

Synthesis and Characterization of New Schiff Base and Polyoxa-aza Cryptands and Their Rare Earth Cryptates with [1+1] Condensation and Reduction Methods

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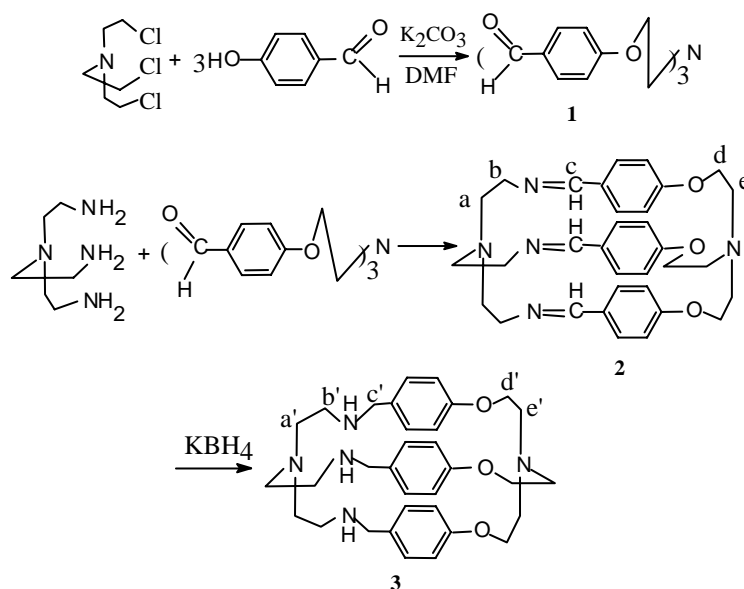
Abstract: The Schiff base cryptand and its cryptates were synthesized with the methods of [1+1] condensation of trialdehyde and tris(2-aminoethyl)amine and obtained in 60-65%, 5-25% and 70-80% yields respectively with or without some rare earth elements as templates. The polyoxa-aza cryptand was produced in 72% and 60-70% yields with reduction of Schiff base and its cryptates respectively.

Keywords: Schiff base, polyoxa-aza, cryptand, rare earth, condensation.

Introduction

With special and novel structures, macropolycyclic molecules present a multitude of new properties¹ and open up vast vistas for applications in many fields^{2,3}, such as supramolecular devices, luminescent labels, fluorescent probes in biological and medical applications, magnetic resonance imaging and catalytic cleavage of RNA, and they are also important ligands⁴ for recognizing inorganic and organic cations, anions and neutral molecules. Because of multi-step process and low yields⁵, the synthesis of macropolycyclic compounds are sometimes very difficult. In comparison with other macropolycyclic agents, Schiff base cryptands and cryptates⁶ give such advantages as simplicity and high yields as they are usually synthesized by the method⁷ of a tripodal [2+3] condensation of dialdehydes and tris(2-aminoethyl)amine with one-step process, both of which give possibility to find their uses in many fields. Besides, hydrogenation of the Schiff bases⁸ gives another efficient and facile way to synthesize saturated polyaza cryptand ligands. In addition to [2+3], a new method of tripodal [1+1] condensation of trialdehyde and tris-(2-aminoethyl)amine was firstly used by K. G. Ragoonathan and coworkers⁴ to synthesize a new cryptand in presence of Cs⁺ ion as template. Herein, we reported that two new Schiff base and polyoxa-aza cryptands were synthesized with methods of the tripodal [1+1] condensation of trialdehyde **1** and tris(2-aminoethyl)amine and reduction with or without rare earth elements as templates as shown in **scheme 1**.

