Research Article

One-Pot Synthesis of Novel Dibenzoxanthenes, Diarylbutanes, and Calix[4]resorcinarenes via Consecutive Pyrrolidine Ring-Closure/Ring-Opening Reactions

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Herein, we report the approach to the otherwise hardly accessible dibenzoxanthenes, diarylbutanes, and calix[4]resorcinarenes possessing urea moieties based on the reaction of *N*-(4,4-diethoxybutyl)ureas with electron-rich aromatics in strongly acidic media. Unlike the previously developed methods, the proposed approach benefits from one-pot procedure and allows to obtain the target compounds with much higher yields.

1. Introduction

Diarylmethane derivatives containing two phenolic moieties are of interest due to their wide spectrum biological activity. These compounds are known to inhibit C-C chemokine receptors [1], possess anti-inflammatory [2], anti-proliferative [3], antimicrobial [4], anti-HIV [5], and anticancer activity [6]. Some compounds of this class exhibit antibacterial properties [7, 8]. Additionally, diarylmethane derivatives containing an urea fragment can be used to treat hyperparathyroidism [9–11], malaria [12], and atherosclerosis [13] and inhibit lysine-specific demethylase 1 (LSD1) [14], DNA topoisomerase [15], and epoxy hydrolase [16].

The most general approach to these compounds is the acidic media condensation of electron-rich aromatic nucleophiles with aldehydes [17–19] or acetals [20–22] (Scheme 1(A)). However, this method is inapplicable in case of acetals containing urea moiety, since these compounds are subject to intramolecular cyclization in acidic media [23–26]. Earlier, we have developed the approach to diarylbutanes, dibenzoxanthenes, and calixarenes possessing urea fragment via acid-catalyzed ring opening of 2-(2-hydroxynaphthalene-1-yl)pyrrolidine-1-carboxamides 1

[27, 28] (Scheme 1(B)). Although the proposed approach benefits from mild reaction conditions and usage of inexpensive trifluoroacetic acid as catalyst, its certain disadvantage is the necessity of preliminary synthesis of intermediate 2-(2-hydroxynaphthalene-1-yl)pyrrolidines 1. At the same time, methods allowing “one-pot” synthesis of the target compounds is of a great importance nowadays due to both their effectiveness and atom economy [29], which are among main principles of green chemistry. Thus, herein we report the improved one-pot approach to the diarylbutane derivatives containing urea moieties starting from easily accessible *N*-(4,4-diethoxybutyl)ureas 2.

2. Results and Discussion

We assumed that pyrrolidine ring opening in strongly acidic media is general for all 2-aryl substituted pyrrolidines. This assumption was supported both by our own observations [27] and synthesis of diphenylbutane derivative upon treatment of *N*-phenacyl-2-phenylpyrrolidine with triflic acid in benzene solution described by King et al. [30] (Scheme 1(C)). Based on this data, we proposed that carrying out the reaction of *N*-(4,4-diethoxybutyl)ureas with

SCHEME 1: Synthesis of diarylmethane derivatives.

phenols in strongly acidic media would allow us to obtain appropriate diarylbutanes in one-pot procedure via consecutive pyrrolidine ring closure-ring opening processes. Thus, the need of preliminary synthesis of 2-(2-hydroxynaphthalene-1-yl)pyrrolidines would be eliminated.

First, we studied the reaction of ureas **2a,c** with 2-naphthol **3**. The reaction was carried out in chloroform solution in the presence of 3-fold excess of trifluoroacetic acid, since these conditions were found to be optimal for the ring opening in 2-(2-hydroxynaphthalene-1-yl)pyrrolidines **1** [27]. However, according to NMR data, in this case the yield of target dibenzoxanthenes **5a,c** appeared to be rather low. The main products were previously described by us 2-naphthylpyrrolidine derivatives **1a,c** [24] (Scheme 2). Next, we gradually increased the amount of trifluoroacetic acid used. Upon increasing the excess of trifluoroacetic acid up to 20-fold, the reaction led to the formation of target dibenzoxanthenes with about 80% yield (Table 1, Nos. 1 and 2). Naphthalene-2,7-diol **4** reacted under the same conditions with urea **2b** with the formation of previously unknown 2,12-dihydroxydibenzoxanthene derivative **6b** containing urea moiety (Table 1, No. 3).

