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SYNTHESIS OF A DIMERIC G-2 MELAMINE DENDRIMER. FIRST USE OF A MASKED PIPERIDONE MOTIF IN DENDRITIC CHEMISTRY

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ABSTRACT. Using iterative aminations of cyanuric chloride, we account the concise synthesis of a dimeric melamine based G-2 dendrimer having 1,4-dioxa-8-azaspiro[4.5]decane (piperidone ethyleneketal) in tandem with 2-amino-2-hydroxymethylbutanol *("ethylserinol"*) as peripheral groups piperazine and 4,4'-bispiperidine as internal and central linker, respectively.

Keywords: amination, dendrimers, iterative synthesis, 4-piperidone, 4,4'-bispiperidine, serinols.

INTRODUCTION

We have recently reported the strong and resourceful nucleophilicity of piperidone or of its ethyleneketal with respect to selective amination of cyanuric chloride [1, 2a]. From our previous contributions in the field of iterative synthesis directed to melamine dendritic structures based on *C*-substituted 2-aminopropane-1,3-diols (*"serinols"*) [2], we also learned that, until now, only *l*-2-amino-1-arylpropane-1,3-diols (enantiomeric *"phenylserinols"*) are suitable starting materials in the above convergent approaches*. Indeed, commercial C-2-substituted-2-aminopropane-1,3-diols [*"methylserinol"*, *"ethylserinol"* and 2-amino-2-(hydroxymethyl)propan-1,3-diol, known as TRIS] provided, up to G-0 dendrons, unstable as difficult to purify intermediates [3].

Therefore, we consider, as an alternative challenging attempt, the use of a C-2-substituted serinol, for example 2-amino-2-(hydroxymethyl)-butanol (*"ethylserinol"*) in tandem with 1,4-dioxa-8-azaspiro[4.5]decane (piperidone ethyleneketal) as peripheral groups in a target dimeric G-2 melamine dendrimer synthesis (Scheme 1).

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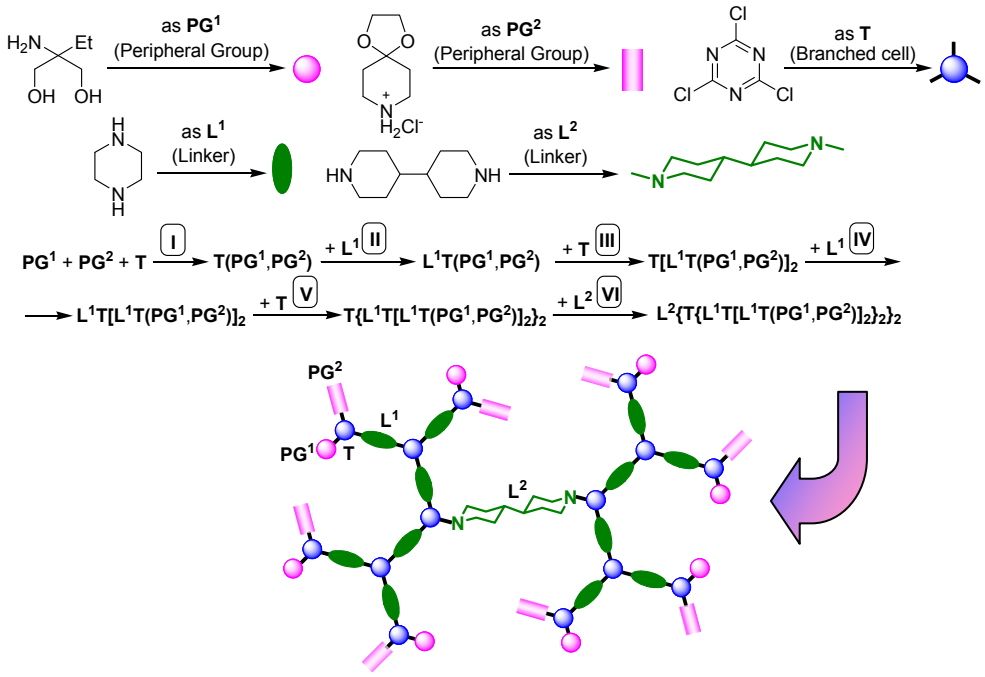
* For continuous discussion in this communication, nomenclature, definitions and concepts according to Tomalia (Ref. [3a]) and Vögtle *et al.* (Ref. [3b]) were used throughout.



Scheme 1

As shown in Scheme 1, our strategy was convergent, consisting of six linear steps, **I – VI**, as ten selective aminations of cyanuric chloride with the depicted amino nucleophiles. We note the use of 4,4'-bispiperidine (**L^2**), ethylserinol (**PG^1**) and piperidone ethyleneketal (**PG^2**) as central linker and peripheral groups respectively, not reported previously. Along with C-2-substituted serinols, only TRIS (2-amino-2-hydroxymethylpropan-1,3-diol) is known, since 1985 [4a], to be a key element in dendritic chemistry, playing all roles, core, branched cell and peripheral group [4]. Concerning linker **L^1**, piperazine, it is nowadays a widely employed structural motif in dendrimer synthesis connecting cores [5a-d], generations [5e-h] or both [5i-l].

