Electronic Supplementary Material (ESI) for ChemComm.

Spontaneous Formation of Organic Helical Architectures from Dynamic Covalent Chemistry

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I. General Information

All reactions were monitored by thin layer chromatography (TLC) visualizing with ultraviolet light (UV), column chromatography purifications were carried out using silica gel. Proton nuclear magnetic resonance (1H NMR) spectra and carbon nuclear magnetic resonance (^{13}C NMR) spectra were recorded on 500 MHz spectrometer in $CDCl_3$ unless otherwise noted. Chemical shifts for protons are reported in parts per million downfield from tetramethylsilane (TMS) and are referenced to residual protium in the NMR solvent ($CHCl_3$ = δ 7.26 ppm). Chemical shifts for carbon are reported in parts per million downfield from tetramethylsilane (TMS) and are referenced to the carbon resonances of the solvent residual peak ($CDCl_3$ = δ 77.16 ppm). NMR data are presented as follows: chemical shift (δ ppm), multiplicity (s = singlet, d = doublet,t = triplet, q = quartet, m = multiplet, br = broad), coupling constant in Hertz (Hz), integration. Mass spectra were recorded on the Bruker MicrOTOF Q II and Autoflex speed TOF.

Computational Methods

All calculations were performed using Gaussian03 program. The hybrid Becke 3-Lee-Yang-Parr (B3LYP) exchange correlation functional was applied for DFT calculations. Geometries were fully optimized at B3LYP level of theory using the 6-31G* basis sets. All stationary points were

characterized as minima by corresponding Hessian indices.

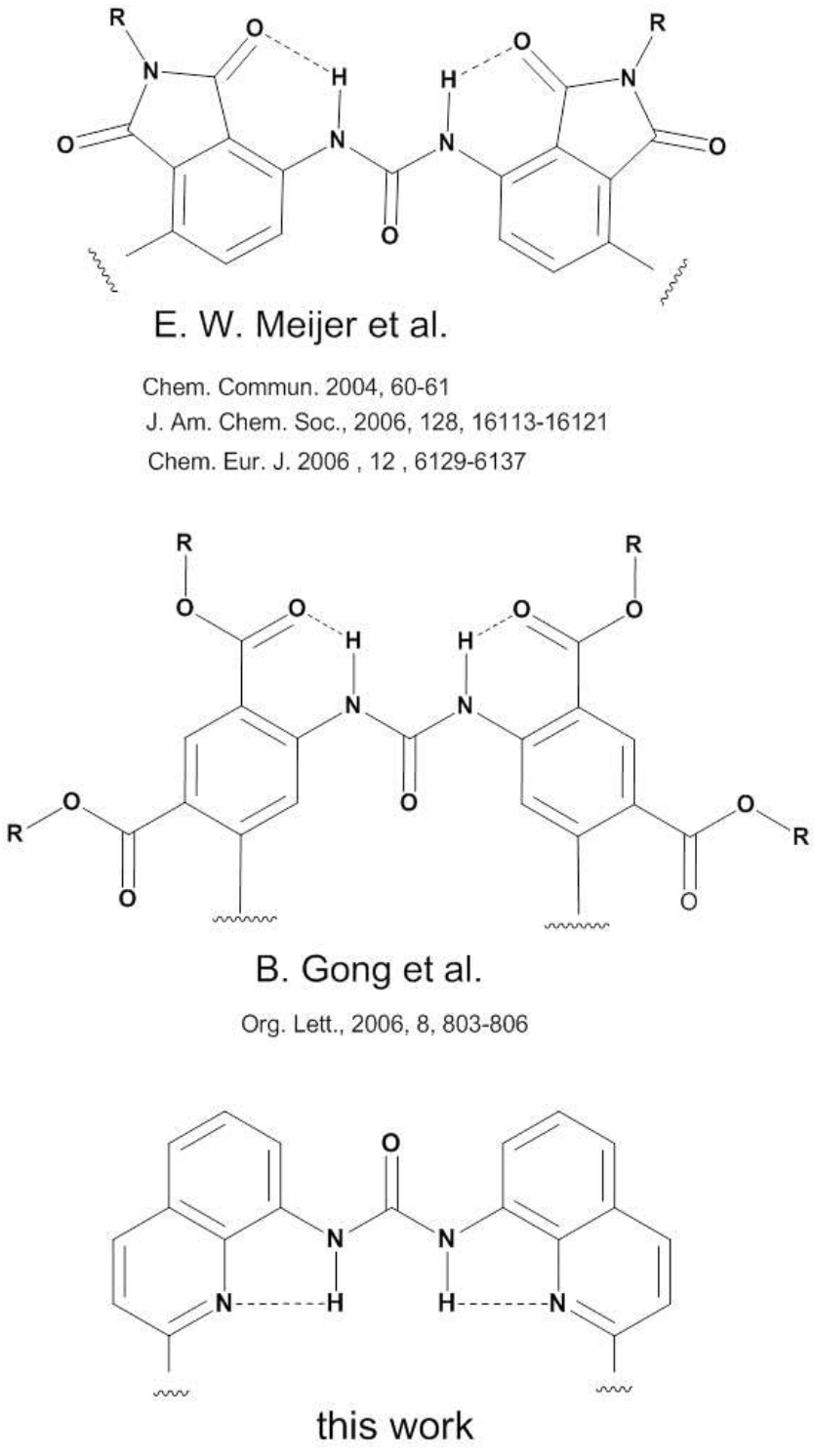


Fig. S1 Design of helical codon based on the previous structures reported by Meijer and Gong, respectively.

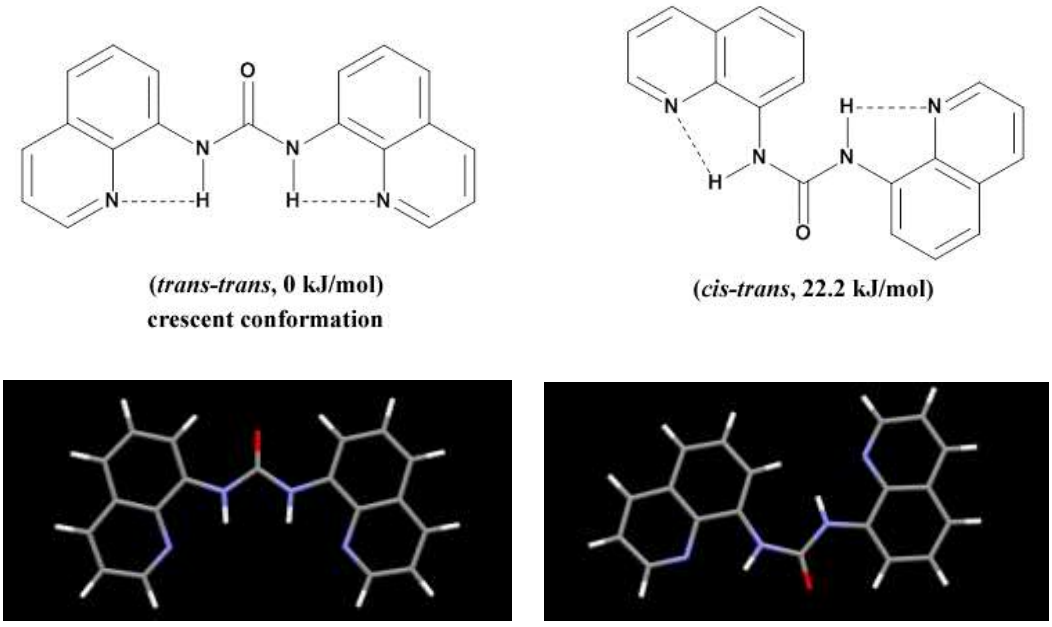


Fig. S2 Conformation analysis of helical codon by calculated at B3LYP/6-31G* level using Gaussian03 program. Computational results underpinned our design of helical codon as evidenced by the fact that the crescent conformation (left) is more stable than the *cis-trans* conformation with an energy difference of 22.2 kJ/mol.

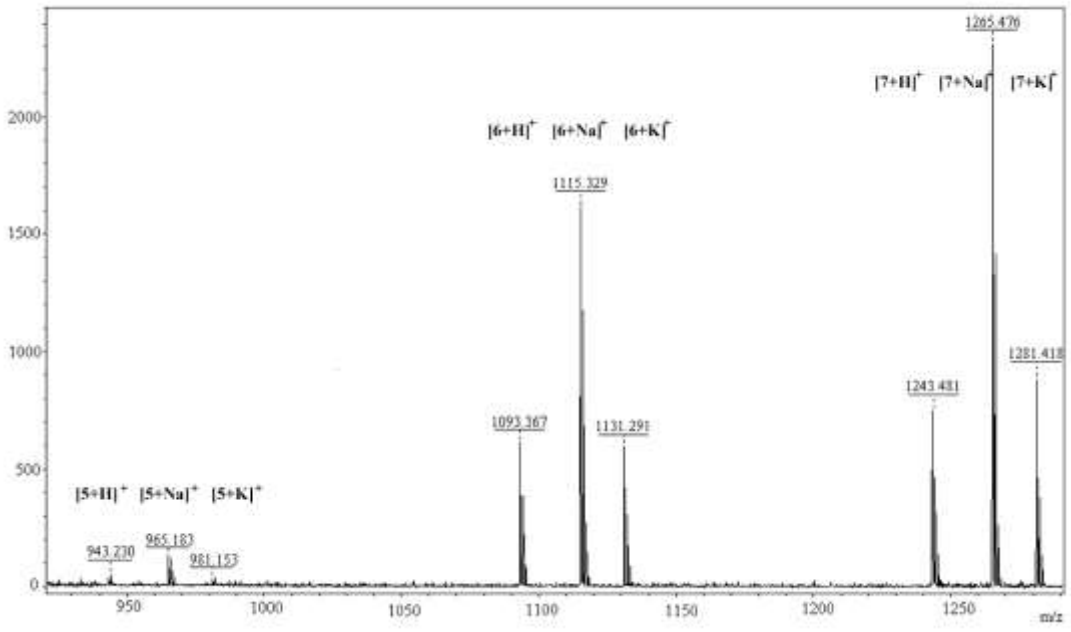


Fig. S3 MALDI-TOF MS of these three tetramers **5**, **6**, and **7** from the mixture of building blocks **1**, **2**, and **3**.

