95. Synthesis and Properties of Macrobicyclic Cryptates Incorporating Five- and Six-Membered Biheteroaryl Units

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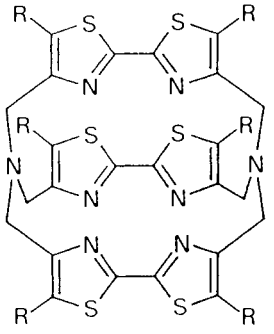
The sodium cryptates of the macrobicyclic ligands **1–6** have been synthesized by direct macrobicyclisation or by stepwise procedures. They incorporate 2,2′-bithiazole, 2,2′-biimidazole, 2,2′-bipyrimidine as well as 2,2′-bipyridine units. Treatment of the sodium complexes with europium(III) chloride gave the corresponding Eu^{III} cryptates. The structural and spectral properties of these compounds are described. The Eu^{III} complexes present characteristic ^{1}H-NMR chemical-shift features. Their luminescence properties are described.

Macrobicyclic ligands containing heterocyclic subunits combine the structural features of cryptands [1] with the special binding and functional (photochemical, electrochemical) properties conferred by aromatic heterocycles. Such subunits were introduced in a large number of macrocyclic compounds [2]. Macrobicyclic metal-ion cryptates incorporating biheteroaryl groups such as 2,2′-bipyridine (bpy) [3–7], 1,10-phenanthroline (phen) [3] [8], and 2,2′-biisoquinoline (biqi) [4] [6] as well as *N*,*N*′-bipyrazole [9] were synthesized and investigated. In particular, it was shown that the corresponding Eu^{III} and Tb^{III} complexes [7] [10] [11] are strongly luminescent, acting as light-conversion devices [10–14]; on the other hand, a species of expanded-atom type, termed sodiocryptatium, was obtained by electroreductive crystallisation of the sodium cryptate of the parent tris-bpy macrobicycle [15].

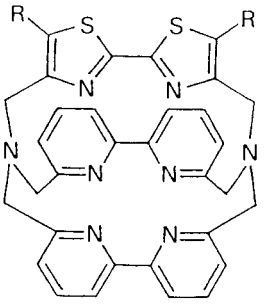
To further investigate the relations between ligand structure and physicochemical properties, novel variations were explored by introducing different kinds of heterocycles into the framework. *E.g.*, the quantum yield for light conversion, *i.e.* the luminescence yield, depends on the efficiency of the energy transfer that occurs between the ligand excited state and the cryptated lanthanide cation, and thus on the nature of the photosensitive ligand subunits.

We describe here the synthesis and some properties of cryptate complexes of the macrobicyclic ligands **1–6** containing 2,2′-bithiazole (btz), 2,2′-biimidazole (biz), 2,2′-bipyrimidine (bpym) as well as 4,4′-disubstituted bpy subunits (for a preliminary report,

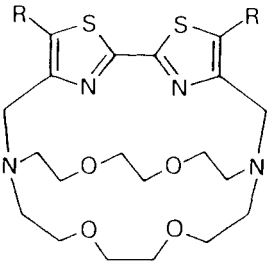
[1]) URA 422 of the C.N.R.S.



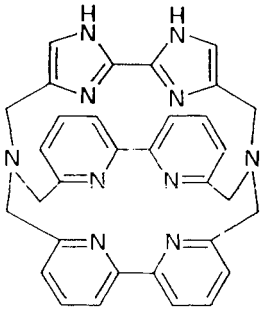
1a R = H
b R = COOEt



2a R = H
b R = COOEt



3a R = H
b R = COOEt



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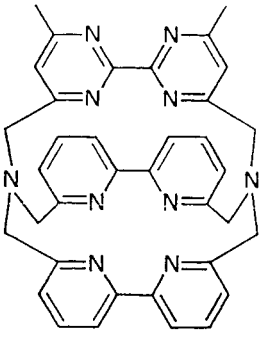

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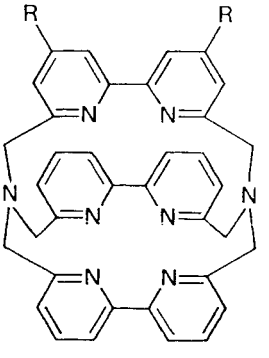
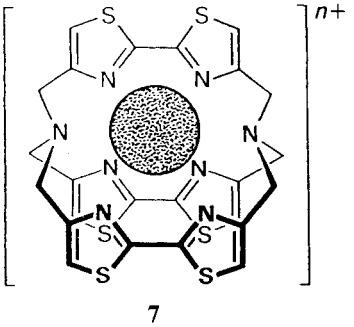


6a R = H
b R = Br
c R = NO_2
d R = COOEt



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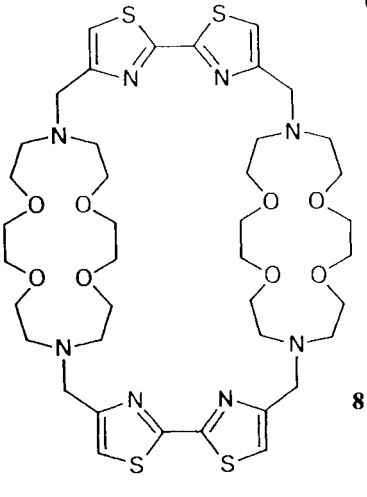

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see [16]). These complexes are expected to be of the inclusion type represented by **7** in the case of cryptand **1a**, as established earlier for related species [6–8]. The macrotricyclic cryptand **8** was also obtained.

Ligand Design. – Polyheterocyclic macrobicyclic ligands may be obtained following different synthetic strategies (see Scheme 1 in [4]). The final cyclisation step, making use of a template effect, yields the corresponding alkali-cation cryptates. Recently, the direct formation of Eu^{III} and Tb^{III} cryptates using this effect was reported [17]. The synthetic procedure requires the preparation of biheteroaryl units bearing bromomethyl or aminomethyl groups in the α and α' positions.

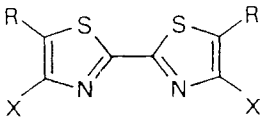
The biheteroaryl units were chosen with three goals in mind: *1*) to influence the energy-transfer processes in the luminescent cryptates through introduction of a new kind of heterocycle or through modification of the bpy unit by means of electro-active substituents, *2*) to introduce potential external complexation sites so as to allow the binding of cations on the outside of the cryptate and the study of interactions between the internal and external cations (see, *e.g.*, [18] for a case of such a type), and *3*) to modulate emission properties *via* external factors, in order to achieve luminescence switching effects.

Bis-heterocyclic Subunits. – *2,2'-Bithiazoles.* The general approach to compounds of this family rests on a double condensation of an α-haloketone with 1,2-dithiooxamide. Various 2,2'-bithiazoles bearing functionalities (CH_2CH_2OH, COOR, CN, $CSNH_2$) in α position to the S-atoms, and Me groups α to the N-sites were prepared earlier [19]. This procedure was adapted to the preparation of 4,4'-bis(chloromethyl)-2,2'-bithiazole from 1,3-dichloroacetone [20]. To obtain the required bis(bromomethyl) analog, we replaced 1,3-dichloroacetone by its brominated analog [21] which gave compound **9**, but in lower yield (7–15%). Treatment of **9** with excess NaN_3 in DMSO afforded the diazide **10** (92% yield) which, after reaction with triphenylphosphine and acidic hydrolysis of the resulting bis(phosphine-imine), gave **11**. The free diamine **12** was then liberated by passing an aqueous solution of **11** over an anion-exchange resin (basic form OH^-; 92% yield).

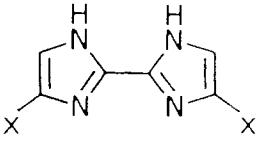
When ester functions were present in α-position to the S-atom, different procedures were employed: direct bromination of diethyl 4,4'-dimethyl-2,2'-bithiazole-5,5'-dicarboxylate [19] with *N*-bromosuccinimide (NBS) under light irradiation gave dibromide **13** (40% yield) together with the monobromide (20%) and the dissymmetric tribromide (9%). Reaction of an excess of NaN_3 with **13** in DMSO gave diazide **14** (87%) which was hydrogenated to diamine **15** (84%).

*2,2'-Bi-1*H*-imidazoles.* Unsubstituted, dimethyl- and tetramethyl-substituted biimidazoles were obtained by a double condensation of an α-ketoaldehyde with glyoxal in the presence of ammonium carbonate [22] [23] or by construction around dimethyl oxalimidate [24]. The tetracyano species was also described [25].

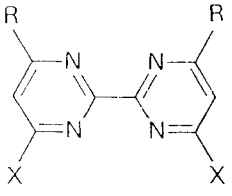
We tried unsuccessfully to functionalize these compounds by different ways. The preparation of 4(5),4'(5')-bis(trifluoromethyl)-2,2'-bi-1*H*-imidazole (**16**) was described and involved a double condensation starting from trifluoromethylglyoxal, ammonolysis in H_2O affording the corresponding dicyano derivative **17** [26]. We modified the synthesis of **16** by the direct preparation of **18** starting from glyoxal 1,1-diethyl acetal [27]. Hydrolysis of **18** afforded 4(5)-(trifluoromethyl)-1*H*-imidazole-2-carbaldehyde, which was then reacted to give **16** as described.



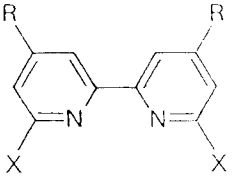
9 R = H, X = CH_2Br
10 R = H, X = CH_2N_3
11 R = H, X = $CH_2NH_3^+Cl^-$
12 R = H, X = CH_2NH_2
13 R = COOEt, X = CH_2Br
14 R = COOEt, X = CH_2N_3
15 R = COOEt, X = CH_2NH_2



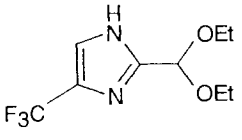
16 X = CF_3
17 X = CN
19 X = $CH_2NH_3^+Cl^-$
20 X = COOH
21 X = COOEt
23 X = CH_2Br ($\cdot$ 2 HBr)
22 X = CH_2OH



24 R = X = Me
25 R = X = Me, di-*N*-oxide
26 R = Me, X = CH_2OCOCF_3
27 R = Me, X = CH_2Br
28 R = Me, X = CH_2Cl
29 R = H, X = Me
30 R = H, X = CHO
31 R = H, X = COOH
32 R = H, X = COOEt



33 R = H, X = Me, di-*N*-oxide
34 R = NO_2, X = Me, di-*N*-oxide
35 R = NO_2, X = CH_2OCOCF_3
36 R = NO_2, X = CH_2Br
37 R = NO_2, X = CH_2OH
38 R = Br, X = CH_2Br
39 R = H, X = CH_2Br



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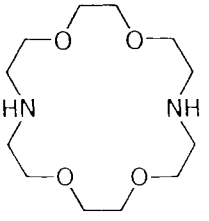

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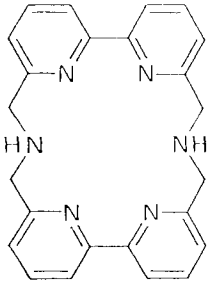

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Reduction of **17** [26] with $BH_3 \cdot THF$ followed by treatment with 6N HCl and purification *via* the picrate salt, afforded diammonium salt **19**. The free base was obtained impure by basification to pH 10 and was directly used in the macrobicyclisation reaction.

Alkaline hydrolysis of the CF_3 groups of **16**, as described for the corresponding monoimidazole [28], gave dicarboxylic acid **20**. Attempts to reduce diester **21** with $LiAlH_4$ were complicated by the lack of solubility of diol **22**. The latter was prepared by reduction

of **20** with $BH_3 \cdot THF$ and was purified *via* its picrate salt. Treatment of **22** with HBr/H_2O at 120° gave a crystalline precipitate which was shown to be the bis(hydrobromide) of the bis(bromomethylated) compound **23**. The free-base form of **23** could not be obtained, as also reported for the corresponding mono-imidazole [29].

2,2′-Bipyrimidines. No 2,2′-bipyrimidines functionalized at C(6) and C(6′) were found in the literature. Unsubstituted, dimethyl- and tetramethyl-substituted bpym were obtained by an *Ullmann*-type coupling over copper bronze of the corresponding 2-bromopyrimidine in boiling DMF [30] [31]. Some di- and tetrasubstituted phenyl and alkyl analogs were prepared using organolithium reagents [32]. We tried unsuccessfully to obtain these compounds by the Ni^0-mediated coupling reaction described for the preparation of 2,2′-bipyridines [33].

