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Heptakis-6-(5-methylene-ureido-5'-methyl-2,2'-Bipyridinyl)-cyclomaltoheptaose as a New Fluorescent Lanthanide Polydentate Ligand

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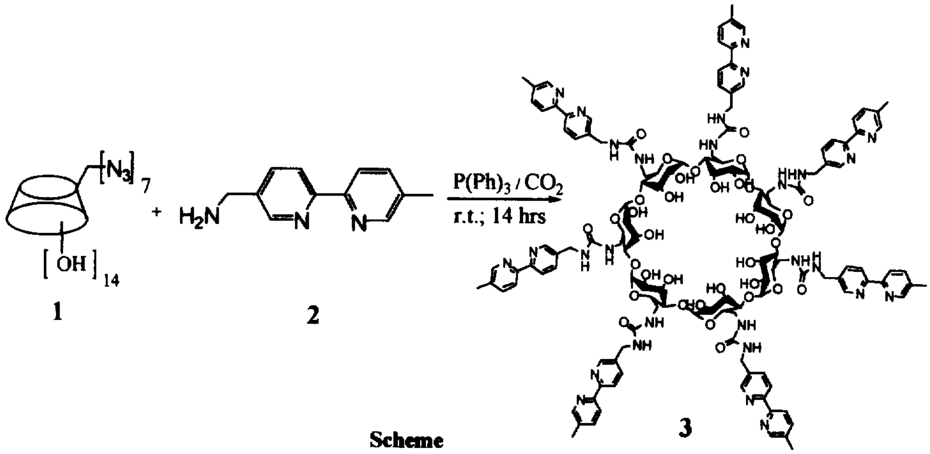
Key words : β-cyclodextrin, bipyridine polydentate, Eu^{III} and Tb^{III} complexes.

Abstract *:* The present work describes the one-pot synthesis of an heptakis-(bipyridinyl-ureido)-β-cyclodextrin in a high coupling average (82%) by the "phosphinimine" approach. The subsequent complexation of **3** with $EuCl_3$ or $TbCl_3$ gives stable complexes **4**. Preliminary results on complexation and fluorescence properties are reported.

Bis-heterocyclic azine building blocks are strategic in the conception of new supramolecular structure frameworks. Introduction in this sense of the 5,5'-dimethyl-2,2'-bipyridine unit in new hemi-barreland and barreland calix[n]arene derivatives have shown significant enhancement of the fluorescence properties[1]. Recently, synthesis and fluorescence of new cyclam-β-cyclodextrin hosts have been reported[2]. Elsewere, absorption-energy-transfer-emission (A-TE-E) light conversion process was also described for a polychromophoric cyclodextrin inclusion complex with merocyanin dye[3].

Pursuing developments of the "phosphinimine approach" for a direct access to new multisite complexing hosts, the present work describes a convenient one-step synthesis of a full-substituted upper ring bipyridinyl-β-cyclodextrin **3** and its fluorescence properties.



