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SUPPORTING INFORMATION

Access of Indenofurans and Indenopyridines via Annulation of Heterocyclic Ketene Aminals, o-Phthalaldehyde and 1.3-dicarbonyles

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1. General information

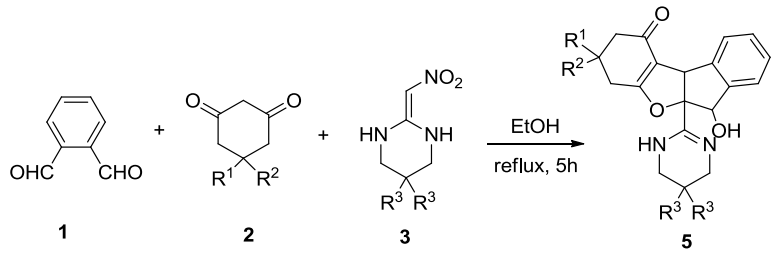
^{1}H NMR and ^{13}C NMR spectra were recorded on BrukerAM-400 (^{1}H at 400 MHz, ^{13}C at 100 MHz) spectrometer with DMSO- d_6 as the solvent and TMS as the internal standard. Chemical shifts are reported in δ (parts per million) values. High resolution electron mass spectra (ESI-TOF) were performed on a Micromass LC-TOF spectrometer. Analytical thin-layer chromatography (TLC) was carried out on precoated plates (silica gel 60 F254), and spots were visualized with ultraviolet (UV) light. Chromatographic analysis was performed using an ACQUITY UPLC-H Class system (Waters Corp., USA), equipped with HSS T3 reversed phase column with 100 mm×2.1 mm i.d. and 1.8 μm particle size, equipped with a quaternary solvent delivery system, a 48-vial autosampler (10 μL loop), and a photodiode array detector (PDA). The UPLC separations were carried out using gradient separation at a flow rate of 0.4 mL min-1. The mobile phase was a mixture of MilliQ ultrapure water with 0.01% trifluoroacetic acid (A) and acetonitrile (B). The following elution gradient totally lasted 15 min: initial mobile-phase composition, 90:10 (v/v) phase A: B; 0-8 min, linear change from 10 to 100% B; 8-10 min 100% B; 10-11 min, 90:10 (v/v) phase A: B. The column and injection chamber were maintained at 40 and 25 ^{o}C, respectively. The sample injection volume was 2 μL and the detector was set at 261 nm. The following abbreviations were used to explain the multiplicities: s = singlet, d = doublet, t =triplet, q = quartet, m = multiplet, br = broad singlet, coupling constant (Hz) and integration. In this paper, yields refer to isolated yields of all diastereoisomers based on HKAs and the ratios of major diastereisomers were determined by ^{1}H NMR of the crude reaction mixture.

Reagents: Heterocyclic ketene aminals (HKAs) were synthesized according to the reported procedures,[1] all other solvents and reagents were purchased directly from commercial suppliers and used as received without further purification

Reference

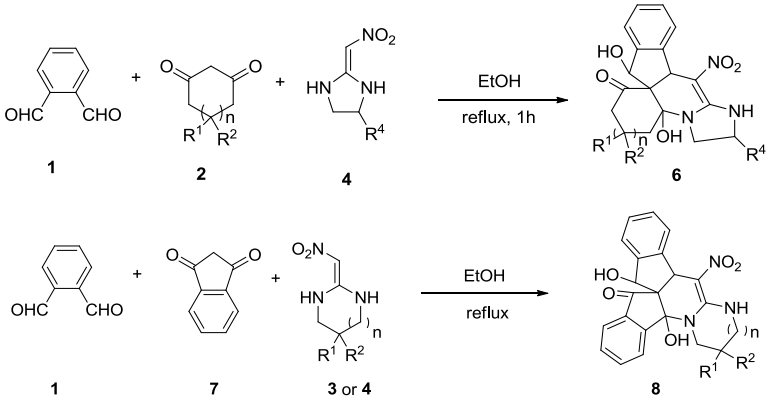
(1) F. Sun, X. Shao, Z. Li, *Synlett*, **2015**, 26, 2306-2312.

2. General procedure for the synthesis of products 5:



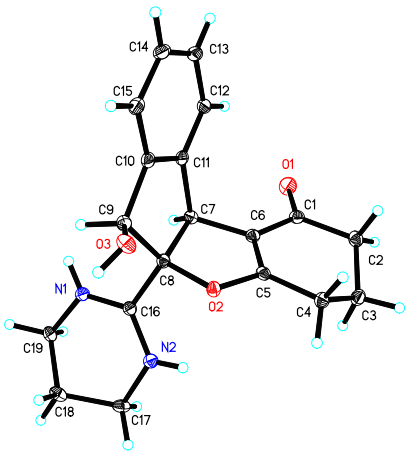
o-phthalaldehydes **1** (161.0 mg, 1.2 mmol, 1.2eq), cyclic1,3-dicarbonyl compounds **2** (1.0 mmol, 1eq), HKAs **3** (1.0 mmol, 1.0eq) and ethanol (10 ml) were placed in a 25ml round-bottom flask and the mixture was stirred under reflux for 5h. After completion of the reaction (confirmed by TLC), the reaction mixture was filtered to afford the product or the solvent was evaporated and the product was obtained by crystallization from dichloromethane. Due to many chiral centers in our products, some products have more than two diastereoisomers. Therefore, we selected the two major diastereoisomers to illustrate the phenomenon and one representative diastereoisomer to identify the structure of products.

