Fast imine equilibration and its consequences for the evaluation of dynamic combinatorial libraries

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Electronic Supplementary Information (ESI)

CONTENTS:

1. General information

All of the reagents and solvents were purchased from commercial sources and used without purification. Chemical shifts in ^{1}HNMR and ^{13}CNMR spectra are reported relative to the signals of tetramethylsilane; C and H atom numbering is the same for all the compounds and is presented in SI (page S8). Column chromatography was performed with silica gel (100−200 mesh) as the stationary phase. For all HPLC measurements, HPLC apparatus equipped with DAD UV/VIS detector and low pressure gradient pump was used. HPLC-grade MeCN, distilled and further deionised water (18.2MΩ) and analytical grade TFA were used as a mobile phase constituents.

2. Synthetic protocols

General procedure for formation of imine libraries and their transformation into corresponding secondary amine libraries. All the reactions used for initial screening of libraries behaviour were prepared on 1 millilitre scale, typically in a series of several experiments. A mixture of dialdehyde **1** and diamine **2** was prepared for the whole series by mixing solutions of dialdehyde **1** and diamine **2** in a proper solvent (MeOH or MeCN, HPLC gradient grade) to get the final concentration of 50 mM in respect to each substrate. Immediately upon mixing this solution was added (1ml) to vials containing proper templates. The vials, protected from air by stopper and parafilm, were then left for one day for equilibration. Then, stirring rods were placed in reaction vials, mixtures were cooled with ice-water bath and of powdered $NaBH_4$ was added (5 equivs in respect to substrates, 0.25mmol per 1ml of solution) while stirring. In case of MeCN based libraries, this was followed by immediate addition of 1ml of 1% TFA in water (v/v). The vials were corked with a needle-punctured stopper and left, with stirring, in ice/water bath till evolution of hydrogen ceased. Then, the resulting secondary libraries of amines were subjected to HPLC analysis.

Equilibration kinetics experiments. The protocols follow the general procedure. Reactions were carried on a higher scale to afford 250µl of solution for every measuring point. Aliquots were added to pre-cooled (+4°C) vials containing 5 equivs of $NaBH_4$ and a stirring bar. In case of equilibration experiments starting from solid [1+1] imine **3** complex, powdered crystals of **3*LiCl** were taken in sufficient amount to afford 250µl of solution for every measuring point.

HPLC analysis. The following settings were used: spectral range 190-400nm; detection: λ=224nm; flow: 2ml/min; injection volume: 20µl. Crude reaction mixtures of amines were diluted 50-times (to c=1mM) with "A" mobile phase and injected directly without any sample pre-treatment on precolumn-guarded *Polaris C-18A* (250x4.6mm, 5µm) column (method: *Polaris*) or precolumn-guarded Supelco HS C18 (250x4.6mm, 5µm) column (method *Supelco*). Gradient program *Polaris*: (0min) 88%"A", 12%"B" → (30min) 69%"A", 31%"B"→ (40min) 50%"A", 50%"B"; gradient program *Supelco*: (0min) 88%"A", 12%"B" → (20min) 75%"A", 25%"B" → (40min) 50%"A", 50%"B"; where „A" is MeCN:H_2O:TFA 10:90:0.1 (v/v/v) and „B" is MeCN:H_2O:TFA 90:10:0.1 (v/v/v).

5,5'-(butane-2,2-diyl)bis(furan-2-carbaldehyde) (1). In a 500ml flask 2,2'-(butane-2,2-diyl)difuran[1] (4.75g, 25mmol) and freshly distilled DMF (18.25g, 250mmol) were placed and cooled to 5°C with ice/water bath. To the vigorously stirred mixture $POCl_3$ (11.4 ml, 125mmol) was

[1] R. G. Ackman, W. H. Brown and G. F. Wright, *J. Org. Chem.*, 1955, **20**, 1147-1158.

added dropwise over 60 min, while the temperature was kept below 10°C. After that the cooling bath was removed and the mixture was stirred for 3 hours at room temperature. Then it was cooled down with ice/water to 5°C and CAREFULLY and SLOWLY 25ml of water was added dropwise, followed by 20% NaOH to neutralize the acids. ADDITION OF WATER AND BASE ARE HIGHLY EXOTHERMIC! The resulting mixture was then extracted 3 times with $CHCl_3$ and combined organic extracts were washed with brine and dried over $MgSO_4$. After removal of solvents, the sticky residue was filtrated through silica (hexanes:ethyl acetate, 2:1). Finally, crystallization from MeOH afforded pure dialdehyde **1** (4.31g, 70%) as yellowish needles; mp (MeOH) 67-68ºC; ^{1}H NMR (200MHz, $CDCl_3$), δ: 0.84 (3H, t, *J*=7.5Hz, C9-*H*), 1.73 (3H, s, C7-*H*), 2.21 (2H, q, *J*=7.4Hz, C8-*H*), 6.38 (2H, d, *J*=3.6Hz, C4-*H*), 7.20 (2H, d, *J*=3.6Hz, C3-*H*), 9.57 (2H, s, C1-*H*); ^{13}C NMR (50MHz, $CDCl_3$), δ: 8.90 (C9), 21.85 (C7), 31.80 (C8), 42.87 (C6), 109.49 (C4), 122.64 (C3), 152.33 (C2), 164.40 (C5), 177.58 (C1); HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{14}H_{14}O_4Na$ 269.0790; Found 269.0800.

(5,5'-(butane-2,2-diyl)bis(furan-5,2-diyl))dimethanol (9). To an ice-water cooled solution of 123mg (0.5mmol) of dialdehyde **1** in 5 ml of methanol 95mg of $NaBH_4$ (5 equivs, 2.5mmol) was added. After the evolution of hydrogen ceased, reaction mixture was acidified with 5% HCl till pH 2, then it was alkalised with 25% ammonia till pH 8. The resulting mixture was extracted five times with $CHCl_3$. Organic extracts were washed with brine and dried with $MgSO_4$. After removal of the solvents crude product was filtrated through silica gel (hexanes:ethyl acetate, 2:1) affording 116mg (93%) of **9** as a colourless, slowly crystallizing solid; mp (MeOH) 93-95ºC; ^{1}H NMR (200MHz, $CDCl_3$), δ: 0.78 (3H, t, *J*=7.4Hz, C9-*H*), 1.56 (3H, s, C7-*H*), 2.04 (2H, q, *J*=7.5Hz, C8-*H*), 2.43 (2H, br, O-*H*), 4.47 (4H, s, C1-*H*), 5.99 (2H, d, *J*=3.0Hz, C4-*H*), 6.16 (2H, d, J=3.2Hz, C3-*H*); ^{13}C NMR (50MHz, $CDCl_3$), δ: 8.97 (C9), 22.28 (C7), 31.73 (C8), 41.63 (C6), 57.55 (C1), 105.98 and 108.44 (C3 and C4), 152.92 (C2), 159.41 (C5); HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{14}H_{18}O_4Na$ 273.1103; Found 273.1107.

[1+1] Imine 3*LiCl complex. The synthesis follows the general procedure, MeCN was used as a solvent and anhydrous LiCl (1 equiv.) as a template. Reaction was carried on 0.5mmol scale, dissolution of LiCl was facilitated by 5 min of sonication. The library was left for 48h for equilibration, then the mixture was filtered through a dense plug of cotton and subjected to slow diethyl ether vapour diffusion, for the first two days at room temperature, then for two weeks in a fridge. Crystals were separated with suction form the mother liquor, washed with Et_2O and vacuum dried to afford 150mg (84%) of **3*LiCl** as off-white prisms.

[1+1] amine 6. ***Method A (library based).*** The synthesis follows the general procedure. Reaction was carried on 0.5mmol scale. $LiClO_4*3H_2O$ (1 equiv.) was used as a template and MeCN as a

solvent. When the reduction was finished, most of the solvents were removed on a rotavap and the residue was acidified with 5% HCl to pH 2, then basified with 25% ammonia followed by 20% NaOH to pH 12 and extracted five times with $CHCl_3$. Extracts were washed with 2% NaOH and dried with Na_2SO_4. Solvents were removed under vacuum. Crude was purified by silica gel column chromatography in a gradient of $CHCl_3$:MeOH 90:10→80:20 to afford 107mg (79%) of amine 6.

[1+1] amine 6. ***Method B (solid imine based)***. Powdered crystals of imine **3*LiCl** complex (100mg, 0.28mmol) were mixed with solid $NaBH_4$ (5 equivs, 1.4mmol, 53mg), the flask was placed in a cooling bath and methanol was added to the stirred solids. Then it was processed as described in *Method A*. Chromatographic purification was not required. Amine **6** was obtained in 93% yield (83mg), that corresponds to the total yield of 78% starting from substrates **1** and **2**.

[1+1] amine 6: pale yellow solid; mp 73-75°C; ^{1}H NMR (500MHz, $CDCl_3$), δ: 0.75 (3H, t, *J*=7.5Hz, C9-*H*), 1.52 (3H, s, C7-*H*), 2.03 (2H, q, *J*=7.0Hz, C8-*H*), 2.20 (2H, brs, N-*H*), 2.65-2.73 (4H, m, C10-*H*), 3.43-3.54 (4H, m, C11-*H*), 3.68 (4H, qAB, *J*=14.1Hz, C1-*H*), 6.02 (2H, d, *J*=3.0Hz, C4-*H*), 6.05 (2H, d, *J*=3.0Hz, C3-*H*); ^{13}C NMR (125MHz, $CDCl_3$), δ: 8.57 (C9), 21.62 (C7), 31.27 (C8), 40.98 (C6), 46.02 and 47.86 (C1 and C10), 69.61 (C11), 104.83 and 107.77 (C3 and C4), 151.73 (C2), 158.90 (C5); HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{18}H_{27}N_2O_3$ 319.4195; Found 319.4178.

