

# Supplementary Information

## Low-Molecular-Weight Gelators – Elucidating the Principles of Gelation Based on Gelator Solubility and a Cooperative Self- Assembly Model

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### TABLE OF CONTENTS

S2	Additional Gelation Data
S3	Scanning Electron Microscopy
S4	Details of Cooperative Model for NMR and Computer Modeling
S5-S7	Synthesis and Characterisation of Gelators
S8	References

## Additional Gelation Data

Table 1. Calculated concentration of gelator present in the fibrillar network ( $C_{\text{crit}}$ ) at selected sol-gel transition temperatures ( $T_{\text{gel}}$ ) related to different gelators at different total concentrations (Total Conc). Errors in parenthesis. Due to the exponential variation of solubility with temperature (Figure 5), reliable values of  $C_{\text{crit}}$  for each system were calculated from experimental points in the respective low temperature range. The data clearly demonstrate that for this family of gelators,  $C_{\text{crit}}$  is effectively invariant with gelator structure and temperature.

Gelator	Total Conc (mM)	$T_{\text{gel}}$ ( $^{\circ}\text{C}$ )	$C_{\text{crit}}$ (mM)
<b>4-Boc</b>	15	12	4 (1)
<b>4-Boc</b>	30	24	6 (3)
<b>2-<math>\epsilon</math>Z</b>	5	21	4 (1)
<b>2-<math>\epsilon</math>Z</b>	20	42	6 (3)
<b>2-<math>\alpha</math>Z</b>	3	31	3 (0.5)
<b>2-<math>\alpha</math>Z</b>	19	76	4 (2)
<b>4-Z</b>	3	25	3 (0.5)
<b>4-Z</b>	10	87	5 (2)