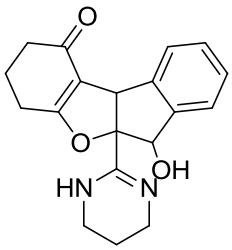
3. General procedure for the synthesis of products 6 and 8:



o-phthalaldehydes **1** (161.0 mg, 1.2 mmol, 1.2eq), cyclic1, 3-dicarbonyl compounds **2** or **7** (1.0 mmol, 1.0eq), HKAs **3** or **4** (1.0 mmol, 1.0eq) and ethanol (10 ml) were placed in a 25ml round-bottom flask and the mixture was stirred under reflux for 1h or 4h. After completion of the reaction (confirmed by TLC), the reaction mixture was filtered to afford the crude product. One representative diastereoisomer was obtained by recrystallization from 95% EtOH. Due to many chiral centers in our products, some products have more than two diastereoisomers. Therefore, we selected the two major diastereoisomers to illustrate the phenomenon and one representative diastereoisomer to identify the structure of products.

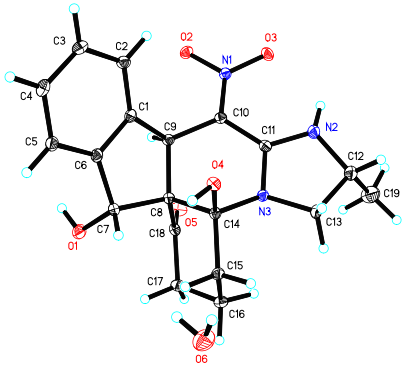
4. Crystal Structure of Products

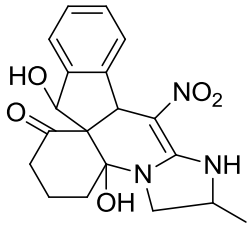




5a

CCDC 1404844



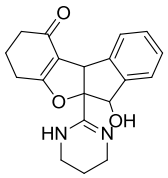


6b

CCDC 1404849

CCDC 1404844 (**5a**) and CCDC 1404849 (**6b**) contain the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data-request/cif.

5. Characterization data of products



6-hydroxy-5a-(1,4,5,6-tetrahydropyrimidin-2-yl)-2,3,4,5a,6,10b-hexahydro-1H-indeno[2,1-b]benzofuran-1-one (5a)

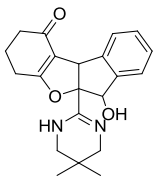
The products of all diastereoisomers were obtained in 77% (250.3 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after filtration according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.01 (s, 2H), 7.32-7.34 (m, 4H), 6.86 (br, 1H) 5.54 (s, 1H), 4.74 (s, 1H), 3.36 (br, 4H), 2.74-2.67 (m, 1H), 2.44-2.39 (m, 1H), 2.32-2.18 (m, 2H), 1.97-1.80 (m, 4H) .

^{13}C NMR (100 MHz, DMSO-d_6) δ 194.1, 176.2, 162.2, 140.6, 140.0, 129.3, 127.9, 124.6, 116.9, 95.1, 80.5, 53.7, 38.6, 36.2, 23.0, 21.1, 17.4.

HRMS (TOF ES^{+}): m/z calcd for $C_{19}H_{21}N_2O_3$ [(M+H) $^{+}$], 325.1552; found, 325.1555.



5a-(5,5-dimethyl-1,4,5,6-tetrahydropyrimidin-2-yl)-6-hydroxy-2,3,4,5a,6,10b-hexahydro-1H-indeno[2,1-b]benzofuran-1-one (5b)

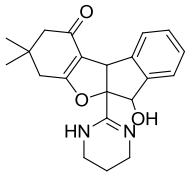
The products of all diastereoisomers were obtained in 74% (261.3 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after crystallization from dichloromethane according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.13 (br, 2H), 7.36-7.31 (m, 4H), 6.74 (br, 1H), 5.53 (s, 1H), 4.74 (s, 1H), 3.13-3.05 (m, 4H), 2.74-2.68 (m, 1H), 2.46-2.40 (m, 1H), 2.30-2.19 (m, 2H), 1.97-1.90 (m, 1H), 1.84-1.81 (m, 1H), 0.98 (s, 6H).

^{13}C NMR (100 MHz, DMSO-d_6) δ 194.1, 176.2, 161.6, 140.7, 139.9, 129.4, 128.0, 124.6, 116.9, 95.1, 80.6, 53.7, 49.5, 36.2, 25.1, 23.3, 23.1, 21.1.

HRMS (TOF ES$^+$): m/z calcd for $C_{21}H_{25}N_2O_3$ [(M+H) $^+$], 353.1865; found, 353.1863



6-hydroxy-3,3-dimethyl-5a-(1,4,5,6-tetrahydropyrimidin-2-yl)-2,3,4,5a,6,10b-hexahydro-1H-indeno[2,1-b]benzofuran-1-one (5c)

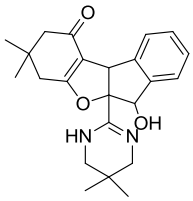
The products of all diastereoisomers were obtained in 85% (300.3 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after crystallization from dichloromethane according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.99 (s, 1H), 7.33-7.29 (m, 4H), 5.57 (s, 1H), 4.72 (s, 1H), 3.36 (br, 4H), 2.62 (d, J = 18.0 Hz, 1H), 2.30-2.24 (m, 2H), 2.08 (d, J = 16.0 Hz, 1H), 1.88-1.86 (m, 2H), 1.03 (s, 3H), 0.80 (s, 3H) .