[2+2] amine 7 and **[3+3] amine 8**. The synthesis follows the general procedure. Reaction was carried on 2.0 mmol scale. MeOH was used as a solvent, there was no template. When the reduction was finished, 40ml of water was added and most of the solvents were removed on a rotavap. The residue was acidified with 5% HCl to pH 2, then basified with 25% ammonia followed by 20% NaOH to pH 12 and extracted five times with $CHCl_3$. Extracts were washed with 2% NaOH and dried with Na_2SO_4. Solvents were removed under vacuum. Amines were separated by silica gel column chromatography in $CHCl_3$:MeOH:$NH_{3aq(25\%)}$ with increasing gradient of methanol and ammonia: 90:10:0→90:10:0.33→83:17:0.75. For every isolated library member, pure fractions were evaporated till dryness, redissolved in $CHCl_3$, dried with Na_2SO_4, then redissolved in a small volume of MeOH and triturated with CH_2Cl_2 to remove dissolved silica. All solvents were evaporated and traces of solvents were removed under high vacuum (<1mmHg) to give 210mg (34%) of [2+2] amine **7**, 84mg (14%) of slightly impure [3:3] amine **8** and 19mg (4%) of diol **10**. [1+1] Amine **6** was not isolated from the non-templated library. Sample of spectrally pure [3+3] **8** macrocycle was obtained by HPLC purification of a crude reaction mixture on a Supelco Discovery HS C18 column (250x10mm, 5μm)*;* spectral range 190-400nm; detection: λ=240nm; flow: 6ml/min; gradient program: (0min) 88%"A",12%"B"→(15min)79%"A", 21%"B"→ (20min)79%"A",21%"B", where „A" is MeCN:H_2O:TFA 10:90:0.1 (v/v/v) and „B" is

MeCN:H_2O:TFA 90:10:0.1 (v/v/v). Collected fractions (r_t=12.3-15.5min) were freeze-dried, then dissolved in $CHCl_3$, washed twice with 10% $NaHCO_3$ and once with brine. Organic phase was dried with Na_2SO_4 and the solvents were removed.

[2+2] amine 7: viscous yellow oil; ^{1}H NMR (500MHz, $CDCl_3$), δ: 0.77 (6H, t+t shifted by 0.02ppm, J=6.5Hz, C9-*H*), 1.53 (6H, s, C7-*H*), 2.01 (4H, q, *J*=7.5Hz, C8-*H*), 2.75 (8H, t, *J*=5.0Hz, C10-*H*), 2.98 (4H, brs, N-*H*), 3.54 (8H, t, *J*=5.0Hz, C11-*H*), 3.73 (8H, s, C1-*H*), 5.94 (4H, d, *J*=3.5Hz, C4-*H*), 6.07 (4H, d, *J*=3.0Hz, C3-*H*); ^{13}C NMR (125MHz, $CDCl_3$), δ: 8.95 (C9), 22.37 (C7), 31.75 (C8), 41.51 (C6), 45.95 and 48.11 (C1 and C10), 70.05 (C11), 105.63 and 107.77 (C3 and C4), 151.93 (C2), 158.76 (C5); HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{36}H_{53}N_4O_6$ 637.3965; Found 637.3963.

[3+3] amine 8: viscous yellow oil; ^{1}H NMR (500MHz, $CDCl_3$), δ: 0.76 (9H, t, *J*=7.5Hz, C9-*H*), 1.53 (9H, s, C7-*H*), 2.10 (12H, M, C8-*H* and N-*H*), 2.74 (12H, t, *J*=5.0Hz, C10-*H*), 3.51 (12H, t, *J*=5.0Hz, C11-*H*), 3.72 (12H, s, C1-*H*), 5.92 (6H, d, *J*=3.0Hz, C4-*H*), 6.05 (6H, d, *J*=3.0Hz, C3-*H*); ^{13}C NMR (50MHz, $CDCl_3$), δ: 9.09 (C9), 22.55 (C7), 31.93 (C8), 41.64 (C6), 46.37 and 48.41 (C1 and C10), 70.51 (C11), 105.74 and 107.41 (C3 and C4), 152.59 (C2), 158.69 (C5); HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{54}H_{79}N_6O_9$ 955.5900; Found 955.5800.

3. UV-VIS determination of imine-to-amine reduction kinetics

Protocol. All measurements were carried using the following settings of the UV-spectrophotometer: optical path: 10mm (quartz cuvette), spectral range: 200-335nm; scan speed: 240nm/min; bandwidth: 1nm; data interval: 1nm; temperature: 20-22^{o}C. The libraries were reduced according to the common protocols. After one minute of reduction 30µl of reaction mixture was taken into 270µl of pure solvent (MeOH or MeCN, same as used to generate the library). Then, 30µl (MeOH libraries) or 60µl (MeCN libraries) of the above solution was injected to UV cuvette filled with 3000µl of corresponding solvent (to the final concentration of ~$5*10^{-5}$M), all was mixed and spectra were recorded. Two dilution steps were used to avoid working with low volumes of bubbling reaction mixture. The whole operation took 20-30 seconds that were not included to "one-minute reaction" time.

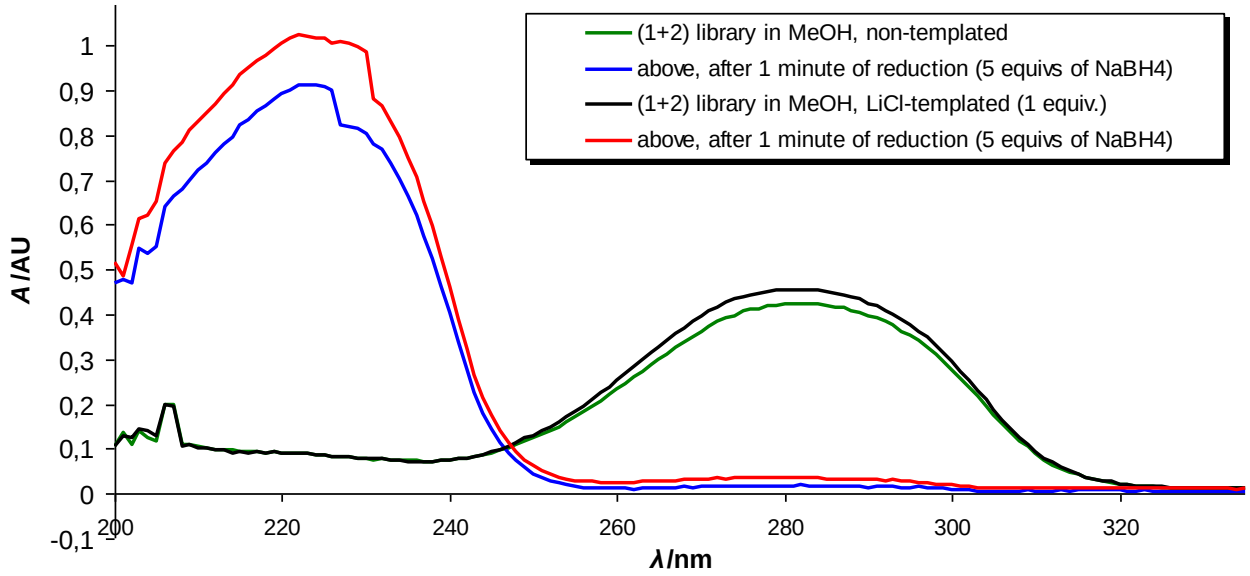


Figure S1. Reduction kinetics in MeOH. UV spectra of (**1**+**2**) imine libraries: (**---**) non-templated c=1.25*10^{-5}M; (**---**) LiCl-templated c=1.25*10^{-5}M; (**---**) non-templated, c~5*10^{-5}M, after 1 minute of reduction by 5 molar eqiuvs of $NaBH_4$; (**---**) LiCl-templated, c~5*10^{-5}M, after 1 minute of reduction by 5 molar eqiuvs of $NaBH_4$.

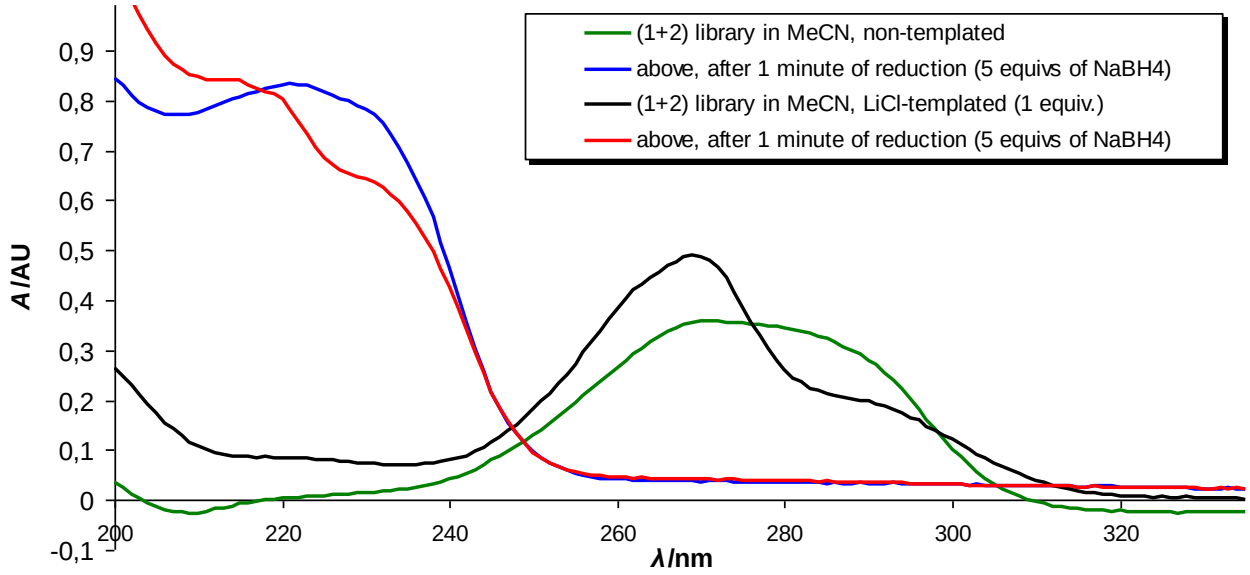


Figure S2. Reduction kinetics in MeCN. UV spectra of (**1**+**2**) imine libraries: (**---**) non-templated c=1.25*10^{-5}M; (**---**) LiCl-templated c=1.25*10^{-5}M; (**---**) non-templated, c~5*10^{-5}M, after 1 minute of reduction by 5 molar eqiuvs of $NaBH_4$; (**---**) LiCl-templated, c~5*10^{-5}M, after 1 minute of reduction by 5 molar eqiuvs of $NaBH_4$.