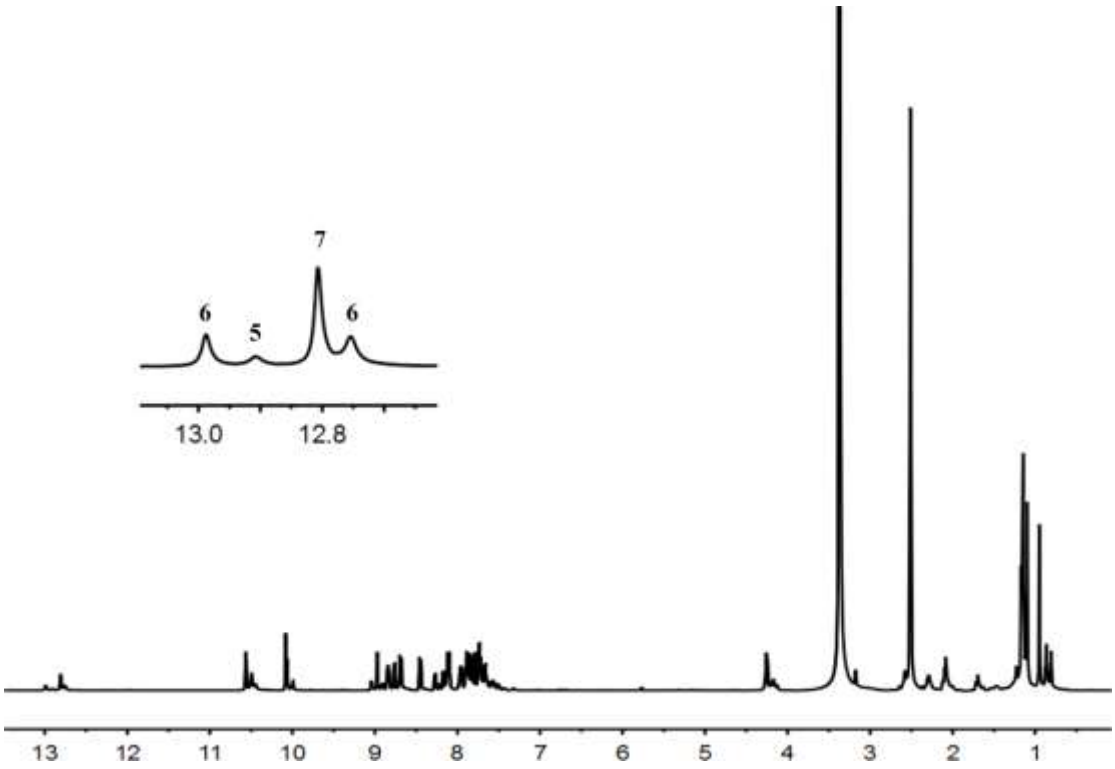


Fig. S4 NMR spectrum of the mixture (ca. 5 mM) of **5**, **6**, and **7** in DMSO-d_6. We found that the racemic tetramer **5**, chiral tetramers **6** and **7** gave 7.8%, 44.8%, and 47.4% yield, respectively, calculated on the basis of the amount of formed Schiff base (chemical shifts of imine protons: 12.7-13.0 ppm).

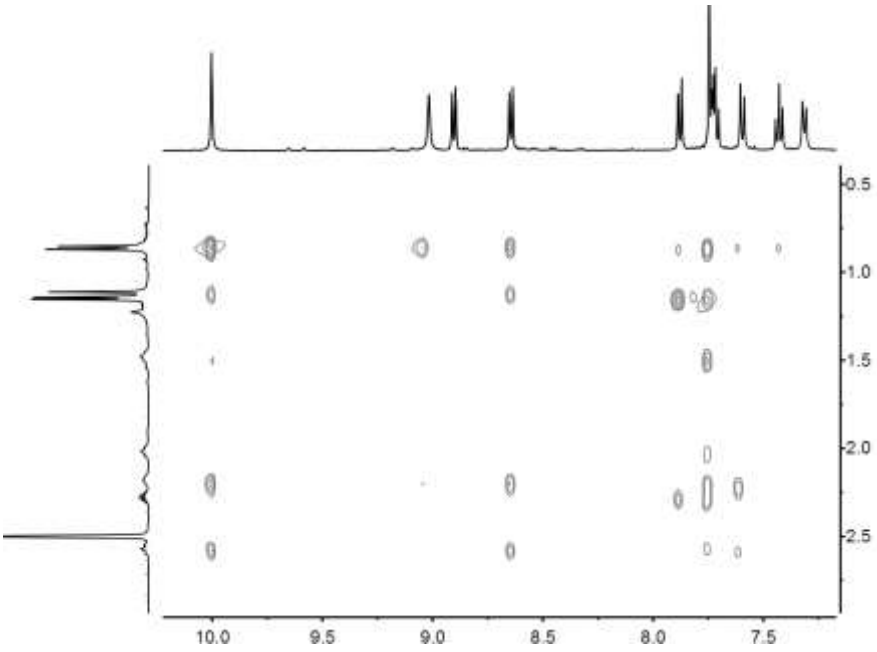


Fig. S5 Partial 2D NMR spectrum of helix **7** (15 mM) in DMSO-d_6 at 298 K showing the NOEs between aromatic protons and alkyl protons.

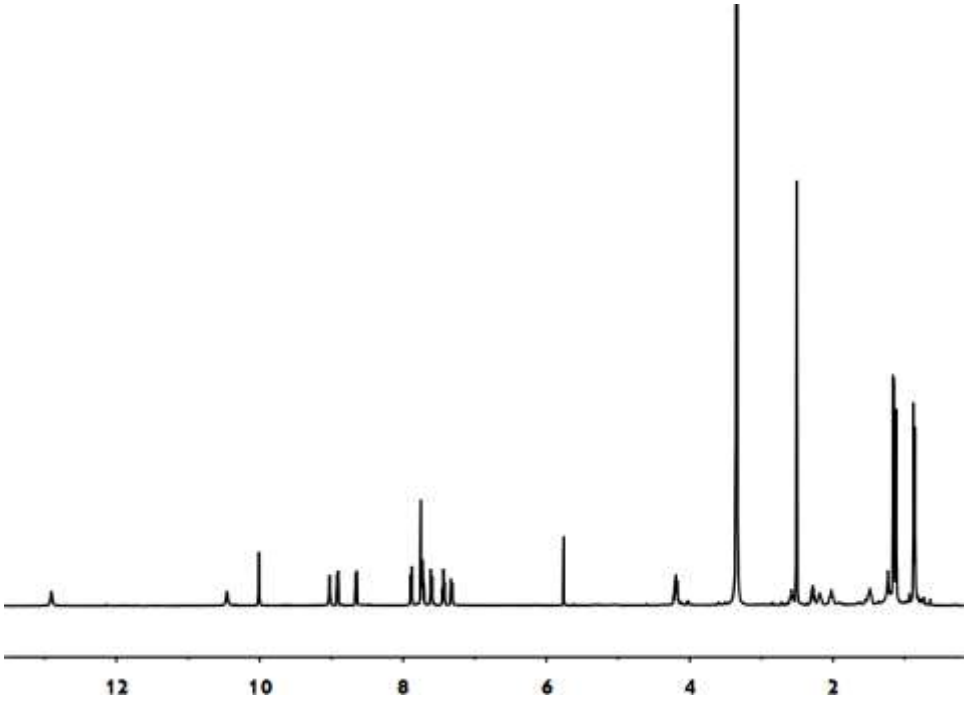


Fig. S6 NMR spectrum of tetramer **7** or **8** in DMSO-d_6.

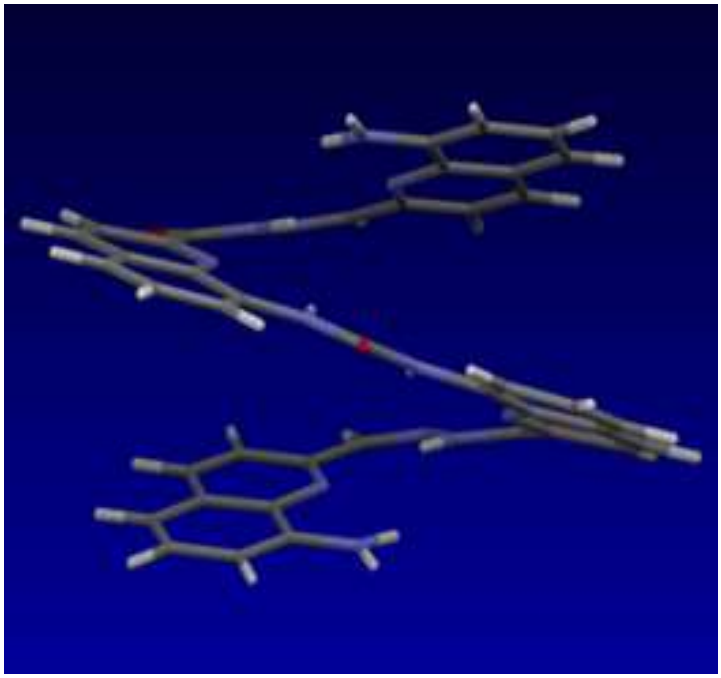


Fig. S7 The most stable conformation of tetramer **5** calculated by Gaussian03 calculation, and presented by PyMOL software.

