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SUPPORTING INFORMATION

for

Cyclic hexapeptoids with *N*-alkyl side chains: solid-state assembly and thermal behaviour

Giovanni Pierri,[a] Rosaria Schettini,[a] Jürgen Nuss,[b] Robert E. Dinnebier,[b] Francesco De Riccardis,[a] Irene Izzo, [a,*] Consiglia Tedesco [a,*]

[a] Department of Chemistry and Biology "A. Zambelli", University of Salerno, Via Giovanni Paolo II 132, 84084 Fisciano (SA), Italy.

[b] Max Planck Institute for Solid State Research, Heisenbergstrasse 1, Stuttgart, D-70569, Germany.

email: iizzo@unisa.it, ctedesco@unisa.it

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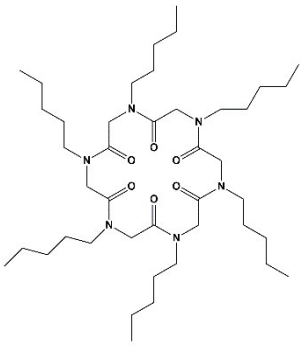
1.0 LIST OF ABBREVIATIONS

DSC: differential scanning calorimetry
DFT: Density Functional Theory

2.0 SYNTHESIS

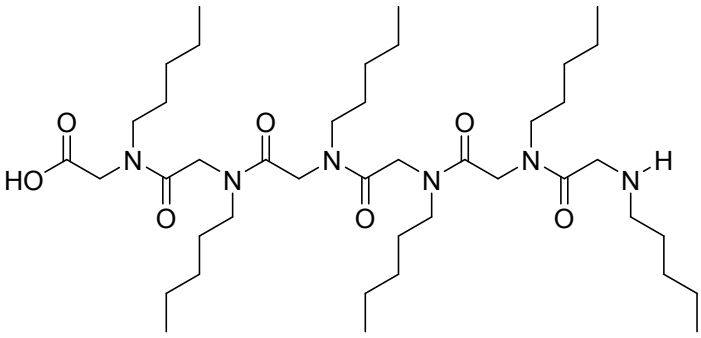
2.1 Synthesis of cyclic peptoid **1**



1

Figure S1. Cyclic peptoid **1,** cyclo-[Namy$_6$], Namy = *N*-(pentyl)glycine.

2.2 HPLC chromatogram of linear precursor of cyclic peptoid **1**.



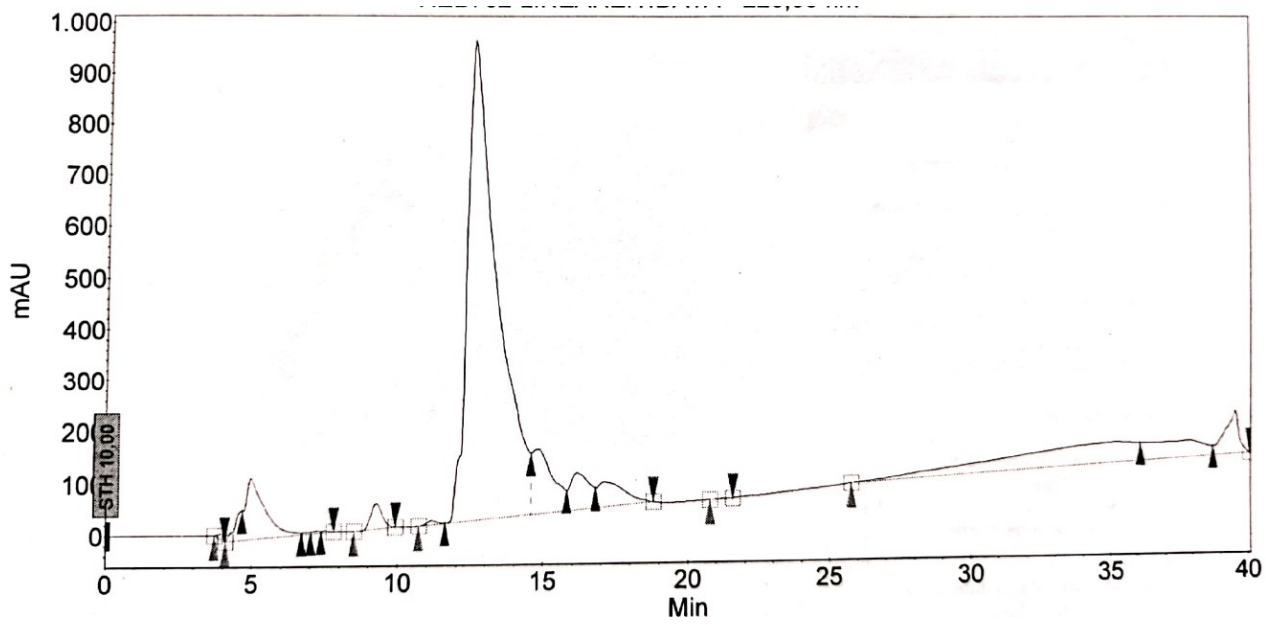


Figure S2. Linear precursor of **1**: white amorphous solid, 0.226 g, 100% yield; t_R: 12.5 min.

2.3 ^{1}H-, ^{13}C NMR of cyclic peptoid **1**

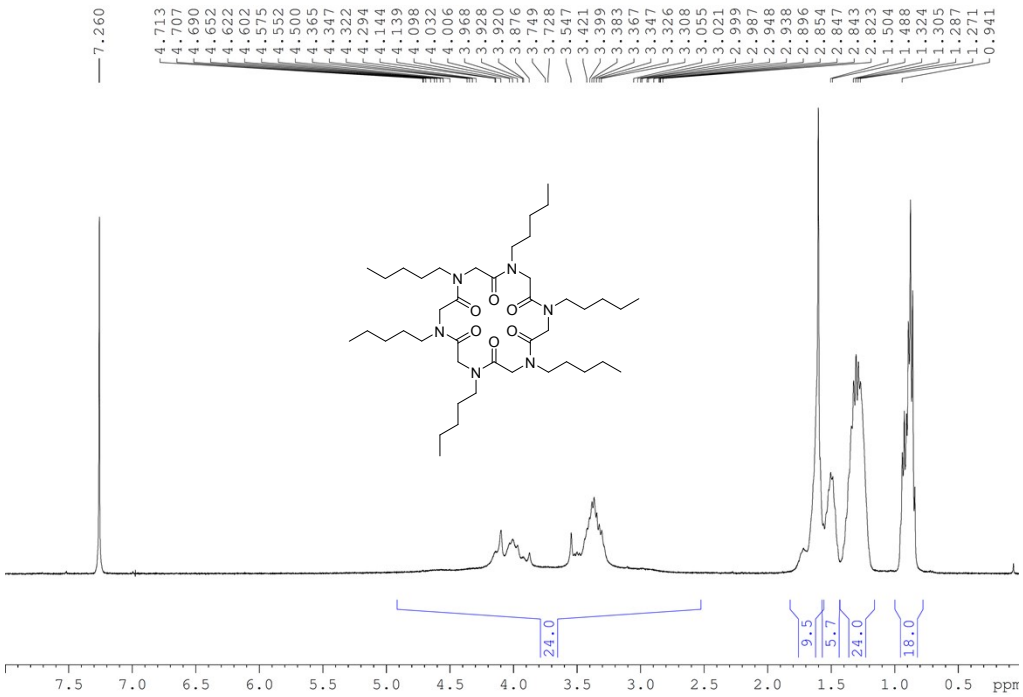


Figure S3. ^{1}H NMR (400 MHz, $CDCl_3$) of cyclic peptoid **1**.

