Aminolysis reaction of calix[4]arene esters and crystal structures and conformational behaviors of calix[4]arene amides

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We first make use of aminolysis of calix[4]arene esters to synthesize calix[4]arene amides. When the two ethyl esters of the calix[4]arene esters are aminolysized, the 1, 3-amide derivative is formed selectively. The crystal structures of the calix[4]arene with two butyl amide (3b) and four butyl amide moieties (4b) were determined. The intermolecular hydrogen bonds make 4b form two-dimensional net work insolid state. The ^{1}H NMR spectra prove that 3b is of a pinched cone conformation, while 4b and tetraheptylamide-calix[4]arene (6b) take fast interconversion between two C_{2v} isomers in solution and appear an apparent cone conformation at room temperature. As decreasing temperature, the interconversion rate decreases gradually and, finally, the interconversion process is frozen at $T_c = -10$℃, which makes both conformations of 4b and 6b the pinched cone structures. The hydrogen bond improves the interconversion barrier, and the large different values of the potential barrier between 6b and 4b (or 6b) may be of forming different hydrogen bonds.

Keywords Calix[4]arene amides, aminolysis reaction, conformation, crystal structure

Introduction

Calixarenes are very useful building blocks in supramolecular chemistry. The introduction of functionality into calixarene continues to be one of the major goals in the rapidly expanding chemistry of those compounds.[1] Various modifications are available both at the phenolic groups (the lower rim) and at the *para*-positions (the upper rim).[2] The present work adds to this list by modifying the lower rim, making use of aminolysis of the calix[4]arene esters to obtain the calix[4]arene amides. When this work was accomplished, we read the paper about calixarenes anhydrides as useful synthetic intermediates, which briefly mentioned the synthesis of the calix[4]arene amides via reaction of the calix[4]-arene anhydrides and amine.[3] Usually, the calixarene amides are synthesized mainly via two routes: (1) the calix[4]arene directly reacts with $BrCH_2CONR_1R_2$.[4] (2) the calix[4]arene reacts with $BrCH_2COOR$ and then the esters undergo hydrolysis to get acids which are converted to the acyl chloride, and the latter reacted with the amine.[5] The experimental results show that the new method——the aminolysis of calix[4]arene esters is facile, economic and with high yields.

Calix[4]arene is cyclic tetramer of phenol that can adopt four extreme conformations in solution, viz cone, partial cone, 1, 2-alternated and 1, 3-alternated. Recently, the cone isomer is receiving the greatest attention as a framework for constructing molecular hosts, templates and pores. Usually the conformation interconversion of calix[4]arenes in solution can take place and be blocked by alkylation of the phenolic oxygens at the lower rim with substituents larger than *n*-propyl.[6] Although it has been reported that the ^{1}H NMR spectra of all homo-tetrasubstituented calix[4]arenes suggest a cone conformation consistent with C_{4v} symmetry, the computational studies predict that a structure with C_{2v} symmetry is more stable than the more symmetrical C_{4v} structure.[7] The C_{2v} symmetry structure has two opposite aromatic rings almost parallel, while the other two adopt a flattened position, which is called the pinched cone confor-

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mation. A few examples have proved that there is a quick exchange between the two equivalent isomers (C_{2v}) via the cone conformation (C_{4v}) in solution.[8-10] The conformational behaviors of the calix [4] arene amides, whose interconversion barriers are improved by the hydrogen bonds, are also discussed in this paper.

Results and discussion

Synthesis

The reactants are the sodium cation inclusion complexes of the tetracthyl esters of *t*-butyl-calix[4]arene (**1a**) and calix[4]arene (**1b**)[6] which depend on using Na_2CO_3 or K_2CO_3 during synthesis of **1a** and **1b**. It is difficult to get these two compounds in sodium-free form. They can be smoothly aminolysized by a variety of amines with larger excess and under refluxing in absolute ethanol. The products of aminolysis reaction lose sodium or potassium cations after recrystallization, and it is easy to recombine sodium cation again from mobile phase such as water and ethanol under ESI-MS. The experimental conditions and results are summaried in Table 1. The products are analyzed by ESI-MS and ^{1}H NMR. The aminolysis reaction follows some regularities: (1) It strongly depends on the activity of amines, for example, all four ethyl esters of **1a** are aminolysized by the ethanol amine, but with *n*-propyl amine, the aminolysis product is a mixture of one and two amide group derivatives, and there are no reactions when benzylamine and aniline are used as the rectants. There are some abnormals during the aminolysis by *n*-amyl amine and *n*-heptyl amine. The reason is so far not clear. Maybe, it is related to the chain length. (2) The steric effect of amines is an important factor for aminolysis reaction. While using the more steric hindrance amines, such as the cyclohexylamine , *t*-butylamine, and the diethylamine as reactants, the aminolysis reactions do not occur for both **1a** and **1b** under above conditions. (3) Comparing the reaction data of **1a** with those of **1b**, it can be found that the aminolysis reactivity is quite different for these two compounds. For example, when reacting with *n*-butylamine under the same conditions including the reaction time, the two ethyl esters of **1b**, but only one ethyl ester of **1a**, are aminolysized. Similar results are also observed with other amines. It is obvious that the substituents on upper rim of calix[4]arene have an important effect on the aminolysis reaction. (4) In DMF solution containing NaH, all the four ethyl esters of **1a** or **1b** are aminolysized by *n*-butylamine at room temperature for 24 h, and one, two, three and four ethyl esters of **1a** are respectively aminolysized by *n*-amylamine under the same conditions, which indicates that the strong base promotes the aminolysis reaction.