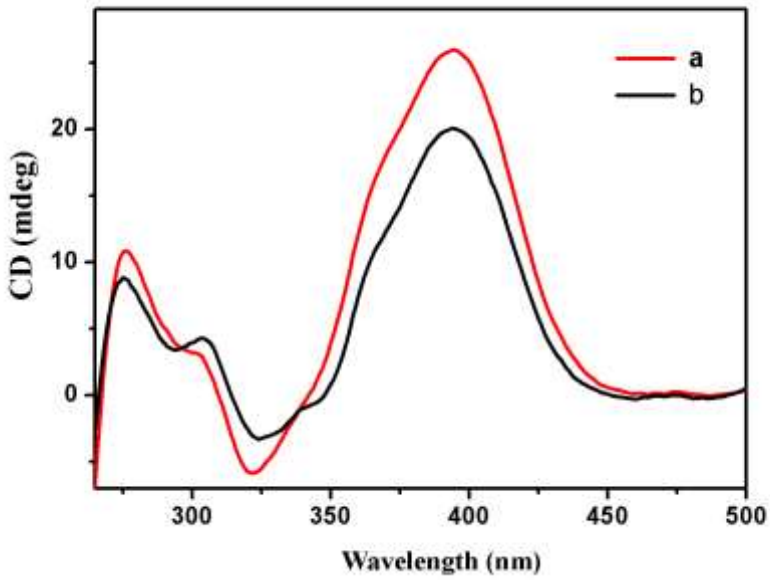


Fig. S8 Change of CD spectra in the mixture of building blocks **1**-**3** (the concentration of **1**, **2**, **3** is 150, 300, 300 μM, respectively) kept for 48 h in acetonitrile at 313 K with (a) or without (b) the addition of a small amount (150 μM) of trifluoroacetic acid (TFA).

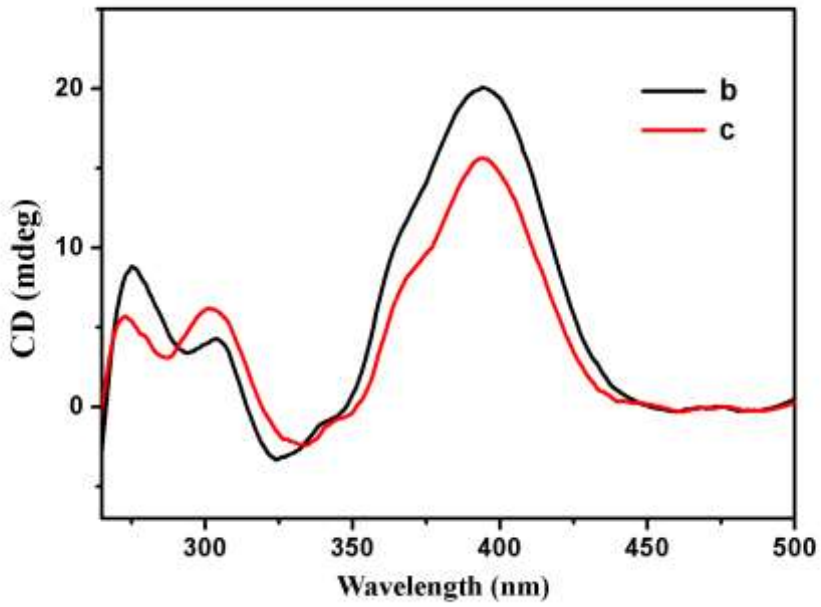
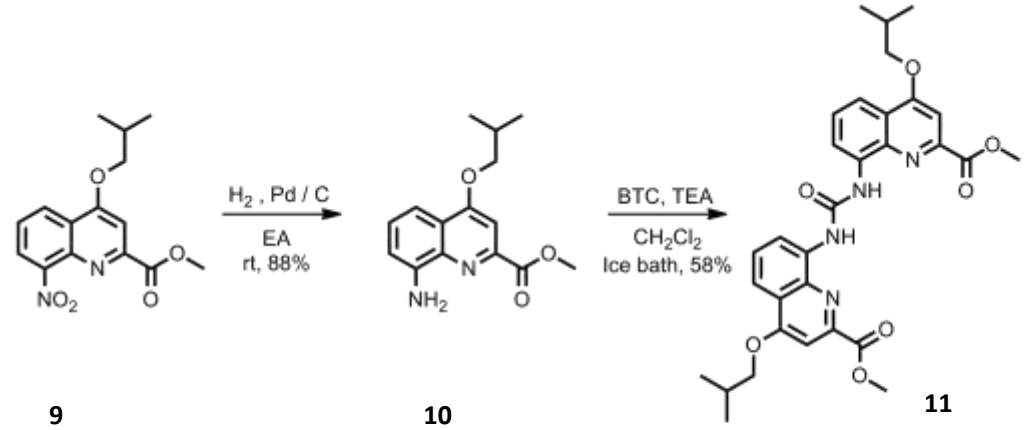
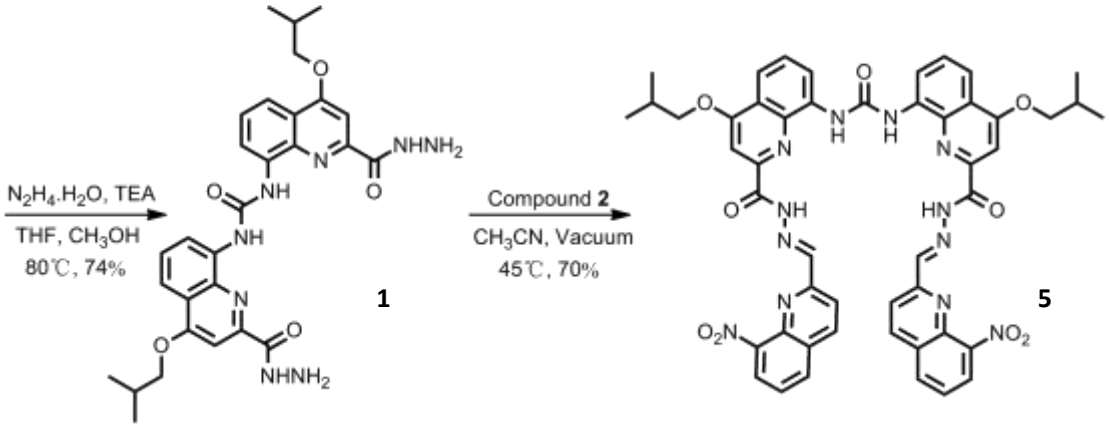


Fig. S9 Change of CD spectra in the mixture of building blocks **1**-**3** (the concentration of **1**, **2**, **3** is 150, 300, 300 μM, respectively) kept for 48 h in acetonitrile at 313 K with (c) or without (b) the addition of triethylamine (150 μM).