The tetramethyl-2,2′-bipyrimidine **24** was symmetrically functionalized *via* its $N^1,N^{1'}$-dioxide **25**, obtained by reaction of **24** with 3-chloroperbenzoic acid in $CHCl_3$. Rearrangement of **25** [34] by treatment with trifluoroacetic anhydride gave the corresponding bis(trifluoroacetate) **26** which, after treatment with LiBr in THF in the presence of a small amount of DMF under anhydrous conditions, afforded the bis(bromomethylated) analog **27** (25% yield). Following a procedure described for pyridine *N*-oxide [35], reaction of **25** with benzenesulfonyl chloride gave the bis(chloromethylated) compound **28** (25%).

The dimethyl-2,2′-bipyrimidine **29** could not be functionalized symmetrically, *e.g.*, by radical halogenation or *via* *N*-oxidation processes. Oxidation with SeO_2 in 1,4-dioxane afforded in low yield the corresponding dicarbaldehyde **30** contaminated by colloidal selenium; reduction of **30** with $NaBH_4$ gave the corresponding diol and acetylation of the crude reduction product a mixture of compounds containing the diacetate; treatment with HBr/AcOH or HBr/H_2O did not yield the bis(bromomethylated) derivative.

Oxidation of **29** with $KMnO_4$ in H_2O afforded the corresponding diacid **31**, but attempts to reduce **31** or its diester **32** into the diol did not give satisfactory results.

2,2′-Bipyridines. Introduction of NO_2 groups in the 4,4′-positions of 2,2′-bipyridine was achieved by several authors [36] by reaction of the *N,N′*-dioxide with H_2SO_4/HNO_3. Under the same conditions, 6,6′-dimethyl-2,2′-bipyridine *N,N′*-dioxide (**33**) [37] gave the 4,4′-dinitro analog **34** [38]. Treatment of **34** with trifluoroacetic anhydride afforded the corresponding diester **35** which was then transformed into its brominated analog **36** by treatment with an excess of anhydrous LiBr in THF in the presence of DMF. Hydrolysis of **35** at neutral pH yielded the corresponding diol **37**. Attempts to transform **37** into **36** with HBr/AcOH afforded in fact the tetrabrominated compound **38**, resulting from the substitution of the NO_2 groups by Br. Such a substitution was also observed for 4,4′-dinitro-2,2′-bipyridine *N,N′*-dioxide [39].

Macrobicyclic Sodium Cryptates of Ligands 1–6. – The macrobicyclic sodium cryptates were obtained by macrobicyclisation pathways corresponding to strategies *A* and *C* outlined earlier (see Scheme 1 in [4]). In all cases, the procedure involved the reaction of a diamine with a dibromide in presence of Na_2CO_3 in refluxing MeCN and afforded the sodium-bromide complex of the macrobicyclic ligand produced.

Direct symmetrical macrobicyclisation gave the NaBr cryptates of **1a** and **1b** from **12** and **9** (2 equiv.), and from **15** and **13** (2 equiv.), respectively, in 48 and 5% yields. This large difference in yields might arise from secondary reactions of the ester functions under the conditions employed.

Direct unsymmetrical macrobicyclisation gave the NaBr cryptates of **2a**, **2b**, and **4** by reaction of **12**, **15**, and the free base of **19**, respectively, with 2 equiv. of dibromide **39** [3], in 21, 18, and 14% yield. In the case of **4**, the overall yield was apparently much higher (*ca.* 40%), but the purification process afforded mother liquors in which the residual cryptate could not be separated from a tary material; purification by chromatography methods was unsuccessful.

The stepwise macrobicyclisation strategy *A* was followed in the condensation of **9** and **13** with the macrocyclic diamine **40** [40], yielding the NaBr cryptates of **3a** (21%) and **3b** (12%), respectively. The sodium-free macrotricyclic cryptand **8** was also isolated in 11% yield from the former reaction. Dibromides **27**, **38**, and **36** reacted with the macrocyclic diamine **41** [3] [41] to give the sodium cryptates **5**, **6b**, and **6c** respectively, in 14, 17, and 14% yield.

Except for **1a**, the yields of the macrocyclisations were low. Possible reasons could be the dissymmetry brought about by the new bis-heterocyclic subunits in the cage structure (cases of the five-membered heterocyclic groups), the reactivity of the substituents (COOEt, Br, or NO_2 groups), or a higher reactivity of the CH_2Br groups under the conditions of the reaction. The cryptates of **6b** and **6c** were unstable during the purification procedure. All new compounds were characterized by their ^1H- and ^{13}C-NMR spectra, FAB mass spectra (positive mode), and elemental analysis.

By analogy with the previously described cryptates of closely related type [3–9], the NaBr complexes obtained with the ligands **1–6** may be expected to present the same cryptate structure [Na ⊂ (ligand)]Br as illustrated by **7** for macrobicycle **1a**.

Except for the cases of ligands **1a** and **1b**, all studied cryptates are dissymmetric, one bridge of the macrobicyclic system being different from the other two. One may, therefore, expect that the protons of the CH_2 groups on the latter bridges be nonequivalent. In fact, because of accidental equivalence under the conditions used, *AB*-type patterns are only observed for the cryptates of **3** and **4** (J = 13 Hz). It was shown previously that torsional motion around the N,N′-bridgehead axis may be observed by variable-temperature ^1H-NMR spectroscopy; *e.g.*, the CH_2 *singlet* of the NaBr cryptate of the parent ligand **6a** splits into an *AB* pattern with a coalescence temperature of 235 K [3]. In the present cases, low-temperature measurements were made difficult by precipitation of the complexes. The cryptate of macrobicycle **5** showed a splitting of the CH_2 signals at low temperature (around 200 K) and a coalescence at *ca.* 245 K.

The UV spectra present absorption bands in the expected spectral domains. In view of the potential significance for the luminescence properties of lanthanide cryptates, one may note that the cryptates containing the btz unit (see **1–3**) or ester substituents present notable shifts towards longer wavelengths by *ca.* 20 nm to 315–320 nm, *e.g.* for **1a**, **2a**, and **3a**. When both structural features are present, shifts of *ca.* 40 nm are found, *e.g.* to *ca.* 345 nm for **2b** and **3b**. The extinction coefficient fo these bands are high in all cases (ε = 10000 (**2a**) – 35000 (**1a**) M^{-1} cm^{-1}; see *Exper. Part*).

Europium(III) Cryptates of the Macrobicyclic Ligands 2, 4, and 5. – The macrobicyclic cryptates obtained here contained a Na^+ cation introduced in the course of the synthesis. This ion was displaced by simply refluxing the complex in presence of an excess of $EuCl_3$ in MeOH solution in a manner similar to the preparation of the lanthanide complexes of the parent ligand **6a** [10] [11]. Thus, the $EuCl_3$ complexes of all ligands **1–5**, **6b**, and **6c** were prepared. However, because of solubility or purification problems, only

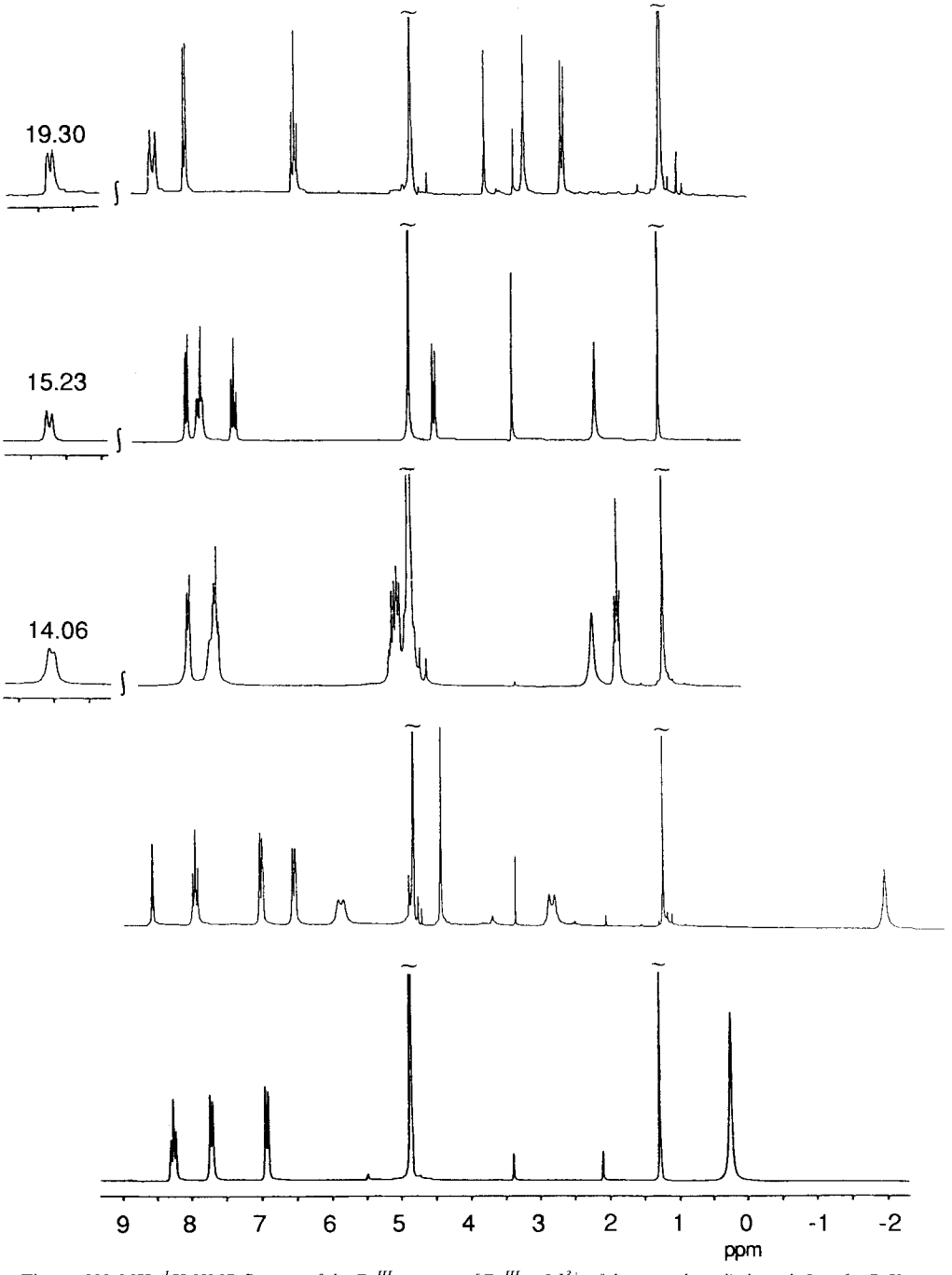

Figure. *200-MHz ^{1}H-NMR Spectra of the Eu^{III} cryptates $[Eu^{III} \subset L]^{3+}$ of the macrobicyclic ligands L* = **6a**, **5**, **2b**, **2a**, *and* **4** (from bottom to top). Aq. solution with *t*-BuOH as internal reference at 1.27 ppm, chemical shifts with respect to TMS.

Table. *^{1}H-NMR Chemical Shifts of Europium(III) Cryptates [$Eu^{III} \subset L$]Cl_3*[a])

L	N–CH_2–py		N–CH_2–heterocycle
	δ [ppm]	$\Delta\delta$ [ppm]	δ [ppm]
2a	7.88, 15.23 (*AX*)	7.35	2.19
2b	7.65, 14.06 (*AX*)	6.41	2.27 (*s*)
4	8.58, 19.30 (*AX*)	10.72	3.25 (*s*)
5	2.85, 5.90 (*AX*)	3.05	–1.89 (*s*)
6a [10]	0.33 (*s*)		
6d [42]	0.9 (*s*)		–0.78 (*s*)

[a]) 200-MHz spectra in aqueous solution containing *t*-BuOH as internal reference.

those of **2a**, **2b**, **4**, and **5** will be discussed here. By analogy to earlier work, the complexes obtained may be expected to be of cryptate type. This was confirmed by crystal-structure determination in the case of the La^{III}, Eu^{III}, and Tb^{III} complexes of the macrobicycles **6a** and **6d** [7].