These results can be understood by the mechanism of aminolysis reaction.[11] Usually the aminolysis reaction proceeds through a tetrahedral addition intermediate, $T^{\pm}$. Many kinds of factors effect on the aminolysis reaction, of which the steric hindrance, pH, and the nucleophilicity are important factors.[12] The more strong nucleophilicity of amines, the more stable of $T^{\pm}$ and in turn, the more easy the amirnolysis reaction proceeds. Hence it is easy for the calix[4]arene esters to be aminolyzed with small amine like ethanol amine, while it is nearly impossible with aniline and benzylamine because of their low nucleophilicity and too big molecular size. The steric factor has a large effect on the forming intermediate $T^{\pm}$. Because the steric hindrance of the calix[4]arene esters **1a** or **1b** itself is very large, if the amine is a molecule somewhat steric molecule, forming relative stable $T^{\pm}$ becomes impossible, which leads to no reaction taking place with cyclohexylamine or diethylamine or *t*-butylamine. The four *t*-butyl groups on upper rim confine the conformational change of **1a** to match the need of forming the tetrahedral intermediate, and makes the aminolysis reaction activity of **1a** be lower than that of **1b**. High basicity of the reaction media is favourable to form T^- intermediate, which promotes the aminolysis reaction.[13]

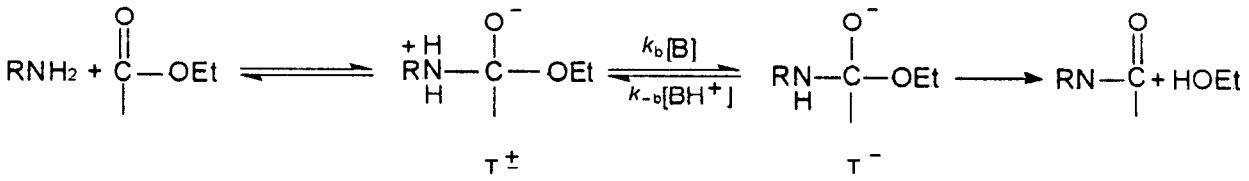
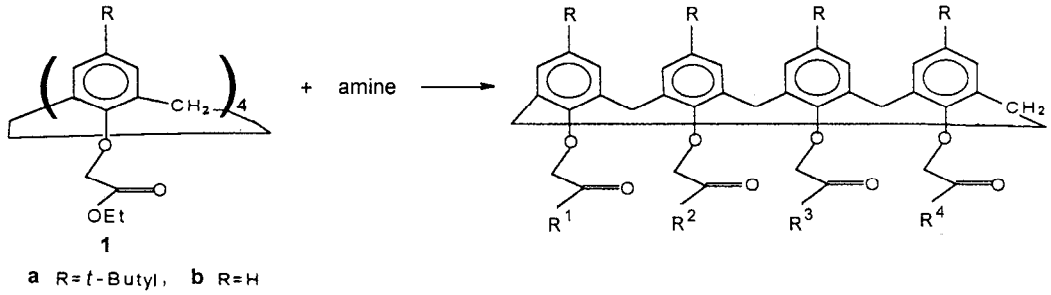


Table 1 Aminolysis of calix[4]arene esters with a varity of amines



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a R=*t*-Butyl, **b** R=H

	Amine	Conditions	Product **a**	Product **b**
1	Ethanol amine	Ethanol, reflux, 24 h, molar ratio 1:10	$R^1 = R^2 = R^3 = R^4 =$ $NHCH_2CH_2OH$	$R^1 = R^2 = R^3 = R^4 =$ $NHCH_2CH_2OH$
2	*n*-Propyl amine	Ethanol, reflux, 48 h, molar ratio 1:40	A mixture: one and two ethyl esters were aminolysized respectively	$R^1 = R^3 = NH(CH_2)_2CH_3$ $R^2 = R^4 = OEt$
3	*n*-Butyl amine	The same as 2	$R^1 = NH(CH_2)_3CH_3$ $R^2 = R^3 = R^4 = OEt$	$R^1 = R^3 = NH(CH_2)_3CH_3$ $R^2 = R^4 = OEt$
4	*n*-Butyl amine	DMF, r.t., 24 h, NaH molar ratio 1:40:8	$R^1 = R^2 = R^3 = R^4 =$ $NH(CH_2)_3CH_3$	$R^1 = R^2 = R^3 = R^4 =$ $NH(CH_2)_3CH_3$
5	*n*-Amyl amine	The same as 2	No reaction	A mixture: one, two and three ethyl esters were aminolysized respectively
6	*n*-Heptyl amine	The same as 2	A mixture: two, three and four ethyl esters were aminolysized respectively	$R^1 = R^2 = R^3 = R^4 =$ $NH(CH_2)_6CH_3$