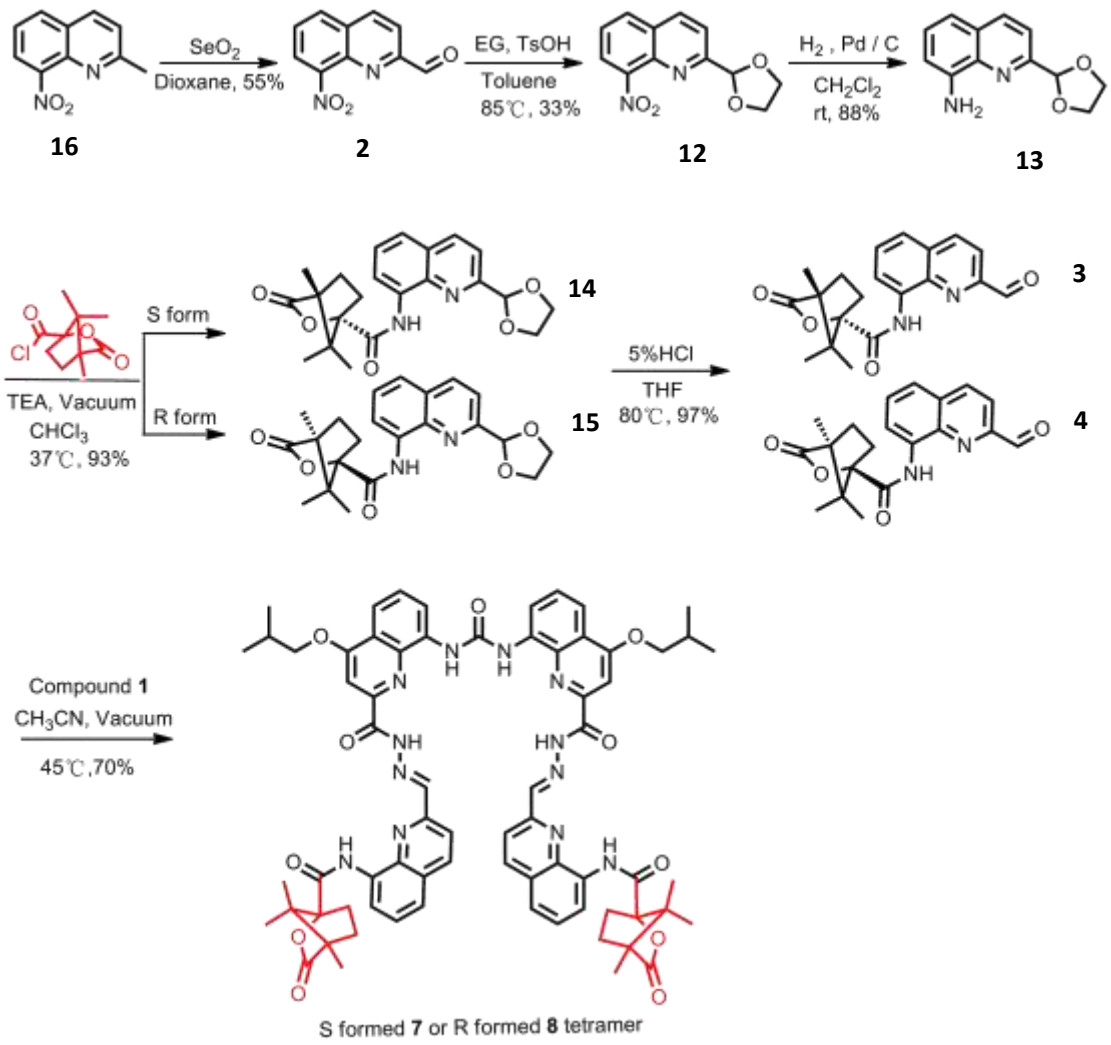
II. Preparation of chiral tetramer



9 **10** **11**



1 **5**



Synthesis of **10**

10% Pd / C (4.2g) was added to a solution of **9** (1g, 3.3 mmol), ammonium metavanadate (1.3g, 11.1mmol) and ammonium formate (5g, 0.08mol) in ethyl acetate (20mL) and stirred for 1.5 h at room temperature. The reaction mixture was filtered through celite and concentrated to give **10** (0.79g, 2.9 mmol, 88%) as a yellow powder. ^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.53 (d, J=8.3, 1H), 7.49 (s, 1H), 7.37 (t, J=7.9, 1H), 6.95 (d, J=7.5, 1H), 4.02 (d, J=8.4, 5H), 2.32 – 2.23 (m, 1H), 1.13 (d, J=6.7, 6H). ^{13}C NMR (126 MHz, $CDCl_3$) δ = 166.54, 162.75, 145.99, 145.00, 138.51, 128.71, 123.14, 110.97, 109.76, 100.93, 75.05, 52.93, 28.36, 19.40. MS ESI: calcd.for $C_{15}H_{18}N_2O_3$([M+H]$^+$): 275.13, found 275.15.

Synthesis of **11**

Dry triethylamine (2.8ml, 20mmol) was added to a solution of **10** (2.5g, 9.1mmol) in dry dichloromethane (8ml), and then a solution of triphosgene (0.43g, 0.01mmol) in small amount of dichloromethane was added under ice bath condition, sealed and

stirred it overnight, the solvent was evaporated to dryness and the residue was purified by column chromatography (SiO_2, CH_2Cl_2) to obtain **11** (1.5g, 2.6mmol, 58%) as a yellow powder. ^{1}H NMR (500 MHz, $CDCl_3$) δ = 10.75 (s, 2H), 8.85 (d, J=7.7, 2H), 7.81 (d, J=8.3, 2H), 7.60 (t, J=8.1, 2H), 7.51 (s, 2H), 4.14 (s, 6H), 4.04 (d, J=6.4, 4H), 2.34 – 2.26 (m, 2H), 1.16 (d, 12H). ^{13}C NMR (126 MHz, $CDCl_3$) δ = 166.27, 163.07, 153.35, 145.60, 139.19, 137.62, 129.10, 122.54, 116.07, 113.49, 101.01, 75.19, 53.20, 28.39, 19.43. MS ESI: calcd. for $C_{31}H_{34}N_4O_7$ ($[M+H]^+$): 575.24, found 575.26.

Synthesis of **1**

Hydrazine hydrate (0.8ml, 16.5mmol) was added to a solution of compound **11** (0.95g, 1.65mmol) in a mixture of 1,4-dioxane (8 mL) and methyl alcohol (1ml), then triethylamine (2.3ml, 16.5mmol) was added and stirred at 80℃ overnight, The solvents were then evaporated to dryness, the residue was dissolved in $CHCl_3$ (3mL) and the solution was dropped in large amount of methanol, centrifuging the solution to give a yellow powder (0.69g,1.2mmol,74%).^{1}H NMR (500 MHz, DMSO) δ = 10.70 (s, 2H), 10.35 (s, 2H), 8.72 (d, J=6.9, 2H), 7.79 (d, J=9.4, 2H), 7.66 – 7.60 (m, 4H), 5.09 (s, 4H), 4.16 (d, J=6.4, 4H), 2.28 – 2.18 (m, 2H), 1.11 (d, J=6.7, 12H). ^{13}C NMR (126 MHz, $CDCl_3$) δ = 167.70, 162.27, 152.35, 148.60, 137.07, 135.46, 126.76, 121.20, 115.45, 114.13, 98.87, 74.49, 28.13, 19.12. MS ESI: calcd. for $C_{29}H_{34}N_8O_5$ ($[M+H]^+$): 575.26, found575.28.

Synthesis of **5**

Dry acetonitrile (6ml) was added to mixture of **1** (0.10g, 0.17mmol) and **2** (0.0735g, 0.37mmol) in vacuum condition, the mixture was sealed and stirred at 45℃ for 24h, The solvent was removed in vacuo and the product was obtained (0.10g, 0.11mmol, 62.5%) as a yellow powder. ^{1}H NMR (500 MHz, DMSO) δ = 12.87 (s, 1H), 10.57 (s, 1H), 9.00 (s, 1H), 8.83 (d, *J*=7.6, 1H), 8.25 (d, *J*=7.0, 1H), 8.09 (dd, *J*=18.8, 8.2, 1H), 7.89 – 7.85 (m, 1H), 7.79 (s, 1H), 7.75 – 7.67 (m, 1H), 4.25 (d, *J*=6.4, 1H), 2.35 – 2.24 (m, 1H), 1.16 (d, *J*=6.7, 3H). MS (TOF MS ES+): calcd. for $C_{49}H_{442}N_{12}O_9Na^{+}$: 965.32; found: 965.29; calcd for $C_{49}H_{42}N_{12}O_9K^{+}$: 981.32: found: 981.25.

Synthesis of **2**

A solution of **16** (2 g, 10.6 mmol) in dioxane (20 mL) was heated to 65℃. To this solution was added SeO_2 (2.12g, 19.1mmol). Then the temperature was increased to 80℃. After 2h, the mixture was cooled to ambient temperature. The precipitate was filtered off. Organic phase was concentrated. The product was obtained by column chromatography (silica gel, dichloromethane/ petroleum ether =1/1) to afford **2** (1.2g, 5.9mmol, 55% yield) as a white powder. ^{1}H NMR (500 MHz, $CDCl_3$) δ = 10.20 (s, 1H), 8.44 (d, J=8.5, 1H), 8.17 (d, J=8.5, 1H), 8.13 (d, J=7.8, 2H), 7.78 (t, J=7.9, 1H). ^{13}C NMR (126 MHz, DMSO) δ = 192.82, 153.41, 147.98, 138.73, 137.93, 132.28,

130.00, 128.43, 124.62, 118.92. MS ESI: calcd. for $C_{10}H_6N_2O_3([M+H]^+)$: 203.04, found 203.05.

Synthesis of **12**

Product **2** (0.19 g, 0.94mmol) and ethylene glycol (0.12 mL, 2.0mmol) were dissolved in toluene (5 mL). p-TsOH (9.7mg, 0.06 mmol) and sodium sulfate were added and the reaction mixture was refluxed under Dean–Stark conditions for 16 h. Afterwards the reaction mixture was diluted by dichloromethane, the organic layer was washed with water, the solvent was removed in vacuo and the product was obtained by column chromatography (silica gel, dichloromethane/ methyl alcohol =200/1) to afford **12** (0.08g, 0.33 mmol, 33%) as a yellow powder. ^{1}H NMR (500 MHz, $CDCl_3$) δ = 8.30 (d, J=8.5, 1H), 8.04 (d, J=7.5, 2H), 7.77 (d, J=8.5, 1H), 7.63 (t, J=7.8, 1H), 5.98 (s, 1H), 4.27 (s, 2H), 4.14 (s, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ = 160.13, 138.80, 137.14, 131.81, 129.18, 125.80, 123.99, 120.28, 120.12, 104.03, 66.05. ESI MS: calcd. for $C_{12}H_{10}N_2O_4$ ($[M+H]^+$): 247.06, found 247.08.

Synthesis of **13**

This compound was obtained as a dark green solid by using the same method with Synthesis of **10**. ^{1}H NMR (500 MHz, DMSO) δ = 8.23 (d, J=8.5, 1H), 7.55 (d, J=8.5, 1H), 7.32 (t, J=7.8, 1H), 7.08 (d, J=7.9, 1H), 6.89 (d, J=7.5, 1H), 5.91 (s, 2H), 5.82 (s, 1H), 4.20 (s, 2H), 4.04 (s, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ = 154.25, 144.19, 137.28, 137.01, 128.95, 127.90, 118.20, 115.66, 110.23, 104.64, 65.73. MS ESI: calcd. for $C_{12}H_{12}N_2O_2([M+H]^+)$: 217.09, found 217.10.

Synthesis of **14**

Dry chloroform (3ml) was added to mixture of **13** (0.1g, 0.46mmol) and (-)-camphanic acid chloride (0.1g, 0.46mmol) in vacuum condition, and then dry triethylamine (0.32ml, 2.3mmol)was added and stirred at 37℃ for 24h, The reaction mixture was quenched with water and the organic layer was dried over magnesium sulfate and filtered. The solvent was removed in vacuo and the product was obtained by column chromatography (silica gel, dichloromethane/ petroleum ether =20/1) to give **14** (0.17g, 0.43 mmol，93%) as a milky white powder. ^{1}H NMR (500 MHz, $CDCl_3$) δ = 10.73 (s, 1H), 8.78 (dd, J=6.0, 3.0, 1H), 8.22 (d, J=8.4, 1H), 7.65 (d, J=8.4, 1H), 7.59 – 7.54 (m, 2H), 6.06 (s, 1H), 4.43 – 4.34 (m, 2H), 4.22 – 4.15 (m, 2H), 2.71 – 2.64 (m, 1H), 2.13 – 1.99 (m, 2H), 1.81 – 1.75 (m, 1H), 1.21 (s, 3H), 1.17 (s, 3H), 1.03 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ = 178.02, 165.81, 156.43, 137.94, 137.42, 133.78, 128.21, 127.71, 122.36, 119.54, 117.18, 104.37, 92.82, 66.16, 66.08, 55.60, 54.45, 30.65, 29.32, 16.93, 16.86, 9.94. MS ESI: calcd. for $C_{22}H_{24}N_2O_5([M+H]^+)$: 397.17, found 397.17. Compound **15** was also synthesized by the same method.