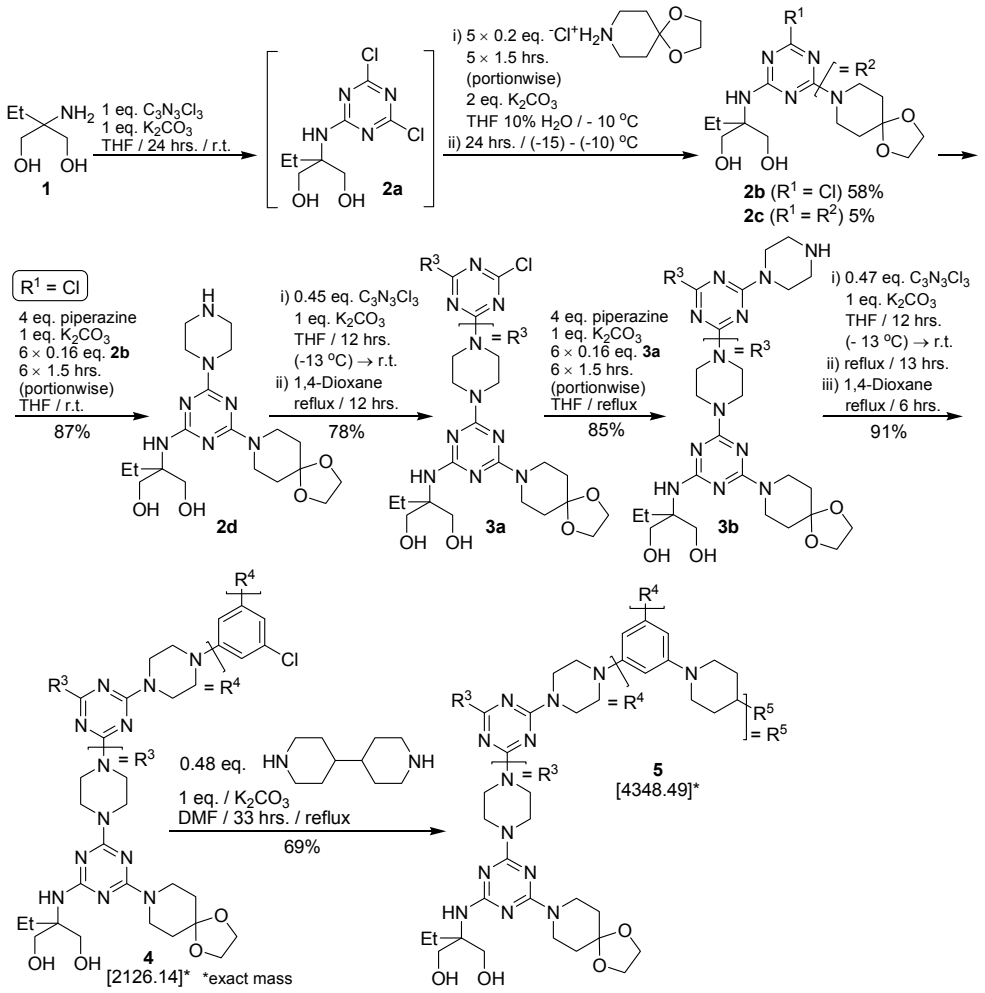
RESULTS AND DISCUSSION

1. Synthesis

We commenced our study (Scheme 2) with the anchorage of peripheral groups on *s*-triazine. Ethylserinol **1**, the less reactive nucleophile, was firstly reacted with cyanuric chloride providing dichloroamino-*s*-triazine **2a** in quantitative yield (TLC monitoring)*. For this reason, **2a** was not isolated but treated with the subsequent nucleophile, piperidone ethylene ketal hydrochloride whose

* We previously discussed the synthesis and structure of **2a**, see Ref. [2a].

free base, generated *in situ*, was, as expected, much more reactive in 10% aq. THF [1]. Indeed, the very mild shown conditions were found step by step, in order to avoid, as much as possible, the complete replacement of chlorine in **2a** by two dioxaazaspiranic units (compound **2c**). We note the optimised yield of **2b**, 58%, to be also mandatory to the purity of commercial **1** (about 80%).



Scheme 2

Reaction of chlorodiamino-*s*-triazine **2b** with excess of piperazine afforded amine **2d** with good yield, following our already established protocol [2a, 2c, 6]. Purification of **2d** by column chromatography on partially deactivated silica gel (eluent *i*-PrOH: aq. NH_3 25% 9:1 v/v) ensured the analytical purity of this intermediate.

With **2d** in our hands, we reiterated the double amination of cyanuric chloride and accessed the G-1 dendron **3a** by operating on a large scale of temperature, from -13 to 102 ^{o}C. That is, only in these conditions we were confident that the contaminating possible side reactions, such as *O*- instead *NH*-anchorage of **2d** on *s*-triazine, were completely eliminated.