4. HPLC data used for determination of equilibration kinetics

4a. Kinetics of library formation in methanol starting from pure crystals of imine **3*LiCl** complex.

Table S1. Relative concentration of the key library members presented as % of the corresponding HPLC peak in respect to whole chromatogram.

time [min]	[1+1] amine **6**	[2+2] amine **7**	[3+3] amine **8**	diol **9**
0[a]	96%	<1%	<1%	0%
0,5	24%	21%	12%	0%
1	11%	29%	16%	1%
2	7%	35%	18%	1%
3	6%	39%	18%	1%
5	7%	43%	18%	1%
7	6%	45%	18%	1%
10	6%	46%	18%	1%
12	6%	46%	18%	1%
15	7%	46%	18%	1%
20	6%	46%	18%	1%
30	6%	46%	18%	1%
45	6%	46%	18%	1%
60	6%	45%	18%	1%
120	6%	46%	18%	1%
240	7%	45%	17%	1%
360	7%	46%	18%	1%
(20 h)	7%	46%	18%	1%

a) "0 min" chromatogram obtained by mixing solid imine and $NaBH_4$ followed by addition of MeOH (see main text for details).

4b. Kinetics of formation of the non-templated library in methanol starting from substrates **1** and **2**

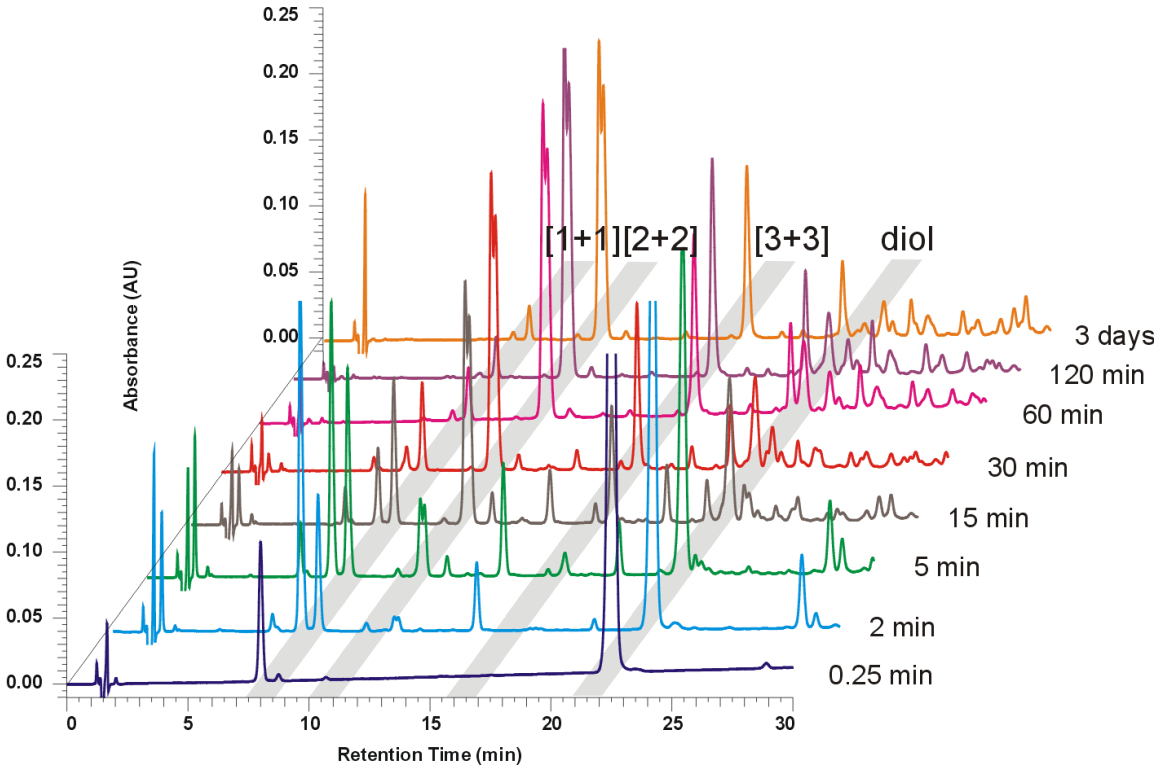


Figure S3. HPLC traces of the corresponding secondary libraries of amines (UV detection at 224 nm, method *Supelco*)

Table S2. Relative concentration of the key library members presented as % of the corresponding HPLC peak in respect to whole chromatogram.

time [min]	[1+1] amine **6**	[2+2] amine **7**	[3+3] amine **8**	diol **9**
0,25	0%	0%	0%	92%
2	8%	0%	0%	56%
5	13%	9%	2%	35%
10	12%	22%	6%	21%
15	10%	29%	9%	16%
20	8%	32%	11%	13%
30	6%	41%	15%	11%
60	4%	44%	18%	9%
120	3%	45%	18%	4%
180	3%	46%	18%	5%
(3 days)	2%	42%	16%	2%

4c. Kinetics of formation of the $NaClO_4$*H_2O (5 equiv.) templated library in methanol starting from substrates **1** and **2**

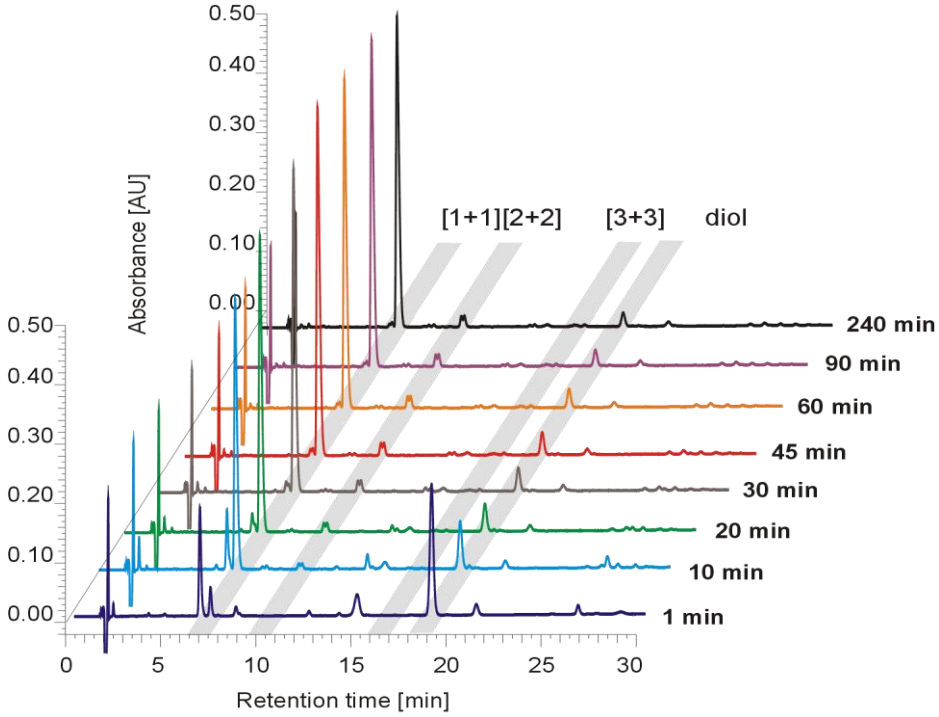


Figure S4. HPLC traces of the corresponding secondary libraries of amines (UV detection at 224 nm, method *Polaris*)

Table S3. Relative concentration of the key library members presented as % of the corresponding HPLC peak in respect to whole chromatogram.

time [min]	[1+1] amine **6**	[2+2] amine **7**	[3+3] amine **8**	diol **9**
1	5%	0%	0%	41%
2	12%	0%	0%	32%
5	34%	1%	0%	23%
10	58%	2%	0%	13%
15	68%	3%	0%	11%
20	74%	3%	0%	9%
30	81%	4%	0%	7%
45	84%	5%	0%	6%
60	85%	5%	0%	6%
90	88%	5%	0%	5%
120	89%	5%	0%	5%
180	89%	5%	0%	4%
240	90%	5%	0%	4%
300	88%	5%	0%	5%

4d. Kinetics of formation of the LiCl (1 equiv.) templated library in methanol starting from substrates **1** and **2**

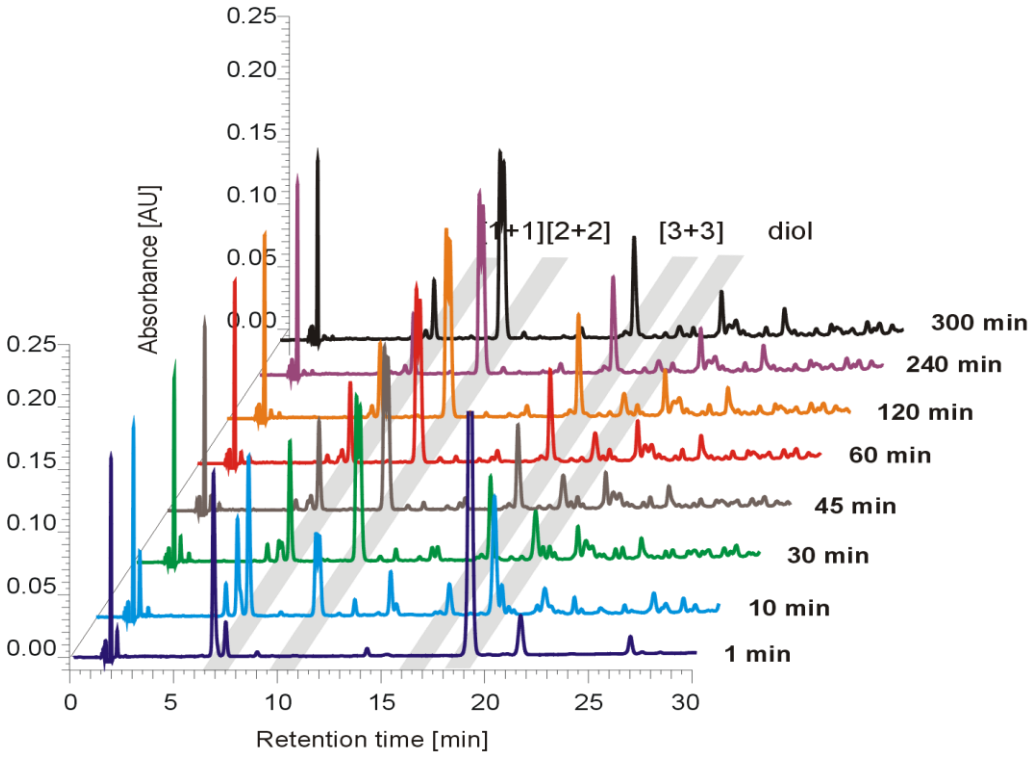


Figure S5. HPLC traces of the corresponding secondary libraries of amines (UV detection at 224 nm, method *Polaris*)