The *^{1}H-NMR spectra* of the $EuCl_3$ cryptates of **2a**, **2b**, **4**, and **5** present several notable features. Some data are listed in the *Table*, together with those obtained for the complexes of ligands **6a** [10] [11] and **6d** [4] [42]. The corresponding spectra are represented in the *Figure* (see also data in the *Exper. Part*). As expected the introduction of the Eu^{III} ion causes a spreading out of the spectra over a wide domain (–2 to +20 ppm) and a broadening of the signals (10–100 Hz). The most interesting observations concern the trends in spectral changes as one goes from the complex of the symmetrical ligand **6a** to the complexes of the mixed ligands. The modifications observed become more and more pronounced along a series **6a**, **6d**, **5**, **2a**, and **4** that follows grossly a sequence of increasing departure from the structure of the symmetrical cryptate [$Eu^{III} \subset$ **6a**]$^{3+}$: *a*) the CH_2–py signal undergoes a very large downfield shift from *ca.* 0.3 (**6a**) to 19.3 ppm (**4**; centre of *AX* system); *b*) at the same time, the separation of the CH_2–py *AX d*'s increases very strongly, up to 10.7 ppm (**4**; *Table*) and, *c*) the CH_2–heterocycle signal undergoes a dowfield shift from –1.89 (**5**) to 3.25 ppm (**4**); *d*) the signals of the aromatic protons of the pyridine units spread out and shift upfield; *e*) the signals of the heterocyclic protons are also markedly affected by the introduction of the Eu^{III} ion, the largest effect being observed in the case of [$Eu^{III} \subset$ **4**]$^{3+}$, for which the imidazole proton shifts to 3.78 ppm from 6.80 ppm in the Na^I cryptate. It would thus appear that these spectral features could, to some extent, be indicative of the dissymmetrisation of the cryptate and of a change in the coordination characteristics of the Eu^{III} cation.

The *luminescence properties* of the Eu^{III} cryptates are much less pronounced than those of the parent complex [$Eu^{III} \subset$ **6a**]$^{3+}$, except in the case of the cryptate of **5**, which displays a very similar Eu^{III} emission spectrum under excitation of the ligand groups at 310 nm. The emission lifetimes of the complexes of **5** [43] and **6a** [10] are also the same (0.34 ms). The complexes containing a btz unit such as [$Eu^{III} \subset$ **2a**]$^{3+}$ display a blue emission at *ca.* 390 nm in addition to the emission from the Eu^{III} ion. The first one may be assigned to the 2,2′-bithiazole unit [44] [45]. A comparative study of the luminescence properties shows that both emissions of cryptate [$Eu^{III} \subset$ **2a**]$^{3+}$ are about an order of magnitude weaker than those of bithiazole reference compounds and of the complex of **6a**. Thus, a partial extinction of both emissions is found. As a consequence of the present observations, the Eu^{III} cryptates of ligands **1**–**4** are not suitable for use as luminescent labels. However, both the absorption and emission features of [$Eu^{III} \subset$ **5**]$^{3+}$ are of interest in this respect.

Outside – Inside Communication. – All ligands **1–5** that contain subunits btz, biz, or bpym present binding sites not only inside but also outside, on the external surface, of the macrobicycle. These subunits make possible a communication between the inside and the outside of the macrobicyclic structure. Thus, one may envisage influencing the properties of the cryptated species by interactions occurring on the outside. Preliminary experiments showed that Cu^{I} ions bind to the external N-sites of the bpym group of the cryptate $[Na^+ \subset \mathbf{5}]^{3+}$; this could allow the formation of a trinuclear species by coordination of two such complexes to a Cu^{I} ion through their bpym site. External effects on the emission of Eu^{III} cryptates would represent a luminescence switching feature which is of interest in the design of triggered molecular devices.

Experimental Part

General. All commercially available chemicals employed were reagent grade and used without further purification, unless stated otherwise. M.p.: *Thomas-Hoover* capillary apparatus; uncorrected. UV Spectra: *Varian-Cary-118* or *-219* spectrophotometer; λ_{max} in nm, ε in mol^{-1} lcm^{-1}. IR Spectra: *Perkin-Elmer-597* apparatus; region 4000–200 cm^{-1}; KBr matrix. Fluorescence: *Shimadzu-RF-540* apparatus (*Hamamatsu-HTV-R-928* photomultiplier), Xe lamp; uncorrected excitation; λ in nm. ^{1}H- and ^{13}C-NMR Spectra: *Bruker-SY-200* spectrometer at 200 and 50.3 MHz, respectively; chemical shifts δ in ppm from TMS (= 0 ppm) as internal standard; J in Hz. The MS (chemical ionization (CI), electron impact (EI), or fast-atom-Bombardment (FAB; pos. mode)) and the microanalyses were performed at the Laboratoire de Spectrométrie de Masse and at the Service Central de Microanalyse du CNRS, Strasbourg or Lyon.

4,4′-Bis(bromomethyl)-2,2′-bithiazole (**9**). A mixture of dithiooxamide (8,34 g, 69 mmol), 1,3-dibromoacetone (30 g, 131 mmol) and $CaCO_3$ (6.9 g, 69 mmol) in Me_2CO (100 ml) was refluxed with stirring for 6 h, then filtered when warm. The solid residue was washed with boiling Me_2CO (3 × 100 ml), and the combined filtrates were evaporated. The resulting solid was chromatographed (silica gel, CH_2Cl_2): **9** (4.4 g, 17%). M.p. 180–181°. UV ($CHCl_3$): 324 (15600). ^{1}H-NMR ($CDCl_3$): 4.58 (*s*, 2 CH_2); 7.40 (*s*, H–C(5), H–C(5′)). ^{13}C-NMR ($CDCl_3$): 26.1 (CH_2); 119.9 (C(5), C(5′)); 153.4 (C(4), C(4′)); 163.0 (C(2), C(2′)). EI-MS: 352, 354, 356 (1:2:1, M^+). Anal. calc. for $C_8H_6Br_2N_2S_2$ (354.1): C 27.11, H 1.69, N 7.91; found: C 27.34, H 1.69, N 7.81.

4,4′-Bis(azidomethyl)-2,2′-bithiazole (**10**). NaN_3 (1.48 g, 22.8 mmol) was suspended in DMSO (11.5 ml) and brought to 70°. Then, 4,4′-bis(chloromethyl)-2,2′-bithiazole (1 g, 3.9 mmol) was added in small portions and the mixture kept at 70° for 2 h. After cooling to r.t. H_2O (20 ml) was added and the mixture extracted with toluene (4 × 30 ml). The org. extracts were evaporated: **10** (1 g, 92%). M.p. 109–110°. UV ($CHCl_3$): 320 (15200). IR (KBr): 2160–2000 (N_3). ^{1}H-NMR ($CDCl_3$): 4.51 (*s*, 2 CH_2); 7.32 (*s*, H–C(5), H–C(5′)). ^{13}C-NMR ($CDCl_3$): 50.0 (CH_2); 118.9 (C(5), C(5′)); 152.6 (C(4), C(4′)); 162.0 (C(2), C(2′)). EI-MS: 278 (M^+), 250 ($[M - N_2]^+$), 236 ($[M - N_3]^+$), 208 ($[M - N_2 - N_3]^+$), 194 ($[M - 2\,N_3]^+$). Anal. calc. for $C_8H_6N_8S_2$ (278.32): C 34.52, H 2.17, N 40.26; found: C 34.65, H 2.02, N 40.11.

4,4′-Bis(aminomethyl)-2,2′-bithiazole Bis(hydrochloride) (**11**). To a soln. of **10** (0.9 g, 3.24 mmol) in dry Et_2O (170 ml), PPh_3 (1.7 g, 6.48 mmol) was slowly added. The soln. was brought to reflux, and a white solid precipitated after 1 h. Reflux was continued for 1 h 30 min and the mixture concentrated to 30 ml; then EtOH (30 ml), H_2O (5 ml), and conc. HCl soln. (2 ml) were added; remaining Et_2O was evaporated, and reflux was continued for 150 h. After cooling, H_2O (20 ml) was added and EtOH evaporated. The resulting suspension was extracted with CH_2Cl_2 to remove PPh_3 and its oxide, then excess of EtOH was added to precipitate **11**: 0.77 g (70%). IR (KBr): 3100–2700 (NH_3^+). ^{1}H-NMR (D_2O/*t*-BuOH): 4.31 (*s*, 2 CH_2); 7.8 (*s*, H–C(5), H–C(5′)). ^{13}C-NMR (D_2O/*t*-BuOH): 40.2 (CH_2); 123.8 (C(5), C(5′)); 150.5 (C(4), C(4′)); 164.0 (C(2), C(2′)). Anal. calc. for $C_8H_{12}Cl_2N_4S_2$ (299.24): C 32.10, H 4.04, N 18.74; found: C 31.98, H 3.92, N 18.52.

4,4′-Bis(aminomethyl)-2,2′-bithiazole (**12**). A soln. of **11** (0.2 g, 0.67 mmol) in bidistilled H_2O (1 ml) was chromatographed on a *Dowex-1 × 8-100* anion-exchange resin to give the free base **12** (0.138 g, 91%). M.p. 146–147°. IR (KBr): 3340, 3065 (NH_2), 1640–1570 (CH_2–NH_2). ^{1}H-NMR (CD_3OD): 3.97 (*s*, 2 CH_2); 7.50 (*s*, H–C(5), H–C(5′)). ^{13}C-NMR ($CDCl_3$/CD_3OD): 41.7 (CH_2); 115.5 (C(5), C(5′)); 158.9 (C(4), C(4′)); 161.2 (C(2), C(2′)). EI-MS: 227 ($[M + H]^+$). Anal. calc. for $C_8H_{10}N_4S_2 \cdot 0.5\,H_2O$ (230.8): C 41.63, H 4.47, N 24.32; found: C 42.05, H 4.50, N 23.95.

Diethyl 4,4'-Bis(bromomethyl)-2,2'-bithiazole-5,5'-dicarboxylate (**13**). A mixture of diethyl 4,4'-dimethyl-2,2'-bithiazole-5,5'-dicarboxylate (0.2 g, 0.59 mmol) and *N*-bromosuccinimide (0.21 g, 1.17 mmol) in CCl_4 (20 ml) was refluxed under N_2 for 20 min, and then benzoyl peroxide (0.005 g) was added. The mixture was refluxed under light irradiation (tungsten lamp, 100 W) for 4 h. After cooling, succinimide was filtered off, and the concentrated filtrate was first chromatographed on a short silica-gel column (CH_2Cl_2), then on a radial centrifugally accelerated prep. TLC plate (*Chromatotron, Harrison Research*; silica gel, CH_2Cl_2/hexane 1:1, then 0.7:0.3) to give **13** (0.12 g, 41%) and the monobromo and the tribromo equivalents (21 and 9.5%, resp.). M.p. 185–186°. UV ($CHCl_3$): 345 (24400). IR (KBr): 1730–1700 (COOEt). ^{1}H-NMR ($CDCl_3$): 1.38 (*t*, *J* = 7.1, 2 CH_3CH_2); 4.39 (*q*, *J* = 7.1, 2 CH_3CH_2); 4.93 (*s*, 2 CH_2Br). ^{13}C-NMR ($CDCl_3$): 14.1 (CH_3CH_2); 21.4 (CH_2Br); 62.2 (CH_3CH_2); 127.6 (C(4), C(4')); 158.6, 160.6, 162.1 (C(2), C(2'), C(5), C(5'), *C*OOEt). EI-MS: 496–498–500 (1:2:1, M^+). Anal. calc. for $C_{14}H_{14}Br_2N_2O_4S_2$ (498.22): C 33.76, H 2.83, N 5.62; found: C 33.88, H 2.81, N 5.49.