^{13}C NMR (100 MHz, DMSO-d_6) δ 193.5, 175.1, 162.0, 140.4, 139.8, 129.3, 127.9, 124.5, 124.4, 115.8, 95.7, 80.4, 53.4, 50.4, 38.7, 36.5, 34.0, 28.3, 27.2, 17.5.

HRMS (TOF ES$^+$): m/z calcd for $C_{21}H_{25}N_2O_3$ [(M+H) $^+$], 353.1865; found, 353.1865



5a-(5,5-dimethyl-1,4,5,6-tetrahydropyrimidin-2-yl)-6-hydroxy-3,3-dimethyl-2,3,4,5a,6,10b-hexahydro-1H-indeno[2,1-b]benzofuran-1-one (5d)

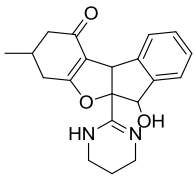
The products of all diastereoisomers were obtained in 31% (118.2 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after crystallization from dichloromethane according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.08 (s, 1H), 7.36-7.34 (m, 3H), 7.29-7.27 (m, 1H), 6.68 (br, 1H), 5.54 (s, 1H), 4.72 (s, 1H), 3.14-3.05 (m, 4H), 2.64-2.59 (m, 1H), 2.33-2.23 (m, 2H), 2.14-2.10 (m, 2H), 1.02 (s, 3H), 0.98 (s, 6H), 0.84 (s, 3H).

^{13}C NMR (100 MHz, DMSO) δ 193.5, 175.2, 140.5, 139.6, 129.4, 128.0, 124.5, 124.4, 115.7, 95.7, 80.5, 53.4, 50.4, 49.6, 36.5, 34.1, 27.9, 27.5, 25.1, 23.2.

HRMS (TOF ES$^+$): m/z calcd for $C_{23}H_{29}N_2O_3$ [(M+H) $^+$], 381.2178; found, 381.2176.



6-hydroxy-3-methyl-5a-(1,4,5,6-tetrahydropyrimidin-2-yl)-2,3,4,5a,6,10b-hexahydro-1H-indeno[2,1-b]benzofuran-1-one (5e)

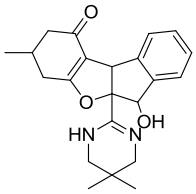
The products of all diastereoisomers were obtained in 70% (237.4 mg) yield.

Two diastereoisomer mixture: The product was isolated as a white solid after crystallization from dichloromethane according to the general procedure.

^{1}H NMR (400 MHz, DMSO) δ 9.98 (s, 4H，both dia), 7.75-6.97 (m, 8H, both dia), 6.74(br, 2H, both dia), 5.54 (s, 2H, both dia), 4.74 (s, 1H, major dia), 4.72 (s, 1H, minor dia), 3.36 (br, 8H, both dia), 2.81-2.77 (m, 1H, major dia), 2.54-2.50 (m,1H, minor dia), 2.42-2.10 (m, 6H, both dia) .2.06-1.99 (m, 2H, both dia), 1.89 (br, 4H, both dia), 1.02 (d, *J* = 6.4 Hz, 3H, major dia), 0.95 (d, *J* = 6.4 Hz, 3H, minor dia).

^{13}C NMR (100 MHz, DMSO) δ 193.7, 193.7, 175.8, 162.1, 140.6, 140.1, 139.8, 129.3, 129.2, 127.9, 124.6, 116.8, 116.5, 95.5, 95.3, 80.5, 80.4, 53.6, 53.6, 44.5, 44.4, 38.7, 30.9, 30.6, 29.3, 29.2, 20.4, 20.3, 17.5.

HRMS (TOF ES$^+$): m/z calcd for $C_{20}H_{23}N_2O_3$ [(M+H) $^+$], 339.1709; found, 339.1706



5a-(5,5-dimethyl-1,4,5,6-tetrahydropyrimidin-2-yl)-6-hydroxy-3-methyl-2,3,4,5a,6,10b-hexahydro-1H-indeno[2,1-b]benzofuran-1-one (5f)

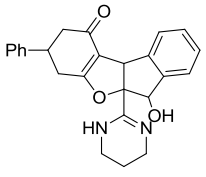
The products of all diastereoisomers were obtained in 64% (235.0 mg) yield.

Two diastereoisomer mixture: The product was isolated as a white solid after crystallization from dichloromethane according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.12 (br, 4H, both dia), 7.33 (m, 8H, both dia), 6.71 (br, 2H, both dia), 5.53 (s, 2H, both dia), 4.74 (s, 1H, major dia), 4.72 (s, 1H, minor dia), 3.19-2.97 (m, 8H, both dia), 2.80 (d, *J* = 13.2 Hz, 1H, major dia), 2.57- 2.47 (m, 1H, minor dia), 2.46-1.96 (m, 8H, both dia), 1.05-0.86 (m, 18H, both dia).

^{13}C NMR (100 MHz, DMSO-d_6) δ 193.7, 175.9, 175.8, 161.5, 140.6, 140.0, 139.7, 129.4, 129.3, 128.0, 124.6, 124.6, 124.5, 116.7, 116.4, 95.5, 95.3, 80.6, 80.5, 53.7, 53.6, 49.6, 44.5, 44.4, 30.9, 30.6, 29.3, 29.2, 25.1, 23.3, 20.3, 20.3.