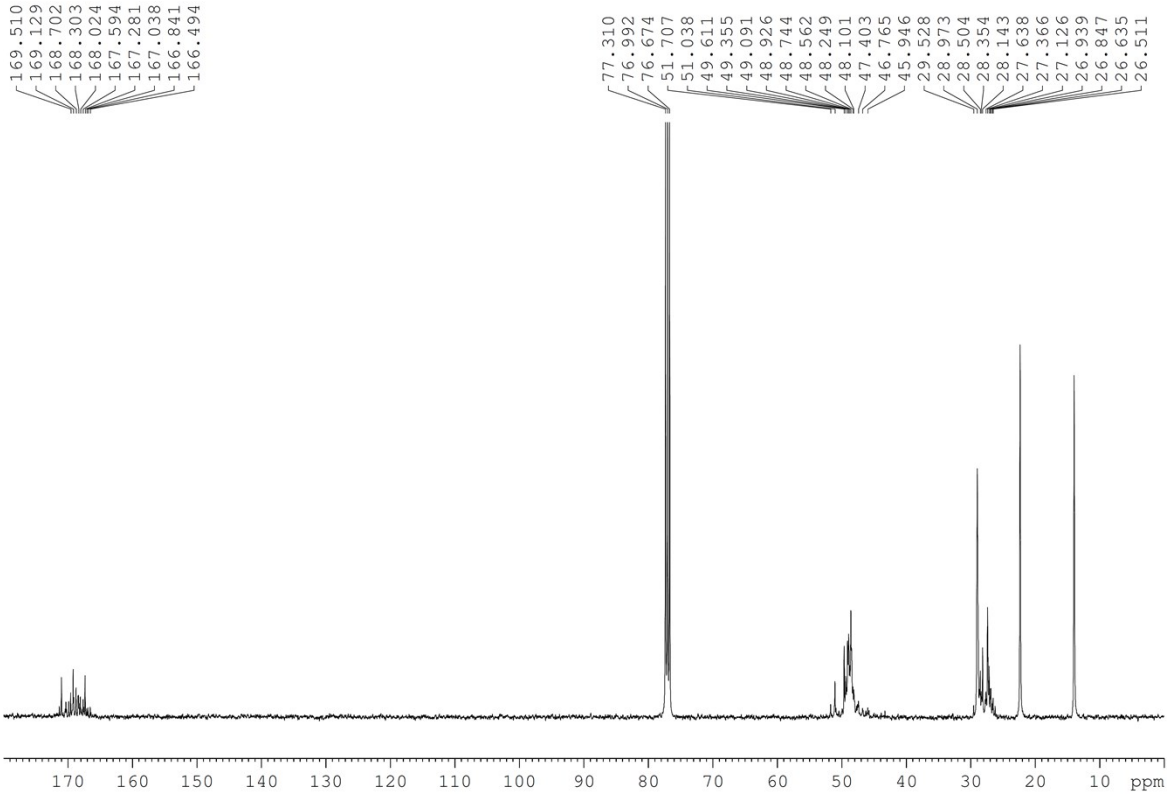


Figure S4. ^{13}C NMR (100 MHz, $CDCl_3$) of cyclic peptoid **1**.

3.0 X-RAY CRYSTALLOGRAPHY

3.1 Torsion angles for compounds **1** and **2**

Table S1. Backbone and side chains torsion angles (°) for $\mathbf{1_{RT}}$, $\mathbf{1_{LT}}$, $\mathbf{2_{LT}}$.

Crystal form	*residue*	ω_i ( )	φ_i ( )	ψ_i ( )	$\chi_{1,i}$ ( )	$\chi_{2,i}$ ( )	$\chi_{3,i}$ ( )	$\chi_{4,i}$ ( )	$\chi_{5,i}$ ( )
$\mathbf{1_{RT}}$	*c*	10.2(2)	-74.2(2)	168.3(2)	-91.5(9)	-2(3)	-165(2)	91(3)	-
	c	-1.6(2)	-72.7(2)	164.4(2)	100.1(3)	-74.2(4)	-175.0(6)	175.0(8)	-
	t	-171.7(1)	-73.9(2)	135.4(2)	-105.4(2)	-173.3(2)	-178.6(2)	178.1(3)	-
$\mathbf{1_{LT}}$	*c*	9.3(3)	-74.7(2)	169.1(2)	-115.1(2)	56.4(3)	169.3(3)	64(1)	-
	c	-2.5(3)	-71.3(2)	167.9(1)	104.0(2)	-71.1(2)	-176.6(2)	-177.2(2)	-
	t	-172.1(2)	-75.2(2)	133.4(2)	-107.6(2)	-174.8(2)	-178.6(2)	-179.6(2)	-
	c	-6.8(3)	73.1(2)	-167.6(2)	78.1(2)	66.2(3)	69.8(3)	171.5(3)	-
	c	2.7(3)	72.5(2)	-165.8(2)	-100.7(2)	74.2(2)	179.8(2)	-173.0(2)	-
	t	169.1(2)	77.6(2)	-136.6(2)	104.0(2)	171.6(2)	178.0(2)	-177.9(2)	-
$\mathbf{2_{LT}}$	*c*	9.5(5)	-70.5(4)	168.3(3)	-104.2(4)	59.1(5)	-179.6(4)	66.1(5)	179.9(4)
	c	-3.9(5)	-69.7(4)	162.3(3)	80.7(4)	-176.0(3)	-69.9(5)	-174.6(4)	177.1(4)
	t	-174.0(3)	-71.3(4)	134.4(3)	-103.8(4)	-171.9(3)	-179.1(3)	173.7(3)	-179.4(3)

[a] For centrosymmetric molecules the torsion angles of opposite side chains have identical values but opposite signs.
[b] For disordered side chains only the atomic positions with the highest occupancy factors were considered.

3.2 ORTEP drawings for compounds **1** and **2**

ORTEP drawings for compounds 1 and 2 were performed using the software OLEX2.[1]

In the following pages the ORTEP diagrams for

- cyclo-[Namy$_6$] measured at 100 K ($\mathbf{1_{LT}}$)
- cyclo-[Namy$_6$] measured at 296 K ($\mathbf{1_{RT}}$)
- cyclo-[Nhex$_6$] measured at 100 K ($\mathbf{2_{LT}}$)
- cyclo-[Nhex$_6$] measured at 296 K ($\mathbf{2_{RT}}$)
- cyclo-[Nhex$_6$] measured at 360 K ($\mathbf{2_{HT}}$)