Table 2 Selected bond distances (nm) and bond angles (°) of **4b**

Bond distances (nm)			
O(1)—C(7) 1.395(5)	O(1)—C(8) 1.437(5)	O(2)—C(9) 1.207(6)	O(3)—C(20) 1.383(5)
O(3)—C(21) 1.428(6)	O(4)—C(22) 1.202(5)	N(1)—C(9) 1.324(7)	N(1)—C(10)′ 1.448(11)
N(1)—C(10) 1.451(13)	N(2)—C(22) 1.330(6)	N(2)—C(23) 1.435(9)	C(1)—C(19) 1.502(6)
C(8)—C(9) 1.485(8)	C(10)—C(11) 1.261(8)	C(11)—C(12) 1.260(7)	C(12)—C(13) 1.246(8)
C(14)—C(15) 1.525(6)	C(21)—C(22) 1.506(7)	C(23)—C(24) 1.398(7)	C(24)—C(25) 1.393(7)
		C(25)—C(26) 1.396(7)	
Bond angles (°)			
C(7)-O(1)-C(8) 113.4(4)	C(9)-N(1)-C(10) 117.4(6)	C(19)-C(1)-C(2) 111.5(4)	C(6)-C(7)-O(1) 119.0(4)
C(2)-C(7)-O(1) 117.4(4)	O(1)-C(8)-C(9) 112.6(4)	O(2)-C(9)-N(1) 124.1(5)	O(2)-C(9)-C(8) 121.2(5)
N(1)-C(9)-C(8) 114.7(4)	C(11)-C(10)-N(1) 119.1(9)	C(12)-C(11)-C(10) 131.7(12)	
C(13)-C(12)-C(11) 144.0(13)		C(6)-C(14)-C(15) 109.4(4)	

Molecular structures and 2-D *network formed via hydrogen bonds*

The crystal structures of the compounds **3b** and **4b** are shown in Fig. 1 and selective bond lengths and bond angles are listed in Tables 2 and 3. The compound **4b** adopts a pinched cone conformation in solid state, with one pair of diametrical phenolic rings toward inner of the cavity and the others tilt to outside. The preliminary molecular structure of compound **3b** shows a similar

