



Synthesis, Characterization and Bioactivity Study of Cobalt(III) and Ruthenium(III) Complexes of 4,4'-Cyclohexylidene Bisphenol

V. JAYAMANI* and P. KALPANA

Department of Chemistry, Sri Sarada College for Women (Autonomous), Salem-636 016, India

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

(Received: 11 August 2010;

Accepted: 3 June 2011)

AJC-10022

Co(III) and Ru(III) complexes of 4,4'-cyclohexylidene bisphenol were synthesized and characterized by physical data, elemental analysis, molar conductance, IR, UV-VIS and TGA studies. Both the ligand and complexes were screened against *Staphylococcus aureus* and *Candida albicans*. They showed little activity when compared to standard drug chloramphenicol.

Key Words: 4,4'-Cyclohexylidene bisphenol, Co(III) complexes, Ru(III) complexes.

INTRODUCTION

Coordination complexes play a vital role in living systems, industry, medicine, etc. Cobalt(III) and ruthenium(III) complexes are very important in coordination chemistry, since they are found to be kinetically inert¹.

Hydrolysis of amino acids, esters, amides, peptides as well as peptide synthesis have been observed to be promoted by cobalt(III). Cobalt complexes have been observed to selectively bind DNA², have been extensively studied in photo chemistry³ and can be used as a cross linker in these polymers²⁻⁶. The growing interest of the chemists in the study of ruthenium complexes is due to their electron transfer properties. Ruthenium complexes are reported⁷ to have carcinostatic, antitumour, antiviral and antibacterial activity. Organometallic ruthenium carbene and allenylidene complexes are found as catalysts for olefin metathesis with important applications in organic and pharmaceutical chemistry⁸.

Hence we report the synthesis of Co(III) and Ru(III) complexes of 4,4'-cyclohexylidene bisphenol.

EXPERIMENTAL

All of the chemicals and reagents were purchased from Madras Scientific Suppliers (Chennai, India) and were used without any further purification. Commercial RuCl₃·3H₂O was purified by repeated evaporation to dryness with concentrated HCl.

Micro analytical (C and H) data were obtained with Perkin-Elmer 2400 CHN elemental analyzer. IR spectra were recorded using Hitachi 270-50 IR spectrometer using KBr disc. ¹H NMR and ¹³C NMR spectra were obtained using 300 MHz

NMR spectrometer. Electronic spectra of the complexes were recorded by UV-VIS spectrometer model-1371. Thermogravimetric data were obtained in air at 25 °C/min in the 50-800 °C range using Perkin-Elmer diamond TG/DTA instrument. Measurements were made at the rate of 25 °C/min in the temperature range 50-800 °C. Molar conductance was measured using Elico CM 185 conductivity bridge.

Synthesis of 4,4'-cyclohexylidene bisphenol: Cyclohexanone (8 mL, 0.08 mol) was saturated with dry HCl gas. Phenol (13.2 mL, 0.15 m) was added and the reaction mixture is shaken well and kept in an atmosphere of dry HCl gas for 2 days. Violet solid obtained was poured into crushed ice, filtered, washed with water and purified by repeated recrystallization. Colourless solid was obtained. Purity was tested by TLC plates. Yield (12.1 g, 57 %), m.p. 198 °C, IR (KBr, cm⁻¹): 3536, 3322, 1382, 3058, 3027, 1606, 1515, 1016, 899, 827, 2935, 2854, 1454, 1382, 1270, 1112. ¹H NMR (CDCl₃, δ/ppm): 9.36, 9.11, (s, 2H, OH), 7.18-6.63 (m, 8H, H-Ph), 3.49-3.42 (m, 4H, -CH₂), 2.51-2.13 (m, 4H, -CH₂), 1.42-1.04 (m, 2H, -CH₂). ¹³C NMR (CDCl₃, δ/ppm): 139, 129, 127, 118, 115, 114, 56, 44, 40, 39.5, 39, 38.9, 38.6, 18.5. Anal. calcd. for C₁₈H₂₀O₂: C, 80.59; H, 7.52. Found: C, 79.68; H, 7.77. R_f: 0.8.