Next, selective amination of **3a** by piperazine was realised similarly as for **2b**, the refluxing solvent being however required in agreement with the stronger solvation of **3a** *vs*. **2b** in THF. Although isolated by column chromatography on partially deactivated silica gel, in order to reach analytical purity, the G-1 aminodendron **3b** needed a supplementary routine recrystallisation.

At this stage, the triple anchorage of **3b** on *s*-triazine skeleton upon treatment with 0.3 eq. of cyanuric chloride failed, presumably because of the already manifested starburst effect [7]. Thus, only the chloro-*s*-triazine G-2 dendron **4** could be isolated with small conversion (about 10%) from a complex polymeric reaction mixture (attempt not depicted in Scheme 1).

Therefore, we had to change the final strategy by using 0.47 eq. of cyanuric chloride against **3b**. In a very clean reaction, we were delighted to obtain the G-2 dendron **4** with an excellent yield in very comparable conditions to those in the case of G-1 analogue **3a**. Finally we coupled two G-2 dendrons **4** through a 4,4'-bispiperidine central linker, seen as a larger divalent central spacer than the trivalent *s*-triazine. Both dendritic structures **4** and **5** were isolated and purified by simple crystallisations.

2. Preliminary structural assignments

Besides synthetic and applied interest [5], dendritic melamines have received increased structural attention in the last period [8], [9].

Starting from the pioneering works of Katritzky, Ghiviriga [8a-c] *et al*. [8d-g] focused on restricted rotations about the C(*s*-triazine)-N(exocyclic) partial double bonds, the current concepts with respect to this expected hindered mobility comprise a more concise terminology. Thus, the above connections are seen by us as (pro)diastereomerism axis [2a, 2b] promoting, in some cases, chirality [2a] or, if dendritically exacerbated, an entire "dendrimeric choreography" [9].

For the present communication, we will limit our discussion to the first isolated intermediate, chlorodiamino-*s*-triazine **2b** and the target dendrimer **5**.

At room temperature, NMR spectra of compound **2b** revealed its frozen rotamerism about C(*s*-triazine)-N(exocyclic) partial double bonds, C-4-N-8' (axis of prodiastereomerism[**]) and C-6-N(serinol) (axis of diastereomerism) as two blocked rotational diastereomers, **2b**-*syn* (minor) and **2b**-*anti* (major) (Figure 1). We discriminated the *anti vs. syn* rotamers by taken into account the strong dipole moment induced by the remainder chlorine substituent at C-2 [2a, 2b, 4c, 9]

[**] C-4-N-8' is also an axis of chirality, see ref. [2a] (to be discussed in the full paper).

creating a more deshielding influence of the protons NH in the **2b**-*anti* environment. *Mutatis-mutandis* the resonance of hydroxyl protons in rotamer **2b**-*anti* was located upfield with respect to **2b**-*syn*.

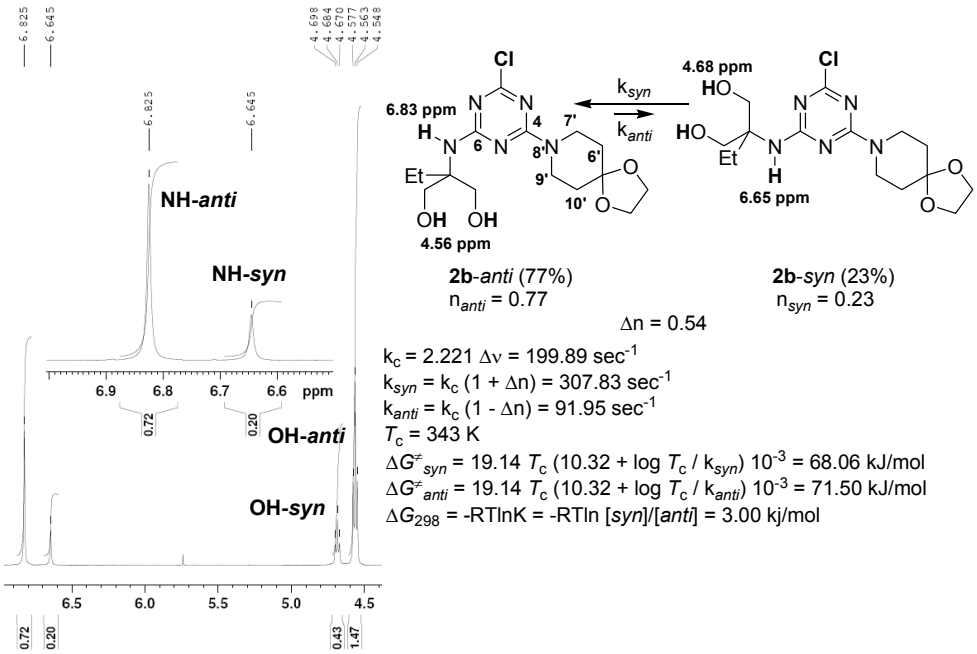


Figure 1. Detailed ^{1}H NMR spectrum (400 MHz, [D_6]DMSO, 293 K) of frozen rotamers of compound **2b**

Evidently, the ^{13}C NMR spectrum exhibited two sets of δ values for almost all positions of the **2b**(*anti* + *syn*) rotameric mixture. For example, although rotamerism about the axis of prodiastereomerism C-4-N-8' was not clearly observed in the ^{1}H NMR spectrum, on 100 MHz time scale, piperidine carbons C-7' *vs.* C-9' and C-6' *vs.* C-10' in the major as detectable **2b**-*anti* rotamer were diastereotopic, Δδ = 0.23 and 0.29 ppm respectively.