Further, 4-bromoresorcinol and sesamol were involved into this reaction. The choice of the substrates was based on their known biological activity. For example, sesamol exhibits antioxidant properties [31, 32] and is a part of the antidepressant paroxetine structure [33–35] and bromoresorcinol dimers are known for their antimicrobial activity [4]. The reaction of these compounds with ureas **2a–c** led to the diarylbutane derivatives **7a** and **8a–c** (Scheme 3, Table 1, Nos. 4–7). Hydroxycoumarine, which is part of the many biologically active compounds [36–39], also successfully undergoes this reaction, leading to the formation of bis(4-hydroxy-2H-chromen-2-one) derivative **9a** (Table 1, No. 8).

The applicability of this approach to the synthesis of macrocyclic compounds has been demonstrated as well using 2-methylresorcinol as a model substrate. The reaction of this phenol with ureas **2a,d** resulted in the appropriate calix[4]resorcinarenes **10a,d** formation with up to 70% yield (Scheme 4, Table 1, No. 9, 10).

As seen from Table 1, using *N*-(4,4-diethoxybutyl)ureas **2** as a starting compounds instead of 2-(2-hydroxynaphthalene-1-yl)pyrrolidines allowed us to increase the yields of the target

compounds by 16% in average. Taking into account the losses of the starting material during the preliminary synthesis of 2-(2-hydroxynaphthalene-1-yl)pyrrolidines, the overall gain in yield was more than 20% (Scheme 5).

Taking into consideration previously published data [30, 40], we proposed the mechanism of this reaction depicted in Scheme 6. The first stage of the reaction is a protonation of ethoxy group and elimination of ethanol molecule. The oxonium cation **A** thus formed may further react with phenol molecule, leading to the 2-arylpyrrolidine derivative **B** as previously described [24]. Subsequent pyrrolidine ring opening in the presence of excess of trifluoroacetic acid followed by interaction with another phenol molecule via the mechanism similar to that of 2-(2-hydroxynaphthalene-1-yl)pyrrolidines [27] results in the formation of target compounds **E**.

In principle, the other pathway is also possible. It includes the protonation of urea moiety of the oxonium cation **A**, leading to the dication **F**. The presence of significant positive charge on the nitrogen atom prevents its intramolecular cyclization, and its further reaction with phenol molecule leads to the acyclic intermediate **H**. Further reaction of this compound with another phenol molecule via the benzylic cation **I** also results in the formation of final compounds **E**.

The experimental data present at the moment does not allow us to unequivocally distinguish between these mechanisms. However, taking into account much higher rate of intramolecular cyclization of *N*-(4,4-diethoxybutyl)ureas **2** compared to their intermolecular interaction with phenols, as well as instability of dicationic species in non-superacidic media, the first pathway seems to be more probable. Additionally, no acyclic intermediates were present in mass-spectra of the reaction mixture, which may also indicate the preference of the first pathway over second one.

3. Conclusions

In conclusion, we have developed one-pot approach to the otherwise hardly accessible dibenzoxanthenes, diarylbutanes, and calix[4]resorcinarenes possessing urea moieties via the reaction of *N*-(4,4-diethoxybutyl)ureas with electron-rich aromatics in strongly acidic media. The

SCHEME 2: Synthesis of dibenzoxanthenes.

TABLE 1: Synthesis of the compounds 5–10.

No.	Compound	Yield (%) ^{a,b}
1	5a	87 (78)
2	5c	79 (53)
3	6b	65 (57)
4	7a	72 (28)
5	8a	95 (74)
6	8b	93 (69)
7	8c	59 (48)
8	9a	42 (60)
9	10a	70 (74)
10	10d	62 (56)

^aIsolated yield; ^byield from 2-(2-hydroxynaphthalen-1-yl)pyrrolidine according to the procedure described in [27] is given in parentheses.