Tris[cyclohexane-1-(4-hydroxyphenyl,4'-oxyphenyl)]-cobalt(III): 4,4'-Cyclohexylidene bisphenol (2.6 g, 9.8 mmol) in cyclohexane (20 mL) was refluxed on a water bath and to the hot solution, pure and dry metallic sodium was added until it was disappeared. This sodium salt of the ligand and CoCl₃·6H₂O (0.7 g, 3 mmol) were refluxed on a water bath for ca. 12 h, with occasional shaking. Then it was shaken vigorously for ca. 0.5 h and poured into water. The blue coloured complex obtained was filtered, dried and recrystallized using

alcohol. Purity was tested by TLC. Yield: (2.1 g, 81 %) m.p. 218 °C. IR(KBr, cm^{-1}): 3226, 1367, 3058, 3017, 2859, 2803, 2686, 1611, 1596, 1510, 1107, 1016, 893, 822, 736, 649, 588, 562, 471. UV-VIS (methanol, m): 350, 525. Anal. calcd. for $\text{C}_{54}\text{H}_{57}\text{O}_6\text{Co}$: C, 75.32; H, 6.68; Found: C, 76.16; H, 6.41; Co, 6.90. Λ_m : $17 \Omega^{-1} \text{cm}^2 \text{mol}^{-1}$, R_f : 0.65.

Tris[cyclohexane-1-(4-hydroxyphenyl,4'-oxyphenyl)]-ruthenium(III): 4,4'-Cyclohexylidene bisphenol (2.6 g, 9.8 mmol) in cyclohexane (20 mL) was refluxed on a water bath and to the hot solution, pure and dry metallic sodium was added until it was disappeared. This sodium salt and ruthenium trichloride (0.8 g, 3 mmol) were refluxed on a water bath for ca. 12 h with occasional shaking. Then it was shaken vigorously for ca. 0.5 h and poured into water. Good yield of green coloured complex was obtained. It was filtered, dried and recrystallized using ethanol. Purity was tested by precoated TLC plates. Yield: (2.2 g, 85 %), m.p. 178 °C. IR (KBr, cm^{-1}): 3226, 1362, 557, 3058, 3022, 1617, 1596, 1510, 1448, 1107, 1016, 822, 812, 731, 669, 639, 593, 2803, 2691, 2609. UV-VIS (methanol, m): 375, 520. Anal. calcd. for $\text{C}_{54}\text{H}_{57}\text{O}_6\text{Ru}$: C, 71.75; H, 6.31; Ru, 11.26. Found: C, 72.06; H, 6.52; Ru, 10.98. λ_m : $18 \Omega^{-1} \text{cm}^2 \text{mol}^{-1}$, R_f : 0.7

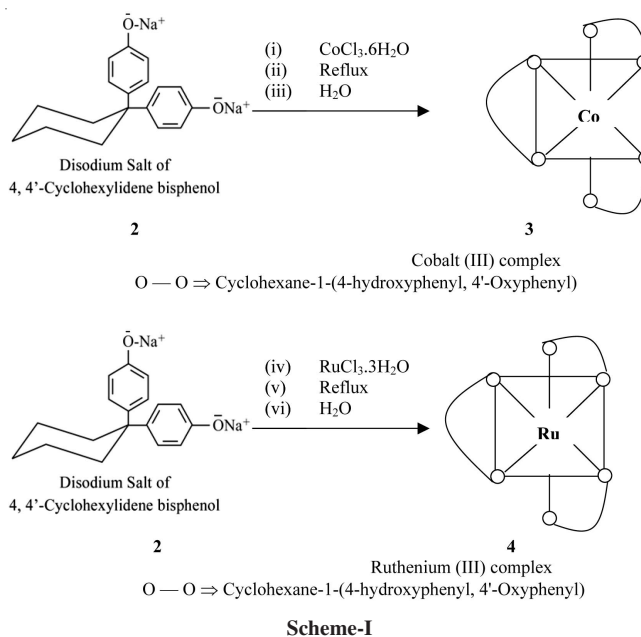
Antimicrobial studies: The antibacterial activity of the ligand and its Co(III) and Ru(III) complexes were determined *in vitro* using paper disc method against the pathogenic microorganism, *Staphylococcus aureus*. Sterile Muller Hinton Agar (pH 7.3) was poured into plates, the depth of the medium should be ca. 4 mm. In an incubator the petri plates were dried for 0.5 h, to remove the excess moisture from the surface. Four-five colonies were selected and inoculated the colonies into trypticase soya broth with the help of a wire loop. The broth culture was incubated at 35-37 °C for 3 h. A sterile cotton swab was dipped into the diluted inoculum and rotated the swab inside the wall of the tube to remove the excess of inoculum. The lid of petriplates were closed and kept at room temperature for 5-10 min to dry the inoculum. Solution of 100 ppm each of 4,4'-cyclohexylidene bisphenol, Co(III) and Ru(III) complexes and control compound chloramphenicol in DMSO were impregnated in 4 mm sterile filter paper disc and dried. The plates containing nutrient agar were seeded with *Staphylococcus aureus* at a concentration of 2.3×10^7 colony forming unit. The impregnated paper disc were placed at different positions in the plates and incubated at 37 °C. After 48 h, the pattern of bacterial growth were recorded. The same procedure was followed for antifungal studies using *Candida albicans*.

