HOST-GUEST COMPLEXES OF CALIX (n) ARENES AND SOME POSSIBILITIES OF MOLECULAR RECOGNITION

by

USHA HOODA
Department of Chemistry

SUBMITTED
IN FULFILMENT OF THE REQUIREMENTS
OF THE DEGREE OF
DOCTOR OF PHILOSOPHY

to the
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
INDIA

February, 1996

To

Lord Shiva

the supreme personality of Godhead

CERTIFICATE

This is to certify that thesis entitled "HOST-GUEST COMPLEXES OF CALIX(n)ARENES AND SOME POSSIBILITIES OF MOLECULAR RECOGNITION" being submitted by Ms. Usha Hooda to the Indian Institute of Technology, Delhi, for the award of Degree of Doctor of Philosophy, is a record of the research work carried out by her. Ms. Usha Hooda has worked under my notional supervision and has fulfilled all the requirements for the submission of this thesis.

(R.C. Anand)
Chairman,
Department Research Committee
Department of Chemistry,
Indian Institute of Technology
New Delhi - 110016
INDIA

ACKNOWLEDGEMENT

The vedic information says "*Matrdevo bhava, Pitrdevo bhava* and *Ācharyadevo bhava*", perhaps due to the profound influence of the parents and mentors on ones lives. It is with the blessings and guidance of these persons, ie. my parents, teachers and my husband only that I am able to take up and execute this work. I offer my humble obeisances into them and dedicate this work to my husband.

It was Dr. H.M. Chawla who introduced me to the world of Calix(n)arenes. It was an entirely different experience to work with him. I am grateful to him for a fruitful association and guidance.

I am grateful to Prof. N.K. Jha, Head of the Department of Chemistry and Prof. R.C. Anand, Chairman, Department Research Committee for providing the necessary facilities in the department.

I wish to express my deep sense of gratitude and respect to Prof. N.K. Jha, Dr. A.K. Singh and Dr. D. Bandhopadhyay, Department of Chemistry, I.I.T. Delhi and Prof. G.S.S. Murthi, Department of Chemistry, North Bengal University, for their able guidance and encouragement for independent work. Their mature criticisms were the key factors that transformed the vague concepts in my mind to this presentable form.

I owe a great deal to my friends, Dr. Veena Singh, Dr. Sumanjeet Kaur, Dr. Pramod Sharma, Messers Abhishek, Kaushik Dutta, Renu Batra and Shashank. This is the most opportune moment to thank all my family members for their encouragement throughout my academic career.

Many a thanks due to all staff members of Instrumental Lab., NMR Lab. and glass blowing section.

Words are no measure to describe the forbearance and fortitude with which my family members encouraged and enthused me.

Care has been taken to give proper credit for work of other authors in the literature. I regret my omission which might have occurred by oversight.

The financial assistance from the Department of Science and Technology is gratefully acknowledged.

Usha Hooda

(USHA HOODA)

ABSTRACT

Calix(n)arenes are recently rediscovered phenolic macrocycles that have immense potential for development of derivatives with ionic and molecular recognition capabilities, new drug delivery systems, chromogenic indicators, sensors and molecular receptors. During the last decade the interest in calixarenes has increased significantly, mainly because they are regarded as host molecules of diverse potentiality. Inclusion of neutral molecules or cations or both, has been reported for calixarenes and their suitable derivatives. To exploit the property of calixarenes to form host-guest complexes due to the recognition capability for small organic molecules and metal ions and to investigate their biomimetic catalytic function, a few calix(n)arene derivatives with potential metal coordination sites have been synthesized and their interaction with metal ions and small organic molecules has been examined during this work.