HRMS (TOF ES$^+$): m/z calcd for $C_{22}H_{27}N_2O_3$ [(M+H) $^+$], 367.2022; found, 367.2019.



6-hydroxy-3-phenyl-5a-(1,4,5,6-tetrahydropyrimidin-2-yl)-2,3,4,5a,6,10b-hexahydro-1H-indeno[2,1-b]benzofuran-1-one (5g)

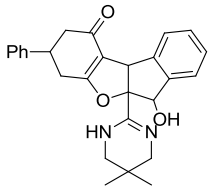
The products of all diastereoisomers were obtained in 72% (288.9 mg) yield.

Two diastereoisomer mixture: The product was isolated as a white solid after crystallization from dichloromethane according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.96 (br, 4H, both dia), 7.41-7.18 (m, 18H, both dia), 6.67 (br, 2H, both dia), 5.56 (s, 2H, both dia), 4.82 (s, 1H, major dia), 4.78 (s, 1H, minor dia), 3.36-3.20 (m, 8H, both dia), 3.05-2.55 (m, 8H, both dia), 2.47-2.33 (m, 2H, both dia), 1.91 (br, 4H, both dia).

^{13}C NMR (100 MHz, DMSO-d_6) δ 193.68, 193.65, 175.76, 162.11, 140.57, 140.08, 139.81, 129.31, 129.22, 127.94, 124.56, 116.81, 116.46, 95.53, 95.32, 80.50, 80.40, 53.63, 53.57, 44.51, 44.44, 38.66, 30.92, 30.58, , 29.25, 29.18, ,20.43, 20.28, 17.45.

HRMS (TOF ES$^+$): m/z calcd for $C_{25}H_{25}N_2O_3$ [(M+H) $^+$], 401.1865, found, 401.1864.



5a-(5,5-dimethyl-1,4,5,6-tetrahydropyrimidin-2-yl)-6-hydroxy-3-phenyl-2,3,4,5a,6,10b-hexahydro-1H-indeno[2,1-b]benzofuran-1-one (5h)

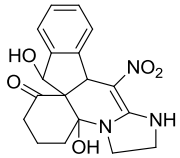
The products of all diastereoisomers were obtained in 54% (231.8 mg) yield.

Two diastereoisomer mixture: The product was isolated as a white solid after crystallization from dichloromethane according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.23 (br, 4H, both dia), 7.66-7.04 (m, 18H, both dia), 5.59 (s, 1H, major dia), 5.58 (s, 1H, minor dia), 4.82 (s, 1H, major dia), 4.79 (s, 1H, minor dia), 3.49-3.36 (m, 2H, both dia), 3.36-3.18 (m, 1H, major dia), 3.11-2.88 (m, 9H, both dia), 2.85-2.53 (m, 4H, both dia), 2.50-2.28 (m, 2H, both dia), 1.00 (s, 6H, both dia), 0.98 (s, 6H, both dia).

^{13}C NMR (100 MHz, DMSO-d_6) δ 192.72, 175.72, 175.43, 161.48, 142.80, 142.66, 140.71, 140.67, 139.88, 139.47, 129.42, 129.27, 128.52, 128.49, 128.04, 127.01, 127.00, 126.79, 124.68, 124.62, 124.60, 124.55, 117.00, 116.67, 95.73, 95.55, 80.57, 80.38, 53.80, 53.63, 49.57, 43.91, 43.47, 30.46, 30.08, 25.13, 23.35.

HRMS (TOF ES$^+$): m/z calcd for $C_{27}H_{29}N_2O_3$ [(M+H) $^+$], 429.2178; found, 429.2177.



4a,14-dihydroxy-9-nitro-2,3,4,4a,7,8,9a,14-octahydroimidazo[1,2-a]indeno[1,2-d]quinolin-1(6H)-one (6a)

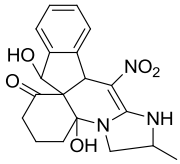
The products of all diastereoisomers were obtained in 84% (319.3 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after crystallization from 95% EtOH according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.32 (s, 1H), 7.30-6.85 (m, 4H), 5.73 (s, 1H), 5.55 (d, J = 7.2 Hz, 1H), 5.35 (s, 1H), 5.27 (d, J = 7.2 Hz, 1H), 3.64-3.62 (m, 1H), 3.44-3.47 (m, 3H), 2.80-2.72 (m, 1H), 2.49-2.37 (m, 1H), 2.27-2.23 (m, 1H), 1.97-1.94 (m, 2H), 1.49-1.48 (m, 1H).

^{13}C NMR (100 MHz, DMSO-d_6) δ 208.0, 156.6, 142.4, 141.3, 126.7, 125.9, 123.2, 121.2, 105.3, 86.5, 79.0, 71.1, 42.3, 42.0, 39.0, 31.7, 19.4.