1

2

3

Scheme

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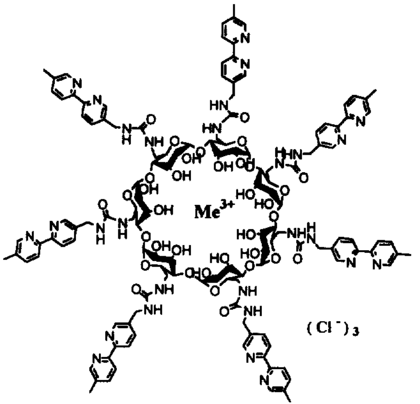
The one-pot condensation of the heptakis-[6-azido]-β-cyclodextrin[4] **1** with an excess of 5- methylene amino-5'-methyl-2,2'-bipyridine[5] **2** (16 equiv.) in presence of triphenyl phosphane (70 equiv.) and anhydrous CO_2 continuous bubbling in anhydrous DMF as solvent, readily gives the desired β-cyclodextrin ligand **3** (L^3) in a good yield (82%). The reaction occurs in mild conditions at room temperature during 14 hours, and pure product is obtained by a simple workup procedure[6]. The structure of the new compound **3** was analyzed by FTIR, UV-Vis, NMR and FABMS and the collected data are in agreement with the proposed structure[6]. The IR spectrum of **3** shows characteristic ν (*CO*-NH) carbonyl frequency of the urea functions and strong ν (*C*=*C*) aromatic frequencies corresponding to the bipyridine units. The characteristic ^{13}C NMR spectrum of **3** exhibits intense aromatic signals between 120 to 160 ppm corresponding to the 5,5'-bipyridine carbon chemical shifts. The complexation behavior towards Eu^{3+} and Tb^{3+} ions was investigated on **3**. The suitable complexes were obtained by stirring $EuCl_3$, 6 H_2O or $TbCl_3$, 6 H_2O (1.2 equiv.) and **3** (1.0 equiv.) in refluxed MeOH (3 days). The pure solid complexes were precipitated from a methanol solution by diffusion of diethyl ether. The electronic spectra of the complexes in MeOH show absorption maxima in the UV region 254nm (π-π*) and 292 nm (n-π*); (ureas [2] and bipyridines) (Fig. 1). The titration of **3** by Eu^{III} shows an isosbestic point at 300 nm along a slight red-shift of the 292 nm maximum absorption to 295 nm, as a result of efficient metal coordination and according to geometrical changes occurring in the ligand **3**. The $[EuL^3]^{3+}$ complex **4** was found of [1:1] stoichiometry (also found for Tb^{III}).



4

Me^{3+} = Eu, Tb

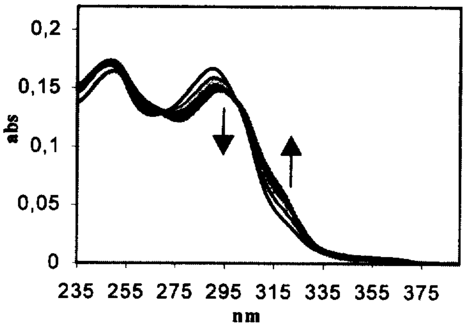


Fig.1 : Absorption spectra of ligand 3 in MeOH
C=1.0 X 10^{-5} $mol.L^{-1}$. Eu^{3+} C= 0.2 to 1.8 equiv.
$\varepsilon_{max\ (292)} = 16500\ M^{-1}\ cm^{-1}$. The arrows show the direction of spectral variations with increasing amounts of Eu^{3+}.

The luminescence excitation spectra of **4** at 292 nm cause structured emission of the $Eu^{3+}$and Tb^{3+} lanthanide ions *via* the absorption-energy transfer-emission (A-TE-E) light conversion process (Fig 2). Thus the bands corresponding to the $^5D_0 \rightarrow {}^7F_J$ (J=1,2,3,4) (*e.g.* Eu^{III}) transitions are observed either in absolute MeOH or wet MeOH. With respect to the complex solubility, addition of some water causes a smooth extinction of emission, indicating that the vibronic deactivation process is quite efficient but seems not to affect the complex stability.

A slightly enhanced $^5D_0 \to ^7F_2$ transition is observed in Eu^{III} complex **4**, indicating probably a proper molecular dissymmetry along the presence of coordinated solvent molecules affecting the coordination ion site. The Eu ^{III} coordination in L^3, only involves carbonyl and nitrogen ureas, which are determining an internal "hard" binding cavity (with respect to a bipyridine external "soft" binding cavity) [7].

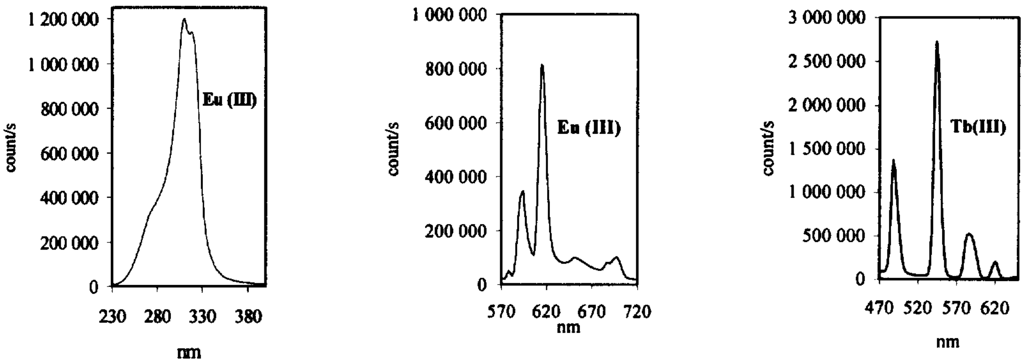


Fig.2 Luminescence excitation spectrum of Eu^{III} complex and luminescence emission spectra of Eu^{III} and Tb^{III} complexes in MeOH; $C = 1.0 \times 10^{-5}$ mol.L^{-1}