## SEM Imaging

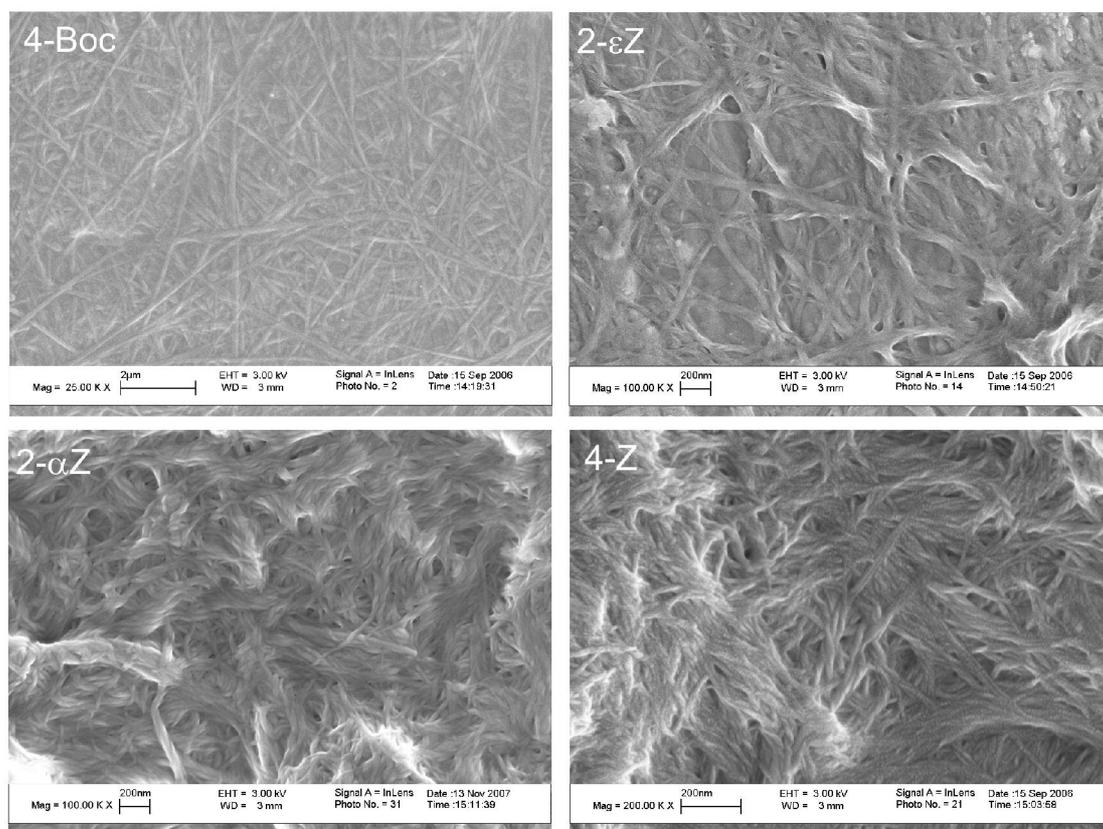


Figure S1. Field emission gun scanning electron microscopy images of gelators in the form of xerogels dried from toluene under ambient conditions.

## Details of Cooperative Model for NMR

We consider a cooperative system where all the constant values for the aggregation steps are identical ( $K_n$ ) except for the first one (dimerization,  $K_2$ ).<sup>1</sup> For such a system the concentration dependence of chemical shifts can be described with the following equation:

$$\frac{(1-P_t)^{1/2}}{(2P_t-1)c^{1/2}} = K_2^{1/2} + K \frac{P_t(1-P_t c)^{1/2}}{2P_t-1}$$

$$P_t = \frac{\delta_a - \delta_{obs}}{\delta_a - \delta_f}$$

$K_2$ : dimerization constant

$K$ : successive aggregation constants after dimerization

$c$ : total concentration of gelator

$\delta_a$ : chemical shift of fully aggregated gelator

$\delta_{obs}$ : observed chemical shift

$\delta_m$ : chemical shift of the free gelator

## Computer Modeling Details

Minimised molecular models were obtained using AMBER\* force field and CHCl<sub>3</sub> GB/SA solvent simulation as implemented in MACROMODEL 9.5 program and Maestro 8.0.

## Synthesis and Characterisation of Gelators

**General Experimental Methods.** Silica column chromatography was carried out using silica gel provided by Fluorochem Ltd. (35-70 $\mu$ ). Thin layer chromatography was performed on commercially available Merck aluminium backed silica plates. Proton and carbon NMR spectra were recorded on a Jeol 400 spectrometer ( $^1\text{H}$  400 MHz,  $^{13}\text{C}$  100 MHz). Samples were recorded as solutions in deuterated NMR solvents as stated and chemical shifts ( $\delta$ ) are quoted in parts per million, referenced to residual solvent. Coupling constant values ( $J$ ) are given in Hz. The level of assignment of  $^1\text{H}$  NMR spectra was achieved using model compounds, literature data and standard knowledge of  $^1\text{H}$  NMR. DEPT experiments were used to assist in the assignment of  $^{13}\text{C}$  NMR spectra. Melting points were measured on an Electrothermal IA 9100 digital melting point apparatus and are uncorrected. Positive and negative ion electrospray mass spectra were recorded on a Finnigan LCQ mass spectrometer. All compounds required in the synthesis were purchased from standard commercial suppliers. Compound **4-Boc** was synthesized according to the method in reference 2.

**Compound 2- $\epsilon$ Z.** 1,9-Diaminononane (0.80 g, 5.05 mmol) was suspended in dichloromethane (100 ml). Triethylamine (2.00 ml, 1.45 g, 14.34 mmol) was added, followed by  $\alpha$ -Boc, $\epsilon$ -Z-L-lysine-OH (5.00 g, 13.14 mmol). The mixture was stirred under nitrogen for 30 minutes. The mixture was cooled to 0 $^\circ\text{C}$ , then hydroxybenzotriazole (HOBt, 3.99 g, 29.29 mmol) and dicyclohexylcarbodiimide (DCC, 6.04 g, 29.29 mmol) were added simultaneously as a mixture of solids. The reaction mixture was allowed to return to room temperature and stirred for 24 h. The precipitate was removed by filtration and washed with dichloromethane then