HRMS (TOF ES$^+$): m/z calcd for $C_{18}H_{19}N_3O_5Na$ [(M+Na) $^+$], 380.1222; found, 380.1224



4a,14-dihydroxy-7-methyl-9-nitro-2,3,4,4a,7,8,9a,14-octahydroimidazo[1,2-a]indeno[1,2-d]quinolin-1(6H)-one (6b)

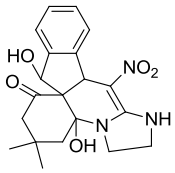
The products of all diastereoisomers were obtained in 77% (303.5 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after crystallization from 95% EtOH according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.40 (s, 1H), 7.20-7.04 (m, 4H), 5.70 (s, 1H), 5.54 (d, *J* = 8.8 Hz, 1H), 5.35 (s, 1H), 5.26 (d, *J* = 8.8 Hz, 1H), 3.93 (br, 1H), 3.60-3.64 (m, 1H), 3.00-2.95 (m, 1H), 2.72-2.80 (m, 1H), 2.36-2.42 (m, 1H), 2.26-2.23 (m, 1H), 1.94 (m, 2H), 1.60-1.40 (m, 1H), 1.27 (d, *J* = 6.0 Hz, 3H).

^{13}C NMR (100 MHz, DMSO-d_6) δ 205.3, 156.5, 145.0, 143.1, 127.5, 125.9, 124.3, 123.5, 105.6, 85.5, 76.6, 68.3, 50.4, 49.7, 38.7, 31.9, 19.3, 19.2.

HRMS (TOF ES$^+$): m/z calcd for $C_{19}H_{21}N_3O_5Na$ [(M+Na) $^+$], 394.1379; found, 394.1378.



4a,14-dihydroxy-3,3-dimethyl-9-nitro-2,3,4,4a,7,8,9a,14-octahydroimidazo[1,2-a]indeno[1,2-d]quinolin-1(6H)-one (6c)

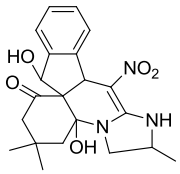
The products of all diastereoisomers were obtained in 86% (332.1 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after crystallization from 95% EtOH according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.32 (s, 1H), 7.09-7.18 (m, 4H), 5.61 (s, 1H), 5.56 (d, *J* = 7.2 Hz, 1H), 5.31 (s, 1H), 5.27 (d, *J* = 7.2 Hz, 1H), 3.59-3.61 (m, 2H), 3.39 (br, 2H), 2.92 (d, *J* = 12.8 Hz, 1H), 2.25 (d, *J* = 15.2 Hz, 1H), 2.03 (d, *J* = 13.2 Hz, 2H), 1.12 (s, 3H), 0.98 (s, 3H).

^{13}C NMR (100 MHz, DMSO-d_6) δ 205.4, 156.0, 144.7, 143.5, 127.5, 126.0, 124.2, 123.3, 106.0, 85.2, 77.1, 67.7, 52.6, 44.1, 43.3, 41.6, 38.8, 32.7, 31.9, 24.9.

HRMS (TOF ES$^+$): m/z calcd for $C_{20}H_{24}N_3O_5$ [(M+H) $^+$], 386.1716; found, 386.1717.



4a,14-dihydroxy-3,3,7-trimethyl-9-nitro-2,3,4,4a,7,8,9a,14-octahydroimidazo[1,2-a]indeno[1,2-d]quinolin-1(6H)-one (6d)

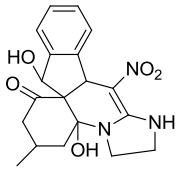
The products of all diastereoisomers were obtained in 69% (291.3 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after crystallization from 95% EtOH according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.48 (s, 1H), 7.03-7.16 (m, 4H), 6.29 (d, J = 8.0 Hz, 1H), 5.35 (s, 1H), 5.14 (d, J = 8.0 Hz, 1H), 4.94 (s, 1H), 3.99 (br, 1H), 3.55-3.57 (m, 1H), 3.32-3.21 (m, 1H), 3.07-2.85 (m, 1H), 2.88-2.65 (m, 1H), 2.20 (br, 1H), 1.89 (br, 1H), 1.22-0.88 (m, 9H).

^{13}C NMR (100 MHz, DMSO-d_6) δ 207.5, 154.6, 142.4, 141.0, 126.9, 126.2, 123.5, 121.4, 105.1, 86.33, 78.5, 67.7, 52.2, 49.5, 49.0, 43.5, 32.3, 21.0.

HRMS (TOF ES$^+$): m/z calcd for $C_{21}H_{25}N_3O_5Na$ [(M+Na) $^+$], 422.1692; found, 422.1694.



4a,14-dihydroxy-3-methyl-9-nitro-2,3,4,4a,7,8,9a,14-octahydroimidazo[1,2-a]indeno[1,2-d]quinolin-1(6H)-one (6e)

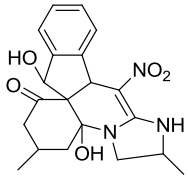
The products of all diastereoisomers were obtained in 84% (331.1 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after crystallization from 95% EtOH according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.32 (s, 1H), 7.32-7.01 (m, 4H), 5.73 (s, 1H), 5.56 (d, J = 4.0 Hz, 1H), 5.35 (s, 1H), 5.26 (d, J = 4.0 Hz, 1H), 3.65 (br, 1H), 3.56-3.39 (m, 3H), 2.68-2.58 (m, 1H), 2.28 (br, 1H), 2.13 (br, 1H), 2.03-1.90 (m, 1H), 1.73 (br, 1H), 1.07 (s, 3H).

^{13}C NMR (100 MHz, DMSO-d_6) δ 204.8, 156.8, 145.0, 143.1, 127.5, 125.9, 124.2, 123.5, 105.9, 84.9, 76.6, 67.5, 46.9, 42.9, 42.1, 26.4, 21.4.