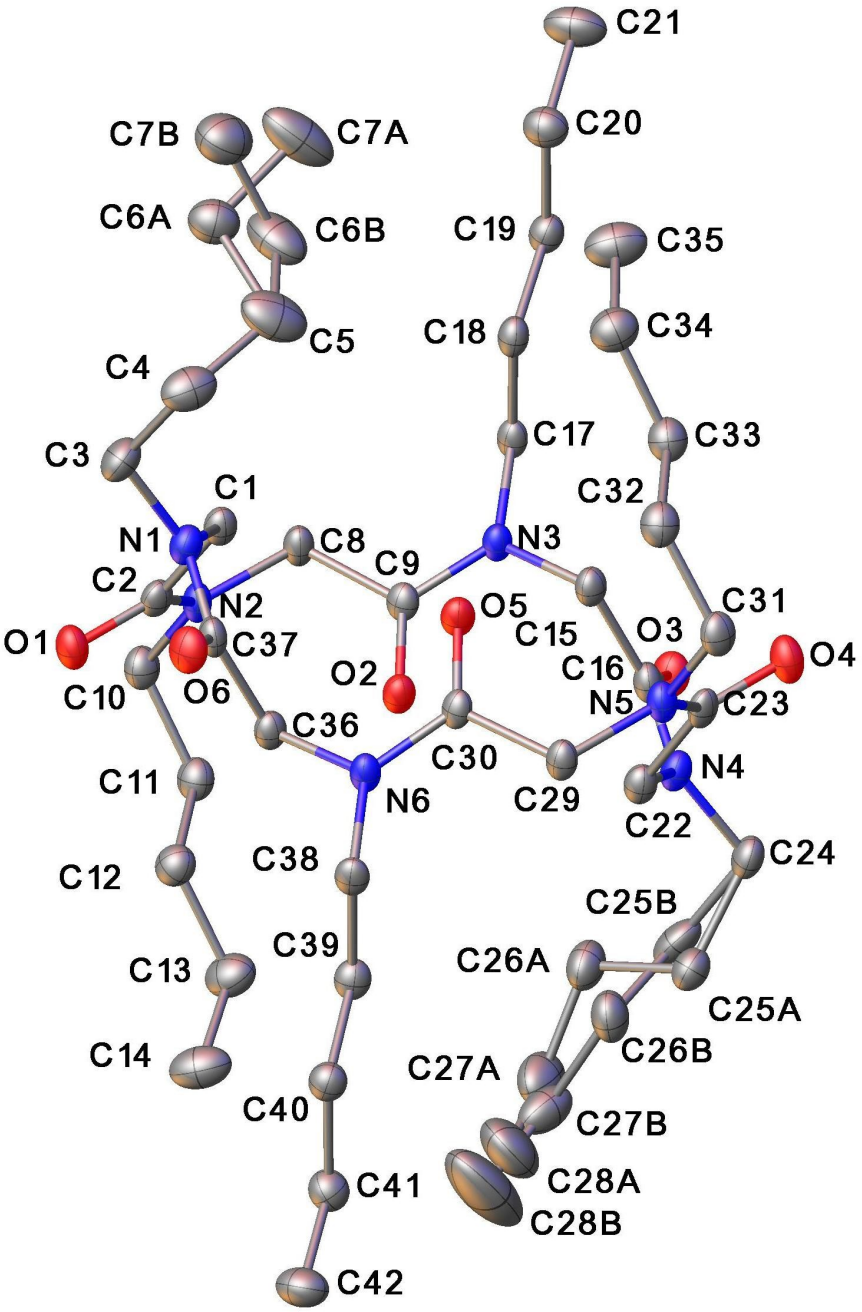


Figure S5. ORTEP diagram for cyclo-[Namy$_6$] measured at 100 K (**1**$_{LT}$), Namy = *N*-(pentyl)glycine. Ellipsoids are drawn at 50% probability level. For clarity hydrogen atoms were omitted.

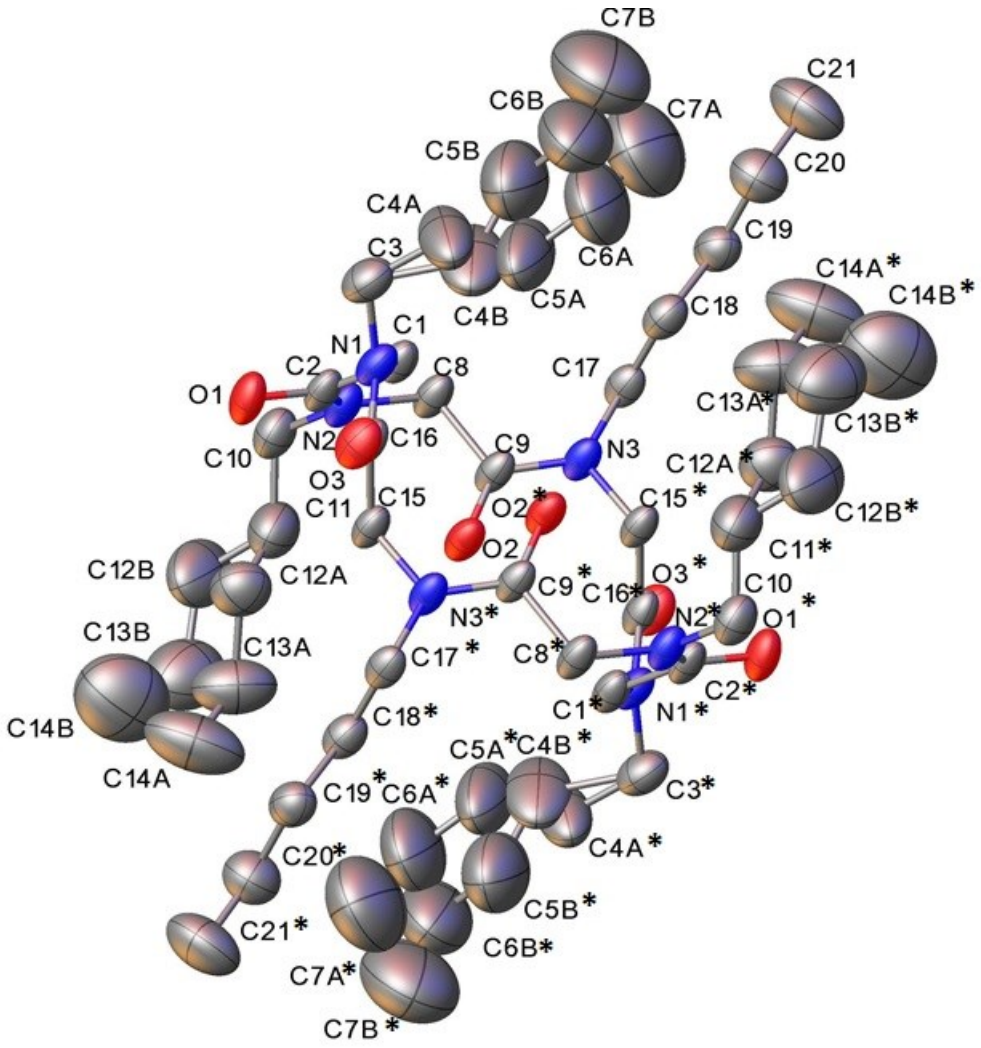


Figure S6. ORTEP diagram for cyclo-[Namy$_6$] measured at 296 K (**1$_{RT}$**), Namy = *N*-(pentyl)glycine. Ellipsoids are drawn at 30% probability level. For clarity hydrogen atoms were omitted. Symmetry equivalent atoms are labeled with an asterisk (*, symmetry op.: 1-*x*, 1- *y*, 1-*z*).