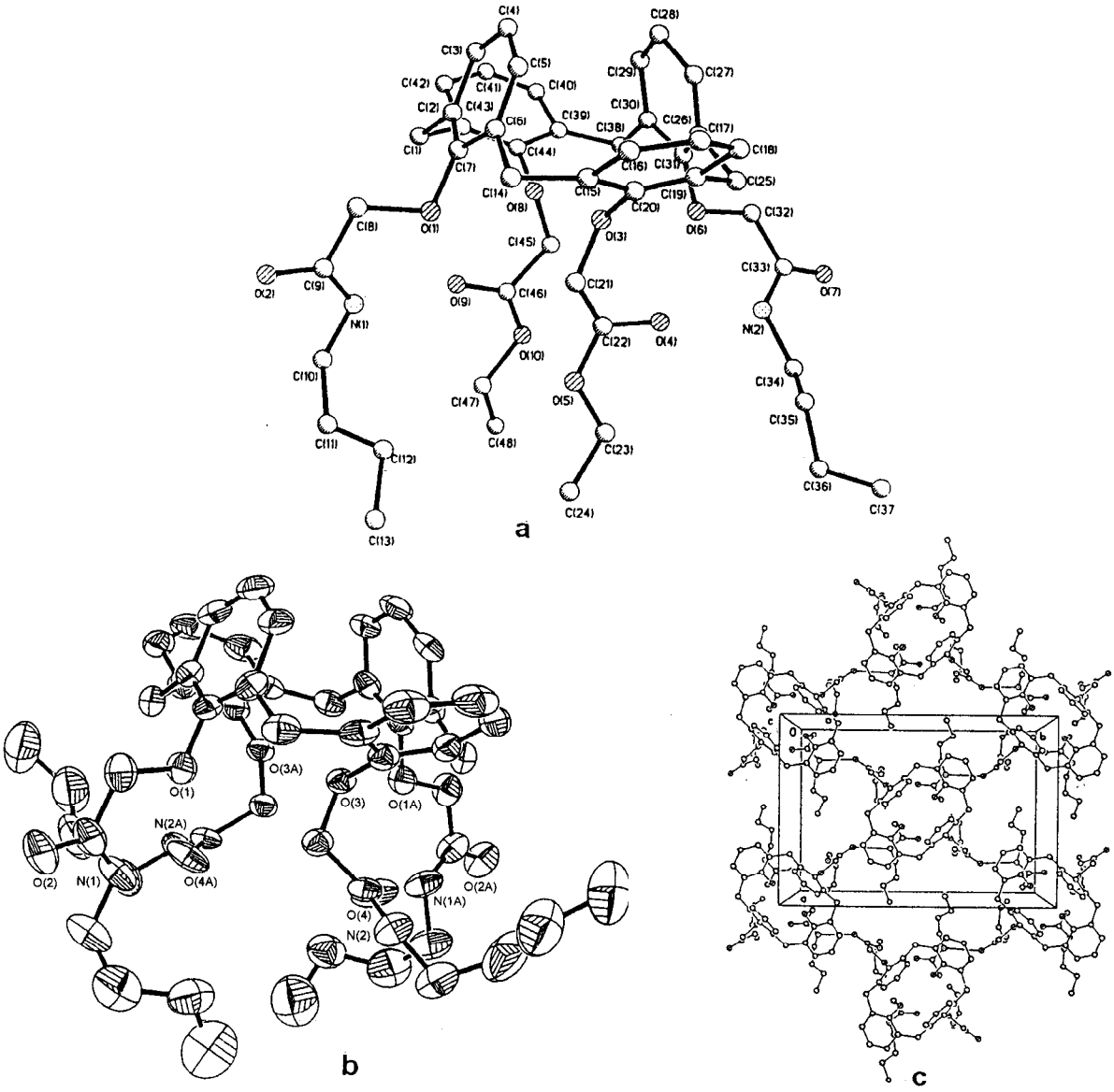

Fig. 1 Molecular structure of the compounds (a) **3b** and (b) **4b** and (c) the crystal cell stacking pattern of compound **4b**.

pinched cone structure. For compound **4b** the dihedral angles between the phenol ring and the plane composed of four oxygen atoms from phenols (mean deviation from the best plane 0.044) are 35.4° and 106.4°, respectively. It is quite different from the compound **3a**, which adopts almost rigid cone geometry.[14,15] Three factors, the bulk of substituents at the upper rim, hydrogen bonding due to the substituents at the lower rim and inclusion complex formation, might have an important effect on the conformation of the calix[4]arene.

From the crystal cell stacking pattern of compound **4b** (Fig.1(c)) we can see that it is composed of two dimensional network via the four equal intermolecular hydrogen bonds. The bond length and angle are: N(2)—H·····O(2) 0.2835 nm, 173.5°.

Conformational behavior of the calix[4]arene amides in solution

The ^{1}H NMR spectrum (500 MHz) of compound **3b** (Fig. 2(a)) in $CDCl_3$ at room temperature gives a splitting pattern that is consistent with a pinched cone

structure. The aromatic protons appear as two groups of doublets and triplets with the intensity ratio 2 : 1 at δ_H 7.12(d), 6.97(t), and 6.01(d), 6.30(t), and the oxymethylene protons appear as two singlets with equal intensity at δ_H 4.77 and 4.26. In the H-H COSY spectrum of **3b** there are no cross peaks between the two groups of aromatic protons and between two singlets of oxymethylene protons, which suggests that compound **3b** has two kinds of phenolic ringmoieties with different orientations. Two kinds of substituents, $-CH_2OEt$ and $-CH_2CONHR$, on the lower rim of **3b**, have little direct effect on ^1H NMR of aromatic protons and oxymethylene protons,[15] because there are quite long distances between them.[15] It should be the main reason for the splitting pattern of aromatic protons and oxymethylene protons that the compound **3b** adopts the pinched cone conformation at room temperature.

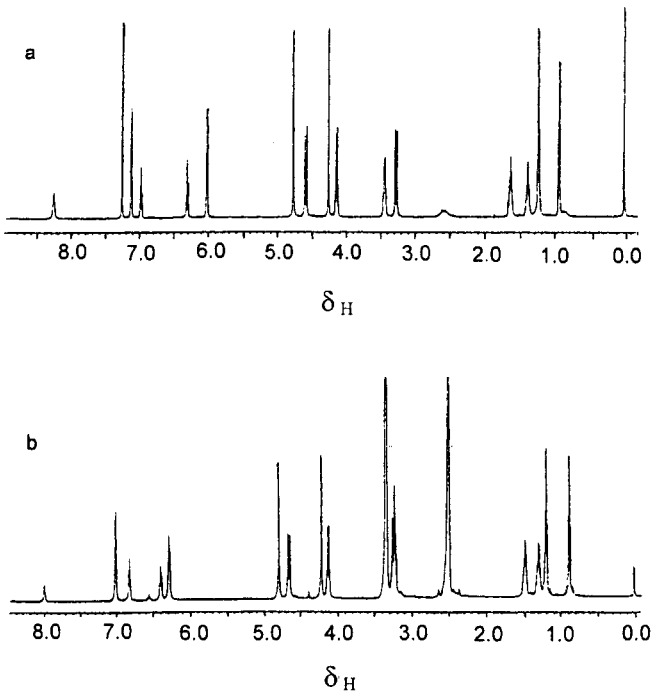

Fig. 2 ^1H NMR (500 MHz) of the compound **3b**. (a) in $CDCl_3$ (b) in DMSO-d_6.