Many reasons and features are in favor of this coordination selectivity. One, is brought by the shift of IR ν (*CO*-NH) frequencies from 1645 cm^{-1}(free ligand) to 1635 cm^{-1} (lanthanide complexes). Another, in relation to the well known general "hard and soft" acid-base theory, classes lanthanide ions as "hard" acids which prefer to coordinate oxygen than nitrogen and a third, is refered to our previous work on ureido-cyclam^2 analogues and to other literature works [8, 9] in which similar coordination selectivities were found for lanthanides, particularly in case of the heterodinuclear "hard and soft" [Eu^{III}/Zn^{II}] trihelical complex [10].

With reference to the above results, we can conclude on another interesting improvement of the "phosphinimine" approach for an easy and direct synthesis of complex multisite coordinating cyclodextrin hosts. The Eu^{III} and Tb^{III} complexes have shown promising fluorescence properties. The syntheses of the α– and γ-cyclodextrin derivatives of **3** and studies of transition metal complexation as second nuclear centers are under way to elucidate differences in complexation and new fluorescence properties along further efforts to obtain suitable crystals for determining their X-ray structures.

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6. Structures of all compounds were assigned by ^{1}H and ^{13}C NMR on a Bruker DRX-400 spectrometer, FTIR spectra were recorded on a Perkin-Elmer1600; UV-Vis on a Safas UVmc^{2}. Luminescence experiments were performed on a Spex Fluorolog II photon counting spectrofluorimeter equipped with a 450W xenon continous wave irradiation source. Mass spectra were recorded in FAB positive mode on a ZAB-SEQ mass spectrometer. The new compounds gave satisfactory spectroscopic data.

   3 : **Heptakis-6-(5-methylene-ureido-5'-methyl-2,2'-bipyridinyl)-cyclomaltoheptaose**. Obtained by condensation of **1** (0.006 mmol, 0.077g,1 equiv.), **2** (0.95 mmol, 0.20g, 16 equiv.) and triphenyl phosphane (4.10 mmol, 1.075g, 70 equiv.). After evaporation of the DMF, the residue was treated with diethyl ether, filtered, treated with methylene chloride then filtered once more to give **3**, an orange pure powder (0.13g, 82%); UV-Vis (λ_{max} nm) : 250, 292, 320 (shoulder); IR : 3358 (N-H, O-H);1645 (C=O urea), 1557 (C=C aromatics); ^{1}H NMR (D$_6$DMSO, 25°) δ (ppm) : 8.48 (s, 1H, (H6,bipyridin)); 8.38 (s, 1H, (H6', bipyridin)); 8.18 (d, 1H, $_3$J = 8.3Hz, (H3, bipyridin)); 8.14 (d, 1H, $_3$J = 8.3 Hz, (H3', bipyridin)); 7.65 (d, 1H, 3J = 8.3 Hz, (H4, bipyridin)); 5.00-5.70 (m, 7H, (H1, cyclodextrin)); 4.30-3.40 (complex m, 44H, (H2, H4, H5, H6 cyclodextrin and CH_2 bipyridin)); 2.50 (s, 3H, (CH_3, bipyridin)). ^{13}C NMR (D$_6$DMSO, 25°) δ (ppm) : 158.0 (N-CO-NH); 154.0 (C2); 152.0 (C2'); 149.0 (C6); 148.0 (C6'); 137.0 (C4); 135.5 (C4'); 135.0 (C5); 133.0 (C5'); 120.0 (C3/C3'); 101.0 (C1); 83.7.(C4); 72.0 (C2,C3,C5); 19.0 (CH3). FABMS (thioglycerol) : 2704.4 (100%), [M+H$^+$]; 2523.0 [M-bipyridinyl].
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