By rising the temperature up to 343 K, compound **2b** reached, at 353 K, the fast exchange status between unequally populated sites as freely rotating structure [10a]. Taking into account Eliel's *et al*. recommended precautions [10b], calculation based on Eyring equations [10a] applied for unequally two terms populated systems [10c] provided plausible data of the rotational barriers about the bond C-6-N(serinol) as Enthalpies of Activation $\Delta G^{\neq}$ [2a, 8]. Indeed, the $\Delta G_{298} = \Delta G^{\neq}_{anti} - \Delta G^{\neq}_{syn}$ value was 3.43 kJ/mol *vs.* 3.00 kJ/mol issued from classical two terms equilibrium relationship (Figure 1).

The ΔG *anti vs. syn* at 343 K and up could be not determined since, upon heating, NH protons changed their character, from an “amide” (6.83 - – 6.65 ppm, “rigid” protons) to an “amine” one (6.41 ppm, “mobile” protons).

All these complex rotational phenomena disappeared in the case of the much less π-deficient melamine **2c** which, at room temperature, already displayed a slow exchange status between unequal populated sites.

The mass spectrum of the dendrimer **5** fully confirmed the designed structure (Figure 2).

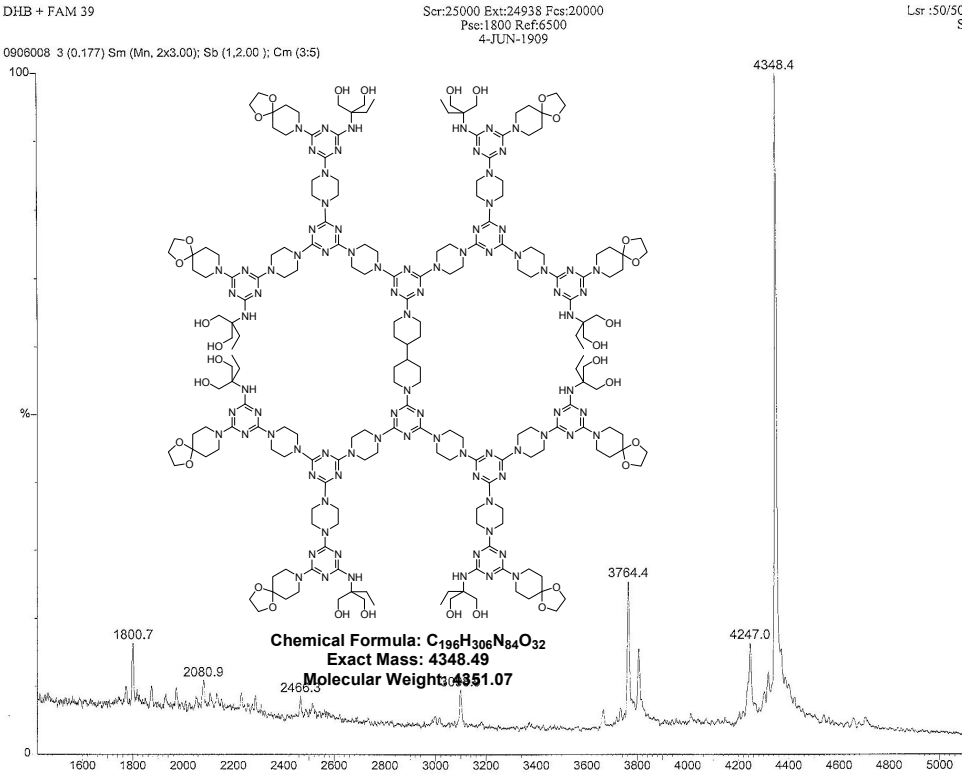


Figure 2. Mass Spectrum of compound **5** (Linear MALDI+ in 2,5-dihydroxybenzoic acid)

The ^{1}H NMR spectrum of **5** (Figure 3) recorded at 353 K indicated for this macromolecule a complex appearance. From rotational point of view, the six membered saturated heterocyclic rings were still in a slow exchange status between unequal populated sites, at least with respect to the ten piperidine peripheral and central units (see the broad signal assigned to the 42 protons at 1.61 ppm). In contrast, the geminal anisochrony of the sixteen peripheral hydroxymethylene groups is clearly visible in the region 3.5 – 3.7 ppm.

