum of ligand (L^2) 2-[(2-hydroxybenzylidene)amino]benzoic acid

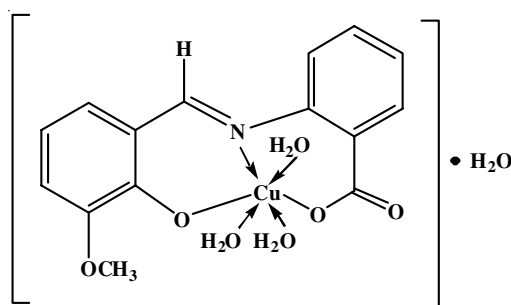
ppm corresponding to the hydroxyl proton of $-\text{COOH}$ proton [12], the peak at $\delta 10.27\text{ ppm}$ is attributed to phenolic $-\text{OH}$ proton [13], the signal at $\delta 8.86\text{ ppm}$ is assigned to $(-\text{CH}=\text{N}-)$ proton and the signals observed in the range $\delta = 7.02\text{--}7.81\text{ ppm}$ corresponds to eight protons of aromatic ring [16].

In ${}^1\text{H}$ NMR spectrum of complexes of Cu(II), absence of the peaks in the region $\delta 10.0\text{ ppm}$ and $\delta 11.0\text{ ppm}$, indicates the removal of protons from phenolic $-\text{OH}$ group and carboxylic $-\text{COOH}$ group and the involvement in bonding. The peak at $\delta 8.8\text{ ppm}$ in ligands is shifted to downfield, it outlines the participation of this group in complexation. From the data, it can be evident that bonding of Cu(II) with ligands L^1 and L^2 is through the phenolic oxygen, carboxylate oxygen and azomethine group [14].

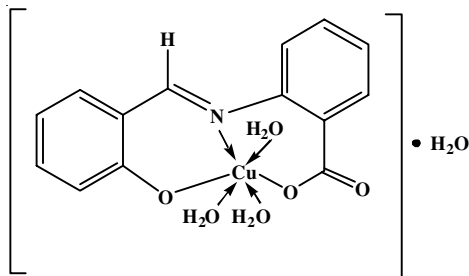
Cyclic voltammetry: In the cyclic voltammogram of complex 1, the peak to peak separation (ΔE_p) is 250 mV and the ratio of anodic to cathodic current (i_p/i_{pc}) is less than unity which confirms the quasi reversible redox process. This complex also shows one irreversible peak in the oxidative response with E_p 0.10 V . For complex 2, the peak to peak separation (ΔE_p) is 100 mV and the ratio of anodic to cathodic current (i_p/i_{pc}) is 2.4 and the cathodic peak current is not equal to the anodic peak current. This indicates the irreversible nature of the electron transfer process [17].

EPR spectra: Both parallel and perpendicular features of copper are resolved in the EPR spectra and were calculated as 2.22 and 2.04 , respectively. The g value of both Cu(II) complexes are found near to be 2.10 , confirming the presence of unpaired electrons in the $d_{x^2-y^2}$ orbital of Cu(II). The g value suggest an octahedral arrangement around Cu(II) complexes. The g value of these complexes were less than 2.3 and it indicates the covalent nature of the M-L bond [10].

Based on the above spectral analysis, the structure of the Schiff base copper(II) complexes are as follows:



Structure of complex 1 Cu(II) complex of L^1

Structure of complex 2 Cu(II) complex of L^2

Antimicrobial activity: Antibacterial and antifungal activity of the Schiff bases and their complexes have been tested by disc diffusion technique. The Gram-positive bacteria *Staphylococcus aureus*, Gram-negative bacteria *Klebsiella aerogenes* and fungi *Aspergillus niger* are used to find out the antimicrobial activity. The results were compared with standard drug ciprofloxacin and nystatin for the bacteria and fungi, respectively. The new complexes showed remarkable biological activities against bacteria and fungi as indicated in Table-2.

