SYNTHESES OF TETRAAZABIS(TROPOCORONAND)S CONTAINING HYDROXY GROUP(S) AND CONFORMATIONAL ANALYSIS OF THEIR NICKEL(II) COMPLEXES IN SOLUTION

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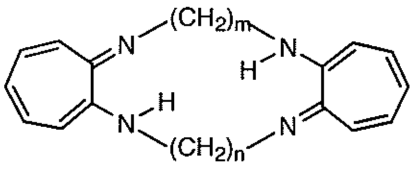
Abstract - The stepwise syntheses of one symmetric and three asymmetric tetraazabis(tropocoronand)s (**12a**-**12d**) having two linker chains, with or without a hydroxy group, of the same or different length are reported. The coordination styles of their nickel(II) complexes (**13a**-**13d**) in solution have also been discussed based on their ^{1}H NMR and UV-VIS. spectral data.

Tetraazabis(tropocoronand)s (TCs, **1**) are interesting macrocyclic ligands, which have two non-benzenoid seven-membered rings and transition metal coordinating ability.[1-6] T. Nozoe and co-workers reported that benzo[*b*]cyclohepta[*e*][1,4]oxazine (**2**)[7,8] reacted with various α,ω-polymethylenediamines (**3**, n > 4) to afford symmetric TCs (**1**, m = n) in high yields.[9,10] Although it is a convenient and useful method, treatment of such short diamines as α,β- or α,γ-diamine (**3**, n = 2 or 3) with **2** afforded 2,3-dihydro-1*H*-cyclobuta[*b*]pyridazine (**4**) or 2-phenyl-3,4,5,6-tetrahydropyrimidine (**5**) respectively.[11] On the other hand such TCs (**1**, m ≠ n) as **6** and **7** must be synthesized stepwise and have been reported not so many.[6,12]

As a part of our study for the synthesis of TCs which have a higher functionality and water solubility, the introduction of a hydroxy group on the linker chains was studied. We report the syntheses of four TCs (**12a**-**12d**) having two linker chains, with or without a hydroxy group, of the same or different length. We have also synthesized their nickel(II) complexes (**13a**-**13d**) and suggested their coordination styles in solution based on their ^{1}H NMR and UV-VIS. spectral data. As to nickel(II) bound to nitrogen and oxygen atoms, an interesting geometry was reported for urease (urea amidohydrogenase),[13] a nickel(II) metalloenzyme,[14] on the basis of a crystal structure[15]; Ni-1 of the bi-nickel center has pseudotetrahedral geometry and Ni-2 has distorted bipyramid or distorted square pyramid.



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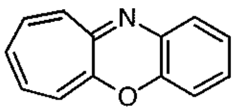

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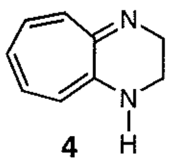
$H_2N(CH)_nNH_2$

3



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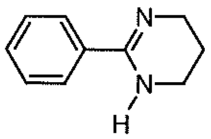

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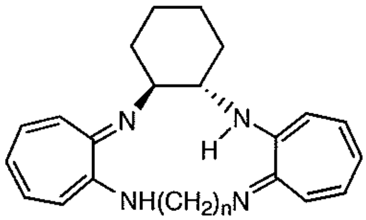
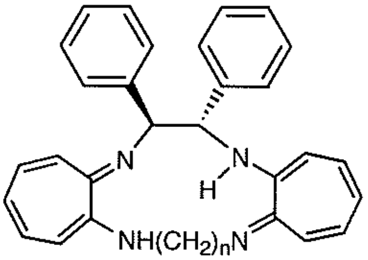