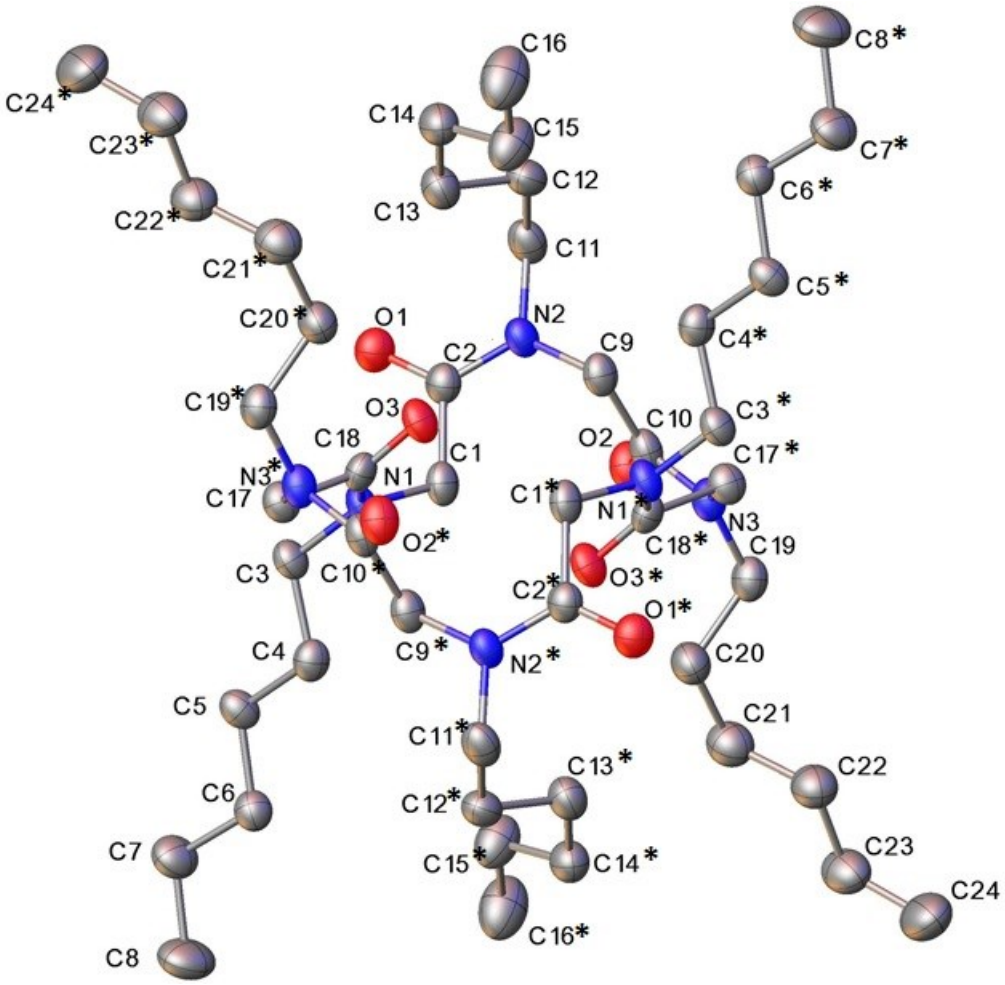


Figure S7. ORTEP diagram for cyclo-[Nhex$_6$] measured at 100 K (**2$_{LT}$**), Nhex = *N*-(hexyl)glycine. Ellipsoids are drawn at 50% probability level. For clarity hydrogen atoms were omitted. Symmetry equivalent atoms are labeled with an asterisk (*, symmetry op.: 1-*x*, - *y*, -*z*).

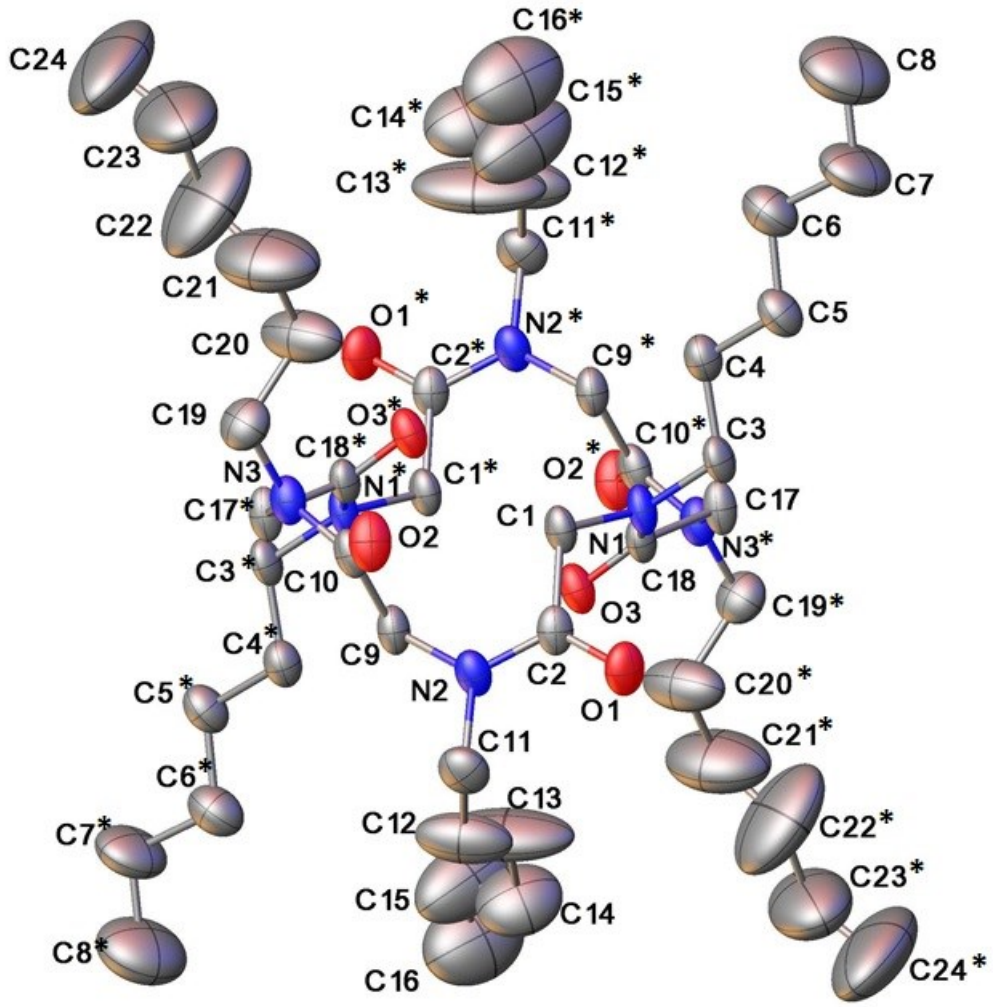


Figure S8. ORTEP diagram for cyclo-[Nhex$_6$] measured at 296 K (**2$_{RT}$**), Nhex = *N*-(hexyl)glycine. Ellipsoids are drawn at 30% probability level. For clarity hydrogen atoms were omitted. Symmetry equivalent atoms are labeled with an asterisk (*, symmetry op.: 2-*x*, - *y*, 1-*z*).