In ^{13}QC NMR spectrum, (Figure 4) from 196 carbon atoms, 194 were assignable. Only the two C-4, -4' carbons of the central 4,4'-bispiperidine linker remained obscured.

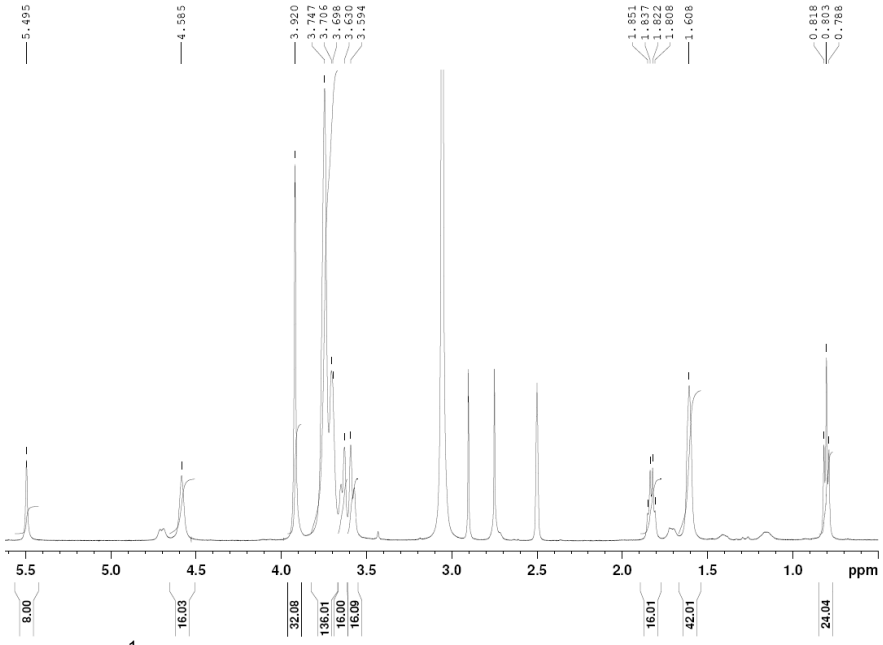


Figure 3. ^{1}H NMR spectrum of compound **5** (500 MHz, [D_6]DMSO, 353 K)

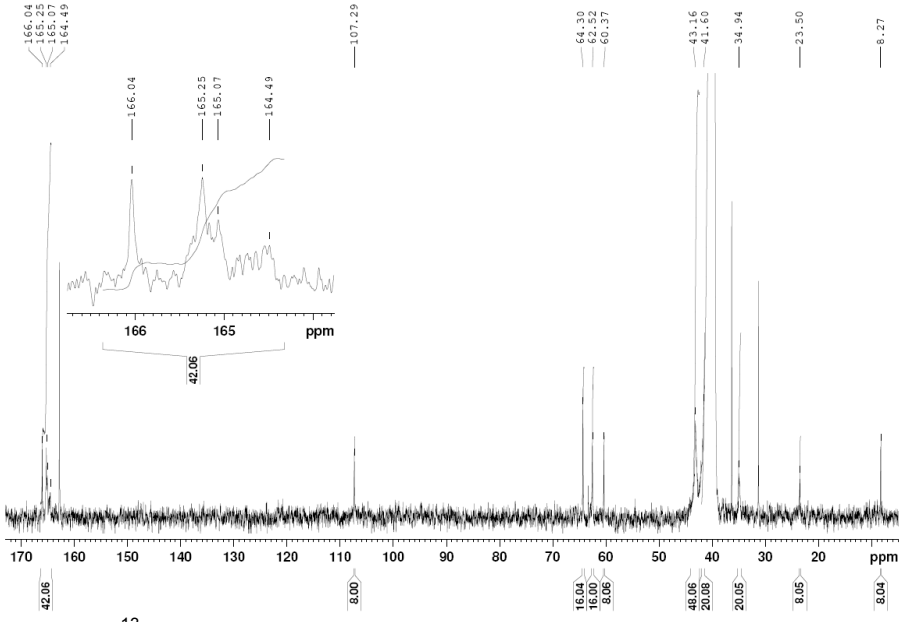


Figure 4. ^{13}QC NMR spectrum of compound **5** (125 MHz, [D_6]DMSO, 298 K)

The signal located at 41.6 ppm (20 carbon atoms) accounts for sixteen piperidine methylenes of the eight spiranic peripheral groups and four piperidine methylenes of the central 4,4'-bispiperidine linker. They are placed at the α-positions with respect to the heterocyclic nitrogens. Accordingly, the signal located at 34.9 ppm discloses the other 20 carbon atoms of the peripheral and central piperidine methylenes located at the β-positions *vs.* azaatom.

Both ^{1}H and ^{13}C NMR spectra also evidenced the presence of DMF, the reaction solvent (Scheme 2), despite of very careful final manipulation of the product. For the moment, we are unable to distinguish between problems of drying the compound or encapsulating phenomena.