Scheme 1



Experimental

Preparation of Trialdehyde 1: 4-Hydroxybenzaldehyde (8.0 g, 0.067 mol) was mixed with tris (2-chloroethyl)amine hydrochloride (4.8 g, 0.02 mol) and anhydrous potassium carbonate in 100 ml dimethyl formamide (DMF) and stirred for 24 hours at 85°C. Then half of solvent was distilled off under reduced pressure and 200 ml of boiled water was added, the reddish precipitate formed immediately, which were filtered off, recrystallized twice from ethanol and ethanol/water and dried *in vacuo*, a snow white crystal was obtained (78% yield), m.p. 95~97°C. IR spectrum gave a strong band of $\nu_{\text{C=O}}$ at 1676 cm^{-1} . Elemental analysis of C, H and N were obtained. ^1H NMR (80MHz, CD_3COCD_3) δ ppm: 3.2 (t, 6H, NCH_2), 4.3 (t, 6H, OCH_2), 7.1 (d, 6H, aromatic), 7.8 (d, 6H, aromatic), 9.8 (s, 3H, CHO).

Preparation of tris(2-aminoethyl)amine: it was prepared from triethanolamine with the method similar to literature⁹.

Synthesis of cryptand 2 with high dilution method: The trialdehyde 1 (1.5 mmol) and tris(2-aminoethyl)amine (1.5 mmol) were dissolved in 60 ml of acetonitrile respectively and added dropwise simultaneously into a solution of 750 ml of acetonitrile (methanol, ethanol or tetrahydrofuran) within 5 hours at ambient temperature, and stirred for 24 hours, a white powder formed slowly. After solvent was distilled off, the solid was recrystallized from $\text{CH}_3\text{CN}/\text{CH}_2\text{Cl}_2$, the white pure cryptand 2 was obtained in 5~25% yields, which quickly turned yellow. IR: 2833, 1644., 1605, 1510, 1304, 1244, 1165, 1031, 831, 524 cm^{-1} .

Template synthesis of rare earth cryptates of cryptand 2: Tris(2-aminoethyl)amine (1.0 mmol) in 30 ml of absolute ethanol was added dropwise into a refluxing

solution of trialdehyde **1** (1.0 mmol) and rare earth nitrates (2.0 mmol) dissolved in 100 ml of absolute ethanol within 2 hours then cooled down to ambient temperature. After stirring for more 24 hours, the precipitates were filtered off and dried under vacuum, pure rare earth cryptates were obtained, yields 70–80%. To protect rare earth ions from hydrolysis, several milliliters of ethyl ortho-formate was added. $\text{La}(\text{NO}_3)_3 \cdot \text{L}^2 \cdot 1.5\text{H}_2\text{O}$ requires: C, 43.76; H, 4.67; N, 12.37; La, 15.34; found: C, 43.97; H, 4.49; N, 12.02; La, 15.54. $\text{Sm}(\text{NO}_3)_3 \cdot \text{L}^2 \cdot 1.5\text{H}_2\text{O}$ requires: C, 43.22; H, 4.62; N, 12.22; Sm, 16.40; found: C, 43.18; H, 4.38; N, 12.08; Sm, 16.23.

Synthesis of cryptand 2 from its cryptates: Some of rare earth ions like La (III), Sm (III), and Y (III) in cryptates were easily removed with several solutions like sodium hydroxide and 1:1 ammonia and extracted with CHCl_3 . After the solvent was distilled off, cryptand **2** was obtained in yields of 60-65%.