Diethyl 4,4'-Bis(azidomethyl)-2,2'-bithiazole-5,5'-dicarboxylate (**14**). To a suspension of NaN_3 (1.04 g, 1.6 mmol) in DMSO (8 ml) at 80°, **13** (0.4 g, 0.8 mmol) was added with 5 ml of DMSO and the mixture stirred for 20 min. After cooling, H_2O (40 ml) was added and the precipitate extracted with toluene (4 × 5 ml). Evaporation gave a solid which, after chromatography (SiO_2, CH_2Cl_2), afforded pure **14** (0.29 g, 87%). M.p. 125–126°. UV ($CHCl_3$): 344 (27600). IR (KBr): 2100 (N_3), 1750–1650 (COOEt). ^{1}H-NMR ($CDCl_3$): 1.37 (*t*, *J* = 7.1, 2 CH_3CH_2); 4.37 (*q*, *J* = 7.1, 2 CH_3CH_2); 4.79 (*s*, 2 CH_2N_3). ^{13}C-NMR ($CDCl_3$): 14.1 (CH_3CH_2); 48.0 (CH_2N_3); 62.5 (CH_3CH_2); 127.6 C(4), C(4')); 157.8, 160.7, 162.5 (C(2), C(2'), C(5), C(5'), *C*OOEt). EI-MS: 422 (M^+), 394 ($[M - N_2]^+$), 380 ($[M - N_3]^+$), 365 ($[M - N_2 - Et]^+$). Anal. calc. for $C_{14}H_{14}N_8O_4S_2$ (422.45): C 39.80, H 3.34, N 26.53; found: C 40.07, H 3.20, N 26.36.

Diethyl 4,4'-Bis(aminomethyl)-2,2'-bithiazole-5,5'-dicarboxylate (**15**). A mixture of **14** (0.05 g, 0.118 mmol) and 5% Pd/C (5 mg) in CH_2Cl_2/EtOH 1:2 (10 ml) was stirred under H_2 (1 atm) at r.t. for 3 h. After filtering through *Celite*, evaporation afforded a brown solid which was dissolved in MeOH (2 ml). The soln. was filtered over coton wool and evaporated: **15** (0.037 g, 84%). IR (KBr; protonated form): 3200–2700 (NH_3^+), 1700 (COOEt). ^{1}H-NMR (CD_3OD): 1.43 (*t*, *J* = 7, 2 CH_3CH_2); 4.26 (*s*, 2 CH_2NH_2); 4.43 (*q*, *J* = 7, 2 CH_3CH_2). FAB-MS (protonated form): 371 (M^+).

*4(5)-(Trifluoromethyl)-1*H*-imidazole-2-carbaldehyde Diethyl Acetal* (**18**). A mixture of 1,1,1-trifluoro-3,3-dibromoacetone (7.4 g, 27.4 mmol), $Na_2CO_3 \cdot 3\ H_2O$ (7.46 g, 54.8 mmol), and H_2O (25 ml) was refluxed for 30 min, cooled to r.t., and then added under stirring to a soln. of glyoxal 1,1-diethyl acetal (3.64 g, 27.4 mmol) in MeOH (135 ml). To this soln. was added conc. NH_3 soln. (*d* = 0.88; 35 ml, 685 mmol), and the resulting mixture was stirred for 4 h and then concentrated *in vacuo* at r.t. to give a voluminous precipitate which was filtered off. The filtrate was concentrated to the tenth to give a second crop of **18**. Total: 3.5 g (53%). M.p. 91–92°. IR (KBr): 1150 ($CH(OEt)_2$), 1130 (CF_3).^{1}H-NMR (CD_3OD): 1.28 (*t*, *J* = 4.5, 2 CH_3CH_2); 3.67 (*q*, *J* = 4.5, 2 CH_3CH_2); 5.61 (*s*, *CH*$(OEt)_2$); 7.57 (*s*, H–C(5 or 4)). ^{13}C-NMR ($CDCl_3$): 14.8 (CH_3CH_2); 62.0 (CH_3CH_2); 96.0 (*C*H$(OEt)_2$); 116.5 (CH(5 or 4)); 121.6 (*q*, $^1J_{(F,C)}$ = 266, CF_3); 131.5 (*q*, $^2J_{(F,C)}$ = 38, C(4 or 5)). EI-MS: 238 (M^+). Anal. calc. for $C_9H_{13}F_3N_2O_2$ (238.21): C 45.38, H 5.50, N 11.76; found: C 45.19, H 5.48, N 11.74.

*4(5),4'(5')-Bis(aminomethyl)-2,2'-bi-1*H*-imidazole Bis(hydrochloride)* (**19**). At 0°, 2,2'-bi-1*H*-imidazole-4(5),4'(5')-dicarbonitrile [26] (**17**; 0.3 g, 1.63 mmol) was added to 0.8M $BH_3 \cdot$THF in THF (25 ml, 20 mmol). The mixture was stirred under N_2 for 3 h at r.t. The resulting suspension was carefully added to anh. MeOH (100 ml) and stirred for 1 h. The precipitate was then filtered off, dried *in vacuo*, and treated 30 min with 6N HCl (20 ml) at 85°. The resulting soln. was evaporated; the solid residue dissolved in the minimum of H_2O, and the soln. basified to pH 10 with 2N NaOH and immediately added to an excess of a warm sat. aq. picric-acid soln. After cooling, the picrates were filtered off, crystallized twice in H_2O and then treated at 80° with 3N HCl (20 ml) in presence of toluene. Picric acid was removed with the org. phase and by multiple washings of the H_2O soln. with Et_2O. Evaporation *in vacuo* of HCl and H_2O afforded a white solid which was dissolved in the minimum of MeOH and precipitated with anh. Et_2O: **19** (0.25 g, 45%). ^{1}H-NMR (D_2O/*t*-BuOH): 4.32 (*s*, 2 CH_2); 7.57 (*s*, H–C(5 or 4), H–C(5' or 4')). ^{13}C-NMR (D_2O/*t*-BuOH): 36.6 (CH_2); 123.3 (CH(5 or 4), CH(5' or 4')); 132.4 (C(4 or 5), C(4' or 5')); 135.2 (C(2), C(2')). FAB-MS: 232 ($[M - 2\ HCl]^+$). Anal. calc. for $C_8H_{12}N_6 \cdot$MeOH $\cdot$ 3 HCl (333.65): C 32.39, H 5.74, N 25.18; found: C 32.11, H 5.53, N 25.95.

*2,2'-Bi-1*H*-imidazole-4(5),4'(5')-dicarboxylic Acid* (**20**). At 95°, 4(5),4'(5')-bis(trifluoromethyl)-2,2'-bi-1*H*-imidazole [26] (**16**, 0.56 g, 2.07 mmol) was dissolved in 1N NaOH (60 ml), and stirring was continued for 2 h. The cooled soln. was acidified to pH 1.5 with 12N HCl and the resulting precipitate recovered by centrifugation, rinsed twice with H_2O, then dried to give **20** · 4 HCl (0.59 g, 77%). ^{1}H-NMR ((D$_6$)DMSO): 7.87 (H–C(5 or 4), H–C(5' or 4')). ^{13}C-NMR (D_2O/*t*-BuOH/NaOD): 133.0 (CH(5 or 4), CH(5' or 4')); 138.1 (C(2), C(2')); 150.2 (C(4 or 5), C(4' or 5')); 174.1 (COOH). Anal. calc. for $C_8H_6N_4O_4 \cdot 4$ HCl $\cdot$ 0.5 H_2O (369.99): C 25.35, H 2.96, N 14.78; found: C 25.15, H 2.30, N 14.63.

*Diethyl 2,2′-Bi-1*H*-imidazole-4(5),4′(5′)-dicarboxylate* (**21**). A mixture of **20** (0.3 g, 0.81 mmol), EtOH (20 ml), and conc. H_2SO_4 soln. (1 ml) was refluxed for 10 h. After cooling, the soln. was neutralized with a sat. aq. K_2CO_3 soln., then extracted with $CHCl_3$ (3 × 100 ml). The combined org. phases were dried ($MgSO_4$) and evaporated: **21** (0.19 g, 81%). M.p. 249–250°. UV (CH_2Cl_2/EtOH 9:1): 282 (26000), 295 (20700), 274 (22900), 308 (9300). ^{1}H-NMR (CD_3OD): 1.41 (*t*, *J* = 6, 2 CH_3CH_2); 4.37 (*q*, *J* = 6, 2 CH_3CH_2); 7.89 (*s*, H–C(5 or 4), H–C(5′ or 4′)). ^{13}C-NMR ($CDCl_3$/CD_3OD): 14.3 (CH_3CH_2); 60.7 (CH_3CH_2); 125.2 (CH(5 or 4), CH(5′ or 4′)); 131.4, 139.5 (C(2), C(2′), C(4 or 5), C(4′ or 5′)); 161.9 (*C*OOEt). EI-MS: 278 (M^+), 160 ([M – COOEt – OEt]$^+$). Anal. calc. for $C_{12}H_{14}N_4O_4 \cdot 0.5\ H_2O$ (278.28): C 50.17, H 5.26, N 19.50; found: C 50.73, H 5.04, N 19.51.

*2,2′-Bi-1*H*-imidazole-4(5),4′(5′)-dimethanol* (**22**). Diacid **20** (0.3 g, 0.81 mmol) was treated by 0.8M $BH_3 \cdot$THF in THF (80 ml, 64 mmol) under N_2 for 24 h at r.t. The resulting mixture was then carefully added to anh. MeOH (100 ml), stirred for 2 h, and evaporated. The solid was treated with 6N HCl (100 ml) at 70° up to dissolution. The resulting soln. was evaporated and the solid dissolved in H_2O (50 ml), then filtered. The filtrate was concentrated and then basified with the minimum of sat. aq. K_2CO_3 soln., the resulting precipitate dissolved with the minimum of 1N H_2SO_4, and the mixture poured in a warm sat. aq. picric-acid soln. (200 ml). After cooling, the picrates were filtered off, crystallized twice in H_2O, and treated with 6N HCl (20 ml) in the presence of toluene at 80°. Picric acid was removed with the org. phase and by multiple washings of the aq. phase with Et_2O. Evaporation of H_2O and HCl afforded **22** · 2 HCl (0.1 g, 46%) which, treated with K_2CO_3, gave quantitatively the insoluble **22**. M.p. > 300°. ^{1}H-NMR ((D$_6$)DMSO): 3.40 (br. *s*, 2 NH); 4.40 (*s*, 2 CH_2); 4.90 (br., 2 OH); 6.91 (*s*, H–C(5 or 4), H–C(5′ or 4′)). Anal. calc. for $C_8H_{10}N_4O_2$ (194.19): C 49.48, H 5.19, N 28.85; found: C 49.17, H 5.44, N 28.79.

22 · 2 HCl: ^{1}H-NMR (D_2O/*t*-BuOH): 4.52 (*s*, 2 CH_2); 7.46 (*s*, H–C(5 or 4), H–C(5′ or 4′)). ^{13}C-NMR (D_2O/*t*-BuOH): 56.2 (CH_2OH); 121.7 (CH(5 or 4), CH(5′ or 4′)); 133.1 (C(2), C(2′)); 138.8 (C(4 or 5), C(4′ or 5′)). EI-MS: 194 (M^+). Anal. calc. for $C_8H_{10}N_4O_2 \cdot 2$ HCl (267.11): C 35.97, H 4.53, N 20.98; found: C 36.07, H 4.40, N 20.72.

*4(5),4′(5′)-Bis(bromomethyl)-2,2′-bi-1*H*-imidazole Bis(hydrobromide)* (**23**). At 120°, **22** · 2 HCl (0.5 g, 1.87 mmol) was treated by 48% HBr in H_2O (25 ml) for 6 h. After solubilisation, a voluminous precipitate was formed, which, after cooling, was filtered off and carefully dried *in vacuo*: unpurified **23** (0.8 g, 89%). M.p. *ca.* 270° (dec.). ^{1}H-NMR ((D$_6$)DMSO): 4.76 (*s*, 2 CH_2Br); 7.69 (*s*, H–C(5 or 4), H–C(5′ or 4′)). CI-MS (MeOH soln., NH_3): 222 (M^+ of bis(methyl ether)). Anal. calc. for $C_8H_8Br_2N_4 \cdot 2$ HBr (481.83): C 19.94, H 2.09, N 11.63; found: C 19.99, H 2.09, N 10.49.