Table S4. Relative concentration of the key library members presented as % of the corresponding HPLC peak in respect to whole chromatogram.

time [min]	[1+1] amine **6**	[2+2] amine **7**	[3+3] amine **8**	diol **9**
1	3%	0%	0%	68%
2	7%	1%	0%	56%
5	13%	6%	1%	34%
10	16%	17%	5%	19%
15	15%	23%	7%	14%
20	14%	28%	9%	11%
30	12%	34%	11%	8%
45	10%	40%	13%	7%
60	9%	41%	14%	5%
90	8%	42%	14%	4%
120	7%	41%	14%	3%
180	8%	43%	14%	3%
240	7%	43%	15%	2%
300	6%	40%	15%	2%

4e. Kinetics of library formation in methanol upon addition of 5 equivs of $NaClO_4*H_2O$ to a pre-equilibrated non-template (**1**+**2**) library

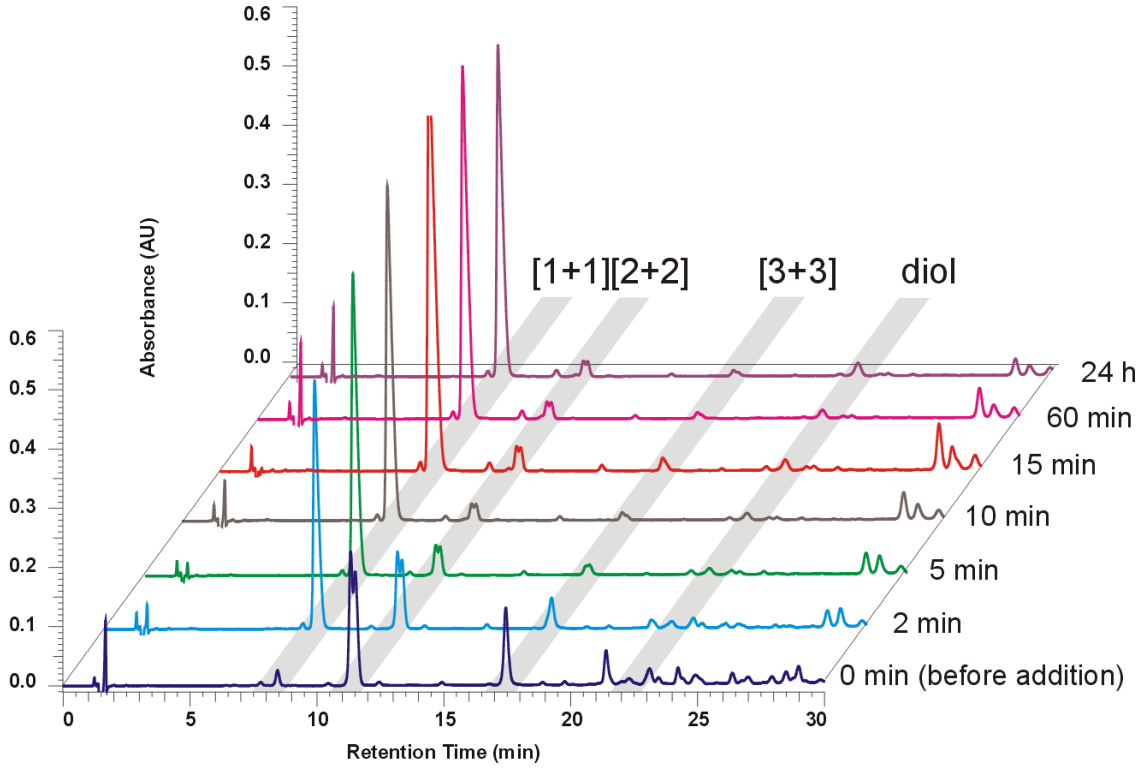


Figure S6. HPLC traces of the corresponding secondary libraries of amines (UV detection at 224 nm, method *Supelco*)

Table S5. Relative concentration of the key library members presented as % of the corresponding HPLC peak in respect to whole chromatogram.

time [min]	[1+1] amine **6**	[2+2] amine **7**	[3+3] amine **8**	diol **9**
0	2%	42%	16%	2%
2	51%	22%	7%	2%
5	73%	10%	3%	2%
10	80%	5%	2%	2%
15	77%	4%	2%	2%
60	81%	5%	1%	2%
(24h)	82%	5%	2%	3%

5. Crystal structure of complex of imine 3*LiCl

Experimental

All measurements of crystal were performed on a KM4CCD κ-axis diffractometer with graphite-monochromated MoK_α radiation. The crystal was positioned at 62 mm from the CCD camera. 3000 frames were measured at 0.4^o intervals with a counting time of 28 sec. The data were corrected for Lorentz and polarization effects. Empirical correction for absorption was applied.[S1] Data reduction and analysis were carried out with the Oxford Diffraction programs.[S2]

The structure was solved by direct methods[S3] and refined using SHELXL.[S4] The refinement was based on F^2 for all reflections except those with very negative F^2. Weighted R factors wR and all goodness-of-fit S values are based on F^2. Conventional R factors are based on F with F set to zero for negative F^2. The $F_o^2 > 2\sigma(F_o^2)$ criterion was used only for calculating R factors and is not relevant to the choice of reflections for the refinement. The R factors based on F^2 are about twice as large as those based on F. All hydrogen atoms were located geometrically and their position were refined. Temperature factors for some hydrogen atoms were fixed. Scattering factors were taken from Tables 6.1.1.4 and 4.2.4.2 in Ref. S5.

CCDC deposition number: **983841**

References

[S1] CrysAlis RED, Oxford Diffraction Ltd.,Version 1.171.28cycle2 beta (release 25-10-2005 CrysAlis171 .NET) (compiled Oct 25 2005,08:50:05). Empirical absorption correction using spherical harmonics, implemented in SCALE3 ABSPACK scaling algorithm.
[S2] CrysAlis CCD, Oxford Diffraction Ltd., Version 1.171.28cycle2 beta; CrysAlis RED, Oxford Diffraction Ltd.,Version 1.171.28cycle2 beta
[S3] G. M. Sheldrick, Acta Crystallogr. **1990**, A46, 467-473.
[S4] G. M. Sheldrick, SHELXL93. *Program for the Refinement of Crystal Structures.*, Univ. of Göttingen, Germany.
[S5] *International Tables for Crystallography*, Ed. A. J. C. Wilson, Kluwer:Dordrecht, **1992**, Vol.C.

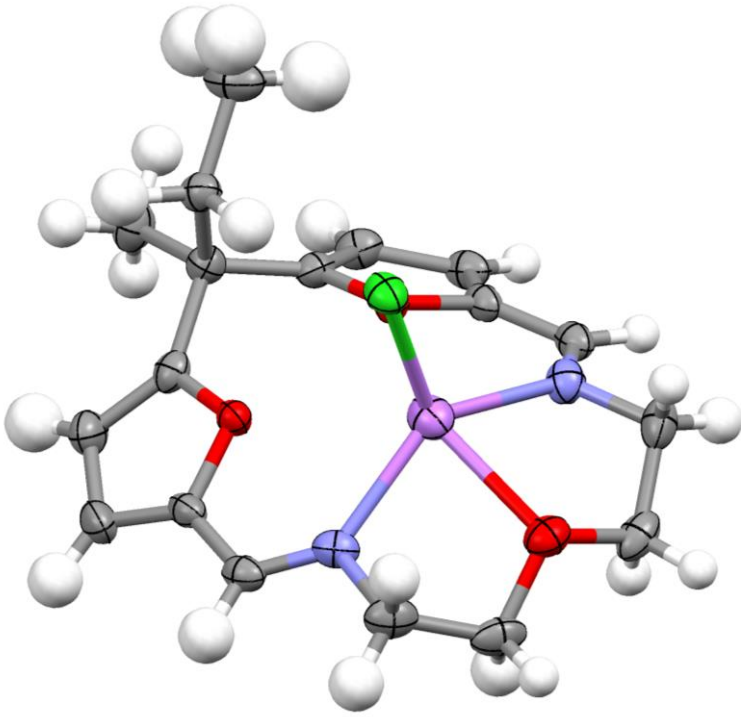
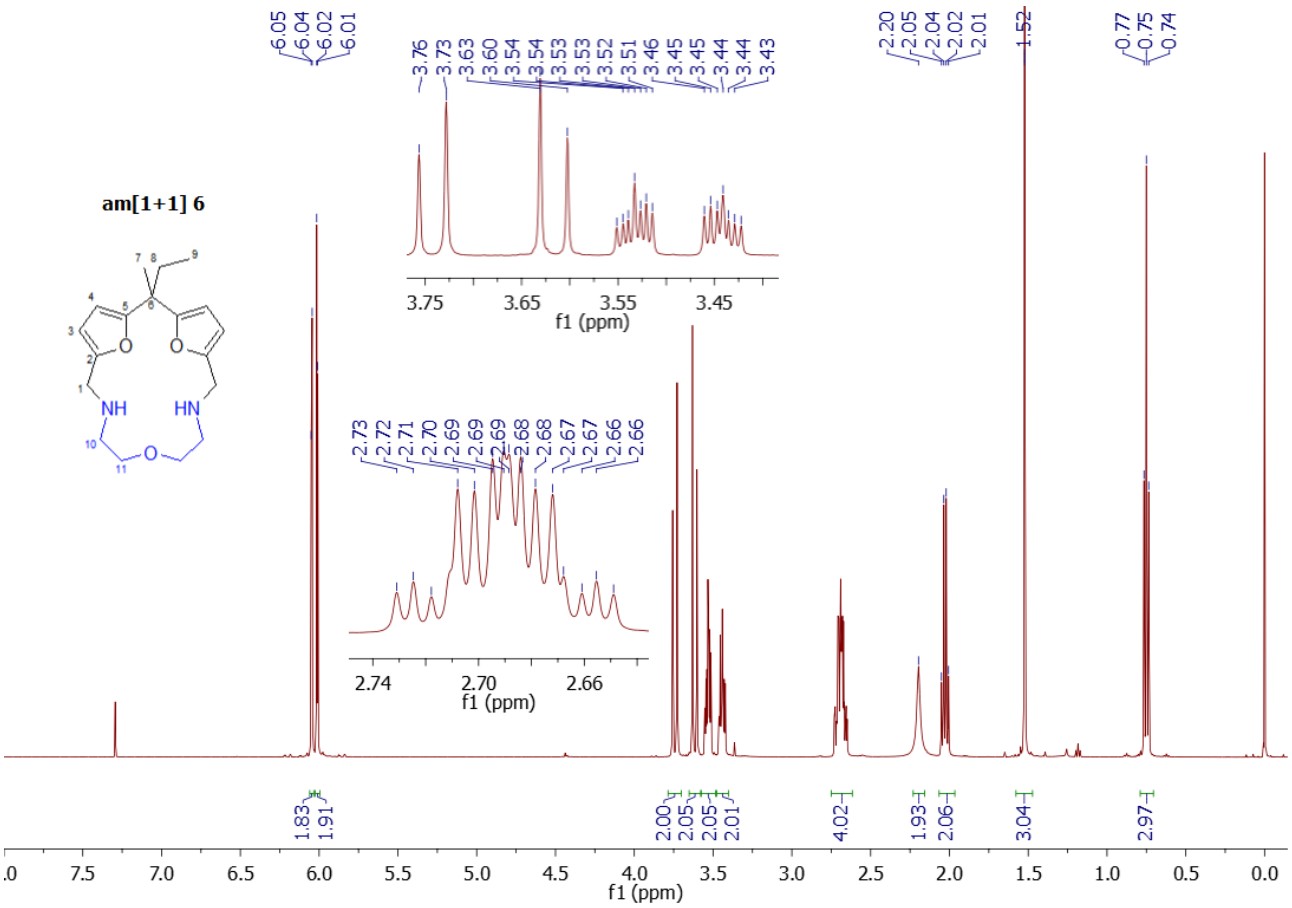


