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The synthesis of some new derivatives of calix[4]arene containing azo groups

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Abstract—Five new compounds *p*-(4-*n*-butyl-phenylazo)calix[4]arene (**1**), *p*-(4-phenylazophenylazo)calix[4]arene (**2**), *p*-(4-acetanilidazo)calix[4]arene (**3**), *p*-(*N*′-2-thiazol-2-ylsulfanylazo)calix[4]arene (**4**) and *p*-(2-thiazolazo)calix[4]arene (**5**) have been synthesized from calix[4]arene by diazo coupling with the corresponding aromatic amines. To elucidate the structures of the compounds elemental analyses, UV–vis, IR, ^{1}H and ^{13}C NMR spectral data have been used.

1. Introduction

Calix[4]arenes, which are accessible by the base-catalyzed condensation of *para*-substituted phenols with formaldehyde, are now well-known compounds. These compounds have lately attracted considerable attention because of their potential as enzyme mimics. The chemistry of calix[*n*]-arenes [*n*=4–8] is well represented in the literature due to the ease with which these molecules can be synthesized.[1–3] Extraction, transport, stability constant and colorimetric measurements, augmented by NMR, X-ray and computer simulation studies, provide evidence that many of these lower rim derivatives have very significant ionophoric properties for cations, several with good selectivity within groups of metals.[4]

Calixarenes, which are appropriately designed, exhibit a large variety of functions; e.g. as inclusion compounds,[5] selective complexing agents for metal ions,[6,7] and catalysts.[8,9]

Nomura et al. described azo group containing compounds which are of interest because of their properties as binding sites for complexation or as chromophores of dyes. They reported the synthesis of a calix[6]arene derivative containing azo groups and its binding properties for metal ions.[10]

Shimuzu et al. synthesized a chromogenic calix[4]arene which has within the molecule a calix[4]aryl triester moiety as a metal binding site and an azophenol moiety as a coloration site.[11] Diazo-coupling reactions of calix[4]arene were studied by Morita et al. and Shinkai et al. and they described the resulting NMR spectra.[12,13]

In our recent work, we have synthesized a *vic*-dioxime derivative of calix[*n*]arene and its complexes,[14–18] polymeric calix[*n*]arene derivatives and selective extraction of transition metal cations.[19–23] In this work, we report the synthesis of five new substituted calix[4]arenes. These were synthesized from calix[4]arene with 4-*n*-butylaniline, 4-(phenylazo)aniline, 4-aminoacetanilide, *N*′-2-thiazol-2-ylsulfanylamide and 2-aminothiazole by diazo coupling.

2. Results and discussion

In this work, five new diazo-coupled calix[4]arenes were synthesized from 5,11,17,23-tetrahydroxycalix[4]arene and 4-*n*-butylaniline, 4-(phenylazo)aniline, 4-aminoacetanilide, *N*′-2-thiazol-2-ylsulfanylamide and 2-aminothiazol (Fig. 1).

p-(4-*n*-Butyl-phenylazo)calix[4]arene (**1**), was obtained by the diazo-coupling reaction in the following manner. First, calix[4]arene was prepared by debutylation of *p*-*tert*-butylcalix[4]arene.[24,25] The coupling reaction of calix[4]arene with 4-*n*-butyl-benzenediazonium chloride in aqueous THF gave *p*-(4-*n*-butylphenylazo)calix[4]arene in 85% yield.

The *p*-(4-phenylazophenylazo)calix[4]arene (**2**), *p*-(4-acetanilidazo)calix[4]arene (**3**), *p*-(*N*′-2-thiazol-2-ylsulfanylazo)calix[4]arene (**4**) and *p*-(2-thiazolazo)calix[4]arene (**5**) were obtained by the same method in 53–81% yield. These yields are in accordance with the literature for similar compounds.[10–13] The obtained compounds were purified by crystallization in the same solvent (acetic acid–MeOH) and were then analyzed.