SCHEME 3: Synthesis of diarylbutanes.

reaction presumably proceeds via consecutive pyrrolidine ring closure-ring opening stages. The proposed approach, in contrast to the previously developed method, does not require an isolation of intermediates and allows to obtain target compounds with much higher yields.

4. Experimental

IR spectra were recorded on a UR-20 spectrometer in the 400–3600 cm^{-1} range in KBr. ^1H NMR spectra were recorded on a Bruker MSL 400 spectrometer (400 MHz)

with respect to the signals of residual protons of deuterated solvent (DMSO-d_6). ^{13}C NMR spectra were recorded on a Bruker Avance 600 (150 MHz) spectrometer relative to signals of residual protons of deuterated solvent (DMSO-d_6). MALDI mass-spectra are obtained on a mass spectrometer UltraFlex III TOF/TOF (Bruker Daltonik GmbH, Bremen, Germany) in a linear mode. The laser is Nd:YAG, $\lambda = 266 \text{ nm}$.

The data were processed with the FlexAnalysis 3.0 program (Bruker Daltonik GmbH, Bremen, Germany). Positively charged ions were fixed, and a metal target was used. 2,5-Dihydroxybenzoic acid (DHB) was used as a matrix. Elemental analysis is performed on a Carlo Erba device EA 1108. The melting points are determined in glass capillaries on a Stuart SMP 10 instrument.

2-(2-Hydroxynaphthalen-1-yl)pyrrolidine-1-carboxamides **1a–d** were obtained as described previously [24, 25].

4.1. General Method for the Synthesis of Dibenzoxanthenes 5a,b and 6c [27]. To a solution of 1.10 mmol naphthol **4** or **5** in 5 ml of dry chloroform, 0.55 mmol 2-(2-hydroxynaphthalen-1-yl)pyrrolidine-1-carboxamides **1** and 2 ml trifluoroacetic acid were added. The mixture was stirred at room temperature for 72 h. Solvent was evaporated in vacuum. Residue was washed with diethyl ether, filtered, and dried in vacuum (1 h, 0.01 Torr) to give the title compound.

4.2. General Method for the Synthesis of Dibenzoxanthenes 5a,c and 6b. To a mixture of 1.17 mmol of naphthol, 5 ml of chloroform and 0.59 mmol of acetal **2**, and 2 ml of trifluoroacetic acid were added. The reaction mixture was stirred for 24 hours at room temperature, the solvent was removed in vacuum, and the residue was washed with diethyl ether and dried in vacuum.

4.2.1. 1-(3-(14H-Dibenzo[a,j]xanthen-14-yl)pro-pyl)-3-phenylurea (5a). White crystals, m.p. 240°C–241°C, yield 87%. IR (cm^{-1} , KBr): 1592, 1650, 2937, 3065, 3328. ^1H NMR (δ ppm, DMSO-d_6): 1.00–1.11 (m, 2H, CH_2), 1.89–1.99 (m, 2H, CH_2), 2.71–2.79 (m, 2H, CH_2), 5.72–5.77 (m, 1H, CH), 5.81–8.84 (m, 1H, NH), 6.82 (t, $J = 7.1 \text{ Hz}$, 1H, CH_{Ar}), 7.13 (t, 2H, $J = 8.2 \text{ Hz}$, CH_{Ar}), 7.23 (d, 2H, $J = 7.8 \text{ Hz}$, CH_{Ar}), 7.44 (d, 2H, $J = 8.9 \text{ Hz}$, CH_{Ar}), 7.49–7.54 (m, 2H, CH_{Ar}), 7.65–7.71 (m,