RESULTS AND DISCUSSION

All synthesis routes are shown in **Scheme-I**. All the synthesized compounds were afforded in good yield. The complexes were characterized by physical data, elemental analysis, molar conductance, IR, UV-VIS and TGA studies.

^1H NMR spectrum of 4,4'-cyclohexylidene bisphenol shows signals at 9.36, 9.11 δ (phenolic OH) 6.63, 7.18 δ (phenyl rings at C1), 3.49-3.42 δ (methylene protons at C2 and C6), 2.51-2.13 δ (methylene protons at C3 and C5) and 1.42 -1.04 δ (methylene protons at C4).

^{13}C NMR spectrum shows the signals at 139.094-114.845 δ (aryl carbons), 56.114, 44.115 δ (carbon at C1), 40.062,



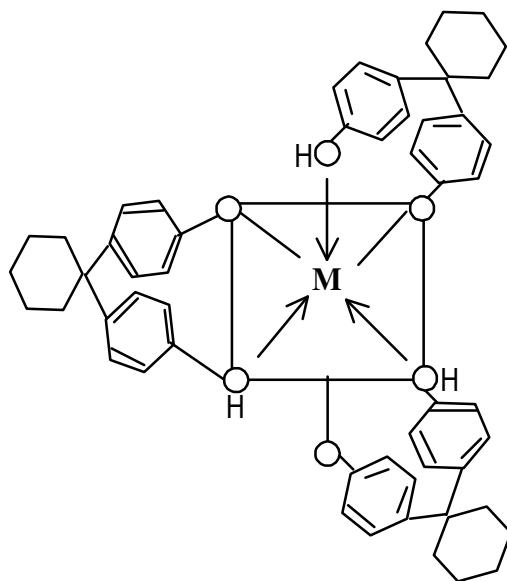
40.338 δ (methylene carbon at C2 and C6) 39.783-36.643 δ (methylene carbon at C3 and C5) and 18.589 δ (methylene carbon at C4). All these results are assigned based on reported^{9,10} values.

By comparison with the ligand, IR spectra of the metal complexes are found to have similar bands. One of the phenolic O-H stretching band is absent in the spectra of the complexes (3536cm^{-1}). Another phenolic O-H stretching band in the complexes 3 and 4 shifts to 3226cm^{-1} from 3322cm^{-1} . Phenolic O-H bending band in the complexes shifts to 1362 and 1367cm^{-1} from 1382cm^{-1} . The $\nu(\text{M}-\text{O})$ stretching frequency of the Co(III) and Ru(III) 471 and 557cm^{-1} , respectively. It is assigned based on the reported^{7,11-15} values. The shift of the bands of the complexes is attributed to the fact that the ligand is coordinated with the metal ions through phenoxy group and non bonding electrons on the oxygen atom of phenol. In addition, the molar conductance values of the Co(III) and Ru(III) complexes in methanol solutions are 17 and $18 \Omega^{-1} \text{cm}^2 \text{mol}^{-1}$, which indicate that the ligand is successfully chelated to metal ions.

UV-VIS spectrum of the complexes have been recorded using methanol from 300-700 nm. Electronic spectrum of Co(III) shows peaks at 350 nm due to $^1\text{A}_{1g} \rightarrow ^1\text{T}_{1g}$ *d-d* transition and 525 nm is assigned to $^1\text{A}_{1g} \rightarrow ^1\text{T}_{2g}$ *d-d* transition. In the case of Ru(III), two peaks are noted at 375 and 520 nm which are assigned to $^2\text{T}_{2g} \rightarrow ^2\text{A}_{2g}$ and $^2\text{T}_{2g} \rightarrow ^2\text{T}_{1g}$ LMCT charge transfer band, respectively. This results support the octahedral nature of the complexes.