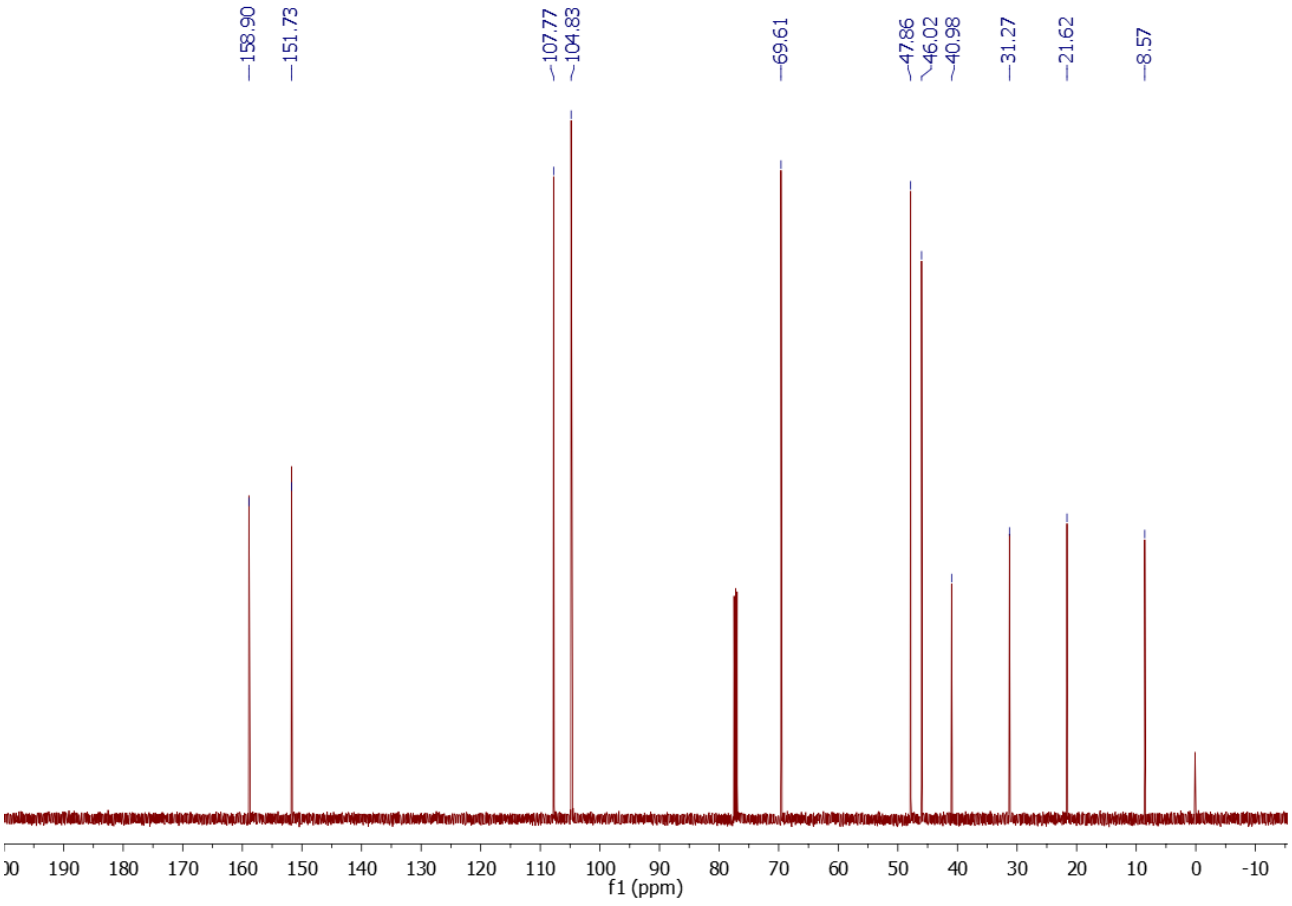
Figure S7. ORTEP view of **3*LiCl**

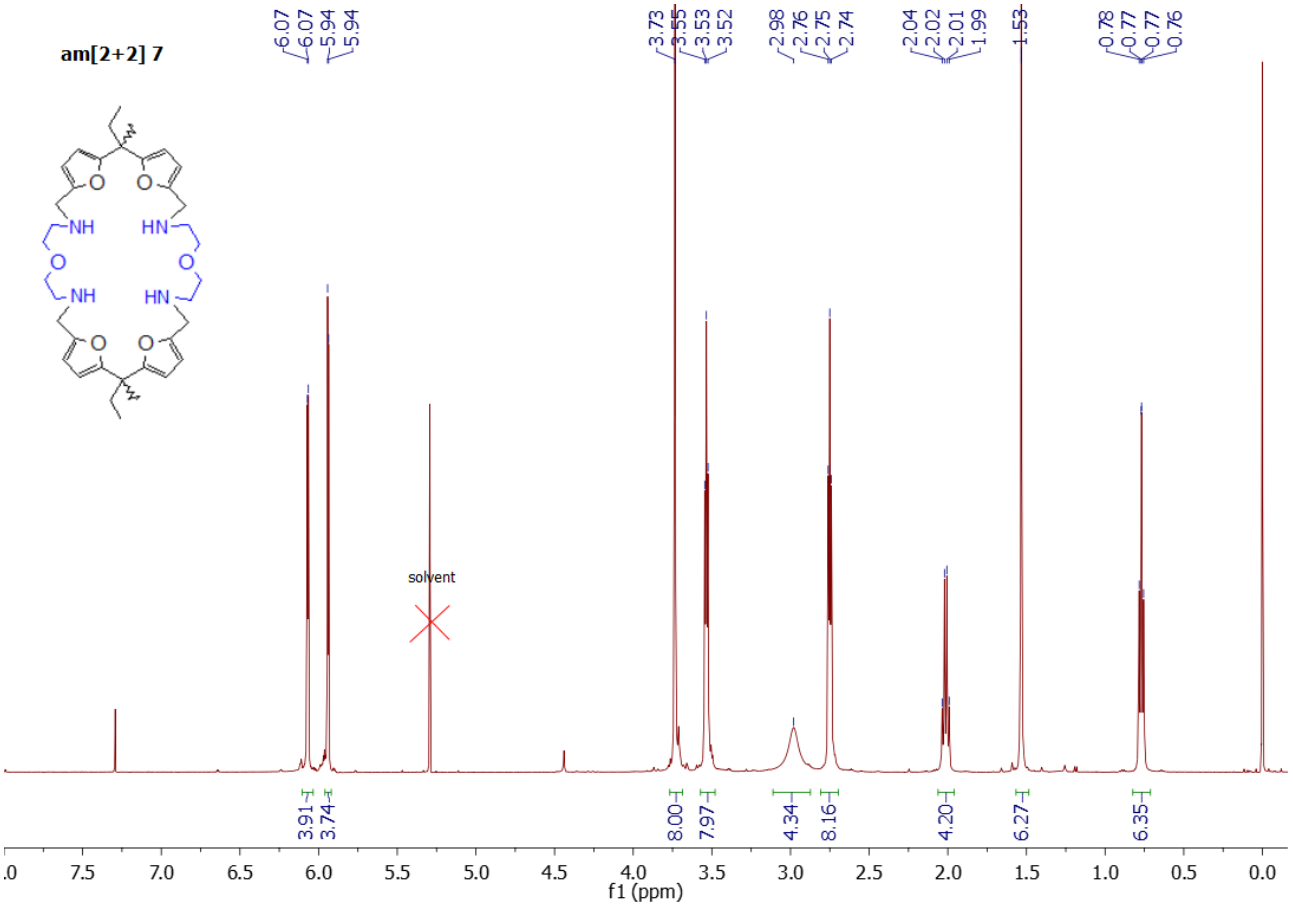
Table S6. Crystal data and structure refinement for compound **3*LiCl**.