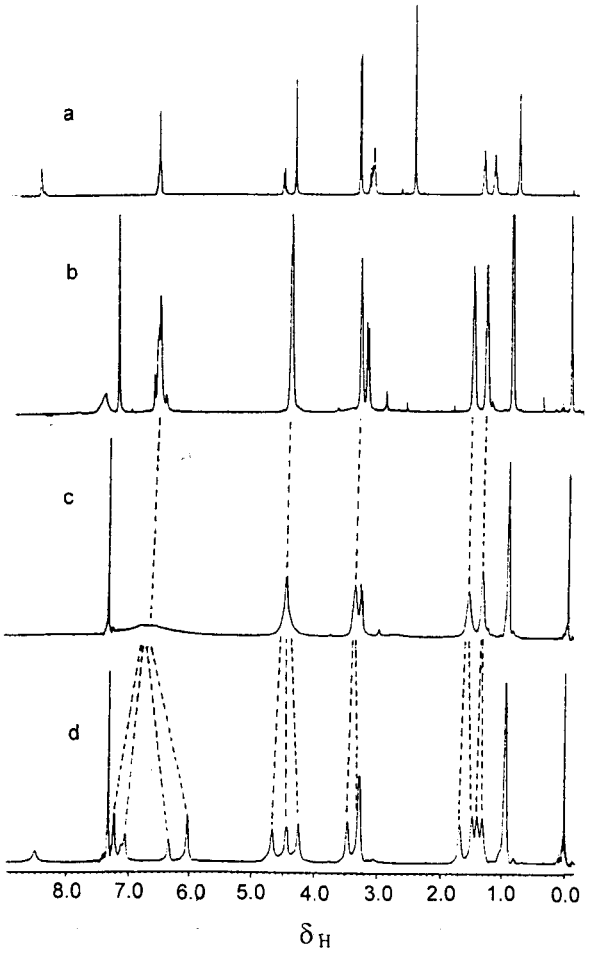

Fig. 3 ^1H NMR spectra of the compound **4b**. (a) in DMSO-d_6 at 20℃ and in $CDCl_3$ at (b) 20℃, (c) −10℃ (d) −40℃.

The ^1H NMR spectrum (500 MHz) of compound **3b** in DMSO-d_6 is shown in Fig.2(b). There are still two groups of doublets and triplets of aromatic protons at δ_H 7.01(d), 6.62(t), and 6.39(t), 6.28(d) except the separation of two groups is apparently smaller in DMSO-d_6 than that in $CDCl_3$. Generally speaking, there has a fast interconversion of two C_{2v} symmetry isomers in solution at room temperature and leads to get an average ^1H NMR spectrum of two C_{2v} isomers, which is equivalentto have a C_{4v} symmetry conformation in solution. According to the ^1H NMR data, we suggest that it is the intramolecular hydrogen bonds between amide and oxygen atom of phenol[14] in $CDCl_3$ that block the inter-

conversion of two C_{2v} symmetry isomers and rigidify the skeleton of calix[4]arene, which promotes the compound **3b** adopting one of the two C_{2v} symmetry isomer-spinched cone structure even at room temperature. In DMSO-d_6 the intermolecular hydrogen bonds between DMSO and amide group are formed instead of the original intramolecular hydrogen bonds because the DMSO is more effective for forming hydrogen bond, which induces the different orientation between the two types of phenyl rings, namely pinched cone conformation, but they are two different pinched cone conformations in DMSO and $CDCl_3$.

To research the conformation behaviors of the compounds **4b** and **6b** in solution, the ^1H NMR spectra from room temperature to $-40℃$ were measured. Fig. 3 (b), (c) and (d) show the temperature-dependent ^1H NMR spectra of the compound **4b**. At 20℃ the signal of the aromatic protons appears as near single broadened peak at about δ_H 6.5. With lowering the temperature it is further broadened and eventually both the *m*-ArH and *p*-ArH split into two peaks with intensity ratio *m*-ArH: *p*-ArH = 2 : 1 at δ_H 7.21, 6.02 and 7.03, 6.32 at $-40℃$. The coalescence temperature (T_c) is $-10℃$. Similarly the signal for the oxymethylene protons is a singlet at 20℃, and finally gives a doublet at δ_H 4.66 and 4.24 at $-40℃$. And the signals of $NCH_2CH_2CH_2$ also split from singlets into doublets. All these facts unequivocally indicate that there exits the C_{2v}—C_{2v} interconversion of the compound **4b** in $CDCl_3$ solution. On the basis of a coalescence temperature, $T_c = -10℃$ and $\Delta\nu = 595$ Hz (the *m*-ArH), the potential barrier for interconversion and pre - exponent factor are $\Delta G^{\neq} = 11.5 \pm 0.1$ kcal/mol, and $\log A = 12.7 \pm 1$[16,17] respectivly. The coalescence temperature T_c ($-10℃$) of the compound **4 b** is rather higher than T_c (lower than $-70℃$) of tetra-alkyl-calix[4]arenes.[10] The reason for this might be that the hydrogen bonds promote the barrier and suppress the rate of C_{2v}—C_{2v} interconversion. Using DMSO-d_6 as solvent, all the ^1H NMR peaks of compound **4b** sharpen (Fig.3(a)), which is quite different from those of compound **3b** (Fig. 2(b)). We might suggest that a inclusion compound via the hydrogen bonding between DMSO and four amide groups of the compound **4b** is formed, which promotes the compound **4b** adopting cone conformation, but in compound **3b**, there are only two amide groups, and the hydrogen bonding between DMSO and two amide groups leads to form a pinched cone conformation. That might explain why the ^1H NMR spectra of the compounds **3b** and **4b** in DMSO are different.