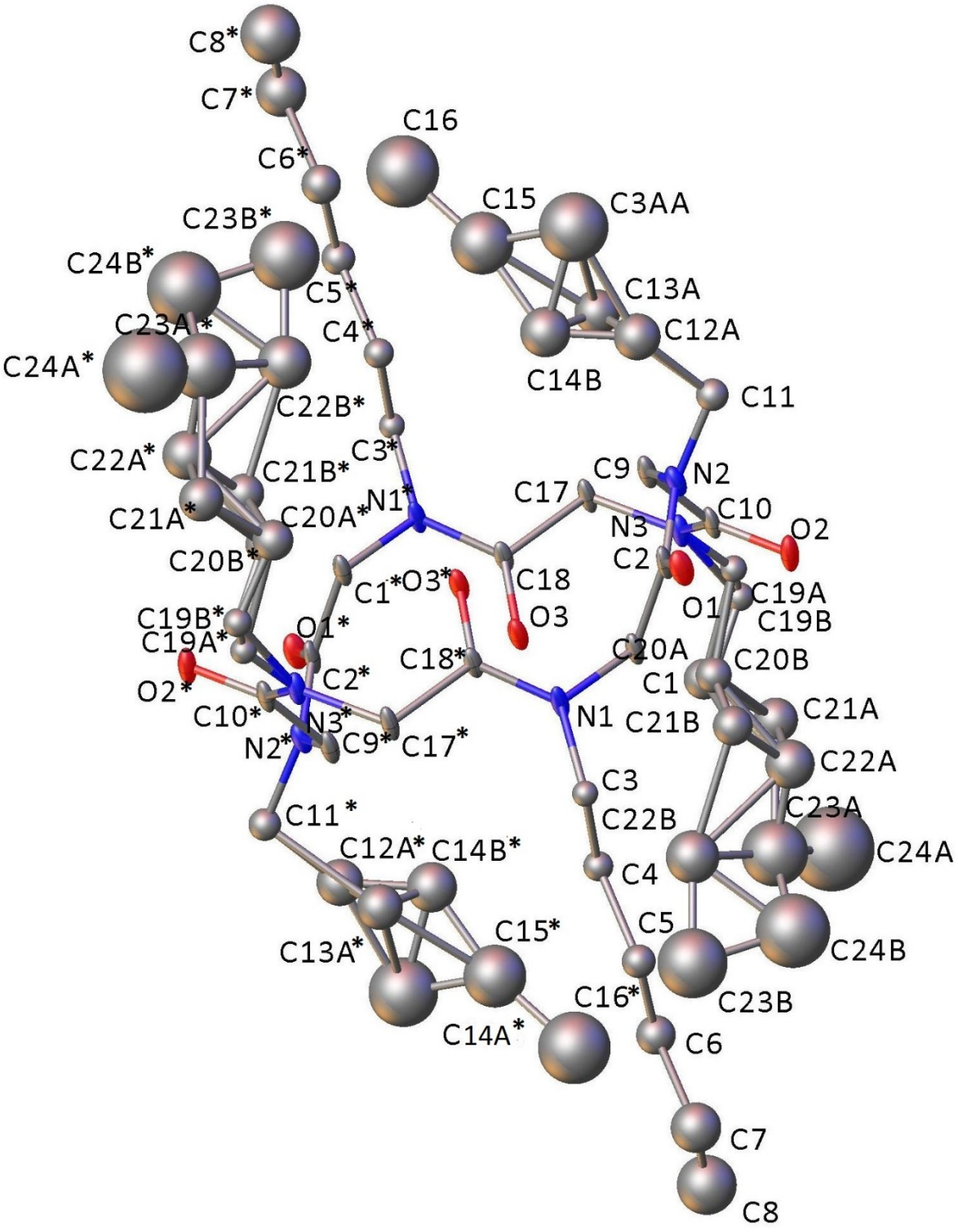


Figure S9. ORTEP diagram for cyclo-[Nhex$_6$] measured at 360 K (**2$_{HT}$**), Nhex = *N*-(hexyl)glycine. Ellipsoids are drawn at 10% probability level. For clarity hydrogen atoms were omitted. Symmetry equivalent atoms are labeled with an asterisk (*, symmetry op.: 1-*x*, - *y*, 1-*z*).

4.0 Gas phase molecular structure optimization

4.1 Gas phase energy optimization

Gas phase energy optimization procedures were performed with Gaussian16,[2] using a 6-311G(d,p) basis set and B3LYP density functional including a the D3 empirical dispersion correction.[3] DFT calculations started from the X-ray molecular structure models of **1** and **2** as obtained at 100 K (for **1** only one possible site was considered for disordered atoms). DFT calculations.

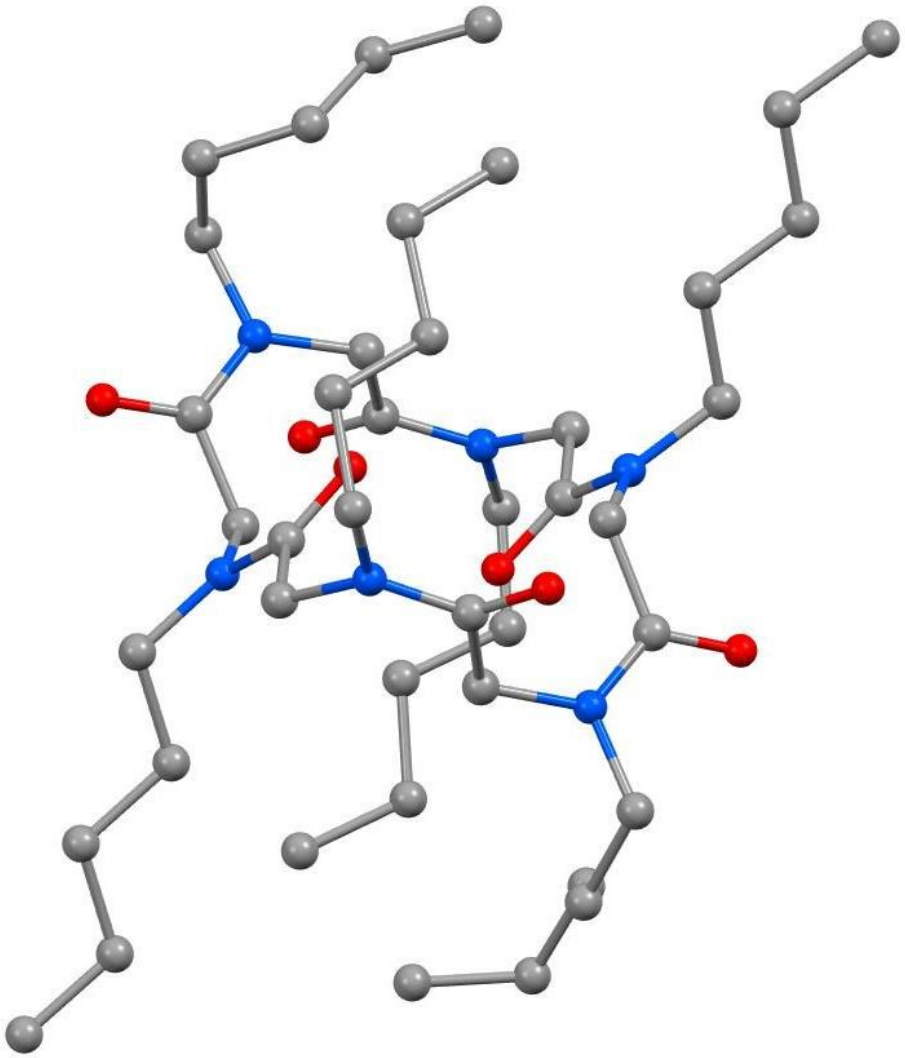


Figure S10. Minimum energy structures of cyclo-[Namy$_6$] **1**. Hydrogen atoms were omitted for clarity. Atom types: C light grey, N blue, O red.

