

Supporting information:

Vibrational circular dichroism and ab initio structure elucidation of a foldamer†

Thierry Buffeteau,^a Laurent Ducasse,^a Legiso,^b Nicolas Delsuc,^b and Ivan Huc*^b

^a Laboratoire de Physico-Chimie Moléculaire, Université Bordeaux I, 351 Cours de la Libération, 33405 Talence, France

^b Institut Européen de Chimie et Biologie, 2 Rue Robert Escarpit, 33607 Pessac Cedex, France. E-mail: i.huc@iecb.u-bordeaux.fr

Experimental Methods

VCD Measurements. VCD spectra were recorded with a ThermoNicolet Nexus 670 FTIR spectrometer equipped with a VCD optical bench.¹ In this optical bench, the light beam was focused by a BaF₂ lens (191 mm focal length) to the sample, passing an optical filter (depending on the studied spectral range), a BaF₂ wire grid polarizer (Specac), and a ZnSe photoelastic modulator (Hinds Instruments, Type II/ZS50). The light was then focused by a ZnSe lens (38.1 mm focal length) onto a 1x1 mm² HgCdTe (ThermoNicolet, MCTA* E6032) detector. VCD spectra were recorded at a resolution of 4 cm⁻¹, by co-adding 60000 scans (20h acquisition time). The sample was held in a variable path length cell with CaF₂ windows. Spectra of tetramer **1** were measured in CDCl₃ at a concentration of 0.009 M and at a path length of 250 μ m (1 mm in the NH stretching region). Baseline corrections of the VCD spectra were performed by subtracting the raw VCD spectra of the solvent. In all experiments, the photoelastic modulator was adjusted for a maximum efficiency at 1600 cm⁻¹ (3000 cm⁻¹ for experiments in the NH stretching region). Calculations were done with the standard ThermoNicolet software, using Happ and Genzel apodization, de-Haseth phase-correction and a zero-filling factor of one. Calibration spectra were recorded using a birefringent plate (CdSe) and a second

BaF₂ wire grid polarizer, following the experimental procedure previously published.²

Theoretical Calculations. Calculations of the optimized geometry of P2, M2 and M3 conformers for the tetrameric oligomer **1** (these three conformers have all been observed in the solid state for the corresponding octamer) were performed at the density functional theory level (B3LYP functional and 6-31G* basis set) with Gaussian 03 program³ on either an IBM P690 or on four processors on a SGI Altix3300. The starting geometries of P2 and M2 conformers were build from the crystal structures found for the corresponding conformers of the octameric compound. To minimize the computational time, the OiBu groups were replaced by OMe groups prior to calculations. Calculating the optimized geometry of this “minimal” tetramer (C₅₂H₄₁O₁₀N₉, 112 atoms) requires 1147 basis functions and 2152 primitives Gaussian. Vibrational frequencies and IR and VCD intensities were calculated at the same level with Gaussian 03 (800 h cpu time for M3, 1002 h cpu time for M2), utilizing the magnetic field perturbation method with gauge-invariant atomic orbitals.⁴ For comparison to experiment, the calculated frequencies were scaled by 0.968 (0.94) and the calculated intensities were converted to Lorentzian bands with half-width of 7 cm⁻¹ or 15 cm⁻¹ for the 1800-1150 cm⁻¹ and 3500-3100 cm⁻¹ spectral ranges, respectively.

Structural details of the optimized conformers

Table SI. Structural parameters of the calculated optimized structures of M2, P2 and M3 conformers of **1**, and of these same conformers as observed in the solid state.