4.2.2. 1-(3-(14H-Dibenzo[a,j]xanthen-14-yl)propyl)-3-hexylurea (5c). White crystals, m.p. 183°C–184°C, yield 79%. IR (cm⁻¹, KBr): 1592, 1625, 2857, 2927, 3069, 3417. ¹H NMR (δ ppm, DMSO-*d*₆): 0.83 (t, 3H, *J* = 7.04 Hz, CH₃), 0.91–1.02 (m, 2H, CH₂), 1.08–1.27 (m, 8H, CH₂), 1.84–1.93 (m, 2H, CH₂), 2.59–2.67 (m, 2H, CH₂), 2.76–2.83 (m, 2H, CH₂), 5.42–5.51 (m, 2H, NH), 5.69–5.74 (m, 1H, CH), 7.43 (d, 2H, *J* = 8.9 Hz, CH_{Ar}), 7.47–7.54 (m, 2H, CH_{Ar}), 7.64–7.70 (m, 2H, CH_{Ar}), 7.91 (d, 2H, *J* = 8.9 Hz, CH_{Ar}), 7.94–7.99 (m, 2H, CH_{Ar}), 8.51–8.56 (m, 2H, CH_{Ar}). ¹³C NMR (δ ppm, DMSO-*d*₆): 14.3, 15.6, 22.5, 26.4, 26.5, 30.3, 31.4, 33.9, 39.4, 117.0, 117.6, 123.5, 124.8, 127.3, 128.9, 129.1, 131.1, 131.5, 149.8, 158.2. MALDI TOF, *m/z*: 489 [M+Na]⁺ [27].

4.2.3. 1-(3-(2,12-Dihydroxy-14H-dibenzo[a,j]xanthen-14-yl)propyl)-3-(4-methoxyphenyl)urea (**6b**). White crystals, m.p. 183–185°C, yield 65%. IR (cm⁻¹, KBr): 1596, 2835, 3195, 3314. ¹H NMR (δ ppm, DMSO-*d*₆): 1.00–1.14 (m, 2H, CH₂), 2.73–2.87 (m, 2H, CH₂), 3.62–3.71 (m, 2H, CH₂), 3.66 (s, 3H, CH₃), 5.25 (t, *J* = 4.7 Hz, 1H, CH), 5.76 (t, *J* = 5.4 Hz, 1H, NH), 6.74 (d, *J* = 8.9 Hz, 2H, CH_{Ar}), 7.08 (d, *J* = 7.6 Hz, 2H, CH_{Ar}), 7.13–7.18 (m, 4H, CH_{Ar}), 7.57 (s, 2H, CH_{Ar}), 7.75 (d, *J* = 8.7 Hz, 2H, CH_{Ar}), 7.80 (d, *J* = 8.7 Hz, 2H, CH_{Ar}), 7.89 (s, 1H, NH), 9.86 (s, 2H, OH). ¹³C NMR (δ ppm, DMSO-*d*₆): 14.52, 26.43, 30.65, 32.69, 55.56, 105.07, 114.21, 114.25, 114.96, 117.05, 119.92, 125.56, 128.67, 130.81, 133.18, 134.01, 150.28, 154.32, 155.67, 156.97. MALDI-TOF: 543 [M+Na]⁺. Anal. Calcd.: C₃₂H₂₈N₂O₅ (520), C, 73.83; H, 5.42; N, 5.38. Found: C, 73.98; H, 5.60; N, 5.48.

4.3. General Method for the Synthesis of Diarylbutanes 7a, 8a–c, 9a [27]. To a mixture of 0.30 mmol pyrrolidine-1-

carboxamide **1** in 5 ml of dry chloroform, appropriate 0.90 mmol phenol and 2 ml trifluoroacetic acid were added. The mixture was stirred at room temperature for 72 h. Solvent was evaporated in vacuum. Residue was washed with diethyl ether, filtered, and dried in vacuum (1 h, 0.01 Torr) to give the title compound **7a**, **8a–c**, **9a**.

4.4. General Method for the Synthesis of Diarylbutanes 7a, 8a–c, 9a. To a mixture of 1.82 mmol of phenol, 5 ml of chloroform, and 0.91 mmol of acetal **2**, 2 ml of trifluoroacetic acid was added. The reaction mixture was stirred for 24 hours at room temperature, the solvent was removed in vacuum, and the residue was washed with diethyl ether and dried in vacuum.