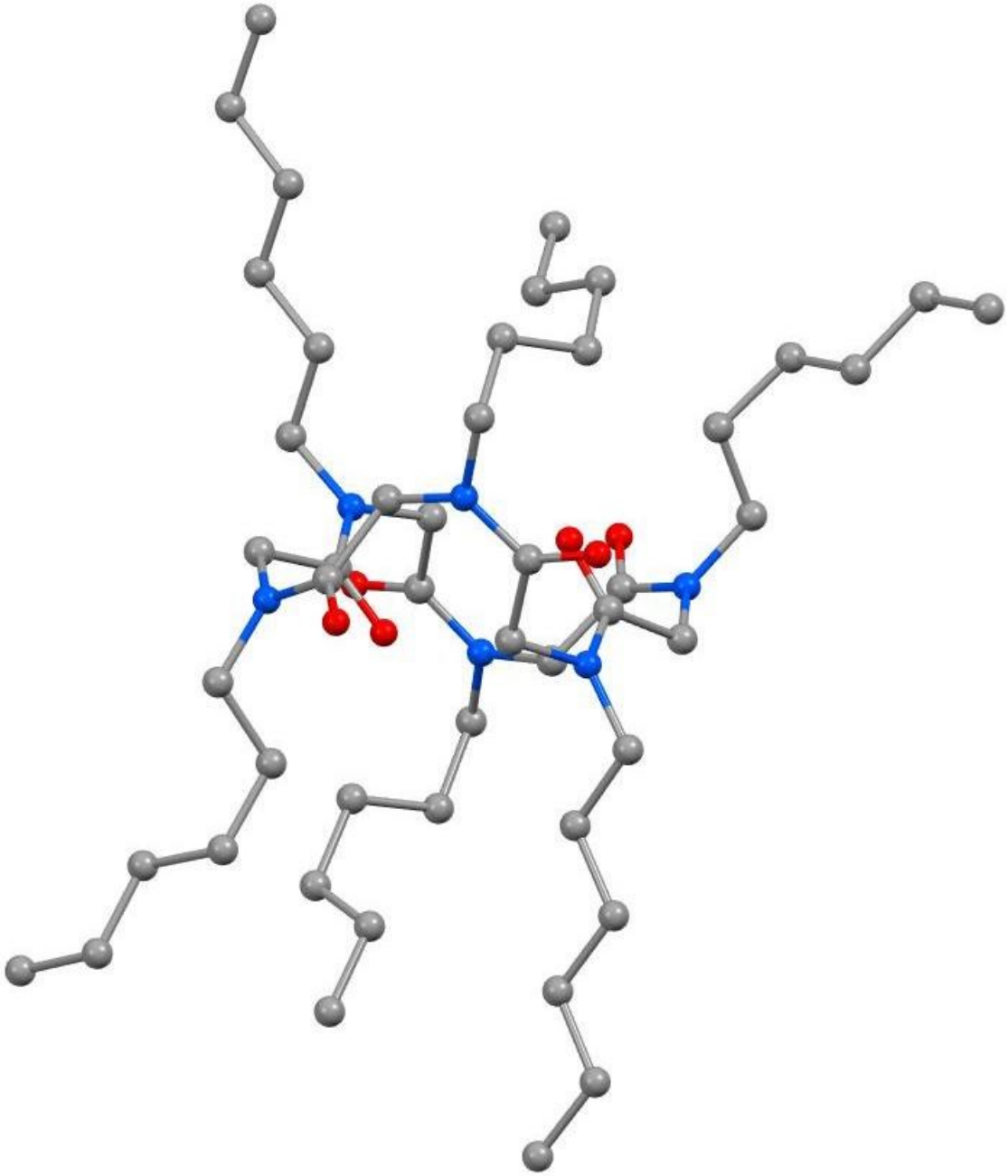


Figure S11. Minimum energy structures of cyclo-[Nhex6] **2**. Hydrogen atoms were omitted for clarity. Atom types: C light grey, N blue, O red.

4.2 Atomic coordinates for $\mathbf{1}_{LT}$

C	-1.458379	-2.347712	-0.843501
C	-0.606115	-2.640501	-2.097500
C	-2.113571	-4.398332	0.470032
C	-3.149605	-4.101107	1.562831
C	-4.093752	-2.929725	1.260447
C	-5.061617	-3.184626	0.097443
C	-5.965774	-1.987843	-0.205902
C	-1.351742	-0.447965	-2.974113
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C	3.855783	-1.069732	-3.393711
C	4.917071	-1.749739	-2.525772
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C	-6.455029	1.952800	-1.351008
C	-7.708759	2.540566	-2.003132
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C	2.248436	4.443174	-0.137840
C	3.638963	3.927613	-0.528941
C	3.633379	3.035879	-1.775225
C	5.020747	2.491904	-2.145854
C	5.598903	1.523028	-1.107460
C	1.249606	0.523340	3.225851
C	0.691025	-0.435858	2.149393
C	-0.387162	1.935851	4.486183
C	-1.616602	1.022436	4.471614
C	-2.625138	1.345793	3.367082
C	-3.815028	0.382332	3.365722
C	-4.804693	0.664678	2.234457
C	1.022809	-2.218255	0.592882
C	-0.072605	-3.206818	1.006505
C	2.767315	-1.819857	2.355756
C	3.972362	-1.259418	1.594484
C	5.312656	-1.729943	2.162332
C	6.516556	-1.178401	1.390882
C	7.856705	-1.657259	1.953823
N	-1.192188	-3.282203	0.232745

N	-0.666314	-1.718894	-3.109622
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N	1.268061	3.371551	0.052938
N	0.502055	1.763342	3.327864
N	1.493770	-1.442386	1.740187
O	0.064510	-3.657028	-2.162966
O	0.424756	0.264799	-1.496446
O	0.080791	3.949155	-1.809943
O	-0.216524	3.690300	2.343088
O	-0.417805	-0.246905	1.655168
O	0.110993	-3.924021	1.981130
H	-2.511871	-2.427109	-1.118350
H	-1.308690	-1.332255	-0.477964
H	-2.586110	-4.645873	-0.483062
H	-1.513685	-5.258037	0.770160
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H	5.715153	3.327776	-2.295498
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H	4.898015	0.709056	-0.903149
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H	2.306439	0.724545	3.034009
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H	8.696773	-1.250036	1.385053
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4.3 Atomic coordinates for $\mathbf{2_{LT}}$

O	0.440705	-1.963098	-3.853960
N	-0.595054	-2.224091	-1.225887
C	-0.913616	-1.097092	-2.105102
C	0.148995	-0.967819	-3.202574
C	-1.272266	-3.500129	-1.476162
C	-2.672581	-3.541865	-0.861742
C	-3.430398	-4.834594	-1.168060
C	-4.831839	-4.857708	-0.549524
C	-5.615138	-6.138135	-0.853837
C	-7.014091	-6.142001	-0.231671
O	-1.692602	1.563670	-3.594139
N	0.719566	0.253929	-3.398036
C	0.461373	1.382422	-2.525608
C	-0.956637	1.963983	-2.708213
C	1.734447	0.408876	-4.442272
C	3.160171	0.469175	-3.874158
C	3.516992	-0.748151	-3.011359
C	4.962551	-0.743619	-2.497260
C	5.263500	0.340493	-1.454776
C	6.706479	0.286424	-0.947757
O	1.032263	-0.983529	-0.262337
N	-1.322747	2.951476	-1.832868
C	0.583049	-3.125520	0.754705
C	0.373309	-2.020453	-0.305481
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C	-3.753162	2.567114	-1.297704
C	-5.144913	3.212383	-1.274270
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C	-6.723715	4.879679	-0.139152
C	-6.884110	5.947166	0.946604
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N	0.392973	2.235202	1.388321
C	0.494882	1.071552	2.266350
C	-0.741346	0.954041	3.167174
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C	5.186982	3.559027	0.627653
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O	1.220602	-1.385558	3.838336
N	-1.269932	-0.294313	3.345976
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C	-3.742571	-0.630999	3.346118
C	-4.053881	0.567400	2.438970
C	-5.133593	0.286051	1.383958
C	-4.661646	-0.656201	0.268040
C	-5.698907	-0.841778	-0.841742
O	-1.294641	1.200142	0.306214
N	1.247841	-2.652903	1.955794