4,4′,6,6′-Tetramethyl-2,2′-bipyrimidine N^1,$N^{1'}$*-Dioxide* (**25**). To a soln. of 4,4′6,6′-tetramethyl-2,2′-bipyrimidine (**24**; 0.5 g, 2.33 mmol) in 5 ml of $CHCl_3$, was slowly added a soln. of 3-chloroperbenzoic acid (1.05 g, 6 mmol) in $CHCl_3$. Addition of a slight excess of 3-chloroperbenzoic acid allowed consumption of the intermediate mono-*N*-oxide. After *ca.* 30 h (TLC monitoring (Al_2O_3, CH_2Cl_2/MeOH 95:5)), the solvent was evaporated and the solid residue chromatographed (alumina, CH_2Cl_2/MeOH 98:2): **25** (0.51 g, 88%). M.p. > 250°. UV (CH_2Cl_2): 279 (15800), 328 (4700). IR (KBr): 1610*s* and 1450 (br., N→O). ^{1}H-NMR ($CDCl_3$): 2.49, 2.51 (2*s*, 4 Me); 7.21 (*s*, H–C(5), H–C(5′)). ^{13}C-NMR ($CDCl_3$): 16.5 (*Me*–C(4), *Me*–C(4′)); 22.6 (*Me*–C(6), *Me*–C(6′)); 121.5 (C(5), C(5′)); 150.3 (C(2), C(2′)); 152.9, 155.4 (C(4), C(4′), C(6), C(6′)). EI-MS: 246 (M^+), 230 ([M – O]$^+$), 214 ([M – 2O]$^+$), 199 ([M – 2O – Me]$^+$). Anal. calc. for $C_{12}H_{14}N_4O_2$ (246.27): C 58.52, H 5.73, N 22.75; found: C 58.03, H 5.60, N 22.39.

4,4′-Dimethyl-2,2′-bipyrimidine-6,6′-dimethyl Bis(trifluoroacetate) (**26**). Compound **25** (0.1 g, 0.4 mmol) was dissolved in trifluoroacetic anhydride (1 ml) at 0° and kept at r.t. under N_2 for 24 h. Excess of anhydride and the resulting acid were evaporated, and the oily residue was dissolved in $CHCl_3$ (20 ml) and the soln. washed with sat. aq. $NaHCO_3$ soln. (1 ml), filtered over cotton wool, and evaporated: **26** which was used without further purification (90% pure by ^{1}H-NMR). ^{1}H-NMR ($CDCl_3$): 2.70 (*s*, 2 Me); 5.54 (*s*, 2 CH_2OCOCF_3); 7.30 (*s*, H–C(5), H–C(5′)).

6,6′-Bis(bromomethyl)-4,4′-dimethyl-2,2′-bipyrimidine (**27**). To a soln. of **26** (obtained from **25** (0.2 g, 0.81 mmol)) in anh. THF under N_2, anh. LiBr (dried *in vacuo*, 150°, 3 h; 0.5 g, 5.7 mmol) was added, followed by anh. DMF (dist. over CaH_2; 0.1 ml). The pH was brought to 7 with Et_3N, the resulting mixture stirred under N_2 for 20 h and evaporated, and the residue chromatographed (alumina, CH_2Cl_2): **27** (0.06 g, 20%). M.p. 148.5–149.5°. ^{1}H-NMR ($CDCl_3$): 2.70 (*s*, 2 Me); 4.57 (*s*, 2 CH_2Br); 7.49 (*s*, H–C(5), H–C(5′)). ^{13}C-NMR ($CDCl_3$): 24.5 (Me); 31.7 (CH_2Br); 120.1 (C(5), C(5′)); 162.3 (C(2), C(2′)); 165.7, 169.5 (C(4), C(4′), C(6), C(6′)). EI-MS: 372 (M^+). Anal. calc. for $C_{12}H_{12}Br_2N_4$ (372.07): C 38.74, H 3.25, N 15.06; found: C 39.01, H 3.26, N 14.92.

6,6′-Bis(chloromethyl)-4,4′-dimethyl-2,2′-bipyrimidine (**28**). A mixture of **25** (0.2 g, 0.81 mmol), benzenesulfonyl chloride (0.5 ml, 4 mmol), and benzene (20 ml) was heated at 65° under N_2 for 25 h. The warm soln. was filtered on cotton wool and evaporated. The oily residue was submitted to prep. TLC (SiO_2, AcOEt) and the desired compound recovered from the support by elution with CH_3COCH_3/CH_2Cl_2 2:8. Crystallization from acetone (slow evaporation) afforded **28** (0.065 g, 25%). M.p. 124–125°. ^{1}H-NMR ($CDCl_3$): 2.71 (*s*, 2 Me); 4.75 (*s*,

2 CH_2Cl); 7.55 (*s*, H–C(5), H–C(5′)). ^{13}C-NMR ($CDCl_3$): 24.7 (Me); 45.2 (CH_2Cl); 118.9 (C(5), C(5′)); 162.0 (C(2), C(2′)); 165.8, 169.7 (C(4), C(4′), C(6), C(6′)). EI-MS: 282 (M^+). Anal. calc. for $C_{12}H_{12}Cl_2N_4 \cdot 0.2\ C_6H_6$ (298.78): C 53.06, H 4.45, N 18.75; found: C 53.26, H 4.41, N 18.35.

2,2′-Bipyrimidine-4,4′-dicarbaldehyde (**30**). A mixture of 4,4′-dimethyl-2,2′-bipyrimidine (**29** [30] [31]; 0.3 g, 1.6 mmol), dioxane (15 ml), H_2O (0.4 ml), and SeO_2 (0.36 g, 3.2 mmol) was heated at 100°. Evolution of the oxydation was monitored by TLC (Al_2O_3, CH_2Cl_2/MeOH 9:1), and addition of a few mg of SeO_2 allowed quasi total consumption of the intermediate mono-aldehyde. The warm mixture was filtered over *Celite* and the metallic residue rinsed with large quantities of boiling dioxane. The filtrates were evaporated, affording a solid containing large amounts of red colloidal Se. Double chromatography over alumina (CH_2Cl_2/MeOH 8:2) gave **30**, always polluted by small amounts of colloidal Se. M.p. 214–216°. IR (KBr): 1570 (CHO). ^{1}H-NMR (CD_3OD): 5.66 (*s*, 2 CHO); 7.83 (*d*, $J = 5$, 2 H, bpym); 9.10 (*d*, $J = 5$, 2 H, bpym). EI-MS: 214 (M^+). Anal. calc. for $C_{10}H_6N_4O_2 \cdot 2\ H_2O \cdot MeOH$ (282.25): C 46.8, H 4.99, N 19.85; found: C 47.3, H 4.95, N 19.54.

2,2′-Bipyrimidine-4,4′-dicarboxylic Acid (**31**). A soln. of **29** [30] [31] (0.4 g, 2.15 mmol) and NaOH (0.1 g, 2.5 mmol) in H_2O (10 ml) was heated under stirring at 90°. A soln. of $KMnO_4$ (1.36 g, 8.6 mmol) in H_2O (90 ml) was slowly added within 10 h. Excess $KMnO_4$ was destroyed by addition of a small amount of EtOH, and the mixture was filtered over *Celite*. The MnO_2 residue was washed with warm H_2O (100 ml), and the combined filtrates were evaporated and then acidified to pH 1.5 with 6N HCl, affording **31** · 2 H_2O (0.32 g, 50%). White solid. IR (KBr): 3700–3000 (br., COOH), 1700 (C=O). ^{1}H-NMR ((D$_6$)DMSO): 8.15 (*d*, $J = 5$, 2 H, bpym); 9.28 (*d*, $J = 5$, 2 H, bpym). Anal. calc. for $C_{10}H_6N_4O_4 \cdot 2\ H_2O$ (282.21): C 42.56, H 3.57, N 19.85; found: C 42.57, H 3.73, N 19.96.

Diethyl 2,2′-Bipyrimidine-4,4′-dicarboxylate (**32**). A mixture of **31** (0.5 g, 0.177 mmol), EtOH (10 ml), and H_2SO_4 (0.01 ml) was refluxed for 16 h. The cooled soln. was then neutralized with a sat. aq. K_2CO_3 soln. and the precipitate extracted with CH_2Cl_2 (100 ml). The org. layer was filtered on cotton wool and evaporated: **32** (0.042 g, 79%). IR (KBr): 1710 (COO). M.p. 167–168°. ^{1}H-NMR ($CDCl_3$): 1.49 (*t*, $J = 7$, 2 CH_3CH_2); 4.55 (*q*, $J = 7$, 2 CH_3CH_2); 8.14 (*d*, $J = 5$, 2 H, bpym); 9.26 (*d*, $J = 5$, 2 H, bpym). ^{13}C-NMR ($CDCl_3$): 14.0 (CH_3CH_2); 62.9 (CH_3CH_2); 120.9, 160.1 (CH, bpym); 156.4 (C(4), C(4′)); 162.4 (C(2), C(2′)); 163.7 (COOEt). EI-MS: 302 (M^+), 230 ([M + H – COOEt]$^+$). Anal. calc. for $C_{14}H_{14}N_4O_4$ (302.79): C 55.63, H 4.67, N 18.53; found: C 55.73, H 4.42, N 18.74.

6,6′-Dimethyl-4,4′-dinitro-2,2′-bipyridine N,N′-*Dioxide* (**34**). A soln. of 6,6′-dimethyl-2,2′-bipyridine *N,N′*-dioxide (**33** [37]; 0.6 g, 2.78 mmol) in conc. H_2SO_4 soln. (2.4 ml) was cooled to 0°. Fuming nitric acid (1.8 ml) was carefully added and the mixture heated to 100° for 6 h. After cooling to 0°, the soln. was added to crushed ice (20 g) and the resulting precipitate filtered off, washed with H_2O (10 ml), and dried in an air current. This solid was dissolved in $CHCl_3$ (150 ml), the residual acidity neutralized with 1.5 ml of aq. sat. $NaHCO_3$ soln., and the org. phase filtered over cotton wool and evaporated: **34** (0.5 g, 60%). M.p. > 250°. IR (KBr): 1510 and 1325 (NO_2), 1275 (N→O). ^{1}H-NMR ((D$_6$)DMSO): 2.48 (*s*, 2 Me and DMSO); 8.53 (*s*, 2 H, bpy); 8.62 (*s*, 2 H, bpy). Anal. calc. for $C_{12}H_{10}N_4O_6 \cdot 0.5\ H_2O$ (315.24): C 45.72, H 3.51, N 17.77; found: C 45.61, H 3.16, N 18.08.

4,4′-Dinitro-2,2′-bipyridine-6,6′-dimethyl Bis(trifluoroacetate) (**35**). A mixture of **34** (0.02 g, 0.066 mmol), trifluoroacetic anhydride (1 ml), and $CHCl_3$ (5 ml) was refluxed under N_2 for 1 h. After evaporation the residue was dissolved in $(CF_3CO)_2O$ (1 ml) and kept under reflux for 60 h. Excess of anhydride and the resulting acid were then evaporated, and the residue was chromatographed (silica gel, CH_2Cl_2): unstable **35** (0.02 g, 60%). ^{1}H-NMR ($CDCl_3$): 5.69 (*s*, 2 CH_2OCOCF_3); 8.17 (*d*, $J = 1.5$, 2 H, bpy); 9.11 (*d*, $J = 1.5$, 2 H, bpy). EI-MS: 401 ([M – CF_3CO]$^+$), 498 (M^+).

6,6′-Bis(bromomethyl)-4,4′-dinitro-2,2′-bipyridine (**36**). To the unpurified **35** (from **34** (0.5 g, 1.65 mmol)) in anh. THF (10 ml) were added anh. LiBr (1.5 g, 17 mmol; dried *in vacuo* at 150°, 5 h) and 4 drops of anh. DMF (dist. over CaH_2). This mixture was stirred for 60 h under N_2 and then evaporated and the tarry residue chromatographed (alumina, CH_2Cl_2): **36** (0.4 g, 56% based on **34**). M.p. 175°. UV (CH_2Cl_2): 320 (10400). IR (KBr): 1580, 1415 (NO_2). ^{1}H-NMR ($CDCl_3$): 4.73 (*s*, 2 CH_2Br); 8.25 (*d*, $J = 1.9$, 2 H, bpy); 9.09 (*d*, $J = 1.9$, 2 H, bpy). ^{13}C-NMR ($CDCl_3$): 32.0 (CH_2Br); 113.7, 117.3 (CH, bpy); 156.0, 156.3 (C(2), C(2′), C(6), C(6′)); 160.0 (C(4), C(4′)). EI-MS: 432 (M^+). Anal. calc. for $C_{12}H_8Br_2N_4O_4$ (432.04): C 33.36, H 1.87, N 12.97; found: C 33.64, H 1.88, N 12.75.