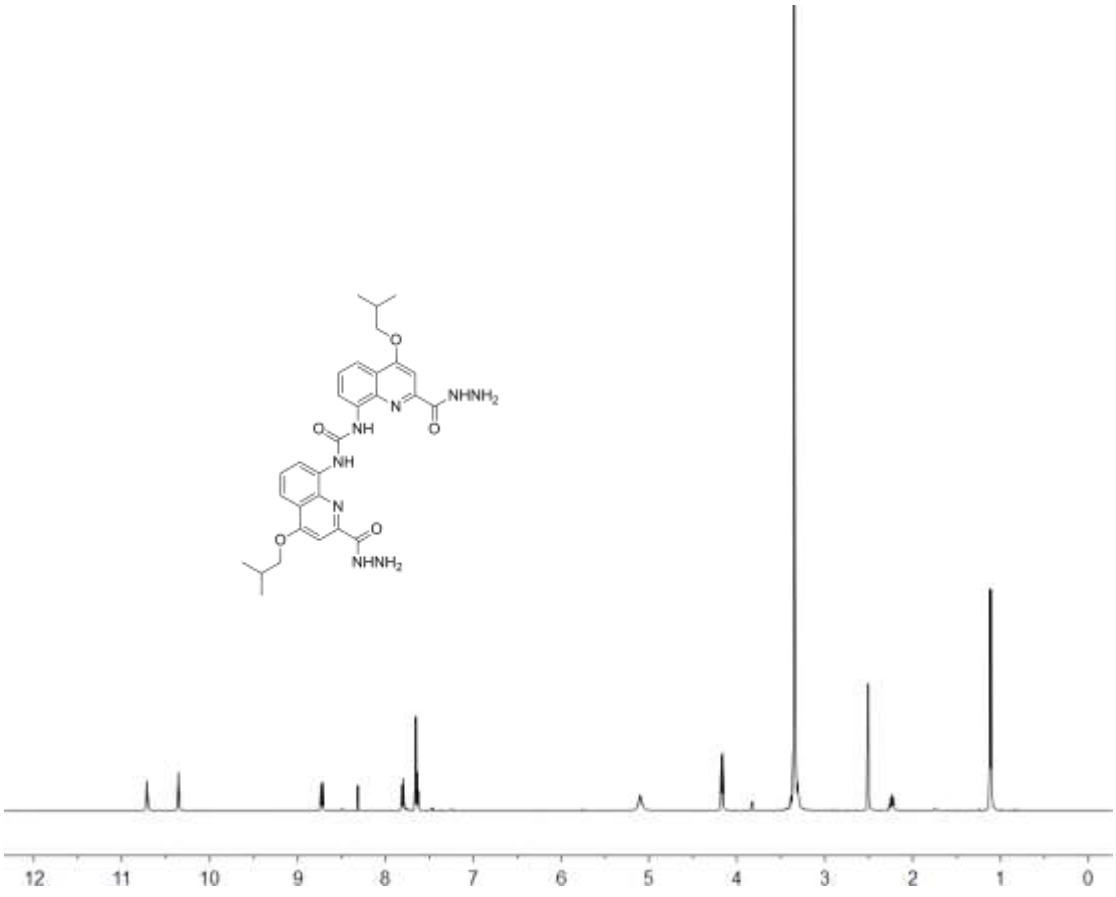
Synthesis of **3**

Excessive 5% HCl was added to a solution of **14** (0.15g, 0.38 mmol) in tetrahydrofur-an, the mixture was stirred at 80℃overnight , removed the THF and HCl in vacuo and the remaining solution was extracted by dichloromethane, the organic layer was washed with water and brine, dried over magnesium sulfate and filtered. After the solvent was removed in vacuo, the residue was purified by open column chromatography (silica gel, dichloromethane) to give **3** (0.13g, 0.37 mmol, 97%) as a yellow solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ = 10.72 (s, 1H), 10.28 (s, 1H), 8.88 (d, J=7.6, 1H), 8.34 (d, J=8.4, 1H), 8.10 (d, J=8.4, 1H), 7.71 (t, J=8.0, 1H), 7.65 (d, J=7.3, 1H), 2.72 – 2.65 (m, 1H), 2.16 – 2.09 (m, 1H), 2.08 – 2.01 (m, 1H), 1.84 – 1.78 (m, 1H), 1.22 (s, 3H), 1.19 (s, 3H), 1.06 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ = 193.15, 177.82, 166.06, 150.73, 138.35, 137.81, 134.45, 130.20, 130.02, 122.49, 118.00, 117.89, 92.73, 55.60, 54.51, 30.72, 29.28, 16.91, 16.81, 9.92. MS ESI: calcd. for $C_{20}H_{20}N_2O_4$ ($[M+H]^+$): 353.14, found 353.15. Compound **4** was also synthesized by the same method.

Synthesis of **7**

Dry acetonitrile (6ml) was added to mixture of **1** (0.13g, 0.23mmol) and **3** (0.16g, 0.46mmol) in vacuum condition, the mixture was sealed and stirred at 45℃ for 24h, The solvent was removed in vacuo and the product was obtained (0.19g, 0.16mmol, 70%) as a yellow powder. ^{1}H NMR (500 MHz, DMSO) δ = 12.90 (s, 1H), 10.45 (s, 1H), 10.00 (s, 1H), 9.02 (s, 1H), 8.90 (d, J=7.7, 1H), 8.64 (d, J=7.6, 1H), 7.88 (d, J=8.2, 1H), 7.77 – 7.70 (m, 3H), 7.60 (d, J=8.6, 1H), 7.43 (t, J=7.9, 1H), 7.31 (d, J=7.9, 1H), 4.26 – 4.15 (m, 2H), 2.61 – 2.53 (m, 1H), 2.28 (dt, J=13.1, 6.5, 1H), 2.22 – 2.15 (m, 1H), 2.05 – 1.98 (m, 1H), 1.51 – 1.45 (m, 1H), 1.15 (d, J=6.7, 6H), 1.11 (s, 3H), 0.86 (d, J=8.7, 6H). MS (TOF MS ES+): calcd for $C_{69}H_{70}N_{12}O_{11}Na^{+}$: 1266.36; found: 1266.15; calcd for $C_{69}H_{70}N_{12}O_{11}K^{+}$: 1282.36: found: 1282.14. The maximum absorption wavelength in CH_3Cl by UV is 328nm. Compound **14** was also synthesized by the same method.