	P2		M2		M3	
	optimized	crystal ^(a)	optimized	crystal ^(a)	optimized	crystal ^(b)
average quinoline N-N distances between consecutive units (Å)	4.28	4.06	4.31	4.15	4.27	4.06
average ether O-O distances between consecutive units (Å)	11.96	11.90	12.01	11.93	11.96	11.91
HN-C*H dihedral angle (°)	110.8	108.6	-132.5	-116.7	167	127.5
HC*-C _{aryl} C _{aryl} dihedral angle (°)	1	8.6	21.2	53.3	22.7	18.8
average quinoline-amide torsion angle (°)	15.4	7.4	10.0	11.0	13.2	11.5
average quinoline-quinoline tilt angle (°)	23.5	19.9	28.3	18.5	24.4	17.7

^(a) From the four terminal units of the crystal structure of an octameric analogue of **1**.⁵

^(b) From the crystal structure of **1**.⁶

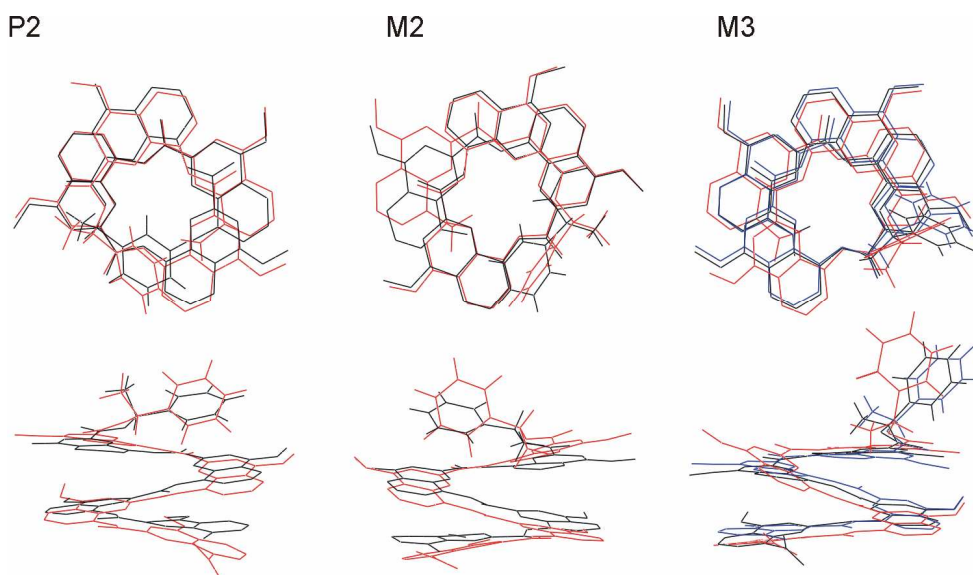


Figure S11. Top view and side view of the overlaid structures of: (left) the optimized structure of the P2 conformation of **1** (red) and the four terminal units of the P2 conformation of an octameric analogue of **1** in the crystal (black);⁵ (middle) the optimized structure of the M2 conformation of **1** (red) and the four terminal units of the M2 conformation of an octameric analogue of **1** in the crystal (black);⁵ (right) the optimized structure of the M3 conformation of **1** (red), the M3 conformation of **1** in the crystal (black) and the four terminal units of the M3 conformation of an octameric analogue of **1** in the crystal (blue).⁶ The three top views show that the inner rim of the helix has a pentagonal geometry that reflects the curvature of the strand (five units per two turns) both in the crystal and in the optimized structures. In P2 and M2 conformers, a discrepancy between optimized and crystal structures is observed at the N-termini because of the presence of a nitro group in the optimized structures that forces the first quinoline ring to slightly tilt out of the plane. This nitro group is absent in the crystal structures of P2 and M2 conformers, and is present in the crystal structure of the M3 conformer of **1**, for which agreement with the optimized structure is better.