discarded. The filtrate was then washed first with an aqueous saturated solution of sodium hydrogen carbonate, then with aqueous sodium hydrogen sulfate (16 g in 100 ml water), before being washed again with aqueous sodium hydrogen carbonate and finally with water. The solution was dried over magnesium sulfate, then rotary evaporated to produce a white solid. This crude product was purified by column chromatography (silica, CH<sub>2</sub>Cl<sub>2</sub>:MeOH 98:2 & 0.1% triethylamine) to give a white solid with a yield of 2.80 g (3.17 mmol, 63%). m.p. 125-126 °C. <sup>1</sup>H NMR (400MHz, CDCl<sub>3</sub>) δ 7.32-7.28 (10H, m, Ar-H), 6.35 (2H, br, CONH), 5.27 (2H, br, OCONH), 5.15-5.05 (4H, m, Ar-CH<sub>2</sub>), 4.99 (2H, br, OCONH), 4.01 (2H, br, COCH(R)NH), 3.25-3.15 (8H, m, NHCH<sub>2</sub>), 1.77 (4H, br, CHCH<sub>2</sub>), 1.64-1.26 (40H, m, CH<sub>2</sub> & CH<sub>3</sub>); <sup>13</sup>C NMR (400MHz, CDCl<sub>3</sub>) δ 172.1 (CONH), 156.7 (OCONH), 136.7 (ArC), 128.6 (ArC), 128.2 (ArC), 127.5 (ArC), 82.5 (C(CH<sub>3</sub>)<sub>3</sub>), 66.7 (ArCH<sub>2</sub>), 54.5 (COCH(R)NH), 40.6 (CH<sub>2</sub>NH), 39.4 (CH<sub>2</sub>NH), 32.7 (CH<sub>2</sub>), 29.6 (CH<sub>2</sub>), 29.4 (CH<sub>2</sub>), 29.0 (CH<sub>2</sub>), 28.8 (CH<sub>2</sub>), 28.5 (CH<sub>3</sub>), 26.6 (CH<sub>2</sub>), 22.7 (CH<sub>2</sub>) v<sub>max</sub> 3317m (N-H), 2974m (C-H), 2928m (C-H), 2854m (C-H), 1682s (C=O), 1654s (C=O), 1519s, 1453m, 1365m, 1319s, 1238s, 1165s, 1045m. [α]<sub>D</sub><sup>589</sup> (acetone, conc. 1g/100ml) -2.7. ESI MS *m/z* 905 ([M+Na]<sup>+</sup>, 100%), 906 (45%), 805 ([M+Na-Boc]<sup>+</sup>, 17%). HRMS-FAB Calculated for C<sub>47</sub>H<sub>74</sub>N<sub>6</sub>O<sub>10</sub>Na, [M+Na]<sup>+</sup>: 905.5364, found 905.5369.

**Compound 2-αZ.** The same method was employed as above except on a slightly smaller scale and using ε-Boc,α-Z-L-lysine-OH and EDC instead of DCC. Yield 1.00 g (1.13 mmol, 87%). m.p. 120-122 °C. <sup>1</sup>H NMR (400MHz, CDCl<sub>3</sub>) δ 7.29-7.26 (10H, m, Ar-H), 6.55 (2H, br, CONH), 5.78 (2H, br, OCONH), 5.06 (4H, s, Ar-CH<sub>2</sub>), 4.75 (2H, br, OCONH), 4.10-4.15 (2H, m, COCH(R)NH), 3.23-3.03 (8H, m, NHCH<sub>2</sub>), 1.83-1.60 (4H, br, CHCH<sub>2</sub>), 1.48-1.22 (40H, m, CH<sub>2</sub> & CH<sub>3</sub>); <sup>13</sup>C NMR (400MHz,

CDCl<sub>3</sub>)  $\delta$  171.9 (CONH), 156.5 (OCONH), 156.3 (OCONH), 136.3 (ArC), 128.6 (ArC), 128.2 (ArC), 128.1 (ArC), 79.2 (C(CH<sub>3</sub>)<sub>3</sub>), 67.0 (ArCH<sub>2</sub>), 55.0 (COCH(R)NH), 40.0 (CH<sub>2</sub>NH), 39.5 (CH<sub>2</sub>NH), 32.3 (CH<sub>2</sub>), 29.7 (CH<sub>2</sub>), 29.3 (CH<sub>2</sub>), 29.0 (CH<sub>2</sub>), 28.8 (CH<sub>2</sub>), 28.5 (CH<sub>3</sub>), 26.5 (CH<sub>2</sub>), 22.7 (CH<sub>2</sub>).  $\nu_{\max}$  3298 $m$  (N-H), 2931 $m$  (C-H), 2855 $m$  (C-H), 1680 $s$  (C=O), 1643 $s$  (C=O), 1526 $s$ , 1454 $m$ , 1364 $m$ , 1241 $s$ , 1166 $s$ . ESI MS  $m/z$  883 ([M+H]<sup>+</sup>, 100%), 884 (53%), 885 (13%), 905 ([M+Na]<sup>+</sup>, 60%), 783.5 ([M+H-Boc]<sup>+</sup>, 9%). HRMS-ESI Calculated for C<sub>47</sub>H<sub>75</sub>N<sub>6</sub>O<sub>10</sub>, [M+H]<sup>+</sup>: 883.5539, found 883.5549.