4,4′-Dinitro-2,2′-bipyridine-6,6′-dimethanol (**37**). To a soln. of **35** (0.245 g, 0.49 mmol) in THF/H_2O 1:1 (10 ml), $NaHCO_3$ (0.14 g, 1.6 mmol) was added. The mixture was stirred at r.t. for 20 h and the resulting precipitate filtered off to give a first fraction of **37**. H_2O (10 ml) was added to the filtrate to precipitate a second crop of **37** (0.14 g, 93% total yield). M.p. 225–226°. IR (KBr): 1525, 1345 (NO_2). ^{1}H-NMR ((D$_6$)DMSO): 4.85 (*d*, $J = 5$, 2 CH_2OH); 5.99 (*t*, $J = 5$, 2 OH); 8.24 (*d*, $J = 1.5$, 2 H, bpy); 8.83 (*d*, $J = 1.5$, 2 H, bpy). ^{13}C-NMR ((D$_6$)DMSO): 64.5 (CH_2OH); 112.3, 114.5 (CH, bpy); 156.0 (C(2), C(2′)); 156.6 (C(6), C(6′)); 167.0 (C(4), C(4′)). Anal. calc. for $C_{12}H_{10}N_4O_6$ (306.23): C 47.06, H 3.30, N 18.29; found: C 46.94, H 3.07, N 18.31.

4,4′-Dibromo-6,6′-bis(bromomethyl)-2,2′-bipyridine (**38**). A soln. of **37** (0.14 g, 0.46 mmol) in 33% HBr in AcOH (8 ml) was heated at 100° for 5 h. Evaporation gave a yellow solid residue which was chromatographed (silica gel, CH_2Cl_2/hexane 1:1): **38** (0.15 g, 65%). M.p. 222–223°. UV (CH_2Cl_2): 290 (18500). ^{1}H-NMR ($CDCl_3$): 4.53 (*s*, 2 CH_2Br); 7.63 (*d*, *J* = 1.7, 2 H, bpy); 8.52 (*d*, *J* = 1.7, 2 H, bpy). ^{13}C-NMR ($CDCl_3$): 32.6 (CH_2Br); 124.0, 127.2 (CH, bpy); 134.6 (C(4), C(4′)); 155.1, 157.6 (C(2), C(2′), C(6), C(6′)). EI-MS: 419 ([*M* − Br]$^+$), 500 (*M*$^+$). Anal. calc. for $C_{12}H_8Br_4N_2$ (499.84): C 28.83, H 1.61, N 5.60; found: C 29.04, H 1.60, N 5.46.

NaBr Complex of 4,4″4‴:4′,4‴,4⁗⁗-Bis[nitrilotris(methylene)]tris(2,2′-bithiazole) ([btz.btz.btz]; **1a**). To a mixture of **12** (0.14 g, 0.61 mmol) and Na_2CO_3 (0.65 g, 6.1 mmol) in MeCN (500 ml) heated at reflux under N_2, solid **9** (0.43 g, 1.2 mmol) was added. Reflux was continued for 15 h, then MeCN was evaporated. The residue was mixed with warm $CHCl_3$ and the resulting soln. filtered (2 × 200 ml). The combined filtrates were concentrated to 150 ml, filtered over paper, and cooled to 4° to give crystals of **1a** (0.19 g). The mother liquor was concentrated, then chromatographed (alumina, CH_2Cl_2/CH_3OH 8:2) to give an other crop of **1a** (0.05 g; total 48%). M.p. > 250°. UV ($CHCl_3$/MeCN 1:1): 315 (34000). ^{1}H-NMR ($CDCl_3$): 3.89 (*s*, 6 CH_2-btz); 7.40 (*s*, 6 H, btz). ^{13}C-NMR ($CDCl_3$/CD_3CN): 51.7 (N−CH_2-btz); 116.0 (CH, btz); 156.0 (C(4), C(4′)); 160.0 (C(2), C(2′)). FAB-MS: 633 [Na ⊂ L]$^+$). Anal. calc. for $C_{24}H_{18}N_8S_6 \cdot NaBr \cdot CHCl_3$ (833.09): C 34.60, H 2.18, N 13.45; found: C 34.51, H 2.12, N 13.34.

NaBr Complex of 6,6″:6′6‴-{N,N′-(2,2′-Bithiazole-4,4′-dimethyl)bis[iminobis(methylene)]}bis(2,2′-bipyridine) ([btz.bpy.bpy]; **2a**). A soln. of 6,6′-bis(bromomethyl)-2,2′-bipyridine (**39**, 0.36 g, 1.06 mmol) in MeCN (400 ml) was refluxed under N_2, and a mixture of solid **12** (0.12 g, 0.53 mmol) and Na_2CO_3 (0.56 g, 5.3 mmol) was added in one portion. Stirring and reflux were continued for 18 h, and the warm mixture was then filtered and evaporated. The solid was dissolved in $CHCl_3$ (10 ml), filtered over cotton wool, and then submitted to prep. TLC (silica gel, CH_2Cl_2/MeOH 8:2): **2a** (0.073 g, 21%). M.p. > 250°. UV (MeOH): 288 (30800), 233 (27600), 322 (11200). ^{1}H-NMR ($CDCl_3$): 3.70 (*s*, 2 CH_2-btz); 3.73 (*s*, 4 CH_2-bpy); 7.33–7.37 (*dd*, *J* = 6, 2, 4 H, bpy); 7.40 (*s*, 2 H, btz); 7.72–7.83 (*m*, 8 H, bpy). ^{13}C-NMR ($CDCl_3$): 53.2 (N−CH_2-btz); 59.3 (N−CH_2-bpy); 117.7 (CH, btz); 121.9, 124.9, 138.1 (CH, bpy); 155.2 (C(4), C(4′) of btz); 156.8, 159.0, 159.2 (C(6), C(6′), C(2), C(2′) of bpy, C(2), C(2′) of btz). FAB-MS: 609 ([Na ⊂ L]$^+$). Anal. calc. for $C_{32}H_{26}N_8S_2 \cdot NaBr \cdot 1.1\ CHCl_3$ (820.96): C 48.43, H 3.20, N 13.65; found: C 48.02, H 3.54, N 13.20.

NaBr Complex of 4,4′-[N,N′:N,N′-Bis(3,6-dioxaoctamethylene)bis(aminomethyl)]-2,2′-bithiazole (= 4,4′-[(1,4,10,12-Tetraoxa-7,16-diazacyclooctadecane-7,16-diyl)bis(methylene)]-2,2′-bithiazole; [2.2.bzt]; **3a**) *and Macrotricyclic Ligand 4,4′-[(2,2′-Bithiazole-4,4′-dimethyl)bis(1,4,10,13-tetraoxa-7,16-diazacyclooctadecane-7,16-diyl)bis(methylene)]-2,2′-bithiazole* ([2.2.btz-2.2-btz]; **8**). Diamine **40** (0.2 g, 0.76 mmol) was dissolved under N_2 in MeCN (100 ml), and Na_2CO_3 (0.8 g, 7.6 mmol) was added before heating to reflux. A soln. of **9** in MeCN (0.27 g, 0.76 mmol; 350 ml) was then added dropwise within 20 min. Reflux was continued for 20 h. Then the mixture, cooled to r.t., was filtered and the solid residue rinsed with warm $CHCl_3$ (100 ml). The combined filtrate was evaporated and the residue submitted to prep. TLC (alumina, CH_2Cl_2/MeOH 95:5): **8** (0.1 g, 11%) and impure **3a**. The latter was repurified by TLC (alumina, CH_2Cl_2/MeOH 96:4): 0.09 g (21%) of **3a**.

3a. M.p. > 250°. UV ($CHCl_3$): 322 (13700). ^{1}H-NMR ($CDCl_3$): 2.56–2.82 (*AB* (*m*), 4 CH_2N); 3.35–3.60 (*m*, 8 CH_2O); 3.73 (*s*, 2 CH_2-btz), 7.32 (*s*, 2 H, btz). ^{13}C-NMR ($CDCl_3$): 53.7 (CH_2N); 54.7 (N−CH_2-btz); 68.6, 69.9 (CH_2O); 116.5 (CH, btz); 156.6 (C(4), C(4′)); 159.4 (C(2), C(2′)). FAB-MS: 477 ([Na ⊂ L]$^+$). Anal. calc. for $C_{20}H_{30}N_4O_4S_2 \cdot NaBr \cdot MeCN$ (599.51): C 44.07, H 5.54, N 11.60; found: C 43.11, H 5.52, N 11.88.

8: M.p. 190–191°. UV ($CHCl_3$): 328 (24300). ^{1}H-NMR ($CDCl_3$): 2.72 (br. *t*, 8 CH_2N); 3.58–3.68 (*t*, *s*, 16 CH_2O); 3.74 (*s*, 4 CH_2-btz); 7.62 (*s*, 4 H, btz). ^{13}C-NMR ($CDCl_3$): 54.9 (CH_2N); 55.7 (N−CH_2-btz); 69.8–71.0 (CH_2O); 117.6 (CH, btz); 156.5 (C(4), C(4′)); 160.7 (C(2), C(2′)). EI-MS: 907.9 (*M*$^+$), 715.8 ([*M* − btz]$^+$), 654.6 ([*M* − $C_{12}H_{24}N_2O_4$]$^+$), 454.7 ([*M* − btz − $C_{12}H_{24}N_2O_4$]$^+$), 194.9 (100, btz). Anal. calc. for $C_{40}H_{60}N_8O_8S_4 \cdot 1.8\ CHCl_3$ (1124.11): C 44.66, H 5.54, N 9.97; found: C 44.66, H 5.50, N 10.03.

NaBr Complex of Hexaethyl 4,4″,4⁗⁗:4′,4‴,4⁗⁗-Bis[nitrilotris(methylene)]tris(2,2′-bithiazole)-5,5′,5″,5‴,5⁗⁗,5⁗⁗⁗-hexacarboxylate ([btz(COOEt)$_2$.btz(COOEt)$_2$.btz(COOEt)$_2$]; **1b**). To a mixture of **15** (0.11 g, 0.3 mmol) and Na_2CO_3 (0.3 g, 0.3 mmol) in MeCN (200 ml) heated at reflux under N_2 was added dropwise a soln. of **13** (0.3 g, 0.6 mmol) in MeCN (200 ml). Reflux was continued for 20 h, and the cooled mixture was filtered. The insoluble material was rinsed with CH_2Cl_2 and the combined filtrate evaporated. The residue was submitted to prep. TLC (alumina CH_2Cl_2/MeOH 95:5; then silica gel, CH_2Cl_2/MeOH 95:5): **1b** (0.015 g, 5%). ^{1}H-NMR ($CDCl_3$): 1.41 (*t*, *J* = 7, 6 CH_3CH_2); 4.27 (*s*, 6 CH_2N); 4.42 (*q*, *J* = 7, 6 CH_3CH_2). FAB-MS: 1065 ([Na ⊂ L]$^+$).

NaBr Complex of Diethyl 4,4′-{N,N′:N,N′-[Bis(2,2′-bipyridine-6,6′-dimethyl)]bis(aminomethyl)}-2,2′-bithiazole-5,5′-dicarboxylate ([btz(CO$_2$Et)$_2$ · bpy · bpy]; **2b**). To a soln. of **39** (0.072 g, 0.21 mmol) in MeCN (70 ml) at reflux under N_2, a mixture of solid **15** (0.039 g, 0.105 mmol) and Na_2CO_3 (0.11 g, 1 mmol) was added in one

portion. Refluxing was continued for 20 h, and the cooled mixture was then filtered. The insoluble material was washed with CH_2Cl_2 (100 ml) and the combined filtrate evaporated. The solid residue was twice submitted to prep. TLC (silica gel, CH_2Cl_2/MeOH 9:1): **2b** (0.016 g, 18%). M.p. 130° (dec.). UV ($CHCl_3$): 290 (28260), 346 (20400). IR (KBr): 1700 (COOEt). ^{1}H-NMR ($CDCl_3$): 1.36 (*t*, *J* = 7, 2 CH_3CH_2); 3.76 (*s*, 4 N–CH_2-bpy); 4.05 (*s*, 2 N–CH_2-btz(COOEt)$_2$); 4.36 (*q*, *J* = 7, 2 CH_3CH_2); 7.37 (*t*, *J* = 4, 4 H, bpy); 7.85 (*d*, *J* = 4, 8 H, bpy). ^{13}C-NMR ($CDCl_3$): 14.1 (CH_3CH_2); 53.0 (N–CH_2-btz(COOEt)$_2$); 59.8 (N–CH_2-bpy); 62.3 (CH_3CH_2); 126.7 (C(5), C(5′) of btz(COOEt)$_2$); 121.9, 124.8, 138.4 (CH, bpy); 156.6, 158.4 (C(6), C(6′), C(2), C(2′) of bpy); 160.1, 160.5 (C(4), C(4′), C(2), C(2′) of btz(COOEt)$_2$); 161.2 (COOEt). FAB-MS: 753 ([Na ⊂ L]$^+$). Anal. calc. for $C_{38}H_{34}N_8O_4S_2 \cdot NaBr \cdot 2\,H_2O$ (869.80): C 52.47, H 4.40, N 12.88; found: C 52.83, H 4.38, N 12.80.