4.4.1. 1-(4,4-Bis(5-bromo-2,4-dihydroxyphenyl)butyl)-3-phenylurea (7a). White crystals, m.p. 132°C–133°C, yield 72%. IR (cm⁻¹, KBr): 1597, 1652, 2868, 2937, 3402. ¹H NMR (δ ppm, DMSO-*d*₆): 1.27–1.37 (m, 2H, CH₂), 1.77–1.86 (m, 2H, CH₂), 3.02–3.10 (m, 2H, CH₂), 4.25 (t, 1H, *J* = 7.9 Hz, CH_{Ar}), 6.08 (t, 1H, *J* = 5.8 Hz, NH), 6.45 (s, 2H, CH_{Ar}), 6.84–6.89 (m, 1H, CH_{Ar}), 7.03 (s, 2H, CH_{Ar}), 7.16–7.22 (m, 2H, CH_{Ar}), 7.33–7.38 (m, 2H, CH_{Ar}). ¹³C NMR (δ ppm, DMSO-*d*₆): 29.0, 31.5, 36.1, 65.4, 98.2, 104.0, 118.1, 121.3, 124.4, 129.0, 131.7, 141.0, 152.7, 155.5, 155.6. MALDI TOF, *m/z*: 589 [M+Na]⁺ [27].

4.4.2. 1-(4,4-Bis(6-hydroxybenzo[d][1,3]dioxol-5-yl)butyl)-3-phenylurea (8a). White crystals, m.p. 165–166°C, yield 95%. IR (cm⁻¹, KBr): 1596, 2935, 3291, 3383. ¹H NMR (δ ppm, DMSO-*d*₆): 1.29–1.39 (m, 2H, CH₂), 1.80–1.89 (m, 2H, CH₂), 3.02–3.10 (m, 2H, CH₂), 4.43 (t, *J* = 7.8 Hz, 1H, CH), 5.83 (d, *J* = 8.3 Hz, 4H, CH₂), 6.07 (s, 1H, NH), 6.38 (s, 2H, CH_{Ar}), 6.69 (s, 2H, CH_{Ar}), 7.20 (t, *J* = 7.6 Hz, 2H, CH_{Ar}), 7.35 (d, *J* = 7.6 Hz, 2H, CH_{Ar}), 8.29 (s, 1H, NH), 8.90 (s, 2H, OH). ¹³C NMR (δ ppm, DMSO-*d*₆): 15.65, 29.08, 31.73, 36.18, 98.01, 100.80, 108.05, 118.09, 121.36, 123.42, 129.05, 140.11, 141.06, 145.47, 149.56, 155.65. MALDI-TOF: 487 [M+Na]⁺, 503 [M+K]⁺. Anal. Calcd.: C₂₅H₂₄N₂O₇ (464), 64.65; H, 5.21; N, 6.03. Found: 64.79; H, 5.11; N, 5.98.

4.4.3. 1-(4,4-Bis(6-hydroxybenzo[d][1,3]dioxol-5-yl)butyl)-3-(4-methoxyphenyl)urea (8b). White crystals, m.p. 130–131°C, yield 93%. IR (cm⁻¹, KBr): 1595, 2818, 3212, 3337. ¹H NMR (δ ppm, DMSO-*d*₆): 1.29–1.37 (m, 2H, CH₂), 1.79–1.86 (m, 2H, CH₂), 2.98–3.08 (m, 2H, CH₂), 3.68 (s, 3H, CH₃), 4.42 (t, *J* = 7.8 Hz, 1H, CH), 5.83 (d, *J* = 9.5 Hz, 4H, CH₂), 5.95 (s, 1H, NH), 6.37 (s, 2H, CH_{Ar}), 6.68 (s, 2H, CH_{Ar}), 6.79 (d, *J* = 9.1 Hz, 2H, CH_{Ar}), 7.24 (d, *J* = 9.1 Hz, 2H, CH_{Ar}), 8.08 (s, 2H, CH_{Ar}), 8.90 (s, 2H, OH). ¹³C NMR (δ ppm, DMSO-*d*₆): 29.15, 31.73, 36.14, 55.61, 55.68, 98.00, 100.80, 108.07, 114.38, 119.89, 123.43, 134.20, 140.10, 145.46, 149.55, 154.34, 155.90. MALDI-TOF: 507 [M+Na]⁺. Anal. Calcd.: C₂₆H₂₆N₂O₈ (494), C, 63.15; H, 5.30; N, 5.67. Found: C, 63.27; H, 5.41; N, 5.85.