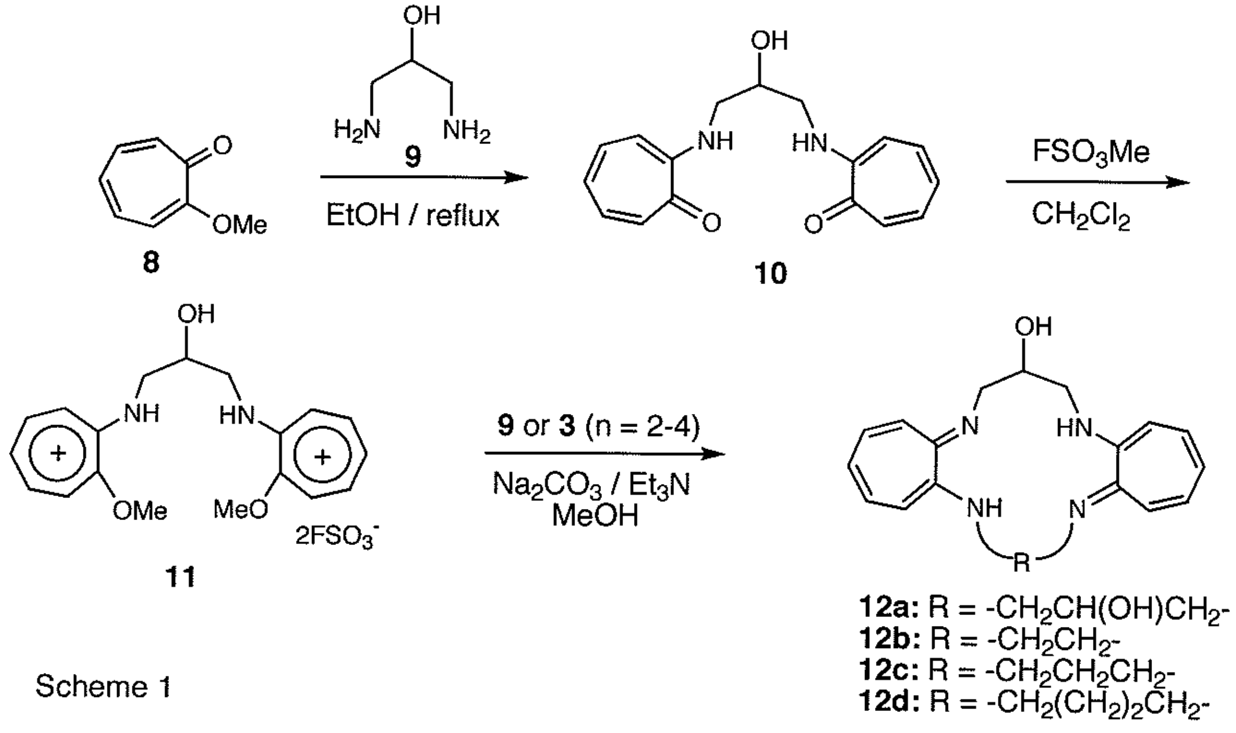
6: n = 3, 4, 6



7: n = 3, 4, 6

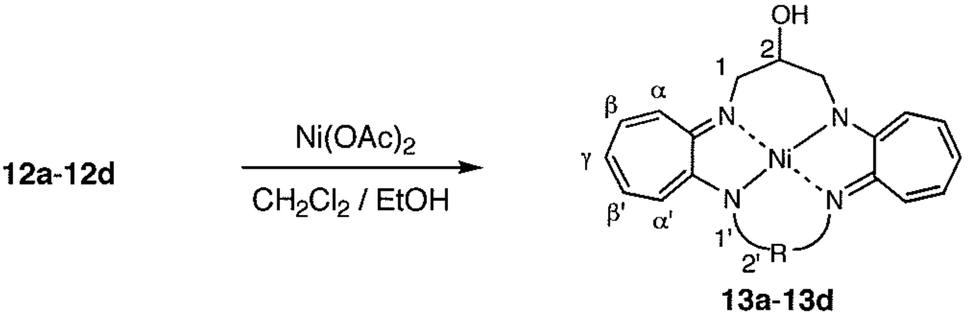
We first planned the synthesis of the dihydroxy TC (**12a**) which could exist as a *cis* or *trans* conformer; the former belongs to C_{2v} and the latter C_{2h} symmetry. Since TCs (**1**, m = n = 3) had not been obtained by the oxazine method[9,10] mentioned above, we synthesized **12a** by the stepwise method[1,3] alternatively (Scheme 1). A mixture of 2-methoxytropone (**8**), 1,3-diamino-2-hydroxypropane (**9**) and *abs*. EtOH was refluxed for 3.5 h to afford the product (**10**, 91% yield, yellow plates, mp 199-201°C). Compound (**10**) was treated with methyl fluorosulfonate in dichloromethane for 40 h at room temperature to give tropenium ion (**11**), which directly reacted with **9**, triethylamine and $NaHCO_3$ simultaneously in methanol at -20 to 15℃ for 24 h to afford TC (**12a**, 21%, yellow solid, mp 218-223℃). Compound (**12a**) showed two pairs of ^1H NMR signals derived from the linker chain protons, suggesting the existence of two isomers (*cis* and *trans* diols, Table 1). One combination (**A**) appeared at δ 3.52 (4H, d, J = 14.4 Hz) and 3.81 (4H, dd, J = 14.4, 5.3 Hz) and the other (**B**) at δ 3.63 (4H, dd, J = 14.2, 1.6 Hz) and 3.71 (4H, dd, J = 14.2, 6.4 Hz) and the integral ratio of **A** and **B** was about 5 : 4. The NMR study could not decide which isomer was *cis* or *trans* diol. However, the results of PM3 calculation[16] of the heats of formation (41.58 kcal·mol^{-1} for *trans* diol vs. 42.60 kcal·mol^{-1} for *cis* isomer) suggest that **A** is of a *trans* diol and **B** is of the isomer.

In order to investigate the scope and limitation of the reaction, we tried the reaction of a common key intermediate (**11**) with some alkanediamines (Scheme 1). Ethylenediamine (**3**, n = 2), 1,3-diaminopropane (**3**, n = 3) and 1,4-diaminobutane (**3**, n = 4) were cyclized to afford corresponding TCs respectively (**12b**, 1%, **12c**, 19% and **12d**, 13%) but 1,5-diaminopentane (**3**, n = 5) and the longer chain diamines were not cyclized. Unexpectedly TCs (**12**) were insoluble in water, however the solubility in water would be improved by transforming their hydroxy group(s) into more polar functional group(s) such as sulfonate, carboxylate and ammonium salt *etc.*