CONCLUSIONS

We realised the concise synthesis of the first dimeric G-2 melamine dendrimer comprising, in tandem, eight C-2-substituted serinolic motifs and eight masked piperidone units as peripheral groups. The overall yield was optimised at 19%. More developments *vs.* inherent restrictions of this convergent strategy will be published in due course.

EXPERIMENTAL SECTION

General. Conventional NMR spectra were recorded on a Bruker® AM 300 instrument operating at 300 and 75 MHz for ^{1}H and ^{13}C nuclei respectively. Bruker® AV400 and DMX500 instruments, operating at 400 (500) and 100 (125) MHz for ^{1}H and ^{13}C nuclei respectively, were used for DNMR and QC experiments. All NMR spectra were measured in anhydrous commercially available deuteriated solvents. No $SiMe_4$ was added; chemical shifts were measured against the solvent peak. TLC was performed by using aluminium sheets with silica gel 60 F_{254} (Merck®); flash column chromatography was conducted on Silica gel Si 60 (40–63 μm, Merck®). Microanalyses were performed on a Carlo Erba® CHNOS 1160 apparatus. Mass spectra (MS) were recorded on Bruker® Esquire Instrument.

Preparation of compound ***2b***

2-Amino-2-hydroxymethylbutanol (*"ethylserinol"*) [1.67 g 80%, Aldrich® (Cat. No. 38, 168-3) 1.34 g 100%, 11.2 mmol] and potassium carbonate (> 99%, 1.55 g 100%, 11.2 mmol, S.C.CRISTAL R CHIM SRL) were suspended with stirring in anh. THF (80 mL) then cooled at 0 °C. At this temperature, cyanuric chloride (> 99%, 2.07 g 100%, 11.2 mmol, Merck®, Cat. No. S4249515 526) as anh. THF (20 mL) solution was rapidly injected and the resulted suspension was let to reach room temperature and stirred for additional 24 hrs. At this stage, TLC monitoring (eluent toluene: isopropanol 2: 1 v/v, visualisation in UV 254 nm) indicated the presence of a single compound. Water (10 mL) and potassium

carbonate (3.10 g, 22.4 mmol) were added and the resulted suspension was cooled at (-10) – (-15) ^{o}C. At this temperature, fine powdered 1,4-dioxa-8-azaspiro[4.5]decane (2.01 g, 11.2 mmol) was added portionwise as 5 equal portions each 90 min. The reaction mixture was stirred at -10 ^{o}C for additional 24 hrs. then let to reach room temperature. The suspension was filtered off and minerals were well washed with anh. THF. The organic filtrate was taken and treated under vigorous stirring, with chloroform (150 mL) and water (75 mL). After separation, the organic layer was washed with water to neutrality (× 25 mL) then the combined aqueous layer was extracted with chloroform (2 × 40 mL). The combined organic layer was dried over sodium sulphate, filtered off and evaporated under reduced pressure to provide the crude material (4.10 g). This was separated by column chromatography (eluent toluene: isopropanol 4:1 v/v) to yield 2.41 g compound **2b** and 0.263 g compound **2c** as side product.