HRMS (TOF ES$^+$): m/z calcd for $C_{19}H_{21}N_3O_5Na$ [(M+Na) $^+$], 394.1379; found, 394.1378.



4a,14-dihydroxy-3,7-dimethyl-9-nitro-2,3,4,4a,7,8,9a,14-octahydroimidazo[1,2-a]indeno[1,2-d]quinolin-1(6H)-one (6f)

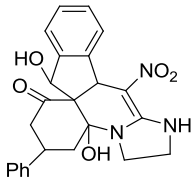
The products of all diastereoisomers were obtained in 69% (281.6 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after crystallization from 95% EtOH according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.44 (s, 1H), 7.25-6.97 (m, 4H), 5.68 (s, 1H), 5.54 (d, J = 7.2 Hz, 1H), 5.33 (s, 1H), 5.25 (d, J = 7.2 Hz, 1H), 4.12 – 3.83 (m, 1H), 3.54-3.59 (m, 1H), 3.11 (d, J = 9.2 Hz, 1H), 2.53-2.56 (m, 1H), 2.29 (m, 1H), 2.09-2.17 (m, 1H), 1.93-1.96 (m, 1H), 1.60 (br, 1H), 1.05-1.07 (m, 6H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 205.7, 156.4, 145.9, 144.0, 128.4, 126.8, 125.2, 124.4, 106.6, 85.6, 77.5, 68.4, 50.3, 50.1, 47.8, 41.2, 27.7, 22.3, 21.4.

HRMS (TOF ES$^+$): m/z calcd for $C_{20}H_{23}N_3O_5Na$ [(M+Na) $^+$], 408.1535; found, 408.1532.



4a,14-dihydroxy-9-nitro-3-phenyl-2,3,4,4a,7,8,9a,14-octahydroimidazo[1,2-a]indeno[1,2-d]quinolin-1(6H)-one (6g)

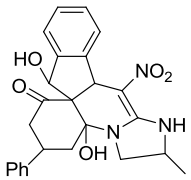
The products of all diastereoisomers were obtained in 85% (369.1 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after crystallization from 95% EtOH according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.37 (s, 1H), 7.45-7.39 (m, 4H), 7.28 – 7.13 (m, 5H), 5.85 (s, 1H), 5.71 (br, 1H), 5.45 (br, *1*H), 5.41(br, 1H), 3.88 – 3.81 (m, 4H), 3.13-3.07 (m,1H), 2.97 (br, 1H), 2.67-2.61 (m, 1H), 2.43-2.41 (m, 1H), 2.089-2.06 (m, 1H).

^{13}C NMR (100 MHz, DMSO-d_6) δ 204.3, 156.8, 144.9, 143.1, 143.0, 128.7, 127.6, 126.9, 126.8, 126.0, 125.9, 124.3, 123.6, 105.9, 84.8, 76.6, 67.8, 45.9, 42.9, 42.2, 36.5.

HRMS (TOF ES$^+$): m/z calcd for $C_{24}H_{24}N_3O_5$ [(M+H) $^+$], 434.1716; found, 434.1717.



4a,14-dihydroxy-7-methyl-9-nitro-3-phenyl-2,3,4,4a,7,8,9a,14-octahydroimidazo[1,2-a]indeno[1,2-d]quinolin-1(6H)-one (6h)

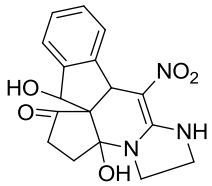
The products of all diastereoisomers were obtained in 59% (264.4 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after crystallization from 95% EtOH according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.51 (s, 1H), 7.44-7.37 (m, 4H), 7.30-7.29 (m, 1H), 7.20-7.13 (m, 4H), 5.83 (s, 1H), 5.71 (d, *J* = 7.2 Hz, 1H), 5.45 (d, *J* = 7.2 Hz, 1H), 5.41 (s, 1H), 4.04 (br, 1H), 3.67-3.62 (m, 1H), 3.23-3.00 (m, 2H), 2.84-2.59 (m, 2H), 2.45 (br, 1H), 2.07-2.10 (m, 1H), 1.21 (d, *J* = 6.0 Hz, 3H).

^{13}C NMR (100 MHz, DMSO-d_6) δ 204.2, 155.5, 144.9, 143.0, 142.8, 128.7, 127.6, 126.9, 126.9, 126.0, 124.3, 123.6, 105.6, 84.6, 76.5, 67.8, 49.6, 49.4, 45.9, 39.2, 37.2, 20.6.

HRMS (TOF ES$^+$): m/z calcd for $C_{25}H_{26}N_3O_5$ [(M+H) $^+$], 448.1872; found, 448.1873.



3a,13-dihydroxy-8-nitro-2,3,3a,5,6,7,8a,13-octahydro-1H-cyclopenta[e]imidazo[1,2-a]indeno[1,2-d]pyridin-1-one (6i)

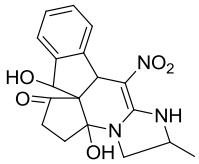
The products of all diastereoisomers were obtained in 67% (245.3 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after crystallization from 95% EtOH according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.28 (s, 1H), 7.31-7.08 (m, 4H), 6.07 (s, 1H), 5.47 (d, *J* = 7.6 Hz, 1H), 5.25 (d, *J* = 7.6 Hz, 1H), 5.13 (s, 1H), 3.72-3.65 (m, 2H), 3.60-3.44 (m, 2H), 2.53-2.46(m, 1H), 2.39-2.32 (m, 2H), 2.28-2.18 (m, 1H).