Ⅲ. NMR spectra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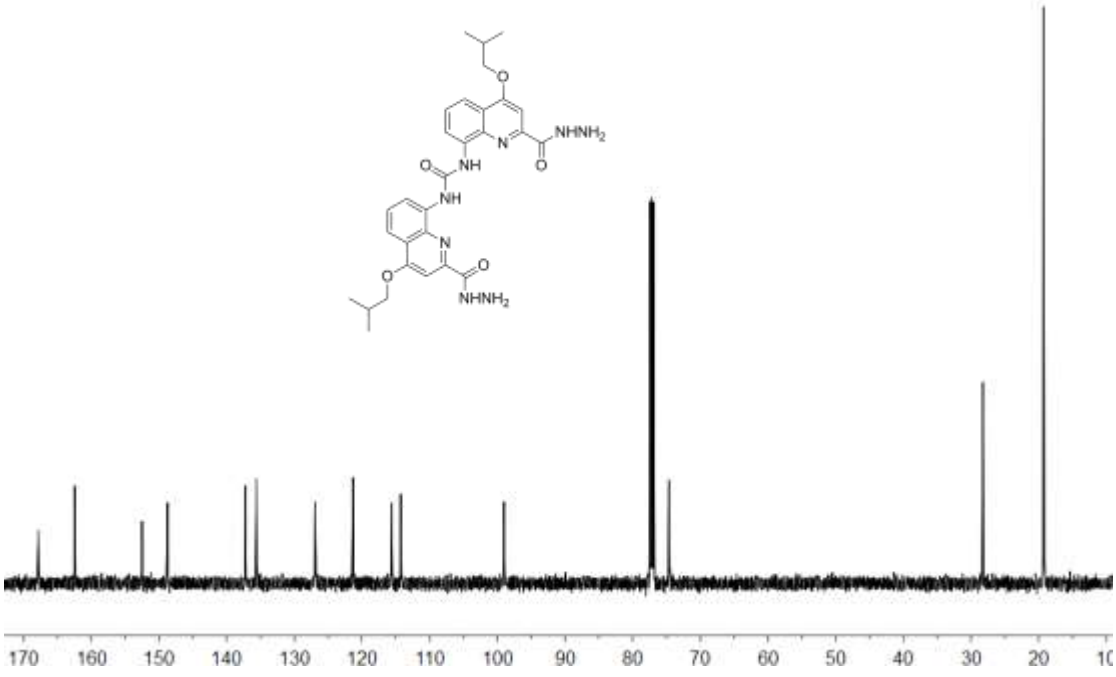
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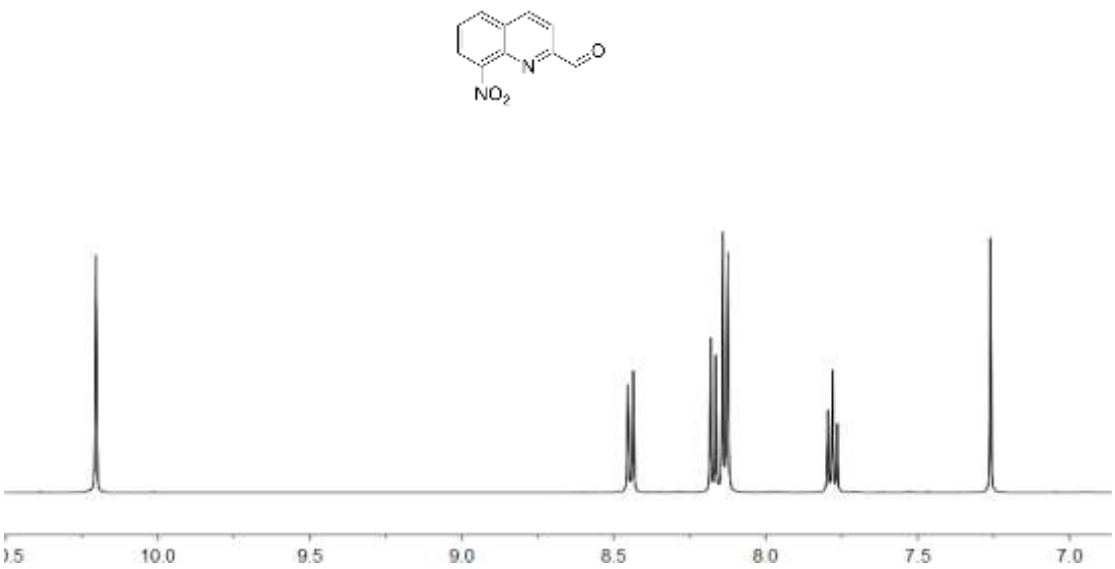
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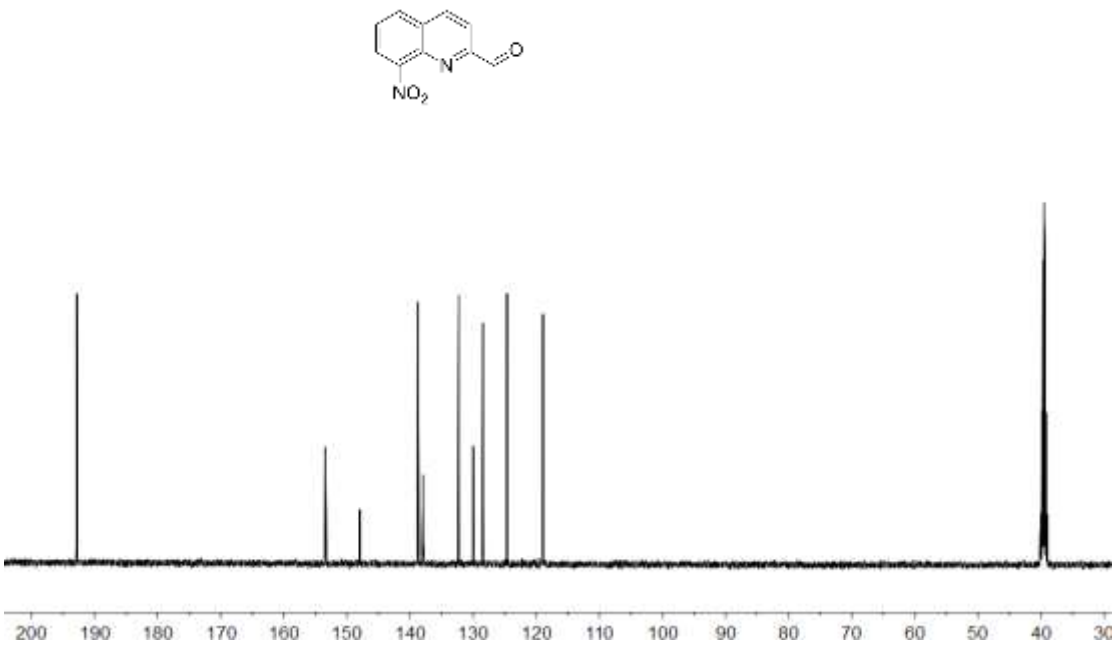
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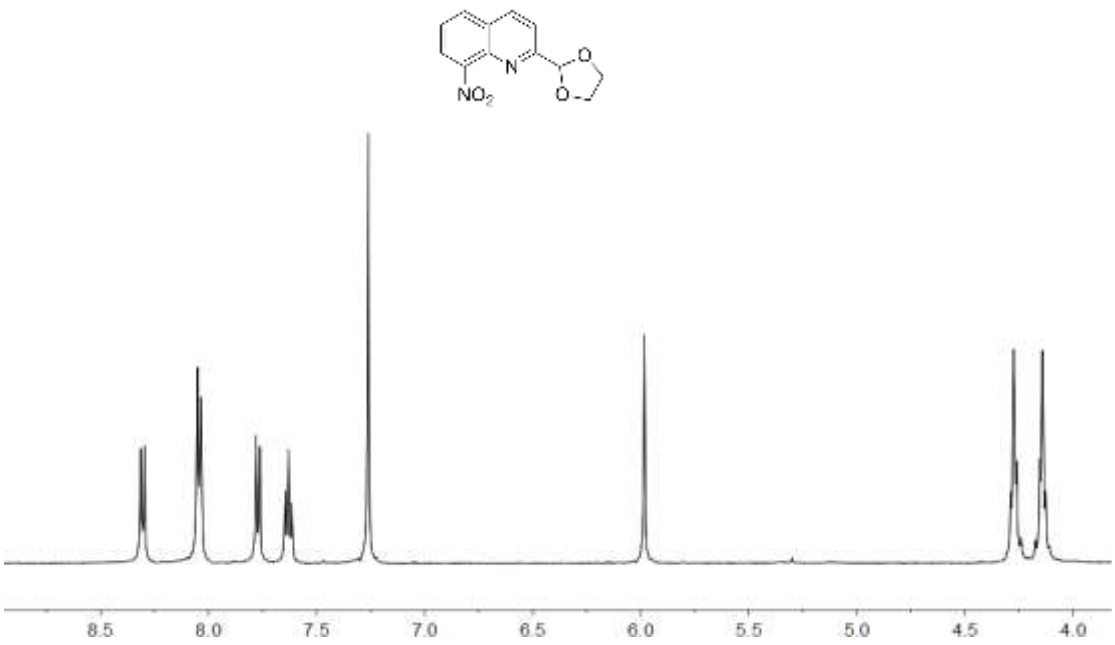