2-Chloro-4-(1,4-dioxa-8-azaspiro[4.5]decan-8-ylamino)-4-[1-hydroxy-2- (hydroxymethyl)but-2-ylamino]-s-triazine ***2b***; white crystalline powder; yield 58%; m.p. = 147.4-152.7 ^{o}C; Anal. calcd. for $C_{15}H_{24}ClN_5O_4$: C, 48.19; H, 6.47; N, 18.73%; found: C, 48.44; H, 6.16; N, 18.66%. R_f (80% toluene/isopropanol) = 0.65. ^{1}H NMR (400 MHz, 293 K, [D$_6$]DMSO) 0.73 ppm (3 H, m, CH_2CH_3, *anti* + *syn*), 1.62 ppm (4 H, m, H-6', -10'-ax., -eq., spirane, *anti* + *syn*), 1.71 (2 H, q, ^{3}J = 7.4 Hz, CH_2CH_3, *anti* + *syn*), 3.46 ppm (2 H, dd, ^{2}J = 10.8 Hz, ^{3}J = 6.0 Hz, CH_2OH, *anti* + *syn*), 3.65 ppm (2 H, dd, ^{2}J = 10.8 Hz, ^{3}J = 6.0 Hz, CH_2OH, *anti* + *syn*), 3.72 ppm (4 H, t, ^{3}J = 5.4 Hz, H-7', -9'-ax., -eq., spirane, *anti* + *syn*), 3.91 ppm (4 H, s, H-2', -3', spirane, *anti* + *syn*), 4.56 ppm (1.47 H, dd as t , ^{3}J = 5.8 Hz, CH_2OH, *anti*), 4.68 ppm (0.43 H, dd as t , ^{3}J = 5.6 Hz, CH_2OH, *syn*), 6.65 ppm (0.20 H, bs, NH, *syn*), 6.83 (0.72 H, bs, NH, *anti*). ^{1}H NMR (400 MHz, 353 K, [D$_6$]DMSO) 0.79 ppm (3 H, t, ^{3}J = 7.4 Hz, CH_2CH_3), 1.66 ppm (2 H, dt, ^{3}J = 5.8, 3.8 Hz, H-6', -10'-ax., -eq., spirane), 1.65 ppm (2 H, dt, ^{3}J = 5.6, 4.0 Hz, H-6', - 10'-ax, -eq., spirane), 1.79 (2 H, q, ^{3}J = 7.4 Hz, CH_2CH_3), 3.57 ppm (2 H, dd, ^{2}J = 11.0 Hz, ^{3}J = 5.4 Hz, CH_2OH), 3.68 ppm (2 H, dd, ^{2}J = 10.8 Hz, ^{3}J = 5.6 Hz, CH_2OH), 3.765 ppm (2 H, dt, ^{3}J = 7.0, 5.0 Hz, H-7', -9'-ax., -eq., spirane), 3.760 ppm (2 H, dt, ^{3}J = 5.6, 4.0 Hz, H-7', -9'-ax., -eq., spirane), 3.93 ppm (4 H, s, H-2', -3', spirane), 4.40 ppm (2 H, bs, CH_2OH), 6.41 ppm (1 H, bs, NH). ^{13}C NMR (100 MHz, 293 K, [D$_6$]DMSO, ppm) 7.9 (1 C, CH_2CH_3, *anti*), 8.1 (1 C, CH_2CH_3, *syn*), 22.4 (1 C, CH_2CH_3, *anti*), 23.0 (1 C, CH_2CH_3, *syn*), 34.9, 34.8, 34.6 (4 C, C-6', -10', spirane, *anti* + *syn*), 42.1, 41.9, 41.4 (4 C, C-7', -9', spirane, *anti* + *syn*), 61.5, 60.8 (4 C, CH_2OH, *anti* + *syn*), 61.4 (2 C, Cq, serinol, *anti* + *syn*), 64.4 (4 C, C-2', -3', spirane, *anti* + *syn*), 106.9 (2 C, C-5', spirane, *anti* + *syn*), 163.6 (1 C, C-4, *s*-triazine, *syn*), 164.2 (1 C, C-4, *s*-triazine, *anti*), 165.1 (1 C, C-6, *s*-triazine, *anti*), 165.8 (1 C, C-4, *syn*), 168.4 (1 C, C-2, *s*-triazine, *anti*), 168.6 (1 C, C-2, *s*-triazine, *syn*).

2,4-Bis(1,4-dioxa-8-azaspiro[4.5]decan-8-ylamino)-6-[1-hydroxy-2-(hydroxy methyl)but-2-ylamino]-s-triazine ***2c***; yellowish crystalline powder; yield 5 %; m.p. = 143.1 – 146.8 ^{o}C; Anal. calcd. for $C_{22}H_{36}N_6O_6$: C, 54.99; H, 7.55; N,

17.49%; found: C, 55.22; H, 7.88; N, 17.55%. R_f (80% toluene/isopropanol) = 0.60 ^{1}H NMR (400 MHz, 298 K, [D$_6$]DMSO) 0.73 ppm (3 H, t, ^3J = 7.4 Hz, CH_2CH_3), 1.57 ppm (8 H, t, ^3J = 5.2 Hz, H-6', -6", -10', -10"-ax., -eq., spirane), 1.77 (2 H, q, ^3J = 7.4 Hz, CH_2CH_3), 3.50 ppm (2 H, dd, ^2J = 10.6 Hz, ^3J = 5.4 Hz, CH_2OH), 3.58 ppm (2 H, dd, ^2J = 10.6 Hz, ^3J = 5.8 Hz, CH_2OH), 3.71 ppm (8 H, t, ^3J = 5.6 Hz, H-7', -7", -9', -9"-ax., -eq., spirane), 3.90 ppm (8 H, s, H-2', -2", -3', -3" spirane), 4.73 ppm (2 H, dd as t , ^3J = 5.8 Hz, CH_2OH), 5.60 ppm (1 H, bs, NH). ^{1}H NMR (400 MHz, 353 K, [D$_6$]DMSO) 0.79 ppm (3 H, t, ^3J = 7.6 Hz, CH_2CH_3), 1.60 ppm (8 H, t, ^3J = 5.6 Hz, H-6', -6", -10', -10"-ax., -eq., spirane), 1.81 (2 H, q, ^3J = 7.4 Hz, CH_2CH_3), 3.57 ppm (2 H, d, ^2J = 10.8 Hz, CH_2OH), 3.63 ppm (2 H, dd, ^2J = 10.4 Hz, CH_2OH), 3.73 ppm (8 H, t, ^3J = 5.8 Hz, H-7', -7", -9', -9"-ax., -eq., spirane), 3.92 ppm (8 H, s, H-2', -2", -3', -3" spirane), 4.56 ppm (2 H, bs, CH_2OH), 5.47 ppm (1 H, bs, NH). ^{13}C NMR (100 MHz, 298 K, [D$_6$]DMSO, ppm) 8.2 (1 C, CH_2CH_3), 23.5 (1 C, CH_2CH_3), 34.8 (4 C, C-6', -6", -10', -10"), 41.5, 41.0 (4 C, C-7', -7", -9', -9", spirane), 60.3 (2 C, Cq, serinol), 62.6 (2 C, CH_2OH), 64.2 (4 C, C-2', -2", -3', -3", spirane), 107.3 (2 C, C-5', -5", spirane), 164.7 (1 C, C-2, -4, *s*-triazine), 166.1 (1 C, C-6, *s*-triazine).