The similar ^1H NMR patterns and results for the compound **6b** are obtained, here, $T_c = -10℃$, $\Delta\nu =$ 610 Hz (the *m*ArH), $\Delta G^{\neq} = 11.6 \pm 0.1$ kcal/mol, $\log A = 12.8 \pm 1$.

Conclusions

Calix[4]arene amides were synthesized via aminolysis of the calix[4]arene esters. The aminolysis products depend on the basicity of amine, steric hindrance and the reaction conditions. When the two ethyl esters of the calix[4]arene esters are aminolysized, 1,3-amide derivative is formed because of the steric hindrance effect. The crystal structure of the compound **4b** reveals that there exists intermolecular hydrogen bonds to form two-dimensional net work. The ^1H NMR spectra show that the compound **3b** adopts a pinched cone conformation, while the compounds **4b** and **6b** adopt apparent near cone conformation at room temperature due to interconversion between two C_{2v} symmetry isomers. By decreasing the temperature the interconversion process was frozen and the coalescence temperature, T_c, is $-10℃$ for both compounds **4b** and **6b**. The hydrogen bond raises the interconversion barrier and the coalescence temperature.

Experimental

^1H NMR and H-H COSY spectra were recorded on a 500 MHz spectrometer with Me_4Si as an internal reference. ESI-MS were recorded on LCQ, Finnigan MAT company, with methanol and water as mobile phase and the samples were dissolved in ethanol, which was distilled over Mg powder before use. DMF was dried with 4Å molecular sieves and distilled under reduced pressure. NaH was 60% spread in mineral oil, Aldrich. All amines were purified according to the literature method, and all reactions were carried out under N_2 atmosphere. The crystals were obtained by slow evaporation of the ethanol solution for about 10 days at room temperature. For the sake of clarity and because of the limited space the name calix[4]arene is used instead of the original IUPAC name.

Crystallographic data collection and structure determination

The crystals were mounted on Siemens SHELXTL P4 diffractometer equipped with graphite-monochromatic Mo K_α($\lambda = 0.071073$ nm) radiation. The relevant crystal data and structural parameters are summarized in the data of relevant compounds **3b** and **4b**. The intensities were collected at 293 K using θ—2θ scan mode with a variable scan speed 5.0 to 50.0 degree per minute in ω. The data were corrected for Lorentz and polarization effects during data reduction using XSCANS.[18] The structure was solved by direct method and refined on F^2 by full-matrix least-squares methods using SHELXTL version 5.0. All the non-hydrogen atoms were refined anisotropically. All the hydrogen atoms were placed in calculated positions assigned fixed isotropic thermal parameters at 1.2 times the equivalent isotropic U of the atoms to which they are attached and allowed to ride on their respective parent atoms. The contribution of these hydrogen atoms were included in the structure-factors calculations. All computations were carried out on a PC-586 computer using the SHELXTL-PC Program Package.[19] Analytical expressions of neutral-atom scattering factors were employed and anomalous dispersion corrections incorporated.

General procedure

Method A: To a solution of calix[4]arene esters (0.5 mmoL) in absolute ethanol (20 mL) was added the purified amine, and the mixture was stirred under reflux for 48 hours. Then the solvent was removed at room temperature *in vacuo*, the white powder was obtained, filtered and washed with water, recrystallized from ethanol.

Method B: To a solution of calix[4]arene esters (0.5 mmol) in DMF (5 mL) was added the purified amine and NaH (160 mg, 4 mmol) and the mixture was stirred at room temperature for 24 hours. The solvent was removed *in vacuo* and the yellow powder was obtained, then washed with water and extractedwith $CHCl_3$. The $CHCl_3$ was removed from the extract solution at room temperature *in vacuo*. The powder was recrystallized from ethanol and the white powder was obtained.

5,11,17,23-*Tetra-butyl*-25,26,27,28-*tetra*-2-*hydroxyethylcarbamoylmethyloxy-calix*[4]*arene* (**1a**)

Method A. 5 mmol amine ethanol. Yield 90%. ν_{max}(KBr): 3317 (OH and NH) 1657 (C = O_{amide}) cm^{-1}. δ_H($CDCl_3$): 7.82—8.03(m, 4H), 6.79(s, 8H), 4.58(s, 8H), 4.53(d, J = 13.0Hz, 4H), 3.75(s, 8H), 3.51(s, 8H), 3.28(d, J = 13 Hz, 4H), 2.14(s, 4H), 1.07(s, 36H). ESI-MS positive m/z: 1075.6([M + Na^+], calcd 1076.3), 1053.6 ([M^+], calcd. 1053.3).