^{13}C NMR (100 MHz, DMSO-d_6) δ 209.9, 156.2, 144.1, 142.5, 127.9, 126.8, 125.1, 124.1, 104.6, 87.6, 76.3, 67.5, 42.4, 42.2, 39.6, 33.8, 28.9.

HRMS (TOF ES$^+$): m/z calcd for $C_{17}H_{17}N_3O_5Na$ [(M+Na) $^+$], 366.1066; found, 366.1067.



3a,13-dihydroxy-6-methyl-8-nitro-2,3,3a,5,6,7,8a,13-octahydro-1H-cyclopenta[e]imidazo[1,2-a]indeno[1,2-d]pyridin-1-one (6j)

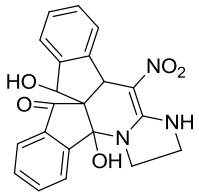
The products of all diastereoisomers were obtained in 83% (315.5 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after crystallization from 95% EtOH according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.38 (s, 1H), 7.33-7.08 (m, 4H), 6.05 (s, 1H), 5.47 (d, J = 7.6 Hz, 1H), 5.24 (d, J = 7.6 Hz, 1H), 5.12 (s, 1H), 3.99-3.96 (m, 1H), 3.83-3.79 (m, 1H), 3.12-3.09 (m, 1H), 2.35-2.19 (m, 4H), 1.26 (d, J = 5.6 Hz, 3H).

^{13}C NMR (100 MHz, DMSO-d_6) δ 209.9, 155.6, 144.1, 142.5, 127.9, 126.8, 125.2, 124.1, 104.2, 87.5, 76.3, 67.2, 50.4, 49.3, 33.7, 28.9, 20.1, 20.0.

HRMS (TOF ES$^+$): m/z calcd for $C_{18}H_{19}N_3O_5Na$ [(M+Na) $^+$], 380.1222; found, 380.1222.



4b,14-dihydroxy-9-nitro-7,8,9a,14-tetrahydro-4bH-imidazo[1,2-a]diindeno[1,2-d:2',1'-e]pyridin-15(6H)-one (8a)

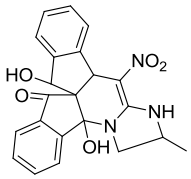
The products of all diastereoisomers were obtained in 75% (290.0 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after crystallization from 95% EtOH according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.10 (s, 1H), 7.93-7.76 (m, 3H), 7.68-7.66 (m, 1H), 7.35-7.11 (m, 4H), 6.10 (s, 1H), 6.02 (d, J = 8.0 Hz, 1H), 5.28 (d, J = 8.0 Hz, 1H), 5.12 (s, 1H), 3.83-3.76 (m, 1H), 3.60-3.57 (m, 1H), 3.47-3.40 (m, 1H), 3.15-3.08(m, 1H).

^{13}C NMR (100 MHz, DMSO-d_6) δ 201.1, 153.5, 152.3, 142.1, 140.3, 135.2, 133.9, 130.1, 127.9, 127.4, 124.3, 124.0, 123.4, 121.8, 104.0, 86.7, 80.7, 73.7, 42.8, 42.0, 39.4.

HRMS (TOF ES$^+$): m/z calcd for $C_{21}H_{17}N_3O_5Na$ [(M+Na) $^+$], 414.1066; found, 414.1064.



4b,14-dihydroxy-7-methyl-9-nitro-7,8,9a,14-tetrahydro-4bH-imidazo[1,2-a]diindeno[1,2-d:2',1'-e]pyridin-15(6H)-one (8b)

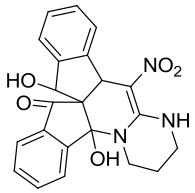
The products of all diastereoisomers were obtained in 65% (278.3 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after crystallization from 95% EtOH according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.25 (s, 1H), 7.83-7.78 (m, 3H), 7.68 -7.66 (m, 1H), 7.32-7.19 (m, 4H), 6.52 (s, 1H), 5.53 (d, *J* = 8.0 Hz, 1H), 5.48 (s, 1H), 4.91 (d, *J* = 8.0 Hz, 1H), 4.12-3.81 (m, 2H), 2.53 (br, 1H), 0.95 (d, *J* = 5.4 Hz, 3H).

^{13}C NMR (100 MHz, DMSO-d_6) δ 197.7, 153.2, 149.7, 144.3, 142.8, 134.2, 130.5, 128.2, 127.1, 125.2, 124.8, 124.1, 123.4, 104.0, 86.2, 79.7, 71.3, 50.0, 49.9, 20.4.

HRMS (TOF ES$^+$): m/z calcd for $C_{22}H_{19}N_3O_5Na$ [(M+Na) $^+$], 428.1222; found, 428.1223.



4b,15-dihydroxy-10-nitro-6,7,8,9,10a,15-hexahydrodiindeno[1',2':4,5;2'',1'':5,6]pyrido[1,2-a] pyrimidin-16(4bH)-one (8c)

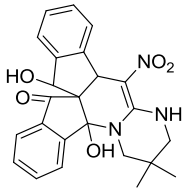
The products of all diastereoisomers were obtained in 84% (359.6 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after crystallization from 95% EtOH according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 12.00 (s, 1H), 7.99-7.61 (m, 4H), 7.34-7.13 (m, 4H), 6.52 (s, 1H), 5.56 (s, 1H), 5.53 (d, *J* = 8.0 Hz, 1H), 4.80 (d, *J* = 8.0 Hz, 1H), 3.77 (br, 1H), 3.50-3.36 (m, 1H), 3.14-3.04 (m, 1H), 2.82-2.66 (m, 1H), 1.72 (s, 2H).