*Preparation of compound **5***

Perfectly dried G-2 dendron **4** (analytically weighted 0.515 g, 0.242 mmol), freshly prepared and perfectly dried 4,4'-bispiperidine (analytically weighted 0.0194 g, 0.115 mmol), potassium carbonate (analytically weighted 0.035 g, 0.253 mmol) and freshly distilled dimethylformamide (DMF) (25 mL) were mixed together and the resulting suspension was heated at 100 ^{o}C (CARE! Avoid refluxing DMF to prevent the solvent decomposition!) for 35 hrs. (TLC monitoring, eluent chloroform: ethanol 3:1 v/v, visualisation in UV 254 nm). DMF was distilled under reduced pressure and the solid residue was taken with distilled water (10 mL), stirred at room temperature for 30 min. then filtered off. The crude product was well washed with distilled water (× 5 mL) to neutrality then dried at 70 ^{o}C to constant weight. The crude product was dissolved in distilled DMF (2 mL), then crystallised by adding anh. diethyl ether (6 mL). The resulted suspension was cooled at – 20 ^{o}C for 24 hrs., filtered off and well washed with anh. diethyl ether. After drying at 70 ^{o}C to constant weight, 0.345 g (0.079 mmol) compound **5** were obtained.

4,4'-{4,6-Bis{4-{4,6-bis{4-{4-(1,4-dioxa-8-azaspiro[4.5]decan-8-ylamino)-6-[1-hydroxy-2-(hydroxymethyl)but-2-ylamino]-s-triazin-2-yl}-piperazin-1-yl}-s-triazin-2-yl}-piperazin-1-yl}-s-triazin-2-yl}-bispiperidine **5**; white amorphous powder; yield 69 %; m.p. = 260 - 261 ^{o}C. R_f (75% chloroform/ethanol) = 0.75. ^{1}H NMR (500 MHz, 298 K, [D$_6$]DMSO) 0.75 ppm (24 H, bs, CH_2CH_3), 1.58, 1.79 ppm (58 H, 2 × bs as: 16 H, CH_2CH_3; 32 H, H-6, -10-ax., -eq., spirane; 10 H, H-3, -5, -3', -5'-ax., -eq., H-4, -4', 4,4'-bispiperidine), 3.91 – 3.52 ppm (200 H, bm, as: 96 H, piperazine; 32 H, H-7, -9-ax., -eq., spirane; 32 H, H-2, -3, spirane; 32 H, CH_2OH; 8 H, H-2, -6, -2', -6'-ax., -eq., 4,4'-bispiperidine),

4.76 ppm (16 H, bs, CH_2OH), 5.63 ppm (8 H, bs, NH); ^{1}H NMR (500 MHz, 353 K, [D_6]DMSO) 0.80 ppm (24 H, t, ^3J = 7.5 Hz, CH_2CH_3), 1.61 ppm (42 H, bs, as: 32 H, bs, H-6, -10-ax., -eq., spirane; 10 H, H-3, -5, -3', -5'-ax., eq., H-4, -4', 4,4'-bispiperidine), 1.85 (16 H, q, ^3J = 7.2 Hz, CH_2CH_3), 3.59 ppm (16 H, d, ^2J = 10.5 Hz, CH_2OH), 3.63 ppm (16 H, d, ^2J = 10.0 Hz, CH_2OH), 3.75 – 3.59 ppm (136 H, bm, as: 96 H, piperazine; 32 H, H-7, -9-ax., -eq., spirane; 8 H, H-2, -6, -2', -6'-ax., -eq., 4,4'-bispiperidine), 3.92 (32 H, s, H-2, -3, spirane), 4.59 (16 H, bs, CH_2OH), 5.50 (8 H, bs, NH). ^{13}QC NMR (125 MHz, 298 K, [D_6]DMSO, ppm) 8.3 (8 C, CH_2CH_3), 23.5 (8 C, CH_2CH_3), 34.9 (20 C as 16 C, C-6, -10, spirane; 4 C, C-3, -3', -5, -5', 4,4'-bispiperidine), 41.6 (20 C as 16 C, C-7, -9, spirane; 4 C, C-2, -6, -2', -6', 4,4'-bispiperidine), 60.4 (8 C, Cq, serinol), 62.5 (16 C, CH_2OH), 64.3 (16 C, C-2, -3, spirane), 107.3 (8 C, C-5, spirane), 164.5, 165.1, 165.3, 166.0 (42 C, *s*-triazine). MS (Linear MALDI+ in 2,5-dihydroxybenzoic acid): 4348.4 (100%) [M^+].

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