The ^{1}H NMR chemical shifts of the calix[4]arene starting materials: –OH (10 ppm), –Ar (6.5–7.5 ppm) and methyl-

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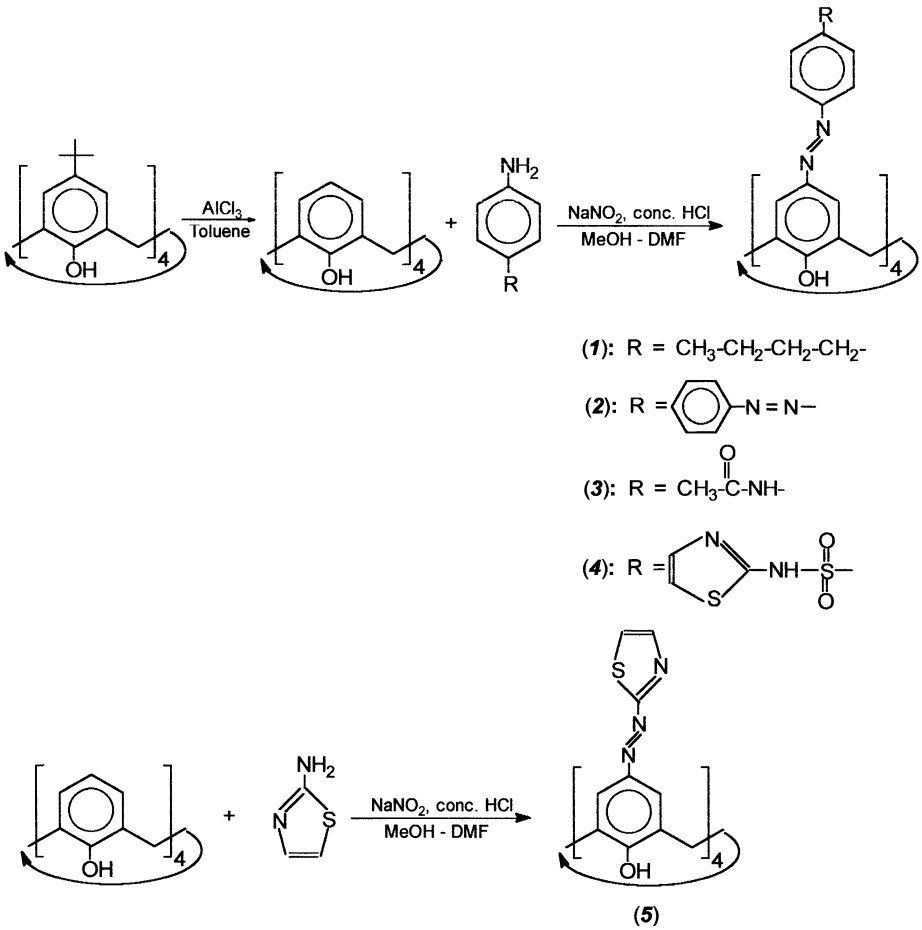

Figure 1. Azo derivatives of calix[4]arene.

ene bridge (3.5–4.5 ppm), are identical with literature values.[12,13] The ^{1}H NMR spectra of compound **1**, $-CH_3$ and $-CH_2-$ protons of the *n*-butyl group are a triplet (0.90 ppm) and multiplets (1.33 or 1.55 ppm), respectively. It was observed that the $-CH_2-Ar$ protons resonate at 2.65 ppm as a doublet.

Although the peaks of the aromatic protons for compound **2** and the calix[4]arene starting materials are complicated, the integration of the peaks show that the initially formed high yield (81%) of the diazo compound is diazotized a second time to give compound **2**. The methyl and –NH– protons of compound **3** resonate at 2.16 and 7.66 ppm, respectively. In compounds **4** and **5**, the two symmetric ═CH– protons of the thiazole ring are observed as two doublets at about 1.25–1.55 ppm. The secondary carbons of the characteristic thiazole ring in ^{13}C NMR spectra appear at about 153.4–143.2 ppm for compounds **4** and **5**, respectively.