4.4.4. 1-(4,4-Bis(6-hydroxybenzo[d][1,3]dioxol-5-yl)butyl)-3-hexylurea (8c). White crystals, m.p. 102–103°C, yield 59%. IR (cm⁻¹, KBr): 1597, 2719, 3147, 3214, 3362. ¹H NMR (δ ppm, DMSO-*d*₆): 0.84 (t, *J* = 6.4 Hz, 3H, CH₃), 1.21–1.27 (m, 8H, CH₂), 1.31–1.35 (m, 2H, CH₂), 1.72–1.85 (m, 2H, CH₂), 2.93–2.99 (m, 2H, CH₂), 4.42 (t, *J* = 7.8 Hz, 1H, CH), 5.83 (d, *J* = 10.8 Hz, 4H, CH₂), 6.39 (s, 2H, CH_{Ar}), 6.67 (s, 2H, CH_{Ar}), 7.67 (s, 2H, OH). ¹³C NMR (δ ppm, DMSO-*d*₆): 14.29, 22.53, 26.51, 29.31, 30.43, 31.50, 31.70, 36.14, 46.68, 55.21, 98.03, 100.76, 107.96, 119.74, 140.11, 149.54, 153.03, 158.70. MALDI-TOF: 495 [M+Na]⁺. Anal. Calcd.: C₂₅H₃₂N₂O₇ (472), C, 63.55; H, 6.83; N, 5.93. Found: C, 63.63; H, 6.99; N, 6.16.

4.4.5. 1-(4,4-Bis(4-hydroxy-2-oxo-2H-chromen-3-yl)butyl)-3-phenylurea (9a). White crystals, m.p. 235–237°C, yield 42%. IR (cm⁻¹, KBr): 1595, 2810, 3198, 3358, 3334. ¹H NMR (δ ppm, DMSO-*d*₆): 1.28–1.45 (m, 2H, CH₂), 2.06–2.20 (m, 2H, CH₂), 2.95–3.10 (m, 2H, CH₂), 4.89 (t, *J* = 8.3 Hz, 1H, CH), 6.84 (t, *J* = 7.5 Hz, 1H, CH_{Ar}), 7.14–7.19 (m, 2H, CH_{Ar}), 7.25–7.30 (m, 3H, CH_{Ar}), 7.32 (d, *J* = 8.6 Hz, 1H, CH_{Ar}), 7.34–7.38 (m, 2H, CH_{Ar}), 7.53 (t, *J* = 6.9 Hz, 1H, CH_{Ar}), 7.64 (t, *J* = 7.6 Hz, 1H, NH), 7.82 (d, *J* = 8.0 Hz, 1H, CH_{Ar}), 7.91 (d, *J* = 6.7 Hz, 2H, CH_{Ar}), 8.27 (s, 1H, NH). ¹³C NMR (δ ppm, DMSO-*d*₆): 27.57, 29.25, 32.16, 61.66, 116.84, 118.07, 123.68, 124.26, 124.39, 129.02, 131.79, 133.17, 141.05, 152.58, 155.60, 162.34, 165.10, 166.10. MALDI-TOF: 513 [M+H]⁺. Anal. Calcd.: C₂₉H₂₄N₂O₇ (512), C, 67.96; H, 4.72; N, 5.47. Found: C, 68.11; H, 4.90; N, 5.59.

4.5. General Method for the Synthesis of Calix[4]resorcinarenes 10a,d [27, 41]. To a mixture of 1.25 mmol pyrrolidine-1-carboxamide **1** and appropriate 0.16 g (1.25 mmol) 2-methylresorcinol in 5 ml dry chloroform, 2 ml trifluoroacetic acid was added. The mixture was stirred at room temperature for 72 h. Solvent was evaporated in vacuum. Residue was washed with diethyl ether and acetone, filtered, and dried in vacuum (1 h, 0.01 Torr) to give the title compound **10**.