**Compound 4Z.** 1,9-Diaminononane (0.5 g, 3.16 mmol) was suspended in dichloromethane (100 ml). Triethylamine (1.27 ml, 0.95 g, 9.48 mmol) was added, followed by  $\alpha$ -Z, $\epsilon$ -Z-lysine-OH (3.14 g, 8.21 mmol). The mixture was stirred under nitrogen for 30 minutes. The mixture was cooled to 0 °C, then hydroxybenzotriazole (HOBt, 2.56 g, 18.9 mmol) and 1-ethyl-3-(3'-dimethylaminopropyl)carbodiimide (EDC, 3.91 g, 18.9 mmol) were added simultaneously as a mixture of solids. The reaction mixture was allowed to return to room temperature and stirred for 24 h. After 24 hours the reaction mixture had gelled. It was left to dry then washed with methanol and finally diethylether. This crude product was purified by column chromatography (silica, CH<sub>2</sub>Cl<sub>2</sub>:MeOH 98:2 & 0.1% triethylamine) to give a white solid with a yield of 1.61 g (1.78 mmol, 56%). m.p 146-148°C. <sup>1</sup>H NMR (400MHz, DMSO-d<sub>6</sub>)  $\delta$  7.82 (2H, t,  $J$ =5.5 Hz, CONH), 7.32-7.29 (22H, m, ArH, OCONH), 7.22 (2H, t,  $J$ =5.5 Hz, OCONH), 5.00 (8H, d,  $J$ =5.8 Hz, Ar-CH<sub>2</sub>), 3.89 (2H, br m, COCH(R)NH), 3.07-2.93 (8H, m, CH<sub>2</sub>NH), 1.54-1.21 (22H, m, CH<sub>2</sub>). <sup>13</sup>C NMR (400MHz, DMSO-d<sub>6</sub>)  $\delta$  171.6 (CONH), 156.1 (OCONH), 155.9 (OCONH), 137.3 (Ar C-H), 137.1 (ArC), 128.34 (ArC), 128.32 (ArC), 127.7 (ArC), 127.6 (ArC), 65.3

(CH<sub>2</sub>O), 65.1 (CH<sub>2</sub>O), 54.7 (CH), 38.4 (CH<sub>2</sub>NH), 33.0 (CH<sub>2</sub>), 31.7 (CH<sub>2</sub>), 29.1 (CH<sub>2</sub>), 29.0 (CH<sub>2</sub>), 28.9 (CH<sub>2</sub>), 28.7 (CH<sub>2</sub>), 26.3 (CH<sub>2</sub>), 22.8 (CH<sub>2</sub>).  $\nu_{\max}$  3302 $m$  (N-H), 2974 $m$  (C-H), 2924 $m$  (C-H), 2855 $m$  (C-H), 1681 $s$  (C=O), 1647 $s$  (C=O), 1519 $s$ , 1454 $m$ , 1365 $m$ , 1238 $s$ , 1149 $s$ , 1045 $m$ .  $[\alpha]_D^{589}$  (MeOH:DCM 1:1, conc. 1g/100ml) - 19.1. ESI MS  $m/z$  973.6 ([M+Na]<sup>+</sup>, 100%), 974.6 (60%). HRMS-ESI Calculated for C<sub>53</sub>H<sub>70</sub>N<sub>6</sub>O<sub>10</sub>Na, [M+Na]<sup>+</sup>: 973.5046, found 973.5064.

## References

1. Akiyama, M.; Ohtani, T. *Spectrochim. Acta Part A* **1994**, *50*, 317-324.
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