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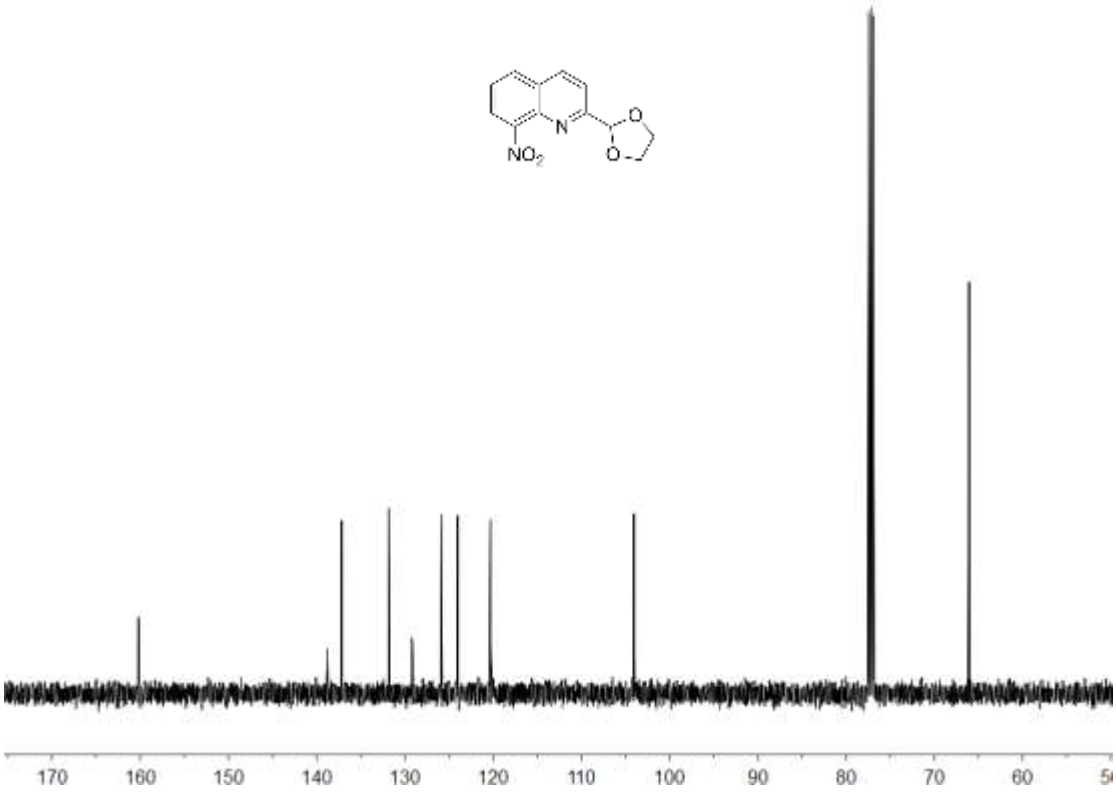
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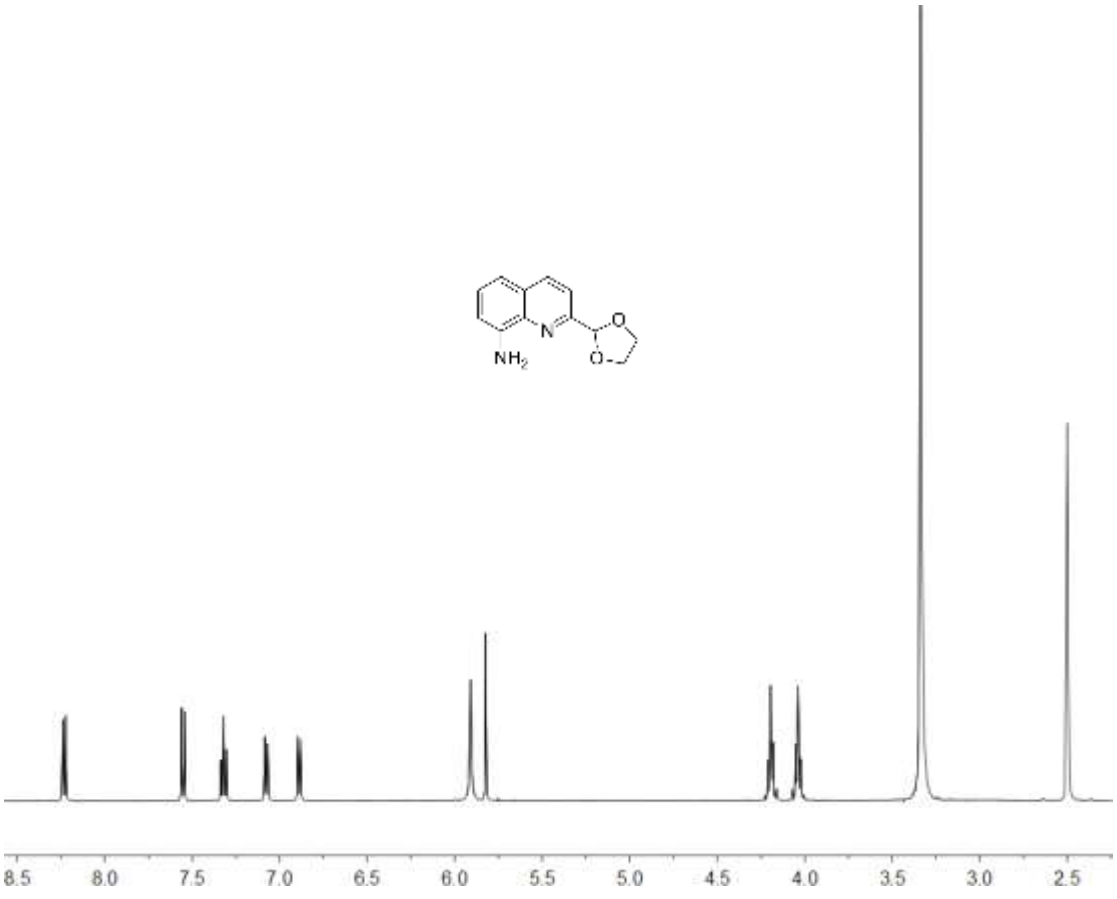
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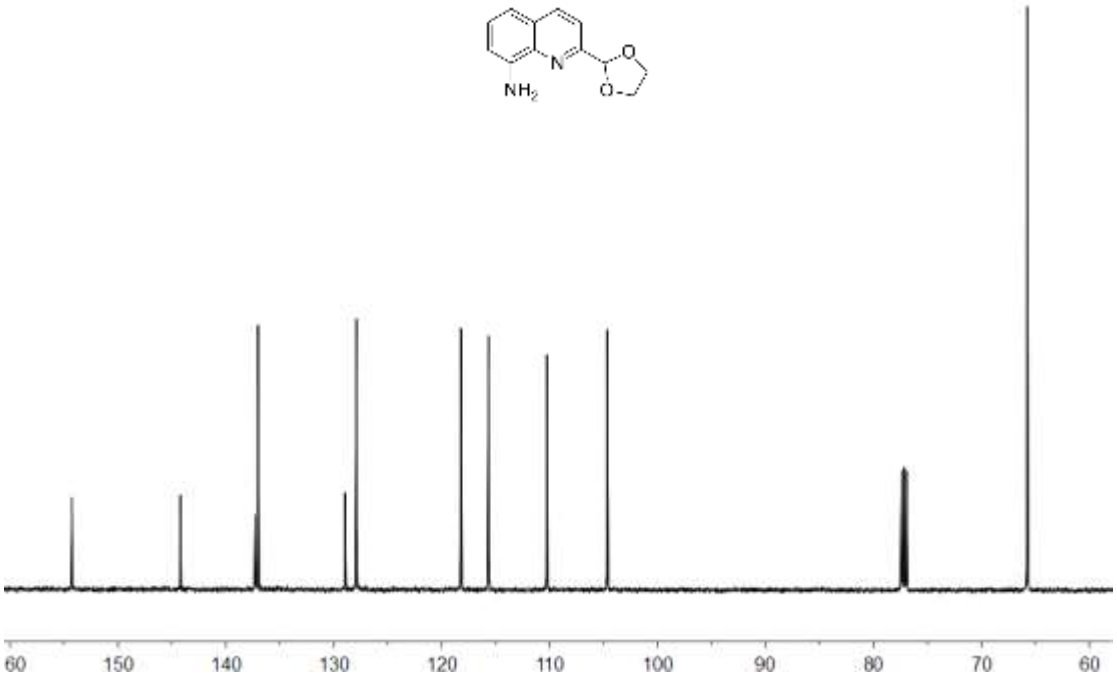
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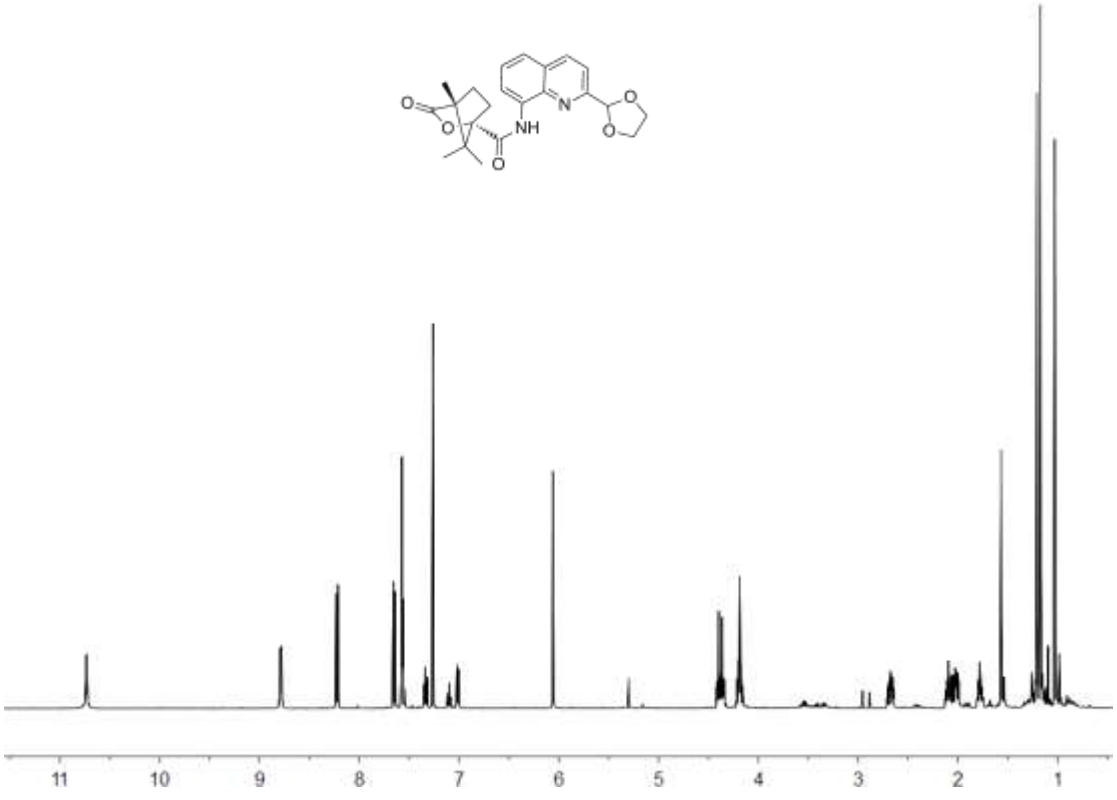