4.6. General Method for the Synthesis of Calix[4]resorcinarenes 10a,d. To a mixture of 0.16 g (1.25 mmol) of 2-methylresorcinol, 5 ml of chloroform, and 1.25 mmol of acetal **2**, 2 ml of trifluoroacetic acid was added. The reaction mixture was stirred for 24 hours at room temperature, the solvent was removed in vacuum, and the residue was washed with diethyl ether and dried in vacuum.

4.6.1. 1,1',1'',1'''-((1⁴,1⁶,3⁴,3⁶,5⁴,5⁶,7⁴,7⁶-Octahydroxy-1⁵,3⁵,5⁵,7⁵-tetramethyl-1,3,5,7(1,3)-tetrabenzenacyclooctaphane-2,4,6,8-tetrayl)tetrakis(propane-3,1-diyl)tetrakis(3-phenylurea) (10a). White crystals, m.p. > 250°C, yield 70%. IR (cm⁻¹, KBr): 1598, 1653, 2862, 2933, 3057, 3387. ¹H NMR (δ ppm, DMSO-*d*₆): 1.43–1.59 (m, 8H, CH₂), 2.00–2.18 (m, 8H, CH₂), 2.04 (s, 12H, CH₃), 2.23–2.32 (m, 8H, CH₂), 3.18–3.28 (m, 8H, CH₂), 4.40 (t, 4H, *J* = 7.80 Hz, CH), 6.90–6.96 (m, 4H, CH_{Ar}), 7.15 (s, 4H, CH_{Ar}), 7.17–7.22 (m, 8H,

CH_{Ar}), 7.27–7.34 (m, 8H, CH_{Ar}). ^{13}C NMR (δ ppm, DMSO- d_6): 8.5, 28.9, 31.4, 34.3, 39.4, 112.4, 119.2, 120.0, 122.2, 124.8, 128.5, 139.4, 149.5, 157.2. MALDI TOF, m/z : 1249 $[\text{M}]^+$; 1250 $[\text{M}+\text{H}]^+$; 1272 $[\text{M}+\text{Na}]^+$; 1288 $[\text{M}+\text{K}]^+$ [27].

4.6.2. $1,1',1'',1'''-(14,16,34,36,54,56,74,76\text{-Octahydroxy-15,35,55,75-tetramethyl-1,3,5,7(1,3)-tetrabenzenacyclooctaphane-2,4,6,8-tetrayl})\text{tetrakis}(\text{propane-3,1-diyl})\text{tetrakis}(3\text{-cyclohexylurea})$ (**10d**). White crystals, m.p. > 250°C, yield 62%. IR (cm^{-1} , KBr): 1642, 2860, 3096, 3198. ^1H NMR (δ ppm, DMSO- d_6): 1.00–1.17 (m, 12H, CH_2), 1.19–1.36 (m, 12 H, CH_2), 1.47–1.55 (m, 4 H, CH_2), 1.58–1.67 (m, 8 H, CH_2), 1.69–1.80 (m, 8 H, CH_2), 1.95 (s, 12 H, CH_3), 2.17–2.29 (m, 4 H, CH_2), 2.96–3.10 (m, 4 H, CH), 3.29–3.47 (m, 8 H, CH_2), 4.16–4.24 (m, 4 H, CH), 5.68 (s, 4 H, NH), 5.79 (s, 4 H, NH), 7.23 (s, 4 H, CH_{Ar}). ^{13}C NMR (δ ppm, DMSO- d_6): 10.46, 24.98, 25.78, 29.47, 30.78, 33.83, 34.51, 38.84, 48.15, 112.18, 121.45, 125.05, 149.58, 157.96. MALDI TOF, m/z : 1273 $[\text{M}+\text{H}]^+$; 1295 $[\text{M}+\text{Na}]^+$ [41].

Data Availability

The NMR source data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Supplementary Materials

Copies of NMR spectra for all of the new compounds. (Supplementary Materials)

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