Scheme 1

Although nitrogen atoms of TCs are well known to coordinate nickel(II),[1-3] we are interested in whether the hydroxy group(s) are taken part in the coordination or not. In dichloromethane and EtOH, TC (**12a**) and nickel(II) acetate reacted to afford the nickel(II) complex (**13a**, 66% yield, reddish brown crystals, mp >300°C). Complexes (**13b**-**13d**) were also led from corresponding TCs (**12b**-**12d**) in 85, 62 and 41% yields respectively (Scheme 2). All of these complexes are unstable and decompose in air.



Scheme 2

^1H NMR chemical shift values of TCs (**12**) and TCs (**13**) are shown in Table 1. Comparison of the symmetric characters of chemical shift and integral values of each proton of TCs (**12**) and those of TCs (**13**) shows that the latters have nickel(II) bonded to the four nitrogen atoms of the tropocoronand ligand. All the protons of TCs (**13a**-**13d**) appeared in the ordinary range (δ 0-10) and did not exhibit isotropic ^1H contact shift, indicating that **13a**-**13d** are low-spin nickel(II) complexes and have square coordination geometry, similar to that of TCs (**1**, m = n = 3 and 4)[3]; it is reported that when the dihedral angle θ between the two N-Ni-N planes of the chelating tropoimine rings of **1** is in the range of 8.3°-28.9°, it takes a distorted planar (S = 0) and when the angle is in the range of 72.1°-85.2° (m = n = 5 and 6), it takes a distorted tetrahedral structure (S = 1). Hydroxy protons were always observed and methylene and methine protons (H-1, H-1', H-2 and H-2') were shifted low field by the influence from nickel's d-lobe, while seven-membered ring protons were almost never shifted. These facts indicate that a hydroxy proton is not concerned with the coordination to nickel(II). All observed protons of **13b** are broad, however, suggesting that the cavity is not large enough to fit to nickel(II) cation and the existence of a certain slow flipping between a concave and convex shapes within the range of θ = *ca.* 30°.