25, 26, 27, 28-*tetra*-2-*hydroxyethylcarbamoylmethyloxycalix*[4]*arene* (**1b**)

Method A. 5 mmol ethanol amine. Yield 70%. ν_{max}(KBr): 3281 (OH and NH), 1656 (C = O_{amide}) cm^{-1}. δ_H($CDCl_3$): 7.99(wide s, 4H), 6.62(wide d, J = 22 Hz, 12H), 4.62 (d, J = 20 Hz, 12H), 3.75 (s, 8H), 3.51(s, 8H), 3.31(d, J = 14 Hz, 4H). ESI-MS positive m/z: 851.5 ([M + Na^+], calcd 851.9).

Products of compound **1a** *reacted with n-propyl amine* (**2a**)

Method A. 20 mmol of *n*-propyl amine. ESI-MS positive m/z: 1015.5([**1a** + Na^+], calcd 1016.2), 1028.5([one ethyl ester of **1a** aminolysized by *n*-propyl amine + Na^+], calcd 1029.2), 1044.5 ([one ethyl ester of **1a** aminolysized by *n*-propyl amine + K^+], calcd 1045.3), 1041.5 ([two ethyl esters of **1a** aminolysized by *n* - propyl amine + Na^+], calcd 1042.2), 1057.5([two ethyl esters of **1a** aminolysized by *n*-propyl amine + K^+], calcd 1058.2).

25,27-*diethoxycarbonylmethyloxy*-26,28-*bis* (*n-propylcarbamoylmethyloxy*)*calix*[4]*arene* (**2b**)

Method A. 20 mmol of *n*-propyl amine. Yield 80%. ν_{max}(KBr): 3392 and 3296(NH), 1756(C = Oester), 1682(C = O_{amide}) cm^{-1}. δ_H($CDCl_3$): 8.22(s, 2H), 7.12(d, J = 7.0 Hz, 4H), 6.98(t, J = 7.5 Hz, 2H), 6.30(t, J = 7.5 Hz, 2H), 6.00(d, J = 7.0 Hz, 2H), 4.77(s, 4H), 4.59(d, J = 14 Hz, 4H), 4.26(s, 4H), 4.13(q, J = 7.0Hz, 4H), 3.40(s, 4H), 3.28(d, J = 14 Hz, 4H), 1.67(t, J

= 7.0 Hz, 4H), 1.24(t, J = 7.0 Hz, 6H), 0.97(t, J = 7.0 Hz, 6H). ESI-MS positive m/z: 817.4([M + Na^+], calcd 817.9), 833.3([M + K^+], calcd 834.0).

5,11,17,23-*Tetra-butyl*-25,26,27-*triethoxycarbonylmethyloxy*-28-*n*-*butylcarbamoylmethyloxy*-*calix*[4]-*arene* (**3a**)

Method A. 20 mmol of *n*-butyl amine. Yield 90%. ν_{max}(KBr): 1754(C = O_{ester}), 1679(C = O_{amide}). δ_H(THF-d_8, 500 MHz): 1.07—1.10(m, 3H), 1.21(s,27H), 1.26(s, 9H), 1.37—1.41(m, 9H), 1.49—1.53(m, 2H), 1.72—1.77(m, 2H), 3.32—3.38(m, 4H), 3.45—3.49(m, 2H), 4.28—4.34(m, 6H), 4.56(s, 2H), 4.76—4.79(d, 2H), 4.85—4.91(m, 4H), 4.98—5.00(m, 2H), 5.01—5.04(m, 2H), 6.94—7.02 (m, 8H). ESI-MS positive m/z: 1043([M + Na^+], calcd 1042).

25,27-*Diethoxycarbonylmethyloxy*-26,28-*bis*(*n*-*butylcarbamoylmethyloxy*)-*calix*[4]*arene* (**3b**)

Method A. 20 mmol of *n*-butyl amine. Yield 80%. ν_{max}(KBr): 3400, 3378 and 3286(NH), 1754(C = O_{ester}), 1678(C = O_{amide}) cm^{-1}. δ_H($CDCl_3$): 8.26(s, 2H), 7.12(d, J = 7.5 Hz, 4H), 6.98(t, J = 7.5 Hz, 2H), 6.30(t, J = 7.5 Hz, 2H), 6.02(d, J = 7.5 Hz, 4H), 4.77(s, 4H), 4.59(d, J = 14.0 Hz, 4H), 4.26(s, 4H), 4.14(q, J = 7.0 Hz, 4H), 3.44 (q, J = 7.0 Hz, 4H), 3.28(d, J = 14.0 Hz, 4H), 1.61—1.71(m,4H)1.34—1.47(m,4H), 1.25(t, J = 7.0 Hz, 6H), 0.95(t, J = 7.5 Hz, 6H). δ_H(DMSO-d_6): 7.99(s,2H), 7.01(d, J = 7.0 Hz, 4H), 6.82(t, J = 7.5Hz,2H), 6.39(t, J = 7.5 Hz, 2H), 6.28(d, J = 7.0 Hz, 2H), 4.79(s, 4H), 4.65(d, J = 13.5 Hz, 4H), 4.21(s, 4H), 4.12(q, J = 7.0Hz,4H), 3.23—3.41(m,8H), 1.45—1.53(m, 4H), 1.28—1.38(m, 4H), 1.20(t, J = 7.0 Hz, 6H), 0.88(t, J = 7.0 Hz, 6H). Crystallography data: orthorhombic, space group *Pcab* with cell dimensions of a = 1.6431 (8), b = 2.0652 (3), c = 2.6532 (4) nm, V = 9.003(5) nm^3, Z = 8, μ = 0.85 cm^{-1}, R_1 = 0.1913, wR_2 = 0.4400. ESI-MS positive m/z: 845.5([M + Na^+], calcd 846.0).