In the IR spectra, the stretching vibrations of the diazo compounds **1**–**5** appear at 3170–3225 cm^{-1} (–OH), 3100–3170 cm^{-1} (aromatic C–H), 1590–1610 cm^{-1} (aromatic –C═C–) and 1470–1550 cm^{-1} (–N═N–). Compounds **1** and **4** have characteristic strong IR absorption bands at 2950 cm^{-1} ($-CH_2-$) and 1320 cm^{-1} ($-SO_2-$), respectively. The characteristic carbonyl band appears at 1710 cm^{-1} for compound **3**.

In the electronic spectra the absorptions at 338 and 384 nm arise from $\pi-\pi^*$ transitions of the –N═N– bond. The synthesis of diazo-coupled calix[4]arene compounds is reported as chromogenic substances.[11]

None of the five compounds dissolves in water, but all are soluble in acetic acid and DMSO. However, they are slightly soluble in 10% HCl and insoluble in 10% NaOH. All the compounds dissolve in EtOH and acetone easily.

The results suggest that the structure consists of isolated molecules with van der Waals contacts and the molecule was essentially planar in the solid state containing a strong intramolecular hydrogen bond between the hydroxyl and azo groups. In calix[4]arene derivatives, the δ_{OH} in ^{1}H NMR shifts to lower magnetic field and the ν_{OH} in IR shifts to lower frequency when the OH groups form strong intramolecular hydrogen bonds,[26] and in this case, the δ_{OH} ($CDCl_3$, 25°C) and the ν_{OH} (KBr) for all compounds appeared at 10.25–9.90 ppm and 3225–3170 cm^{-1} (broad), respectively.

3. Conclusion

Diazo-coupling reactions are shown in Fig. 1. This pathway is the most convenient method which gives the best yield of diazo-coupling calixarene compounds.

We studied the diazo-coupling reactions of calix[4]arene with benzendiazonium chloride, 4-*n*-butylaniline, 4-(phenylazo)aniline, 4-aminoacetanilide, *N*′-2-thiazol-2-ylsulfanylamide and 2-aminothiazole.

Five new type of calixarene-based receptors with hydrogen-bonding groups immersed in a large cavity has been proposed and synthesized. Syntheses of all diazo-coupling compounds were achieved by the combination of the Morita. These reactions proceeded smoothly to produce the corresponding azo compounds in good yield.

On the other hand, the azo groups of these compounds are interesting because they act as metal binding sites as well as chromophores. We are currently working on these azo group containing calix[4]arene derivatives and in particular their binding properties for metal ions.

4. Experimental

All reagents used were purchased from Merck or Carlo-Erba and were chemically pure. Melting points were determined on an Electrothermal IA9100 digital melting point apparatus and are uncorrected. ^{1}H NMR spectra were referenced to tetramethylsilane (TMS) at 0.00 ppm as an internal standard and recorded on a Bruker 200 MHz spectrometer at room temperature (25±1°C), and ^{13}C NMR spectra were referenced to $CDCl_3$ (77.00 ppm) or to TMS (0.00 ppm) and also recorded at room temperature (25±1°C). IR spectra were recorded on a Mattson 1000 FTIR spectrometer as KBr pellets. UV–vis spectra were obtained on a Shimadzu 160A UV–visible recording spectrophotometer. The elemental analyses were performed in the TUBITAK Laboratory (Center of Science and Technology Research of Turkey). Osmometric molecular weight determinations were carried out on a Knauer vapor pressure osmometer at concentrations of ca. 10^{-3} mol/L in $CHCl_3$.

4.1. Preparation of the ligands

p-tert-Butylcalix[4]arene[24] and calix[4]arene[25] were synthesized as described by a previously reported method.