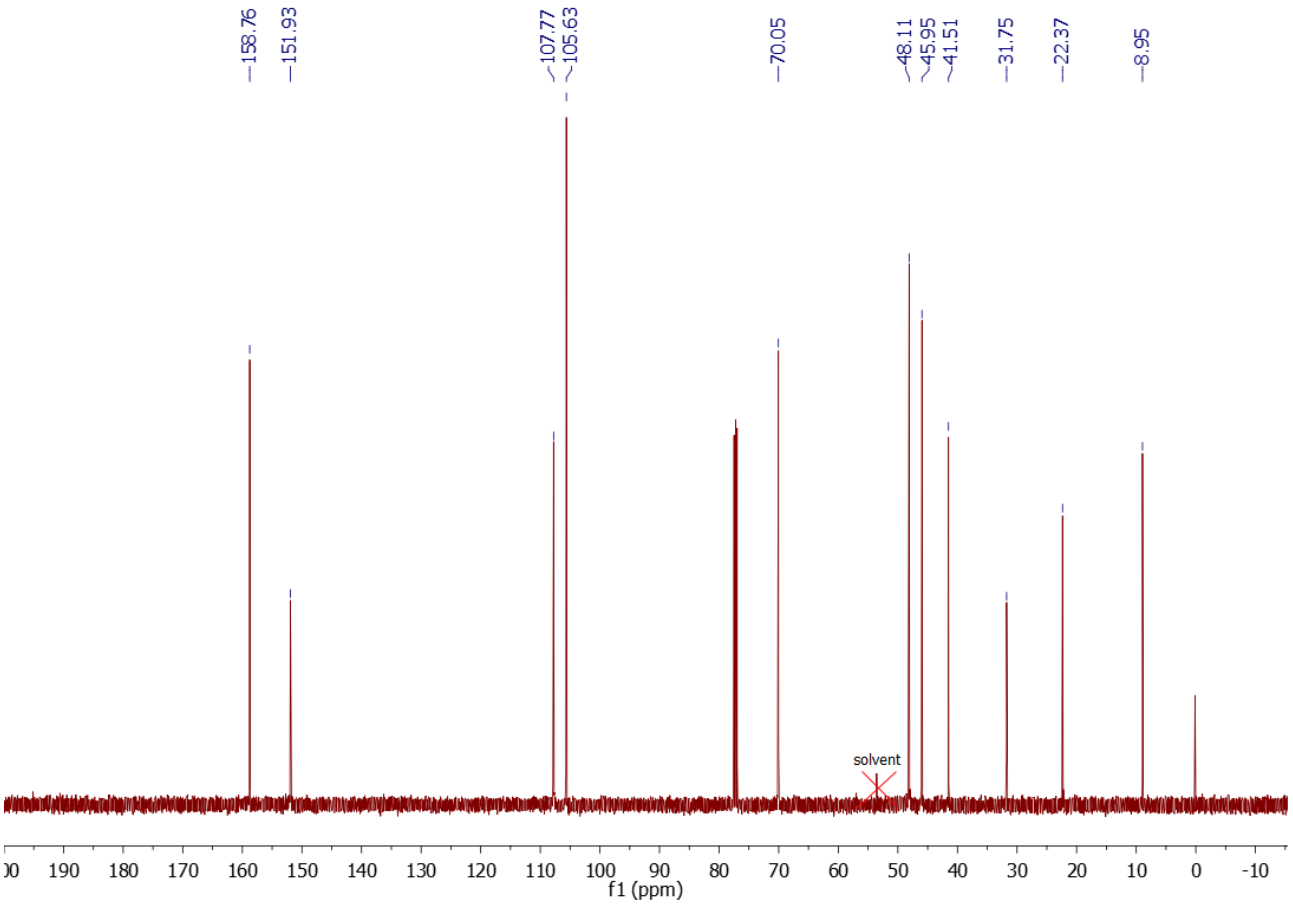
Identification code	aq678
Empirical formula	C18 H22 Cl Li N2 O3
Formula weight	356.77
Temperature	100(2) K
Wavelength	0.71073 A
Crystal system, space group	Monoclinic, Cc
Unit cell dimensions	a = 21.6473(8) A alpha = 90 deg.
	b = 7.6201(3) A beta = 123.262(4) deg.
	c = 13.1540(4) A gamma = 90 deg.
Volume	1814.33(14) A^3
Z, Calculated density	4, 1.306 Mg/m^3
Absorption coefficient	0.229 mm^-1
F(000)	752
Crystal size	0.29 x 0.21 x 0.05 mm
Theta range for data collection	2.90 to 28.71 deg.
Limiting indices	-29<=h<=28, -10<=k<=10, -17<=l<=17
Reflections collected / unique	16503 / 4423 [R(int) = 0.0195]
Completeness to theta = 28.00	99.3 %
Absorption correction	Semi-empirical from equivalents
Max. and min. transmission	0.99 and 0.92
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	4423 / 2 / 309
Goodness-of-fit on F^2	0.933
Final R indices [I>2sigma(I)]	R1 = 0.0233, wR2 = 0.0466
R indices (all data)	R1 = 0.0299, wR2 = 0.0474
Absolute structure parameter	0.00(4)
Largest diff. peak and hole	0.192 and -0.160 e.A^-3