5,11,17,23-*Tetra-butyl*-25,26,27,28-*tetra-n-butylcarbamoylmethyloxycalix*[4]*arene* (**4a**)

Method B. 20 mmol *n*-butyl amine. Yield 80%. ν_{max}(KBr): 3411(NH), 1613(C = O_{amide}) cm^{-1}. ESI-MS positive m/z: 1101.7([M^+], calcd 1101.5). ^1H NMR ($CDCl_3$) is very complicated due to various conformatied coexisting.

25,26,27,28-*Tetra*-*n*-*butylcarbamoylmethyloxycalix*-[4]-*arene* (**4b**)

Method B. 20 mmol of *n*-butyl amine. Yield 80%. ν_{max}(KBr): 3285(NH), 1657(C = O_{amide}) cm^{-1}. δ_H($CDCl_3$): 7.47(wide s, 4H), 6.4—6.7(m, 12H), 4.45—4.55(m, 12H), 3.35(wide s, 8H), 3.24(d, J = 13.5 Hz, 4H), 1.50—1.62 (m, 8H), 1.30—1.42(m, 8H), 0.92(t, J = 7.0 Hz, 12H); δ_H(DMSO-d_6): 8.45(s, 4H), 6.32—6.57(m, 12H), 4.58(d, J = 14Hz, 4H), 4.39(s, 8H), 3.19(d, J = 13.5 Hz, 4H), 3.15(q, J = 6.5 Hz, 8H), 1.38—1.47(m, 8H), 1.18—1.26(m, 8H), 0.84(t, J = 7.5 Hz, 12H). ESI-MS positive m/z: 899.6([M + Na^+], calcd 900.1). Crystallography data: Orthorhombic, space group *Aba*2 with cell dimensions of a = 1.3425(4), b = 1.8830(5), c = 2.0126 (5) nm, V = 5.088(3) nm^3, Z = 4, μ = 0.77 cm^{-1}, R_1 = 0.0723, wR_2 = 0.2054.

Products of compound **1b** *reacted with n-amyl amine* (**5b**)

Method A. 20 mmol of *n*-amyl amine. ESI-MS positive m/z: 791.5([**1b** + Na^+], calcd 791.8), 832.5([one ethyl ester of **1b** aminolysized by *n*-amyl amine + Na^+], calcd 832.8), 873.5 ([two ethyl esters of **1b** aminolysized by *n*-amyl amine + Na^+], calcd 874.0), 914.5 ([three ethyl esters of **1b** aminolysized by *n*-amyl amine + Na^+], calcd 915.1).

Products of compound **1a** *reacted with n-heptyl amine* (**6a**)

Method A. 20 mmol of *n*-heptyl amine. ESI-MS positive m/z: 1153.3 ([two ethyl esters of **1a** aminolysized by *n*-heptylamine + Na^+], calcd 1054.1), 1169.7

([two ethyl esters of **1a** aminolysized by *n*-heptyl amine + K^+], calcd 1070.2), 1222.7 ([three ethyl estersof **1a** aminolysized by *n*-heptyl amine + Na^+], calcd 1223.4), 1238.7 ([three ethyl esters of Ia aminolysized by *n*-heptyl amine + K^+], calcd 1239.5), 1292.6([all ethyl esters of **1a** aminolysized by *n*-heptyl amine + Na^+], calcd 1292.6), 1308.8([all ethyl esters of **1a** aminolysized by *n*-heptyl amine + K^+], calcd 1308.7).

25, 26, 27, 28-*Tetra-n-heptylcarbamoylmethyloxycalix*[4]-*arene* (**6b**)

Method A. 20 mmol of *n*-heptyl amine. Yield 85%. ν_{max} (KBr): 3309 (NH), 1656 (C = O_{amide}) cm^{-1}. δ_H($CDCl_3$): 7.42(wide s, 4H), 6.5—6.7(m, 12H), 4.4—4.6(m, 12H), 3.34(wide s, 8H), 3.24(d, J = 13.5Hz, 4H), 1.57(wide s, 8H), 1.30(wide s, 32H), 0.87(t, J = 6.0 Hz, 12H). δ_H (DMSO-d_6): 8.43(s, 4H), 6.56(m, 12H), 4.56 (d, J = 13.5 Hz, 4H), 4.38(s, 8H), 3.18(d, J = 13.5 Hz, 4H), 3.13(q, J = 6.5 Hz, 8H), 1.42(m, 8H), 1.22(wide s, 32H), 0.85(t, J = 6.5 Hz, 12H). ESI-MS positive m/z: 1067.8([M + Na^+], calcd 1068.4).

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