VCD Spectra

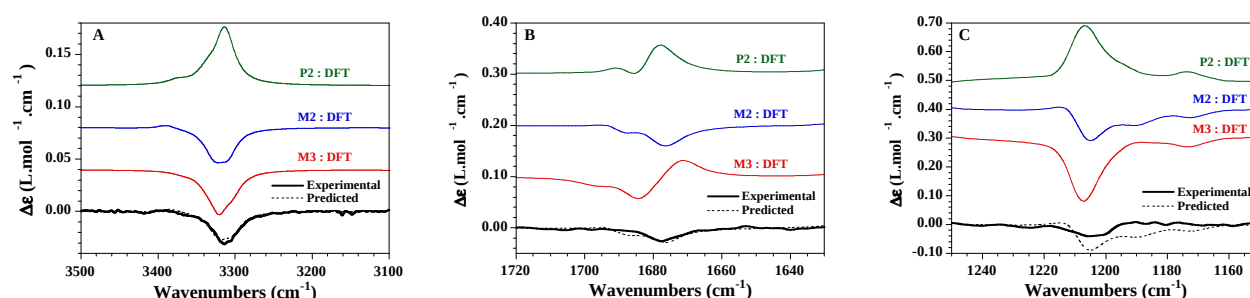


Figure S12. Comparison of the experimental VCD (lower frame, black solid line) spectrum of tetramer **1** with DFT calculated spectra of the M3 (red solid line), M2 (blue solid line) and P2 (green solid line) conformations of **1** and the predicted spectrum of the Boltzmann population-weighted sum of the three conformers (lower frame, black dashed line). (A) NH stretching region; (B) C=O stretching region; and (C) the CN stretching region. Calculated DFT spectra of M3, M2 and P2 conformations of **1** are vertically offset for clarity.

References

- (1) T. Buffeteau, F. Lagugné-Labarthe and C. Sourrisseau, *Appl. Spectrosc.*, 2005, **59**, 732-745.
- (2) L. A. Nafie and D. W. Vidrine, In *Fourier Transform Infrared Spectroscopy*, J. R. Ferraro and L. J. Basile, Eds (Academic Press, New York 1982), Vol. 3, p. 83.
- (3) M. J. Frisch, G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, J. A. Montgomery, Jr., T. Vreven, K. N. Kudin, J. C. Burant, J. M. Millam, S. S. Iyengar, J. Tomasi, V. Barone, B. Mennucci, M. Cossi, G. Scalmani, N. Rega, G. A. Petersson, H. Nakatsuji, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, M. Klene, X. Li, J. E. Knox, H. P. Hratchian, J. B. Cross, C. Adamo, J. Jaramillo, R. Gomperts, R. E. Stratmann, O. Yazyev, A. J. Austin, R. Cammi, C. Pomelli, J. W. Ochterski, P. Y. Ayala, K. Morokuma, G. A. Voth, P. Salvador, J. J. Dannenberg, V. G. Zakrzewski, S. Dapprich, A. D. Daniels, M. C. Strain, O. Farkas, D. K. Malick, A. D. Rabuck, K. Raghavachari, J. B. Foresman, J. V. Ortiz, Q. Cui, A. G. Baboul, S. Clifford, J. Cioslowski, B. B. Stefanov, G. Liu, A. Liashenko, P. Piskorz, I. Komaromi, R. L. Martin, D. J. Fox, T. Keith, M. A. Al-Laham, C. Y. Peng, A. Nanayakkara, M. Challacombe, P. M. W. Gill, B. Johnson, W. Chen, M. W. Wong, C. Gonzalez and J. A. Pople, *GAUSSIAN 03*; Revision B.04, Gaussian Inc., Pittsburgh, PA, 2003.
- (4) J. R. Cheeseman, M. J. Frisch, F. J.; Delvin and P. J. Stephens, *Chem. Phys. Lett.*, 1996, **252**, 211-220.
- (5) H. Jiang, C. Dolain, J.-M. Léger, H. Gornitzka and I. Huc, *J. Am. Chem. Soc.*, 2004, **126**, 1034-1035.
- (6) C. Dolain, H. Jiang, J.-M. Léger, P. Guionneau, I. Huc, *J. Am. Chem. Soc.*, 2005, **127**, 12943-12951.