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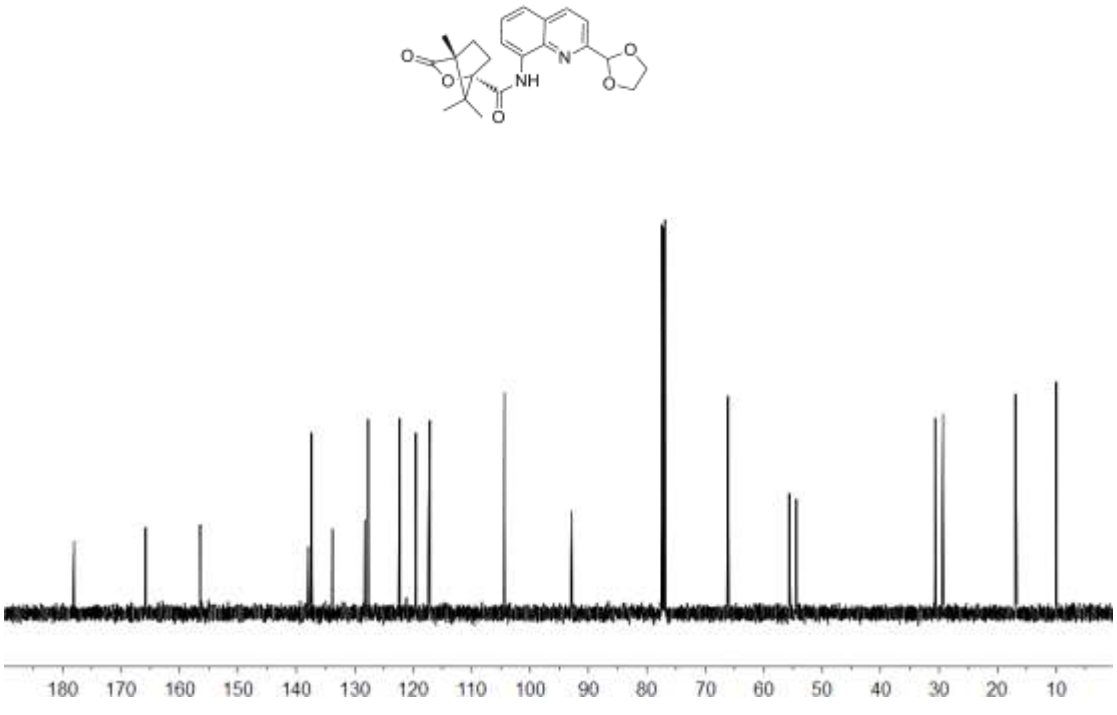
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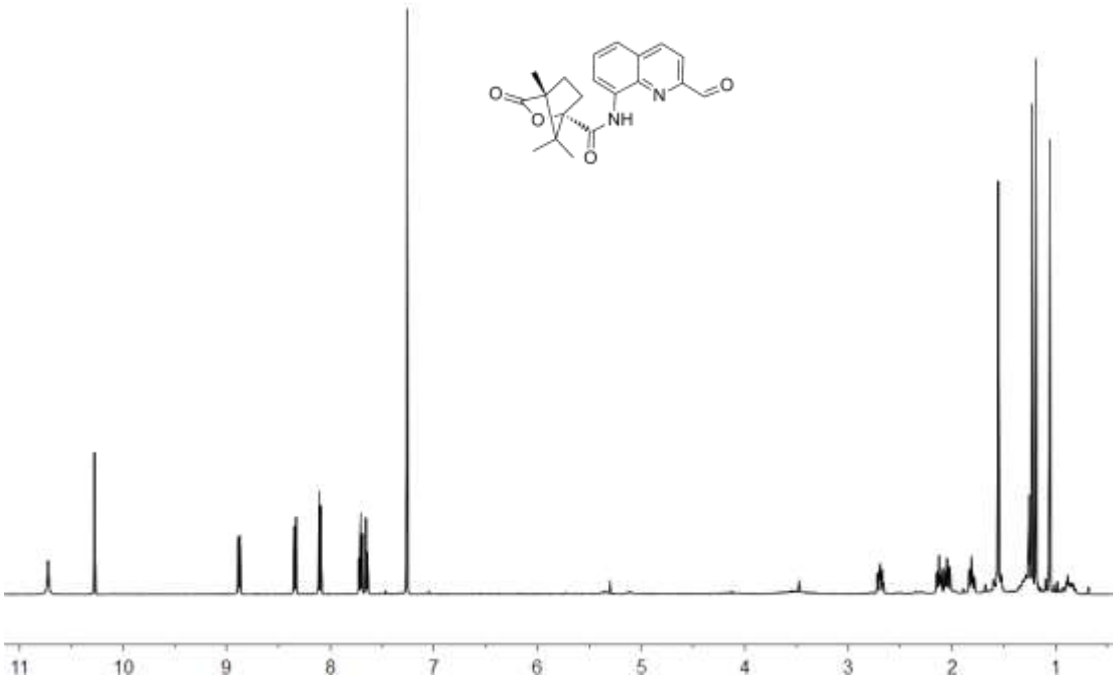
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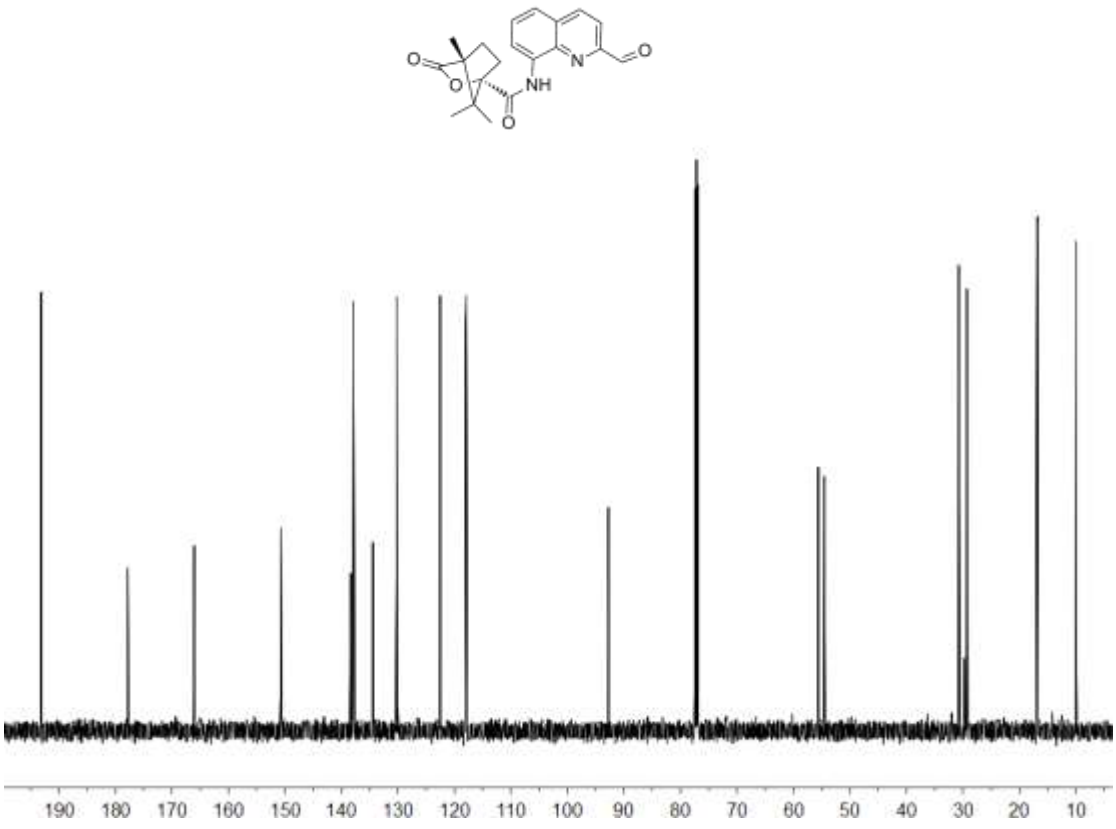
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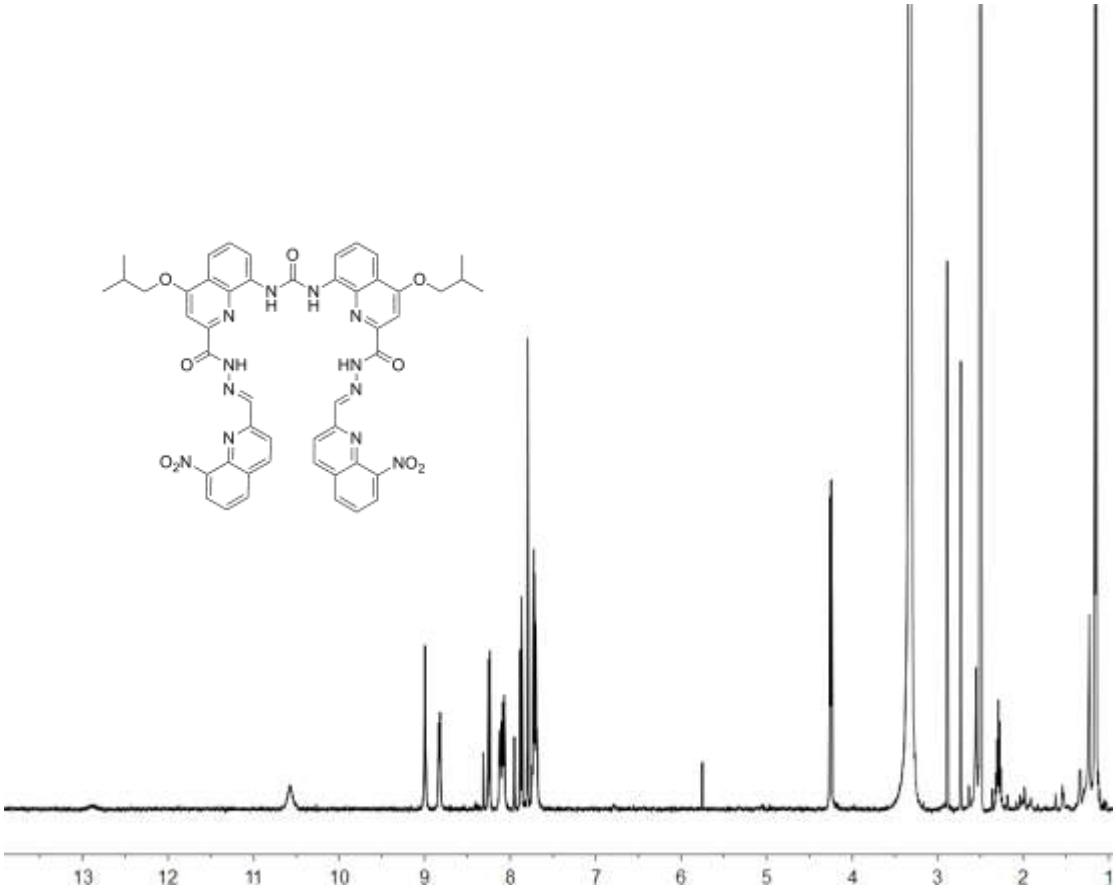
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