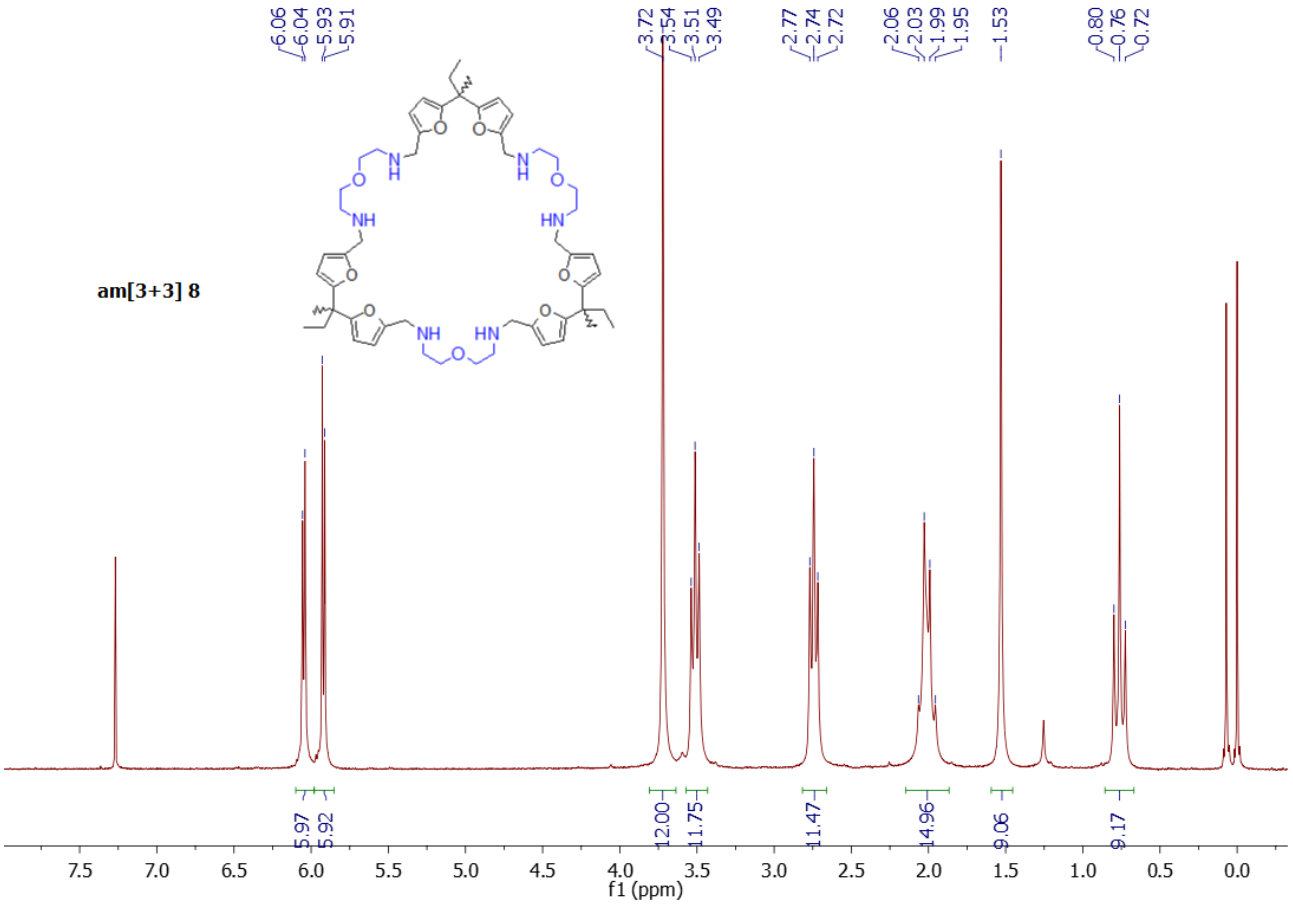
6. Copies of ^{1}H and ^{13}C NMRs

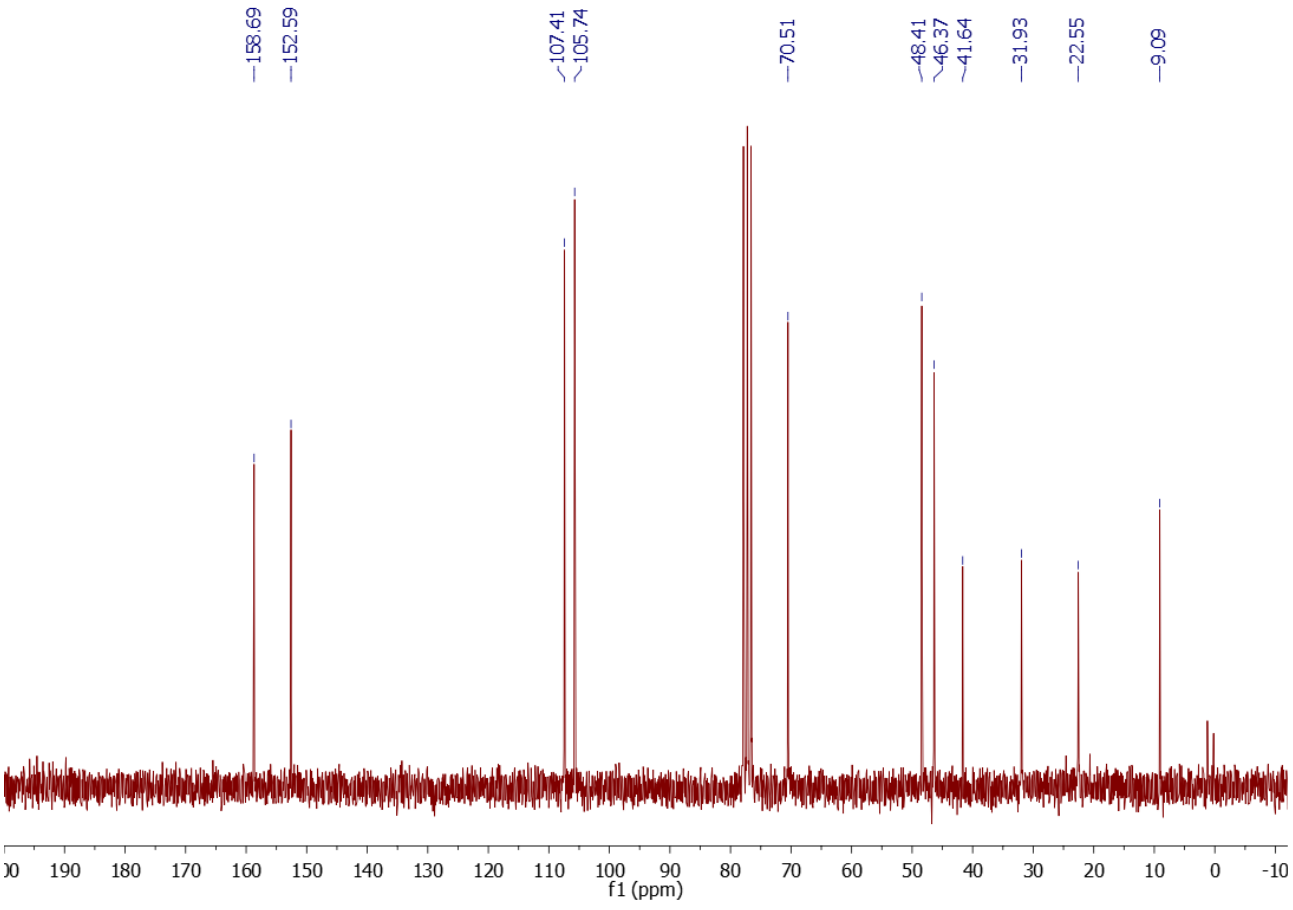


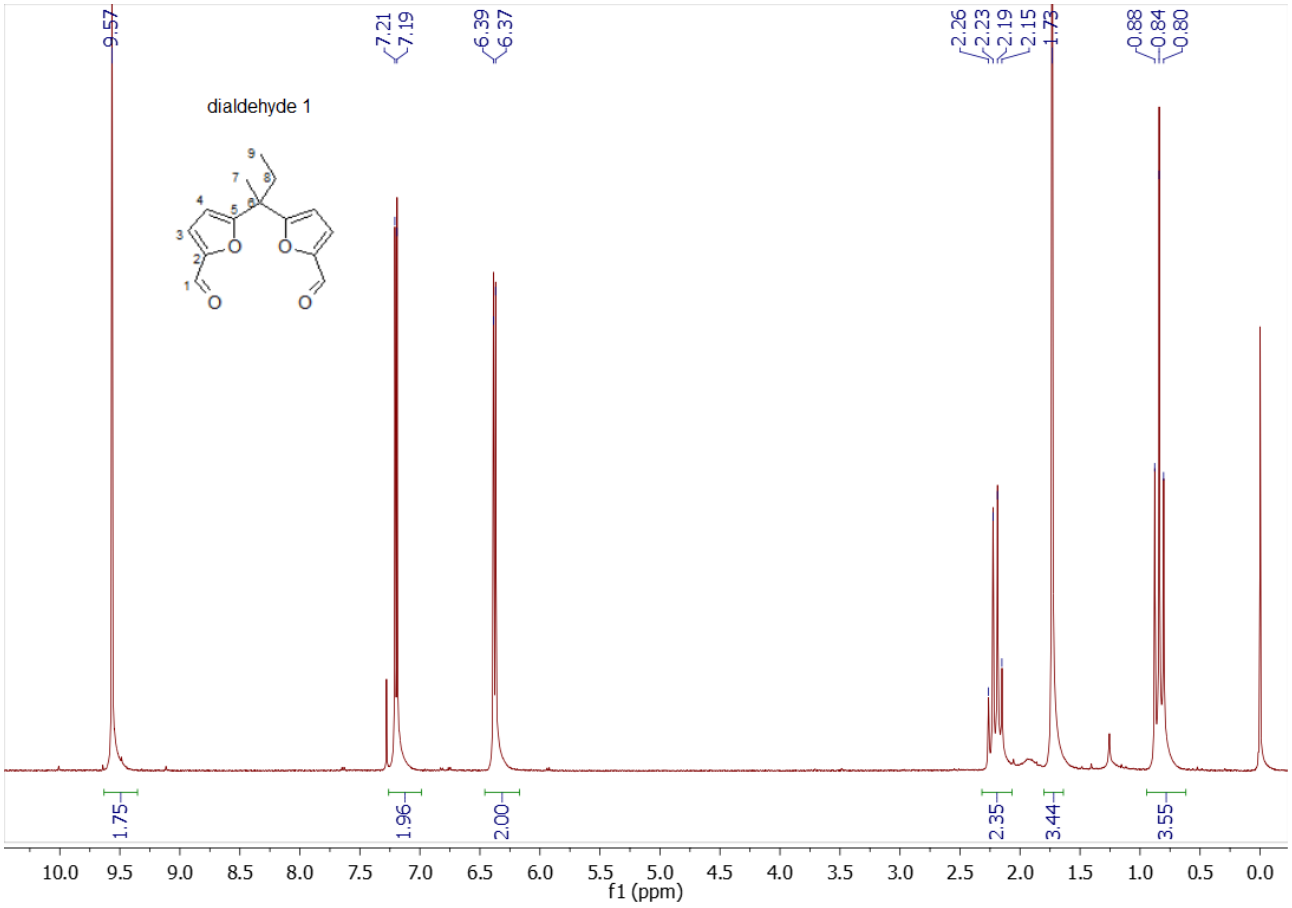


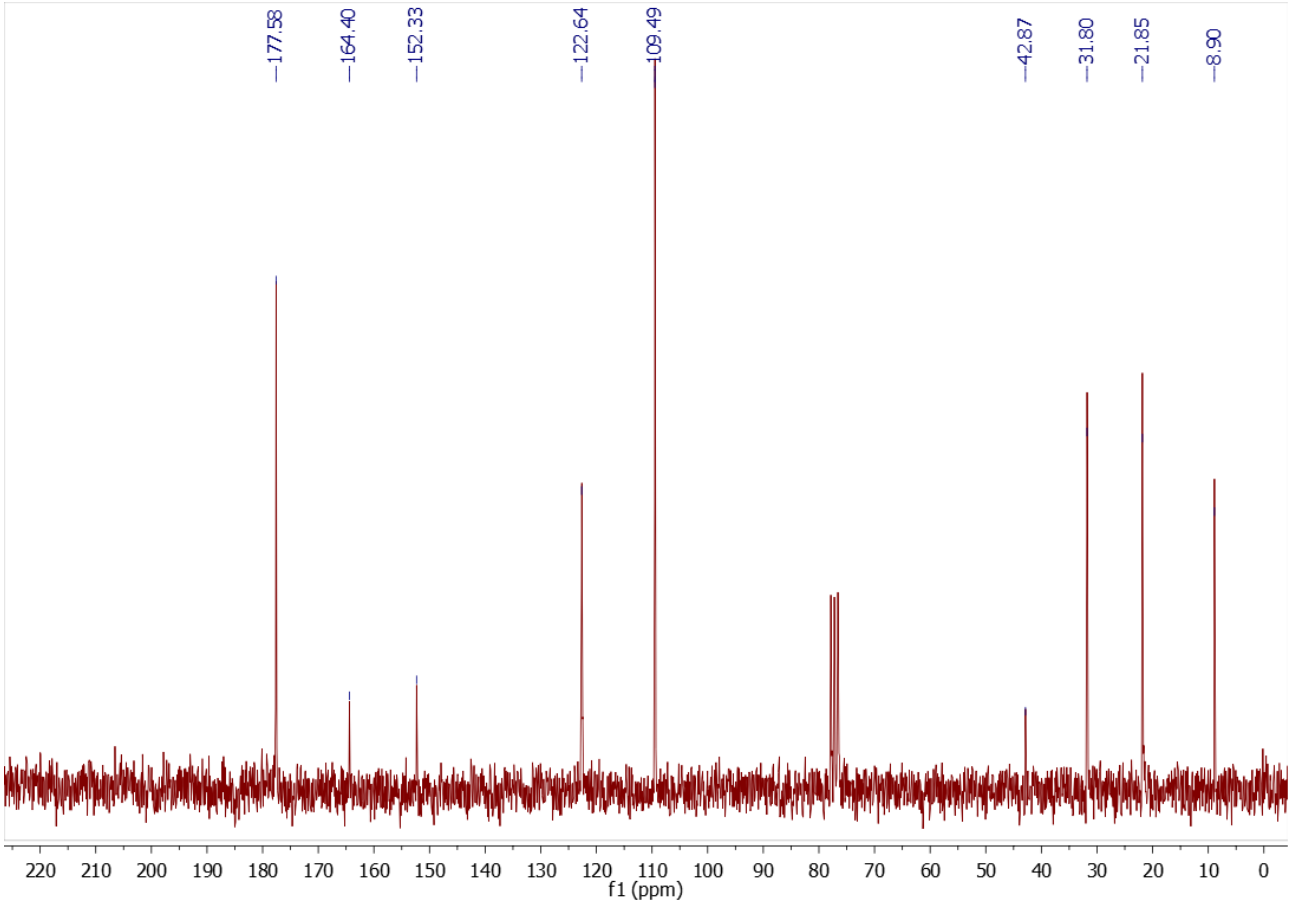

am[2+2] 7
6.07
6.07
5.94
5.94
3.73
3.55
3.53
3.52
2.98
2.76
2.75
2.74
2.04
2.02
2.01
1.99
1.53
0.78
0.77
0.77
0.76
solvent
3.91
3.74
8.00
7.97
4.34
8.16
4.20
6.27
6.35
f1 (ppm)