4.1.1. Synthesis of *p*-(4-*n*-butylphenylazo)calix[4]arene (1). *General procedure*.[12] A solution of 4-*n*-butylphenyldiazonium chloride, which was prepared from 4-*n*-butylaniline (1.49 g, 10 mmol), sodium nitrite (0.69 g, 10 mmol) and conc. HCl (7 mL) in water (25 mL), was added slowly into a cold (5°C) solution of calix[4]arene (1.0 g, 2.36 mmol) and sodium acetate trihydrate (4.08 g, 30 mmol) in MeOH–DMF (26 mL, 5:8, v/v) to give a red suspension. After being allowed to stand for 2 h at room temperature, the suspension was acidified with aqueous HCl (150 mL, 0.25%). The mixture was warmed to 60°C for 30 min to produce **1** in near quantitative yield (2.42 g, 93%) as a reddish solid, which was filtered and washed with water and MeOH. A sample for analysis was obtained as follows. Compound **1** was dissolved in 100 mL of a hot $NaHCO_3$ (4.2 g) solution. To this solution was added activated charcoal (1 g). After the charcoal was filtered, the filtrate was cooled (room temperature) and acidified with conc. HCl (1 or 2 mL). The solution was heated (60°C) again for 30 min and cooled. The resulting solid was filtered, washed with water, and dried. Yield, 2.21 g (85%) as a dark yellow solid, mp 248°C; [Found: C 75.22; H 7.07; N 10.03. $C_{69}H_{76}N_8O_5$ requires C 75.51; H 6.98; N 10.22]. $\lambda_{max}(\varepsilon)$: 338 (8970). ν_{max}: 3200, 3170, 2950, 1600, 1470 cm^{-1}. ^{1}H NMR ($CDCl_3$, 25°C): δ_H: 0.90 (12H, t, J=13.6 Hz, –CH_3), 1.33 (8H, m, –CH_2–), 1.55 (8H, m, –CH_2–), 2.65 (8H, t, J=13.6 Hz, –CH_2–), 3.80–4.40 (8H, d, J=13.3 Hz, Ar–CH_2–Ar), 7.20–7.70 (24H, s, Ar-H), 10.25 (4H, s, –OH). ^{13}C NMR ($CDCl_3$, 25°C): δ_C: 139.7, 135.2, 134.7, 132.3, 130.4, 128.7, 122.9, 120.1, 30.7, 20.2, 19.9, 18.1, 17.4.

This compound **1** was soluble in EtOH, diethyl ether, acetone, acetic acid, benzene, $CHCl_3$, DMSO and insoluble in water.

4.1.2. Synthesis of *p*-(4-phenylazophenylazo)calix[4]-arene (2). Compound **2** was prepared as described above, using 4-(phenylazo)aniline and obtained as a dark brown solid, which was filtered and washed with water and MeOH. Yield, 2.48 g (81%) as a dark brown solid, mp 146°C; [Found: C 71.42; H 4.78; N 17.12. $C_{77}H_{60}N_{16}O_5$ requires C 71.71; H 4.69; N 17.39]. $\lambda_{max}(\varepsilon)$: 374 (4830). ν_{max}: 3225, 3100, 1610, 1480 cm^{-1}. ^{1}H NMR ($CDCl_3$, 25°C): δ_H: 3.90–4.70 (8H, d, J=13.3 Hz, Ar–CH_2–Ar), 6.80–7.70 (44H, s, Ar-H), 9.90 (4H, s, –OH). ^{13}C NMR ($CDCl_3$, 25°C): δ_C: 145.1, 144.2, 139.5, 135.5, 135.1, 132.3, 123.4, 120.9, 32.4.

Compound **2** was soluble in EtOH, acetone, acetic acid, benzene, $CHCl_3$, DMSO, and slightly soluble in diethyl ether, and insoluble in water.