C	-0.528123	3.274407	-0.663640
C	-0.518092	2.149017	0.395210
C	2.692806	-2.878564	2.118792
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C	5.696783	-3.021894	1.039281
C	7.200601	-3.164647	1.294230
C	7.855403	-4.238432	0.421518
H	-1.053621	-0.218397	-1.485072
H	-1.859295	-1.302183	-2.606312
H	-0.660080	-4.322626	-1.102612
H	-1.310491	-3.626254	-2.560488
H	-3.244289	-2.684773	-1.228966
H	-2.593604	-3.403968	0.223190
H	-2.856041	-5.695846	-0.802336
H	-3.509434	-4.960089	-2.255138
H	-5.399692	-3.991121	-0.909583
H	-4.749542	-4.733572	0.538258
H	-5.048050	-7.003934	-0.490736
H	-5.695797	-6.260530	-1.940631
H	-7.610913	-5.303073	-0.602931
H	-7.554048	-7.063885	-0.463486
H	-6.960121	-6.051831	0.857871
H	1.183716	2.166871	-2.763742
H	0.644308	1.090313	-1.490592
H	1.504299	1.314478	-5.012807
H	1.632247	-0.446059	-5.108983
H	3.285339	1.389799	-3.292013
H	3.856830	0.547040	-4.717840
H	3.335712	-1.654993	-3.597018
H	2.831886	-0.798530	-2.158151
H	5.655736	-0.635208	-3.342188
H	5.181448	-1.721809	-2.052790
H	4.568935	0.229337	-0.613796
H	5.069462	1.331191	-1.879489
H	7.416093	0.445520	-1.765807
H	6.897292	1.050475	-0.190190
H	6.928586	-0.688449	-0.505024
H	1.197117	-3.915284	0.316284
H	-0.372979	-3.586251	1.011738
H	-2.917131	3.614330	-2.987664
H	-2.690974	4.464262	-1.458743
H	-3.445970	2.296586	-0.285203
H	-3.773074	1.639655	-1.874380
H	-5.894566	2.433205	-1.100532
H	-5.377110	3.635232	-2.260576
H	-4.594363	5.106278	-0.362776
H	-5.057602	3.859647	0.779546
H	-7.441503	4.068670	0.034065
H	-6.977653	5.307023	-1.116860
H	-6.200604	6.785524	0.777991
H	-7.901592	6.346882	0.970566
H	-6.663225	5.536027	1.936606
H	1.350458	1.198738	2.928644
H	0.685581	0.205300	1.641770
H	1.474179	3.497916	2.618503
H	1.012821	4.222324	1.102037
H	2.623476	2.717785	-0.120445
H	3.069667	1.967438	1.392755

H	3.904408	4.198094	2.242366
H	3.509863	4.921015	0.692755
H	5.097832	3.324791	-0.440249
H	5.490739	2.624010	1.114535
H	6.366657	4.848810	1.892101
H	5.979820	5.542588	0.328920
H	7.588762	3.935760	-0.781719
H	8.405049	4.931500	0.429602
H	7.985432	3.255061	0.797088
H	-0.993479	-1.250467	1.509480
H	-1.456179	-2.294131	2.840791
H	-2.537400	0.445327	4.796567
H	-2.310794	-1.307967	4.841926
H	-4.579755	-0.811071	4.031078
H	-3.647623	-1.541410	2.743167
H	-3.142960	0.877727	1.921218
H	-4.351997	1.414133	3.066001
H	-5.439849	1.236008	0.932439
H	-6.032583	-0.128585	1.859691
H	-4.414579	-1.634821	0.691846
H	-3.730771	-0.261249	-0.153432
H	-5.934997	0.111300	-1.323245
H	-5.340588	-1.521189	-1.620771
H	-6.632517	-1.254207	-0.445808
H	-0.941312	4.176883	-0.208287
H	0.495695	3.519475	-0.955771
H	2.937987	-3.810846	1.605723
H	2.884263	-3.021747	3.183614
H	3.199901	-0.807666	2.101958
H	3.354857	-1.569489	0.532963
H	5.210075	-2.089359	2.929186
H	5.559712	-0.961803	1.634436
H	5.525869	-2.826782	-0.026952
H	5.212329	-3.982323	1.253283
H	7.364852	-3.397178	2.353256
H	7.690562	-2.199799	1.117480
H	7.736338	-4.005131	-0.641292
H	8.925947	-4.325376	0.625936
H	7.401777	-5.219131	0.596956

5.0 VT-XRPD

5.1 VT-XRPD of compound **1**

X-ray powder diffraction experiment was performed at Max Planck Institute for Solid State Research using a Stadi P-Diffraktometer (Stoe), Cu$K\alpha_1$ radiation from a primary Ge(111)-Johann-type monochromator and three Mythen 1 K detectors (Dectris). The temperature was controlled by an Oxford Cryostream 500.
For the VT-XRPD analysis on compound **1**, the powder sample was loaded on a 0.7 mm diameter thin-walled glass capillary and heated up with a rate of 5 K/min from 293 K to 413 K increasing the temperature in steps of 20 K and then it was cooled down again to 293 K reducing the temperature in steps of 20 K. At each temperature, a powder diffraction pattern was collected after a delay time of 10 minutes in order to guarantee the thermal equilibration of the sample. Data were collected in a 2θ range from 2.0° to 115.0° measuring the sample for a total scan time of 2 hours.
For clarity, in Figure S12 are reported the powder pattern collected at every 40 K.

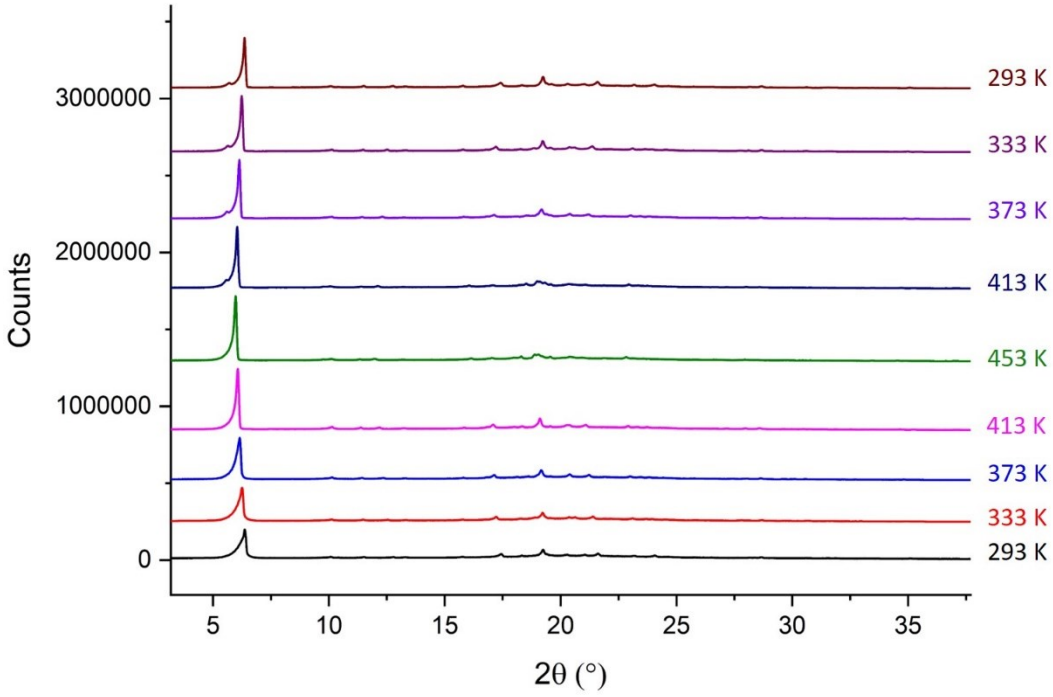

Figure S12. VT-XRPD patterns for compound **1**.