The thesis consists of five chapters. The chapter I includes a brief review of the synthesis, structure and some reactions of calixarenes. Chapter II comprises of two sections (A&B) where section A deals with the studies involving the interaction of urea (**A**), monoacetylurea (**B**), dibenzoylurea (**C**), 4,5-diphenylimidazolin-2-one (**D**) and guanidine (**E**) with 5,11,17,23-tetra-*p*-*tert*-butyl-25,26,27,28-tetrahydroxycalix(4)arene (**2**);5,11,17,23,29,35-hexa-*p*-*tert*-butyl-37,38,39,40,41,42-hexahydroxycalix(6)arene(**4**); 5,11,17,23-tetra-*p*-*tert*-butyl-25,26,27-tribenzoyloxy-28-hydroxycalix(4)arene (**16**) and 5,11,17,23-tetra-*p*-*tert*-butyl-25,26,27,28-tetrabenzoyloxycalix(4)arene(**17**)by UV (Mole ratio plots), IR and NMR spectroscopy. The results indicated the formation of (1:1)

molecular complexes of **A** and **E** with **2,4** and **16**, while no complex formation was noticed with **17**. On the other hand **B**, **C** and **D** did not reveal the formation of host-guest complexes with **2,4,16** and **17**. From low temperature ^1H NMR spectroscopic and CPK model studies, it appears that **A** and **E** get encapsulated within the cavity of calix(n)arene receptors (**2,4** and **16**) and are stabilised through hydrogen bonding. From UV spectral data, the overall association complex constants were calculated using Benesi-Hildebrand equation which are found to be of the order of $\sim 10^{-2}\ M^{-1}$.

Calixarenes have been used as carrier for a few biologically important amino acids. Section B includes the study of three amino acids namely glycine (**G**), L-histidine (**H**) and L-arginine (**Ar**) with calix(n)arenes. Infrared and ultraviolet spectral analyses of the interaction of **G**, **H** and **Ar** with **2,4** and **16** indicated the formation of molecular complexes between the studied substrates and the macrocyclic hosts. Job's and mole ratio plots show that **G**, **H** and **A** form 1:1 molecular complexes with **2,4** and **16**. The overall association constants as calculated using Benesi-Hildebrand equation are of the order of 10^{-3}-$10^{-2}\ M^{-1}$. It seems that amino acids form exo-complexes with calix(n)arenes i.e there is no encapsulation by calix(n)arenes. The weak ionic interaction between the Zwitterionic amino acids and anionic calix(n)arene is speculated.

Calix(8)arene with a largest readily available species amongst calix(n)arenes, forms a series of homo- and heterobimetallic complexes with lanthanide ions.

Chapter III reports the synthesis of homobimetallic cerium (IV)-calix(8)arene complex from dimethyl sulfoxide solutions viz. $[Ce_2(L\text{-}6H)(dmso)_5].2dmso$. The ability of *p-tert.*butylcalix(8) arene to form a complex with Ce(IV) is a reflection of this ligand's impressive coordinating ability. The Ce(IV)-calix(8)arene complex was characterized by X-ray powder diffraction study, elemental analyses, vibrational and electronic spectra, magnetic susceptibility data and thermal analyses.

Very few methods that promote direct hydroxylation of aromatic substrates are known. The yields in such reactions are generally poor probably owing to further oxidation of the resulting phenols. Chapter III also includes a novel method for the regioselective hydroxylation of phenolic substrates under ambient conditions using the homobimetallic Ce(IV) complex and H_2O_2 in acetonitrile.

The solubility of calixarenes in polar solvents can be increased by replacing the alkyl groups at the upper rim by sulfonate groups. It has been observed previously that the water soluble calix(4)arene sulfonates such as Na_5[Calix(4)arenesulfonate].12 H_2O and related alkali metal derivatives crystallize with a high degree of hydration.

Chapter IV deals with the reaction of tetrasodiumcalix(4)arene sulfonate (TSCS) with transition metal (M) nitrates [M (III)=Cr, Co and Fe] which provide a good yield of the corresponding complexes viz. $[Cr(OH_2)_6]$[Na][TSCS](acetone).$10.5H_2O$, $[Co(OH_2)_6]$[Na][TSCS].$7.5H_2O$ and $[Fe(OH_2)_6]$[Na][TSCS].$10H_2O$. As single crystals of these complexes could not be obtained, their characterization on the basis of X-ray powder diffraction pattern, elemental analyses, vibrational electronic spectra, magnetic susceptibility data and thermal analysis has been made.

The chapter V contains the experimental details.

LIST OF CONTENTS

CHAPTER V Experiment