TABLE-2
ANTIMICROBIAL ACTIVITY OF SCHIFF
BASES AND ITS Cu(II) COMPLEXES

Microorganisms	Antimicrobial activity			
	L^1	L^2	A	B
<i>Staphylococcus aureus</i>	++	++	+++	+++
<i>Klebsiella aerogenes</i>	++	++	+++	+++
<i>Aspergillus niger</i>	++	++	++	+++

A = $[Cu(L^1-2H)(H_2O)_3] \cdot H_2O$; B = $[Cu(L^2-2H)(H_2O)_3] \cdot H_2O$

Hence it is evident that overall potency of uncoordinated compound is enhanced on coordination with metal ion. Thus both the copper(II) complexes were observed to be more active against *Staphylococcus aureus* and *Klebsiella aerogenes*. Complex of Cu(II) with the Schiff base ligand L^2 is found to be slightly more active than that of complex with ligand L^1 against *Aspergillus niger*.

Conclusion

The free Schiff base ligands L^1 , L^2 and Cu(II) complexes of both ligands have been structurally characterized. Based on the above results, both the Schiff bases are tridentative in nature

and complexes are said to have a distorted octahedral structure. Ligands and its copper(II) complexes have been screened against both Gram-positive and Gram-negative bacteria and fungal pathogens. The ability of complexes to show more antibacterial and antifungal activity than ligands suggests that it can be potentially used to control the bacterial and fungal species.

ACKNOWLEDGEMENTS

The authors are thankful to The Secretary, Seethalakshmi Ramaswami College, Tiruchirappalli, India for providing laboratory and research facilities.

REFERENCES

1. A.M. Abu-Diefab and I.M.A. Mohamed, *Beni-Suef Univ. J. Basic Appl. Sci.*, **4**, 119 (2015); <https://doi.org/10.1016/j.bjbas.2015.05.004>.
2. S. Kumar, D.N. Dhar and P.N. Saxena, *J. Sci. Ind. Res.*, **68**, 181 (2009).
3. N.K. Gupta, M.A. Quraishi, C. Verma and A.K. Mukherjee, *RSC Adv.*, **6**, 102076 (2016) <https://doi.org/10.1039/C6RA22116E>.
4. T. Shamspur, I. Sheikhshoae and M.H. Mashhadizadeh, *J. Anal. At. Spectrom.*, **20**, 476 (2005); <https://doi.org/10.1039/B416097E>.
5. S. Di Bella, I. Fragalà, A. Guerri, P. Dapporto and K. Nakatani, *Inorg. Chim. Acta*, **357**, 1161 (2004); <https://doi.org/10.1016/j.ica.2003.09.023>.
6. J. Xie, J. Qiao, L. Wang, J. Xie and Y. Qiu, *Inorg. Chim. Acta*, **358**, 4451 (2005); <https://doi.org/10.1016/j.ica.2005.08.018>.
7. M. Sivasankaran Nair and D. Arish, *J. Indian Chem. Soc.*, **88**, 265 (2011).
8. I. Rama and R. Selvameena, *J. Indian Chem. Soc.*, **91**, 1877 (2014).
9. G. Valarmathy and R. Subbalakshmi, *Asian J. Chem.*, **25**, 2077 (2013); <https://doi.org/10.14233/ajchem.2013.13322>.
10. H.N. Aliyu and I. Ado, *Biokemistri*, **23**, 9 (2011).
11. V. Gomathi and R. Selvameena, *Main Group Chem.*, **12**, 275 (2013); <https://doi.org/10.3233/MGC-130107>.
12. V. Govindaraj and S. Ramanathan, *Turk. J. Chem.*, **38**, 521 (2014); <https://doi.org/10.3906/kim-1301-83>.
13. V. Gomathi, R. Selvameena, R. Subbalakshmi and G. Valarmathy, *Int. J. Recent. Sci. Res.*, **4**, 80 (2013).
14. B.S. Ade, M.N. Deshpande and D.G. Kolhatkar, *Int. J. Pharm. Biomed. Res.*, **3**, 449 (2012).
15. K. Mounika, B. Anupama, J. Pragathi and C. Gyanakumari, *J. Sci. Res.*, **2**, 513 (2010).
16. G. Matela, R. Aman, C. Sharma and S. Chaudhary, *J. Indian Adv. Chem. Sci.*, **1**, 157 (2013).
17. K. Geetha and S. Santhalakshmi, *Res. J. Chem. Sci.*, **4**, 68 (2014).