4.1.3. Synthesis of *p*-(4-acetanilidazo)calix[4]arene (3). Compound **3** was prepared as described above, using 4-aminoacetanilide and obtained as a pale brown solid, which was filtered and washed with water and MeOH. Yield, 1.39 g (53%) as a pale brown solid, mp 174°C; [Found: C 66.88; H 5.47; N 15.10. $C_{61}H_{56}N_{12}O_9$ requires C 66.52; H 5.13; N 15.27]. $\lambda_{max}(\varepsilon)$: 274 (2120), 360 (1580). ν_{max}: 3200, 3100, 1710, 1610, 1480 cm^{-1}. ^{1}H NMR ($CDCl_3$, 25°C): δ_H: 2.16 (12H, t, J=13.5 Hz, –CH_3), 3.60–4.30 (8H, d, J=13.3 Hz, Ar–CH_2–Ar), 6.72–7.25 (24H, s, Ar-H), 7.66 (4H, s, NH), 10.19 (4H, s, –OH). ^{13}C NMR ($CDCl_3$, 25°C): δ_C: 167.9, 144.5, 134.7, 133.7, 133.2, 131.7, 124.9, 121.2, 32.2, 21.3.

Compound **3** was soluble in EtOH, acetone, acetic acid, benzene, $CHCl_3$, DMSO, and slightly soluble in diethyl ether, and insoluble in water.

4.1.4. Synthesis of *p*-(*N*′-2-thiazol-2-ylsulphanylazo)-calix[4]arene (4). Compound **4** was prepared as described above, using 4-*N*′-2-thiazol-2-ylsulfanylamide and was obtained as an orange solid, which was filtered and washed with water and MeOH. Yield, 2.63 g (72%) as an orange solid, mp 162°C; [Found: C 50.84; H 3.82; N 14.38; S 16.35. $C_{66}H_{56}N_{16}S_8O_{14}$ requires C 51.02; H 3.64; N 14.43; S 16.48]. $\lambda_{max}(\varepsilon)$: 274 (220), 349 (1570). ν_{max}: 3170, 3100, 1590, 1550, 1320 cm^{-1}. ^{1}H NMR ($CDCl_3$, 25°C): δ_H: 1.25–1.54 (8H, two d, J=13.4 Hz, =CH–), 3.50–4.35 (8H, d, J=13.3 Hz, Ar–CH_2–Ar), 6.72–7.26 (24H, s, Ar-H), 7.70

(4H, s, NH), 10.18 (4H, s, –OH). ^{13}C NMR ($CDCl_3$, 25°C): δ_C: 152.7, 146.1, 143.2, 137.1, 135.7, 133.3, 131.4, 130.2, 123.9, 120.6, 119.9, 31.7.

Compound **4** was soluble in EtOH, acetone, acetic acid, DMSO, and slightly soluble in diethyl ether, $CHCl_3$ and insoluble in water.

4.1.5. Synthesis of *p*-(2-thiazolazo)calix[4]arene (5). Compound **5** was prepared as described above, using 2-aminothiazol and obtained as a dark red solid, which was filtered and washed with water and MeOH. Yield, 1.51 g (68%) as a dark red solid, mp 312°C; [Found: C 53.73; H 4.13; N 17.85; S 13.44. $C_{42}H_{36}N_{12}S_4O_6$ requires C 54.07; H 3.89; N 18.03; S 13.72]. $\lambda_{max}(\varepsilon)$: 384 (1890). ν_{max}: 3200, 3120, 1600, 1480 cm^{-1}. ^{1}H NMR ($CDCl_3$, 25°C): δ_H: 1.25–1.55 (8H, 2d, J=13.4 Hz, =CH–), 3.60–4.30 (8H, d, J=13.3 Hz, Ar–CH_2–Ar), 6.71–7.25 (8H, s, Ar-H), 10.16 (4H, s, –OH). ^{13}C NMR ($CDCl_3$, 25°C): δ_C: 153.4, 144.8, 144.6, 135.7, 124.3, 121.1, 120.3, 31.5.

This compound **5** was soluble in acetone, acetic acid, $CHCl_3$, DMSO, and slightly soluble in EtOH, diethyl ether, and insoluble in water.