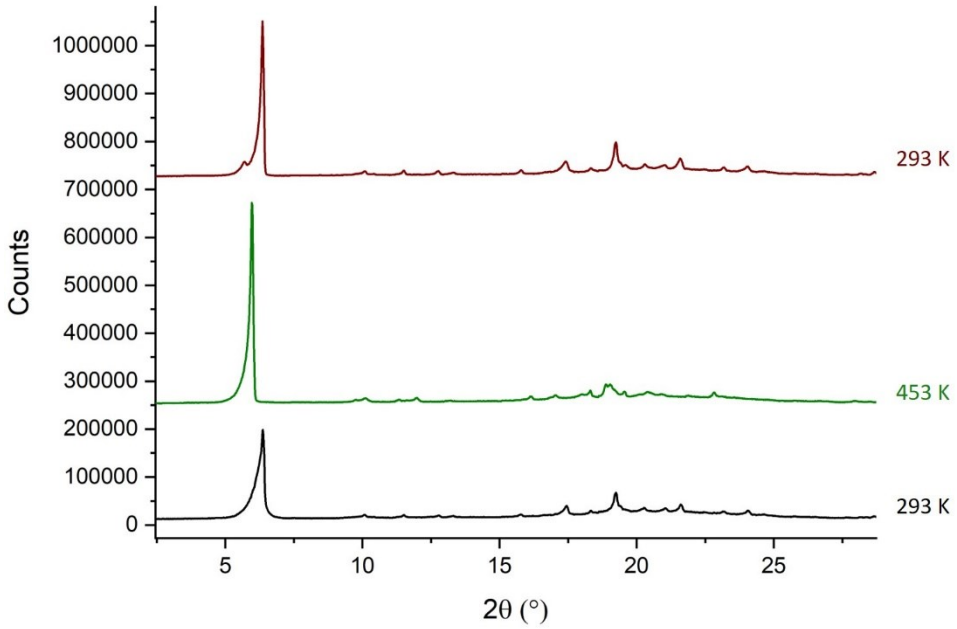

Figure S13. Comparison between the powder pattern obtained at 293 K, 453 K and back to 293 K for compound **1.**

5.2 VT-XRPD of compound **2**

To evaluate the lattice parameters variation with temperature a Pawley refinement was performed for each XRPD pattern using TOPAS V6.[6] The obtained cell parameters are reported in Figure S14.

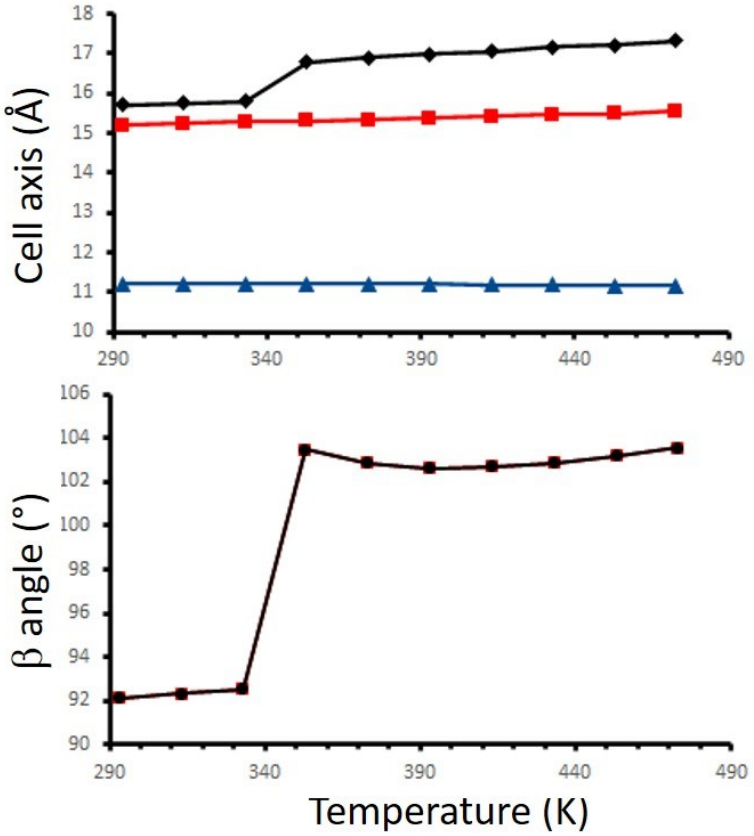

Figure S14. Lattice parameters variation vs temperature. Top: *a* axis (rhombuses), *b* axis (squares), *c* axis (triangles). Bottom: β axis (squares). Lines The lines are guide for the eye.

6.0 REFERENCES

1 O. V. Dolomanov, L. J. Bourhis, R. J. Gildea, J. A. K. Howard and H. J. Puschmann, *J. Appl. Cryst.*, 2009, **42**, 339–341.

2 Gaussian 16, Revision C.01, M. J. Frisch, G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, G. Scalmani, V. Barone, G. A. Petersson, H. Nakatsuji, X. Li, M. Caricato, A. V. Marenich, J. Bloino, B. G. Janesko, R. Gomperts, B. Mennucci, H. P. Hratchian, J. V. Ortiz, A. F. Izmaylov, J. L. Sonnenberg, D. Williams-Young, F. Ding, F. Lipparini, F. Egidi, J. Goings, B. Peng, A. Petrone, T. Henderson, D. Ranasinghe, V. G. Zakrzewski, J. Gao, N. Rega, G. Zheng, W. Liang, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, T. Vreven, K. Throssell, J. A. Montgomery, Jr., J. E. Peralta, F. Ogliaro, M. J. Bearpark, J. J. Heyd, E. N. Brothers, K. N. Kudin, V. N. Staroverov, T. A. Keith, R. Kobayashi, J. Normand, K. Raghavachari, A. P. Rendell, J. C. Burant, S. S. Iyengar, J. Tomasi, M. Cossi, J. M. Millam, M. Klene, C. Adamo, R. Cammi, J. W. Ochterski, R. L. Martin, K. Morokuma, O. Farkas, J. B. Foresman, and D. J. Fox, Gaussian, Inc., Wallingford CT, 2016.

3 S. Grimme, J. Antony, S. Ehrlich, H. Krieg, *J. Chem. Phys.* **2010**, 132, 154104.

4 Topas (version 6.0), general profile and structure analysis software for powder diffraction data, Bruker AXS, Karlsruhe (Germany), **2017**.