Table 1. ^{1}HNMR Data of Azatropocoronands (**12**) and Their Ni(II) Complexes (**13**) (δ, TMS, $CDCl_3$)

Proton No.	**12a**[a]	**13a**[a]	**12b**	**13b**	**12c**	**13c**	**12d**	**13d**
α	6.32 / 6.33	6.40 / 6.39	6.37	6.1-6.4 (br)	6.31	6.36	6.36	6.35
α'	- / -	- / -	6.31	6.1-6.4 (br)	6.28	6.33	6.32	6.30
β	6.88 / 6.87	6.90 / 6.90	6.84	6.82 (br)	6.83	6.85	6.84	6.84
β'	- / -	- / -	6.82	6.82 (br)	6.83	6.85	6.83	6.82
γ	6.27 / 6.26	6.30 / 6.30	6.22	6.1-6.4 (br)	6.20	6.23	6.22	6.22
1	3.52, 3.81 / 3.63, 3.71	3.09, 3.20 / 3.13, ND[b]	3.55, 3.86	3.1-3.9 (br)	3.56, 3.75	3.09, 3.16	3.60, 3.80	3.07, 3.12
2	4.39 / 4.40	4.18 / 4.16	4.35	4.12 (br)	4.41	4.19	4.33	4.07
1'	- / -	- / -	3.61, 3.68	3.1-3.9 (br)	3.44, 3.59	2.92, 2.98	3.35-3.45	3.15-3.3
2'	- / -	- / -	-	-	2.24, 2.29	2.00	1.89	1.93, 2.15
OH	2.7 (br) / 2.7 (br)	2.12 / 2.95	2.9 (br)	ND[b]	3.00	3.36	ND[b]	3.65
NH	8.5 (br) / 8.5 (br)	-	9.3 (br)	-	8.8 (br)	-	ND[b]	-

a **12a** and **13a** contain *cis*- and *trans* -diols each other. b Not determined.

Table 2. UV-VIS. Spectral Data of Azatropocoronands (**12**) and Their Ni(II) Complexes (**13**) (λ_{max} (CH_2Cl_2) / nm, log ε)

Assign	**12a**	**13a**	**12b**	**13b**	**12c**	**13c**	**12d**	**13d**
L[a]	266 (3.76)	276 (3.73)	265 (3.33)	277 (3.26)	267 (3.74)	278 (3.74)	259 (4.00)	258 (3.91)
	360 (3.58)	360 (3.50)	361 (3.10)	358 (3.06)	360 (3.55)	364 (3.50)	353 (3.71)	349 (3.61)
	407 (3.37)		407 (2.90)		407 (3.36)		404 (3.55)	
CT[b]		466 (3.43)		496 (3.01)		468 (3.47)		460 (3.42)
	-	493 (3.48)	-	532 (2.99)	-	495 (3.51)	-	510 (3.32)
		620 (2.34)		620 (2.05)		620 (2.36)		650 (2.24)

a Transition derived from ligands. b Charge transfer transition.[3,17]

From UV-VIS. spectra, the different coordination style of **13b** can also be recognized (Table 2). Spectral patterns of **13a**, **13c** and **13d** are similar, while that of **13b** is not like them; spectral bands by the transition from the ligand and by the charge transfer from ligand to metal are both different from those of the others, supporting the reasoning from ^{1}H NMR analysis.

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