References

1. Gutsche, C. D. *Calixarenes Revisited*; Royal Society of Chemistry: Cambridge, 1998 23.
2. Gutsche, C. D. *Acc. Chem. Res.* **1983**, *16*, 161–170.
3. Gutsche, C. D. *Prog. Macrocycl. Chem.* **1987**, *3*, 93–165.
4. McKervey, M. A.; Schwing-Weill, M. J.; Arnaud-Neu, F. *Comprehensive Supramolecular Chemistry*; Gokel, G. W., Ed.; Pergamon: New York, 1996; Vol. 1, p 537.
5. McKervey, M. A.; Steward, E. M.; Ferguson, G.; Ruhl, B. L. *J. Org. Chem.* **1986**, *51*, 3581–3592.
6. Arduini, A.; Pochini, A.; Reverberi, S.; Ungaro, R.; Andretti, G. D.; Ugozzoli, F. *Tetrahedron* **1986**, *42*, 2089–2098.
7. Shinkai, S.; Koreishi, K.; Ukeda, K.; Arimura, T.; Manabe, O. *J. Am. Chem. Soc.* **1987**, *109*, 6371–6376.
8. Ikeda, A.; Nagasaki, T.; Araki, K.; Shinkai, S. *Tetrahedron* **1992**, *48*, 1059–1070.
9. Araki, K.; Yanagi, A.; Shinkai, S. *Tetrahedron* **1993**, *49*, 6763–6772.
10. Nomura, E.; Taniguchi, H.; Tamura, S. *Chem. Lett.* **1989**, 1125–1126.
11. Shimuzu, H.; Iwamato, K.; Fujimoto, K.; Shinkai, S. *Chem. Lett.* **1991**, 2147–2150.
12. Morita, Y.; Agawa, T.; Nomura, E.; Taniguchi, H. *J. Org. Chem.* **1992**, *57*, 3658–3662.
13. Shinkai, S.; Araki, K.; Shibata, J.; Tsugawa, D.; Manabe, O. *J. Chem. Soc., Perkin Trans. 1* **1990**, 3333–3335.
14. Yilmaz, M.; Deligöz, H. *Synth. React. Inorg. Met.-Org. Chem.* **1993**, *23*, 67–75.
15. Deligöz, H.; Yilmaz, M. *Synth. React. Inorg. Met.-Org. Chem.* **1996**, *26*, 943–953.
16. Deligöz, H. *Org. Prep. Proced. Int.* **1999**, *31*, 173–179.
17. Deligöz, H.; Pekacar, A. I.; Özler, M. A.; Ersöz, M. *Separation Sci. Technol.* **1999**, *34*, 3297–3304.
18. Deligöz, H.; Alpoguz, H. K.; Çetisli, H. *J. Macromol. Sci.,-Pure Appl. Chem.* **2000**, *37*, 407–415.
19. Deligöz, H.; Tavasli, M.; Yilmaz, M. *J. Polym. Sci., Part A: Polym. Chem.* **1994**, *32*, 2961–2964.
20. Deligöz, H.; Yilmaz, M. *J. Polym. Sci., Part A: Polym. Chem.* **1995**, *33*, 2851–2853.
21. Yilmaz, M.; Deligöz, H. *Separation Sci. Technol.* **1996**, *31*, 2395–2402.
22. Memon, S.; Yilmaz, A.; Yilmaz, M. *J. Macromol. Sci., Pure Appl. Chem.* **2000**, *37*, 865–879.
23. Memon, S.; Uysal, G.; Yilmaz, M. *Separation Sci. Technol.* **2000**, *35*, 1247–1254.
24. Gutsche, C. D.; Iqbal, M. *Org. Synth.* **1990**, *68*, 234–238.
25. Gutsche, C. D.; Iqbal, M.; Stewart, D. *J. Org. Chem.* **1986**, *51*, 742–745.
26. Araki, K.; Iwamoto, K.; Shinkai, S.; Matsuda, T. *Bull. Chem. Soc. Jpn* **1990**, *63*, 3480–3485.