Thermogravimetric analysis of the ligand shows one step decomposition. The decomposition starts at 250 °C and ends at 380 °C leaving no residue. Thermogram of the Co(III) complex shows decomposition at 70.65-206.45 °C (loss of phenyl and phenol fragment), 394.46- 475 °C (formation of Co_2O_3) and finally CoO is formed at 509.24 °C as stable product. Thermogram of the Ru(III) complex indicates the decomposition in the range 125-225 °C (loss of phenyl, phenol groups, oxygen atoms and like), at 404.30 °C (loss of all the ligand). RuO is formed as a final product at 404.30 °C and the decomposition completes at 650 °C.

Based on the foregoing discussion the following structure proposed for the synthesized compounds.



Antimicrobial studies: Antimicrobial studies of the ligand and Co(III) and Ru(III) were compared among them as well as with control compound. 4,4'-Cyclohexylidene bisphenol and *tris*[cyclohexane-1-(4-hydroxyphenyl,4'-oxyphenyl)]cobalt(III) show moderate antibacterial activity against *Staphylococcus aureus* whereas *tris*[cyclohexane-1-(4-hydroxyphenyl,4'-oxyphenyl)]ruthenium(III) shows little antibacterial activity when compared to control. Results are shown in the Table-1. Inhibition zones of the tested compounds with that of control show that all have little antifungal activity.

TABLE-1
INHIBITION ZONES OF 4,4'-CYCLOHEXYLIDENE BISPHENOL AND ITS COMPLEX WITH COBALT(III) AND RUTHENIUM(III)

Compound	Zone of inhibition (mm)	
	<i>S. aureus</i>	<i>C. albicans</i>
4,4'-Cyclohexylidene bisphenol	18	22
<i>Tris</i> [cyclohexane-1-(4-hydroxyphenyl, 4'-oxyphenyl)]cobalt(III)	16	20
<i>Tris</i> [cyclohexane-1-(4-hydroxyphenyl, 4'-oxyphenyl)]ruthenium(III)	10	22
Chloramphenicol	25	30

REFERENCES

1. K.F. Purcell and J.C. Kotz, Inorganic Chemistry, W.B. Saundar Company, p. 710.
2. A.M. Pyle and J.K. Parton, *Prog. Inorg.*, **38**, 413 (1990).
3. A.W. Adamson and P.D. Fleischauer, Concepts of Inorganic Photochemistry, Wiley Inter Science Publications, Toronto (1975).
4. B. Krautler and C. Kratky, *Angew. Chem.*, **35**, 167 (1996).
5. P.A. Sutton and D.A. Backingham, *Acc. Chem. Res.*, **20**, 357 (1987).
6. E. Tsuchida and H. Nishide, *Adv. Polym. Sci.*, **24**, 1 (1977).
7. M.B.H. Howlader, M.B. Hossain and N. Akthar, *Indian J Chem.*, **47A**, 214 (2008).
8. P. Viswanathamurthy and K. Natarajan, *Transition Met. Chem.*, **24**, 638 (1999).
9. R.M. Silverstein and F.X. Webster, Spectrometric Identification of Organic Compounds, John Wiley & Sons, Inc New York, edn. 6, p. 226, 261 (1996).
10. W. Kemp, NMR in Chemistry-A Multinuclear Introduction, McMillan, pp. 56-59 (1986).
11. R.N. Prasad, K.M. Sharma and A. Agrawal, *Indian J. Chem.*, **46A**, 600 (2007).
12. R.C. Maurya, J. Chourasia and P. Sharma, *Indian J. Chem.*, **47A**, 517 (2008).
13. J. Mohan, Organic Spectroscopy-Principles and Applications, Narosa Publishing House, pp. 81-82 (2001).
14. J.R. Dyer, Application of Absorption Spectroscopy of Organic Compounds, Prentice Hall of India Private Limited, pp. 33-34 (1984).
15. E. Pretsch, P. Bühlmann and C. Affolter, Structure Determination of Organic Compounds, Springer International Edition, p. 256 (2000).