Synthesis of cryptand 3 with reduction method: The cryptand **2** (or its cryptates of La (III), and Y (III), 1 mmol) was mixed with KBH_4 (10 mmol for cryptand and 30 mmol for cryptates) in 50 ml of absolute methanol, stirred for half an hour and refluxed for three hours, then the solvent was distilled off and precipitate was washed twice with water and dissolved with CHCl_3 . After the chloroform was removed, the product was recrystallized twice with $\text{CH}_3\text{CN}/\text{CH}_2\text{Cl}_2$, pure cryptand **3** was obtained (yields 72% and 60-70% respectively), m.p. 196-198°C. $\text{C}_{33}\text{H}_{45}\text{N}_5\text{O}_3 \cdot 0.5\text{H}_2\text{O}$ (obtained from cryptand **2**) requires: C, 69.69; H, 8.15; N, 12.31; found: C, 69.76; H, 7.95; N, 12.18. $\text{C}_{33}\text{H}_{45}\text{N}_5\text{O}_3 \cdot \text{H}_2\text{O}$ (obtained from cryptates) requires: C, 68.60; H, 8.20; N, 12.12; found: C, 68.82; H, 8.11; N, 12.03. ^1H NMR (80 MHz, CDCl_3), δ ppm: 1.8 (s, br, 3H, -NH), 2.7 (t, 6H, a'), 2.8 (t, 6H, b'), 3.1 (t, 6H, e'), 3.6 (s, br, 6H, c'), 4.0 (t, 6H, d'), 6.3 (d, 6H, benzene), 6.8 (d, 6H, benzene). ^{13}C NMR (100MHz, CDCl_3) δ ppm: 46.93 (3C, a') 51.42 (3C, b'), 54.35 (3C, e'), 58.36 (3C, c'), 68.60 (3C, d'), 114.62 (6C), 128.43 (6C), 131.62 (3C), 158.42 (3C, aromatic), EI-MS: found $m/z = 559$, calcd for $\text{C}_{33}\text{H}_{45}\text{N}_5\text{O}_3$ is 559.

Synthesis of rare earth cryptates of cryptand 3: The cryptand **3** (0.1 mmol) and rare earth nitrates (0.3 mmol) were mixed in 15 ml absolute acetonitrile and 0.1 ml ethyl ortho-formate and stirred for 24 hours, then filtered off, washed twice with acetonitrile and dried *in vacuo*, pure cryptates were obtained.

Results and Discussion

The trialdehyde underwent [1+1] condensation with tris(2-aminoethyl)amine in the presence of several elements as templates and formed the desired products. Without templates, several solvents like methanol, ethanol, acetonitrile and tetrahydrofuran were chosen as good media for reaction. The yields in these solvents were different from each other, the sequence is as follows: tetrahydrofuran < methanol < acetonitrile < ethanol

No cryptand **2** was obtained in THF, only 5% in methanol, 15% in acetonitrile and 25% in ethanol. The reaction temperature was also an important factor. No reaction occurred for two days below -15°C, no desired product was obtained over 60°C because all polymerized. The range of temperature for synthesis was 0-25°C. Only IR was

used to detect it and showed special adsorption of $\nu_{C=N}$ at 1644cm^{-1} because the cryptand **2** turned yellow quickly in the air. After change of color, it did not dissolve in chloroform again. After reduction, the IR spectrum showed that the peak of $\nu_{C=N}$ disappeared and new peak of N–H appeared at 3304 cm^{-1} .

Several nitrates of rare earth elements like La, Ce, Sm, Eu, Gd, Tb, Dy, Y and Sc were chosen as templates to synthesize cryptand **2** in yields of 60-65% and its rare earth cryptates in yields of 70-80%. To protect rare earth nitrates from hydrolysis, several milliliters of ethyl ortho-formate were added in the process. The smaller the rare earth ions, the lower the pH value of hydrolysis and the more the volumes of ethyl ortho-formate added. The nitrates of Cu^{2+} and Zn^{2+} were also used as templates to synthesize cryptand **2**, but removal of ions in their cryptates was more difficult than rare earth ions. The Schiff base cryptates of rare earth elements were only obtained with template synthesis and results showed that rare earth elements really played important roles in synthesis of cryptands and elemental analysis indicated that all rare earth ions used as templates formed 1:1 complexes with cryptand **2** in ethanol and stably existed in DMF, but except La and Sc cryptates, others decomposed in DMSO. The rare earth nitrates formed 2:1 complexes in reaction of cryptand **3** with rare earth nitrates in acetonitrile and can stably exist in solvents like DMF and DMSO. All the cryptates of Sm (III), Eu (III), Tb (III), and Dy (III) of cryptand **2** and cryptand **3** showed their special fluorescences under excitation of ultraviolet light. Several methods like elemental analysis, IR, NMR and DTA(TG) were used to study all cryptates.

The single crystal of cryptand **3** was obtained. Other studies on electrochemical, fluorescent and other properties of these systems are now in progress.

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