*NaBr Complex of Diethyl 4,4′-[*N,N′:N,N′*-Bis(3,6-dioxaoctamethylene)bis(aminomethyl)]-2,2′-bithiazole-5,5′-dicarboxylate* (= *Diethyl 4,4′-[(1,4,10,13-Tetraoxa-7,16-diazacyclooctadecane-7,16-diyl)bis(methylene)]-2,2′-bithiazole-5,5′-dicarboxylate*; [2.2.btz(COOEt)$_2$]; **3b**). To a soln. of **13** (0.095 g, 0.191 mmol) in MeCN (85 ml) at reflux under N_2 were added Na_2CO_3 (0.2 g, 1.9 mmol) and **40** (0.05 g, 0.19 mmol). Reflux was continued for 28 h and the cooled mixture then filtered. The insoluble material was washed with CH_2Cl_2 (100 ml) and the combined filtrate evaporated. The residue was then submitted to prep. TLC (silica gel, CH_2Cl_2, then CH_2Cl_2/MeOH 94:6): **3b** (0.016 g, 12%). M.p. 200° (dec.). UV ($CHCl_3$): 344 (25300). IR (KBr): 1700 (COOEt). ^{1}H-NMR ($CDCl_3$): 1.36 (*t*, *J* = 7, 2 CH_3CH_2); 2.58–2.93 (*AB* (*m*), 4 CH_2N); 3.42–3.72 (*m*, 8 CH_2O); 4.11 (*s*, 2 N–CH_2-btz(COOEt)$_2$); 4.36 (*q*, *J* = 7, 2 CH_3CH_2). ^{13}C-NMR ($CDCl_3$): 14.0 (CH_3CH_2); 54.0 (CH_2N); 54.6 (N–CH_2-btz(COOEt)$_2$); 62.15 (CH_3CH_2); 68.2, 69.6 (CH_2O); 125.4 (C(5), C(5′) of btz(COOEt)$_2$); 160.1, 160.3 (C(2), C(2′), C(4), C(4′) of btz(COOEt)$_2$); 162.7 (COOEt). FAB-MS: 621 ([Na ⊂ L]$^+$). Anal. calc. for $C_{26}H_{38}N_4O_8S_2 \cdot NaBr$ (701.64): C 44.51, H 5.46, N 7.98; found: C 44.24, H 5.29, N 7.82.

NaBr Complex of 6,6″:6′,6‴-{N,N′*-(2,2′-Bi-1*H*-imidazole-4,4′-dimethyl)bis[iminobis(methylene)]*}*bis(2,2′-bipyridine)* ([biz·bpy·bpy]; **4**). To a soln. of **39** (0.5 g, 1.46 mmol) in MeCN (0.6 l) at reflux under N_2 were added Na_2CO_3 (0.83 g, 7.8 mmol) and the diamine obtained by basification of a soln. of **19** (0.26 g, 0.78 mmol) in H_2O at pH 10 with 1N NaOH and after drying *in vacuo*. Reflux was continued for 30 h, the mixture cooled to r.t. and filtered, the insoluble material washed with boiling CH_2Cl_2 (200 ml), and the combined filtrate evaporated. The residue was partially dissolved in CH_2Cl_2 (50 ml) and filtered again, the filtrate containing **4** and starting **39**. After evaporation of CH_2Cl_2, **39** was extracted with warm hexane. The remaining solid residue was then dried *in vacuo* and dissolved in 4.5 ml CH_2Cl_2/MeOH 8:1 and the soln. slowly evaporated: **4** (0.07 g, 14%). Needles. M.p. > 250°. UV (CH_2Cl_2/MeOH 92:8): 278 (31500), 236 (23600). ^{1}H-NMR ($CDCl_3$/CD_3OD): 3.49 (*s*, 2 N–CH_2-biz); 3.73 (*AB*, J_{AB} = 13, 4 N–CH_2-bpy); 6.80 (*s*, 2 arom. H, biz); 7.26 (*dd*, *J* = 7, 1, 4 H, bpy); 7.60 (*dd*, *J* = 7, 1, 4 H, bpy); 7.70 (*t*, *J* = 8, 4 H, bpy). ^{13}C-NMR ($CDCl_3$/CD_3OD): 50.9 (N–CH_2-biz); 59.2 (N–CH_2-bpy); 113.4 (CH, biz); 122.3, 124.6, 137.5 (CH; bpy); 138.4, 139.4 (C(2), C(2′), C(4), C(4′) of biz); 157.9, 159.8 (C(6), C(6′), C(2), C(2′) of bpy). FAB-MS: 575 ([Na ⊂ L]$^+$). Anal. calc. for $C_{32}H_{28}N_{10} \cdot NaBr$ (655.55): C 58.63, H 4.30, N 21.36; found: C 58.18, H 4.43, N 20.78.

NaBr Complex of 4,4′-{N,N′*:N,N′-[Bis(2,2′-bipyridine-6,6′-dimethyl)]bis(aminomethyl)*}*-6,6′-dimethyl-2,2′-bipyrimidine* ([bpym(Me)$_2$·bpy·bpy]; **5**). To a mixture of Na_2CO_3 (0.65 g, 6 mmol), **41** (0.27 g, 0.67 mmol), and MeCN (500 ml) at reflux under N_2 was added over 3 h a soln. of **27** (0.25 g, 0.67 mmol) in MeCN (100 ml). Reflux was continued for 30 h, the mixture, cooled to r.t., filtered, the solid material washed with boiling CH_2Cl_2 (2 × 100 ml), and the combined filtrate evaporated. The residue was submitted to prep. TLC (CH_2Cl_2/MeOH 96:4): **5** (0.07 g, 14%). UV (CH_2Cl_2): 246 (37250), 269 (22200), 310 (13000). ^{1}H-NMR ($CDCl_3$): 2.65 (*s*, 2 Me); 3.84 (*s*, 4 N–CH_2-bpy, 2 N–CH_2-bpym(Me)$_2$); 7.31–7.35 (*s*, *d*, 2 arom. H of bpym(Me)$_2$, 4 H of bpy); 7.75–7.89 (*d*, *t*, 8 H, bpy). ^{13}C-NMR ($CDCl_3$): 24.5 (Me); 58.4 (N–CH_2-bpym(Me)$_2$); 59.3 (N–CH_2-bpy); 120.6, 124.3, 138.2 (CH, bpy); 121.1 (arom. CH, bpym(Me)$_2$); 153.3, 158.3 (C(6), C(6′), C(2), C(2′) of bpy); 161.9 (C(2), C(2′) of bpym(Me)$_2$); 167.5, 169.5 (C(6), C(6′), C(4), C(4′) of bpym(Me)$_2$). FAB-MS: 627.6 ([Na ⊂ L]$^+$), 643.6 ([K ⊂ L]$^+$). Anal. calc. for $C_{36}H_{32}N_{10} \cdot NaBr \cdot 1.5\,H_2O$ (734.64): C 58.86, H 4.80, N 19.06; found: C 58.78, H 4.80, N 17.58.

NaBr complexes of **6** and **7** were synthesized according to the same procedure as described for **5**.

NaBr Complex of 4,4′-Dibromo-6,6″,6‴″:6′6‴,6⁗-bis[nitrilotris(methylene)]tris(2,2′-bipyridine) ([bpy(Br)$_2$.bpy.bpy]; **6b**). From **41** and **38**. Yield 17%. UV (CH_2Cl_2): 248 (30800), 296 (33000). ^{1}H-NMR ($CDCl_3$): 3.81 (*s*, 4 N–CH_2-bpy, 2 N–CH_2-bpy(Br)$_2$); 7.32 (*d*, *J* = 7, 4 H, bpy); 7.49 (*s*, 2 H, bpy(Br)$_2$); 7.75–7.90 (*s*, *d*, *t*, 8 H of bpy, 2 H of bpy(Br)$_2$). ^{13}C-NMR ($CDCl_3$): 58.8 (N–CH_2-bpy(Br)$_2$); 59.3 (N–CH_2-bpy); 120.3, 124.1, 138.2 (CH, bpy); 123.5, 127.3, 134.6 (CH, CBr of bpy(Br)$_2$); 155.1, 158.1 (C(2), C(2′), C(6), C(6′) of bpy); 155.2, 160.3 (C(2), C(2′), C(6), C(6′) of bpy(Br)$_2$). FAB-MS: 755 ([Na ⊂ L]$^+$). Anal. calc. for $C_{36}H_{28}Br_2N_8 \cdot NaBr \cdot 2\,H_2O$ (871.42): C 49.61, H 3.70, N 12.86; found: C 50.09, H 3.84, N 11.99.

NaBr Complex of 6,6″,6‴″:6′6‴,6⁗-Bis[nitrilotris(methylene)]-4,4′-dinitrotris(2,2′-bipyridine) ([bpy(NO$_2$)$_2$.bpy.bpy]; **6c**). From **41** and **36**. Yield 14%. UV (CH_2Cl_2): 240 (48750), 298 (31580), 335 (7750). IR (KBr):

1525, 1345 (NO_2). ^{1}H-NMR ($CDCl_3$): 3.92 (*s*, 4 N–CH_2-bpy); 4.11 (*s*, 2 N–CH_2-bpy(NO_2)$_2$); 7.35 (*d*, J = 20, 4 H, bpy); 7.77–7.81 (*t*, *d*, 8 H, bpy); 8.14 (*d*, J = 1.5, 2 H, bpy(NO_2)$_2$); 8.57 (*d*, J = 1.5, 2 H, bpy(NO_2)$_2$). ^{13}C-NMR ($CDCl_3$): 59.3 (N–*C*H_2-bpy, N–*C*H_2-bpy(NO_2)$_2$); 120.5, 124.3, 138.5 (CH, bpy); 113.4, 117.3 (CH, bpy(NO_2)$_2$); 155.1, 158.0 (C(2), C(2′), C(6), C(6′) of bpy); 156.3, 163.2 (C(2), C(2′), C(6), C(6′) of bpy(NO_2)$_2$); no signal found for C–NO_2. FAB-MS: 687 ([Na ⊂ L]$^+$), 703 ([K ⊂ L]$^+$). Anal. calc. for $C_{36}H_{28}N_{10}O_4 \cdot NaBr \cdot CHCl_3$ (886.97): C 50.10, H 3.29, N 15.79; found: C 50.28, H 3.48, N 15.86.

{6,6″:6′,6‴-{N,N′-(2,2′-Bithiazole-4,4′-dimethyl)bis[iminobis(methylene)]}bis(2,2′-bipyridine)}europium (III) Chloride ([Eu ⊂ **2a**]Cl_3). [Na ⊂ **2a**]Br (0.01 g, $1.23 \cdot 10^{-5}$ mol) and $EuCl_3 \cdot 6\,H_2O$ (0.0067 g, $1.84 \cdot 10^{-5}$ mol) were refluxed in MeOH (2 ml) for 38 h. The solvent was then evaporated , the residue rinsed with $CHCl_3$ (2 ml), then dissolved in the minimum of MeOH, and filtered on cotton wool. Anh. Et_2O was added carefully until the apparition of a slight trouble. The mixture was cooled to 4°, giving monocrystals or precipitate (0.01 g, 79%). UV (H_2O): 306 (31150), 340 (12000), 356 (9600). Emission (H_2O; $\lambda_{exc.}$, 312 nm): 618.8, 393.0. ^{1}H-NMR (D_2O/*t*-BuOH): 2.19 (*s*, $\Delta\nu_{1/2}$ = 8.5, 2 N–CH_2-btz); 4.96 (*d*, J = 7.8, 4 H, bpy); 7.35 (*t*, J = 7.8, 4 H, bpy); 7.86 (*d* from *AX*, *s*, 2 H of btz, 2 N–CH_2-bpy); 8.06 (*d*, J = 7.6, 4 H, bpy); 15.23 (*d* from *AX*, J = 15, 2 N–CH_2-bpy). FAB-MS: 809 (20, [[Eu ⊂ L]Cl_2]$^+$). Anal. calc. for $C_{32}H_{26}N_8S_2 \cdot EuCl_3 \cdot {}^1/_3\,EuCl_3 \cdot H_2O \cdot 2$ MeOH (1013.26): C 40.30, H 3.58, N 11.05; found: C 40.97, H 3.47, N 10.84.