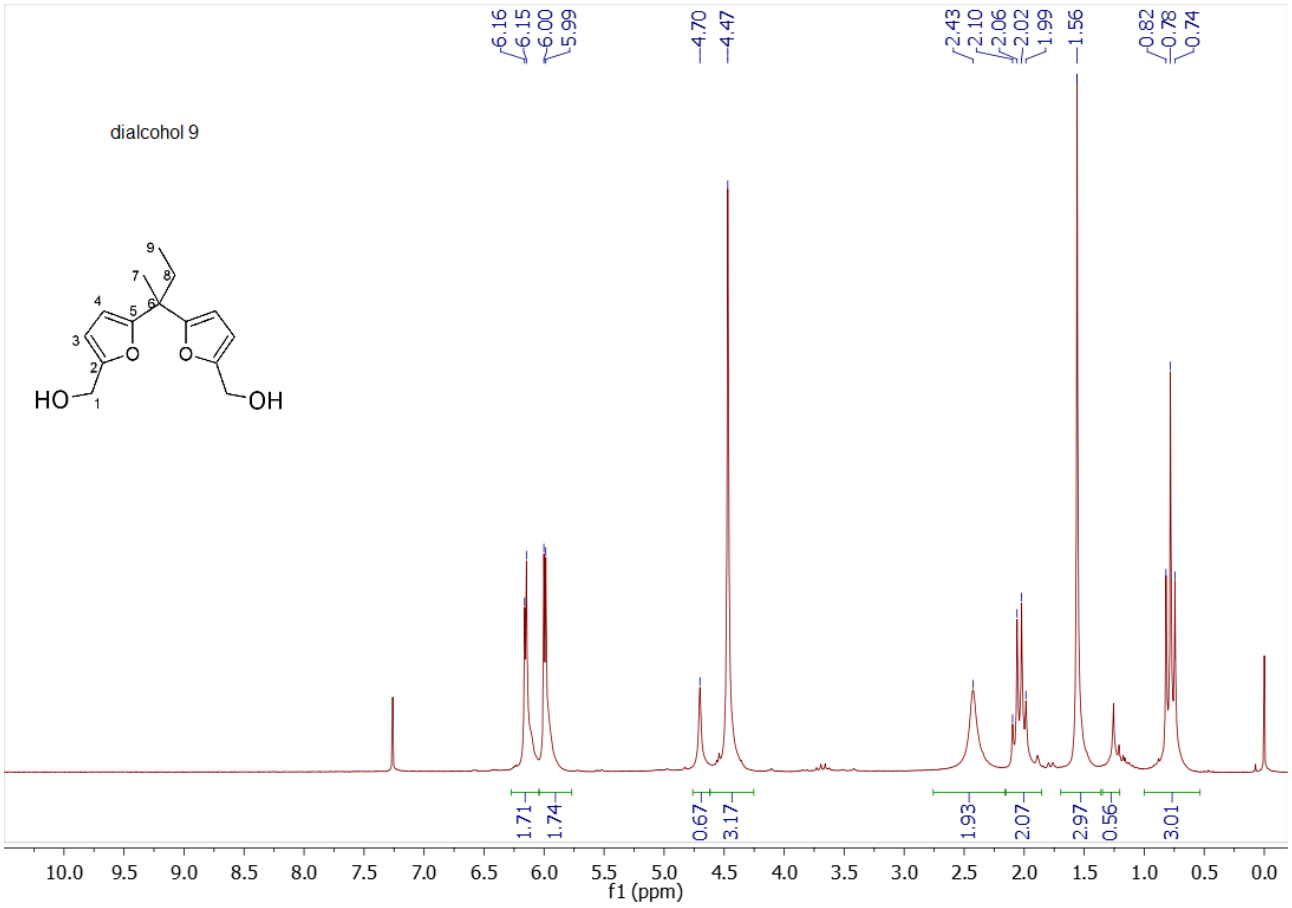

158.76
151.93
107.77
105.63
70.05
48.11
45.95
41.51
31.75
22.37
8.95
solvent
f1 (ppm)

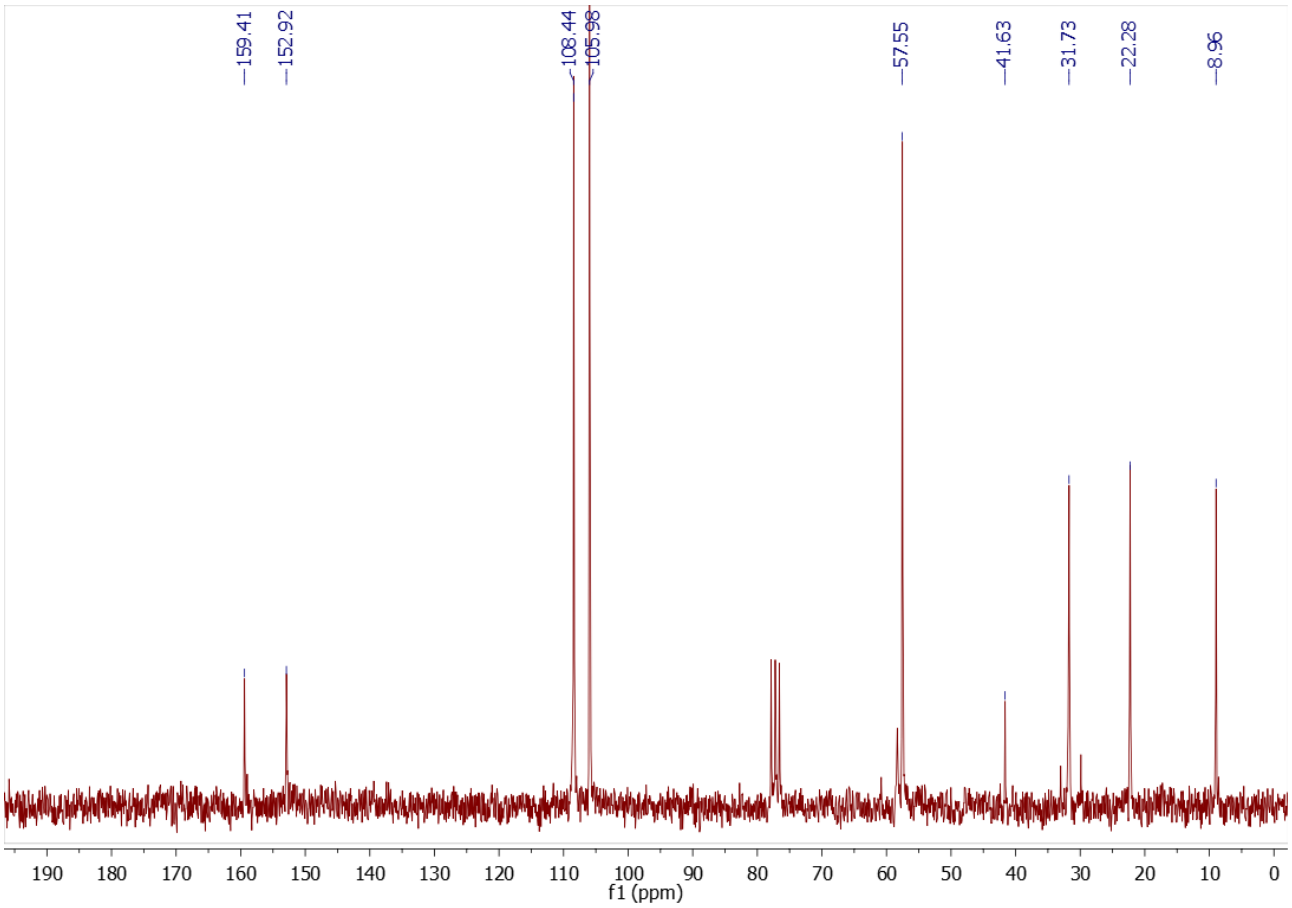

am[3+3] 8
6.06
6.04
5.93
5.91
3.72
3.54
3.51
3.49
2.77
2.74
2.72
2.06
2.03
1.99
1.95
1.53
0.80
0.76
0.72
5.97
5.92
12.00
11.75
11.47
14.96
9.06
9.17
f1 (ppm)


158.69
152.59
107.41
105.74
70.51
48.41
46.37
41.64
31.93
22.55
9.09
f1 (ppm)


9.57
7.21
7.19
6.39
6.37
2.26
2.23
2.19
2.15
1.73
0.88
0.84
0.80
dialdehyde 1
1.75
1.96
2.00
2.35
3.44
3.55
f1 (ppm)


177.58
164.40
152.33
122.64
109.49
42.87
31.80
21.85
8.90
f1 (ppm)


dialcohol 9
HO
OH
6.16
6.15
6.00
5.99
4.70
4.47
2.43
2.10
2.06
2.02
1.99
1.56
0.82
0.78
0.74
1.71
1.74
0.67
3.17
1.93
2.07
2.97
0.56
3.01
f1 (ppm)


159.41
152.92
108.44
105.98
57.55
41.63
31.73
22.28
8.96
f1 (ppm)