{Diethyl 4,4′-{N,N′:N,N′-[Bis(2,2′-bipyridine-6,6′-dimethyl)]bis(aminomethyl)}-2,2′-bithiazole-5,5′-dicarboxylate}europium(III) Chloride ([Eu ⊂ **2b**]Cl_3). As described for [Eu ⊂ **2a**]Cl_3. Uncrystallized. ^{1}H-NMR (D_2O/*t*-BuOH): 1.91 (*t*, J = 7, 2 CH_3CH_2); 2.27 (*s*, $\Delta\nu_{1/2}$ = 11, 2 N–CH_2-btz(COOEt)$_2$); 4.93–5.17 (*q*, *d*, 2 CH_3CH_2, 4 H of bpy); 7.60–7.80 (*t*, *d*, from *AX*, 4 H of bpy, 2 N–CH_2-bpy); 8.04 (*d*, J = 7.6, 4 H, bpy); 14.05 (br. *d* from *AX*, J = 15, 2 N–CH_2-bpy).

{6,6″:6′,6‴-{N,N′-(2,2′-Bi-1H-imidazole-4,4′-dimethyl)bis[iminobis(methylene)]}bis(2,2′-bipyridine)}europium(III) Chloride ([Eu ⊂ **4**]Cl_3). As described for [Eu ⊂ **2a**]Cl_3. Uncrystallized. ^{1}H-NMR (D_2O/*t*-BuOH): 2.63 (*d*, J = 7.8, 4 H, bpy); 3.25 (*s*, $\Delta\nu_{1/2}$ = 8.5, 2 N–CH_2-biz); 3.78 (*s*, 2 H, biz); 6.49 (*t*, J = 7.8, 4 H, bpy); 8.08 (*d*, J = 7.8, 4 H, bpy); 8.58, 19.31 (*AX*, J_{AX} = 15, 4 N–CH_2-bpy). FAB-MS: 739.4 ([[Eu ⊂ (L – H$^+$)], Cl]$^+$), 702.4 ([Eu ⊂ (L – H$^+$)]$^+$), 370.1 ([[Eu ⊂ L]Cl)$^+$).

{4,4′-{N,N′:N,N′-[Bis(2,2′-bipyridine-6,6′-dimethyl)]bis(aminomethyl)}-6,6′-dimethyl-2,2′-bipyrimidine}europium(III) Chloride ([Eu ⊂ **5**]Cl_3). As described for [Eu ⊂ **2a**]Cl_3. Crystallized (50%). UV(H_2O): 248 (28300), 307 (18200), 324 (sh, 11600). ^{1}H-NMR (D_2O/*t*-BuOH): –1.88 (*s*, $\Delta\nu_{1/2}$ = 13.3, 2 N–CH_2-bpym(Me)$_2$); 2.85 (*d* from *AX*, J = 15, 2 N–CH_2-bpy); 4.46 (*s*, 2 Me); 5.90 (*d* from *AX*, J = 15, 2 N–CH_2-bpy); 6.57 (*d*, J = 8, 4 H, bpy); 7.04 (*d*, J = 8, 4 H, bpy); 7.98 (*t*, J = 8, 4 H, bpy); 8.59 (*s*, 2 arom. H, bpym(Me)$_2$). FAB-MS: 871 ([[Eu ⊂ L]Cl, Br]$^+$), 827 ([[Eu ⊂ L]Cl_2]$^+$), 792 ([[Eu ⊂ L]Cl]$^+$), 754 ([Eu ⊂ (L – H$^+$)]$^+$), 396 ([[Eu ⊂ L]Cl]$^+$). Anal. calc. for $C_{36}H_{32}N_{10} \cdot EuCl_3 \cdot NaBr \cdot 2.5\,H_2O$ (1010.97): C 42.77, H 3.69, N 13.85; found: C 43.05, H 4.26, N 13.80.

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REFERENCES

[1] J.-M. Lehn, *Struct. Bond.* **1973,** *16,* 1; *Acc. Chem. Res.* **1978,** *11,* 49; *Pure Appl. Chem.* **1978,** *50,* 871.
[2] G. R. Newkome, J. D. Sauer, J. M. Roper, D. C. Hager, *Chem. Rev.* **1977,** *77,* 513.
[3] J.-C. Rodriguez-Ubis, B. Alpha, D. Plancherel, J.-M. Lehn, *Helv. Chim. Acta* **1984,** *67,* 2264.
[4] B. Alpha, E. Anklam, R. Deschenaux, J.-M. Lehn, M. Pietraszkiewicz, *Helv. Chim. Acta* **1988,** *71,* 1042.
[5] H. Dürr, K. Zengerle, H. P. Treitweiler, *Z. Naturforsch., B* **1988,** *43,* 361.
[6] M. Ccsario, J. Guilhem, C. Pascard, E. Anklam, J.-M. Lehn, M. Pietraszkiewicz, *Helv. Chim. Acta* **1991,** *74,* 1157.
[7] I. Bkouche-Waksmann, J. Guilhem, C. Pascard, B. Alpha, R. Deschenaux, J.-M. Lehn, *Helv. Chim. Acta* **1991,** *74,* 1163.
[8] A. Caron, J. Guilhem, C. Riche, C. Pascard, B. Alpha, J.-M. Lehn, J.-C. Rodriguez-Ubis, *Helv. Chim. Acta* **1985,** *68,* 1577.
[9] O. Juanez, J. de Mendoza, J.-C. Rodriguez-Ubis, *J. Chem. Soc., Chem. Commun.* **1985,** 1795.
[10] B. Alpha, J.-M. Lehn, G. Mathis, *Angew. Chem.* **1987,** *99,* 259; *ibid. Int. Ed.* **1987,** *26,* 266.
[11] B. Alpha, Thèse de Doctorat ès Sciences, Université Louis Pasteur, Strasbourg, 1987.
[12] a) J.-M. Lehn, in 'Supramolecular Photochemistry', Ed. V. Balzani, Reidel, Dordrecht, 1987, p. 29; b) N. Sabbatini, S. Perathoner, V. Balzani, B. Alpha, J.-M. Lehn, *ibid.*, p. 187.

[13] B. Alpha, V. Balzani, J.-M. Lehn, S. Perathoner, N. Sabbatini, *Angew. Chem.* **1987,** *99,* 1310; *ibid. Int. Ed.* **1987,** *26,* 1266.
[14] B. Alpha, R. Ballardini, V. Balzani, J.-M. Lehn, S. Perathoner, N. Sabbatini, *Photochem. Photobiol.* **1990,** *52,* 299.
[15] L. Echegoyen, A. DeCian, J. Fischer, J.-M. Lehn, *Angew. Chem.* **1991,** *103,* 884; *ibid. Int. Ed.* **1991,** *30,* 838.
[16] J.-M. Lehn, J.-B. Regnouf de Vains, *Tetrahedron Lett.* **1989,** *30,* 2209.
[17] H. Takalo, J. Kankare, *Finn. Chem. Lett.* **1988,** *15,* 95.
[18] E. Müller, G. Bernardinelli, A. von Zelewsky, *Inorg. Chem.* **1988,** *27,* 4645.
[19] a) P. Karrer, M.C. Sanz, *Helv. Chim. Acta* **1944,** *27,* 619; b) P. Karrer, P. Leiser, W. Graf, *ibid.* **1944,** *27,* 624; c) P. Karrer, F. Forster, *ibid.* **1945,** *28,* 315; d) P. Karrer, W. Graf, *ibid.* **1945,** *28,* 824.
[20] a) Y.F. Chi, T.I. Chu, *Sci. Record (Peking)* **1957,** *1,* 45; *Chem. Abstr.* **1958,** *52,* 632a,b; b) Y.F. Chi, T.I. Chu, *Sci. Sinica (Peking)* **1957,** *6,* 467.
[21] F. Weygand, V. Schmied-Kowarzik, *Chem. Ber.* **1949,** *82,* 335.
[22] a) R. Kuhn, W. Blau, *Ann. Chem.* **1957,** *605,* 32; b) H. Debus, *ibid.* **1958,** *107,* 199.
[23] E. Duranti, C. Balsamini, *Synthesis* **1974,** 815.
[24] D.P. Matthews, J.P. Whitten, J.R. McCarthy, *Synthesis* **1986,** 336.
[25] P.G. Rasmussen, R.L. Hought, J.E. Anderson, O.H. Bailey, J.C. Bayon, *J. Am. Chem. Soc.* **1982,** *104,* 6155.
[26] D.P. Matthews, J.P. Whitten, J.R. McCarthy, *J. Org. Chem.* **1986,** *51,* 3228; *ibid.* **1986,** *51,* 1891.
[27] H.O.L. Fischer, E. Baer, *Helv. Chim. Acta* **1935,** *18,* 514.
[28] J.J. Baldwin, P.A. Kasinger, F.C. Novello, J.M. Sprague, D.E. Duggan, *J. Med. Chem.* **1975,** *18,* 895.
[29] W. Schunack, *Arch. Pharm.* **1974,** *307,* 46.
[30] a) D.D. Bly, M.G. Mellon, *J. Org. Chem.* **1962,** *27,* 2945; b) D.D. Bly, *ibid.* **1964,** *29,* 943.
[31] E.V. Dose, L.J. Wilson, *Inorg. Chem.* **1978,** *17,* 2660.
[32] a) P. Marnot, Thèse de Doctorat, Université Louis Pasteur, Strasbourg, 1984; b) R. Ziessel, unpublished results.
[33] M. Tiecco, L. Testaferri, M. Tingoli, D. Chianelli, M. Montanucci, *Synthesis* **1984,** 736.
[34] a) I.J. Pachter, *J. Am. Chem. Soc.* **1953,** *75,* 3036; b) V. Boeckelheide, D.L. Harrington, *Chem. Ind.* **1955,** 1423; c) V.J. Traneylis, R.F. Martello, *J. Am. Chem. Soc.* **1958,** *80,* 6590.
[35] R.R. Hunt, J.F.W. McOmie, E.R. Sayer, *J. Chem. Soc.* **1959,** 525.
[36] a) H.J. Den Hertog, W.P. Combe, *Recl. Trav. Chim. Pays-Bas* **1951,** *70,* 58; b) J. Haginawa, *J. Pharm. Soc. Jpn.* **1955,** *75,* 731; c) I. Murase, *Nippon Kagaku Zasshi* **1956,** *77,* 682; d) G. Maerker, F.H. Case, *J. Am. Chem. Soc.* **1958,** *80,* 2745; e) D. Wenkert, R.B. Woodward, *J. Org. Chem.* **1988,** *48,* 283.
[37] G.R. Newkome, W.E. Puckett, G.E. Kiefer, V.K. Gupta, Y. Xia, M. Coreil, M.A. Hackney, *J. Org. Chem.* **1982,** *47,* 4116.
[38] R. Deschenaux, J.-M. Lehn, unpublished results.
[39] R.A. Jones, B.D. Roney, W.H.F. Sasse, K.O. Wade, *J. Chem. Soc. (B)* **1967,** 106.
[40] B. Dietrich, J.-M. Lehn, J.-P. Sauvage, J. Blanzat, *Tetrahedron* **1973,** *29,* 1629.
[41] G.R. Newkome, S. Pappalardo, V.K. Gupta, F.R. Fronczeck, *J. Org. Chem.* **1983,** *48,* 4848.
[42] R. Deschenaux, J.-M. Lehn, unpublished results.
[43] G. Mathis, unpublished results (*ORIS Industrie,* Centre de Marcoule).
[44] R. Phan-Tan-Luu, J.-M. Surzur, J. Metzger, J.-P. Anne, C. Dupuy, *Bull. Soc. Chim. Fr.* **1967,** 3274.
[45] a) R. Stämpfli, *Helv. Phys. Acta* **1943,** *1,* C54; b) P. Karrer, M.-C. Sanz, *Helv. Chim. Acta* **1943,** *26,* 1778.