^{13}C NMR (100 MHz, DMSO-d_6) δ 197.8, 151.1, 150.0, 144.0, 142.9, 134.5, 133.8, 130.5, 128.1, 127.0, 126.5, 125.5, 124.1, 123.1, 106.2, 89.3, 80.4, 69.4, 41.5, 38.7, 37.9, 19.0.

HRMS (TOF ES$^+$): m/z calcd for $C_{22}H_{19}N_3O_5Na$ [(M+Na) $^+$], 428.1222; found, 428.1223



4b,15-dihydroxy-7,7-dimethyl-10-nitro-6,7,8,9,10a,15-hexahydrodiindeno[1',2':4,5;2'',1'':5,6] pyrido[1,2-a]pyrimidin-16(4bH)-one (8d)

The products of all diastereoisomers were obtained in 75% (325.6 mg) yield.

Representative diastereoisomer: The product was isolated as a white solid after crystallization from 95% EtOH according to the general procedure.

^{1}H NMR (400 MHz, DMSO-d_6) δ 11.95 (s, 1H), 7.97 (d, *J* = 7.6 Hz, 1H), 7.87 -7.72 (m, 2H), 7.67 (t, *J* = 7.6 Hz, 1H), 7.31-7.13 (m, 4H), 6.66 (s, 1H), 5.56 (s, 1H), 5.53 (d, *J* = 8.0 Hz, 1H), 4.82 (d, *J* = 8.0Hz, 1H), 3.20 (d, *J* = 12.4 Hz, 1H), 3.04-2.94 (m, 2H), 2.80 (d, *J* = 12.4 Hz, 1H), 0.82 (s, 3H), 0.40 (s, 3H).

^{13}C NMR (100 MHz, DMSO-d_6) δ 197.7, 150.6, 150.2, 143.9, 142.8, 134.5, 133.7, 130.6, 128.2, 127.0, 126.4, 125.3, 124.1, 123.2, 106.1, 89.7, 80.3, 69.7, 51.1, 49.3, 26.1, 23.7, 22.5.

HRMS (TOF ES$^+$): m/z calcd for $C_{24}H_{24}N_3O_5$ [(M+H) $^+$], 434.1716; found, 434.1714.

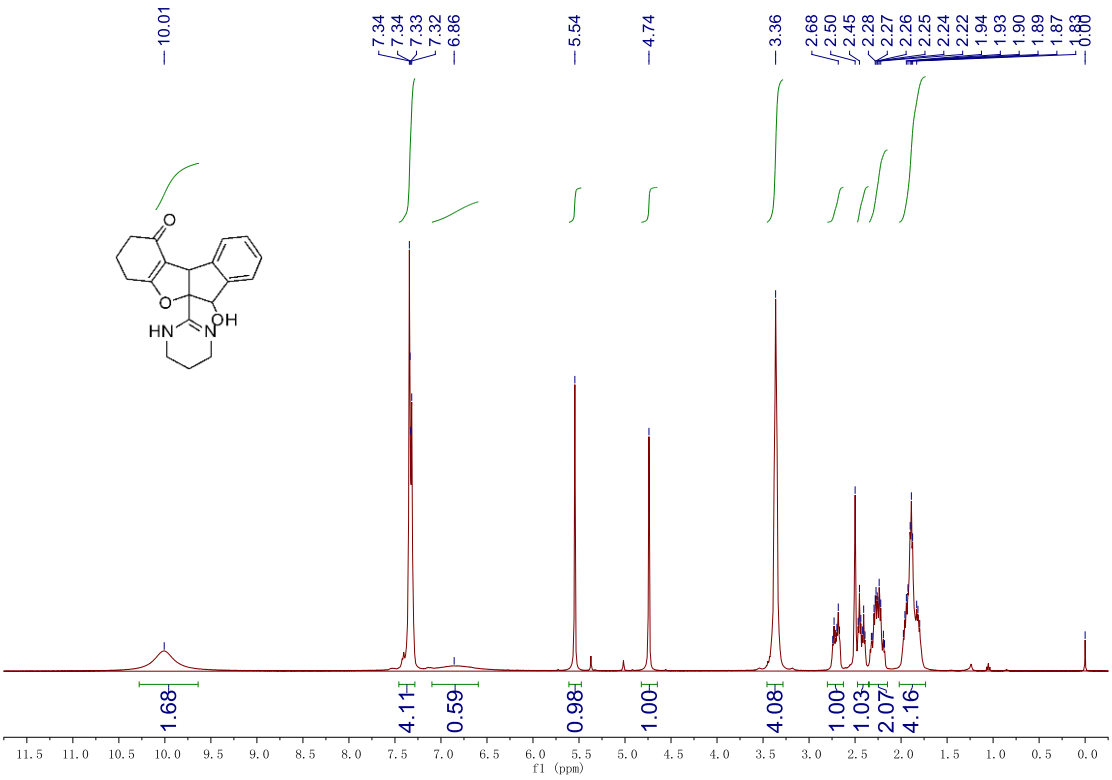


Figure 1. ^{1}H NMR (400 MHz, DMSO) spectra of compound 5a

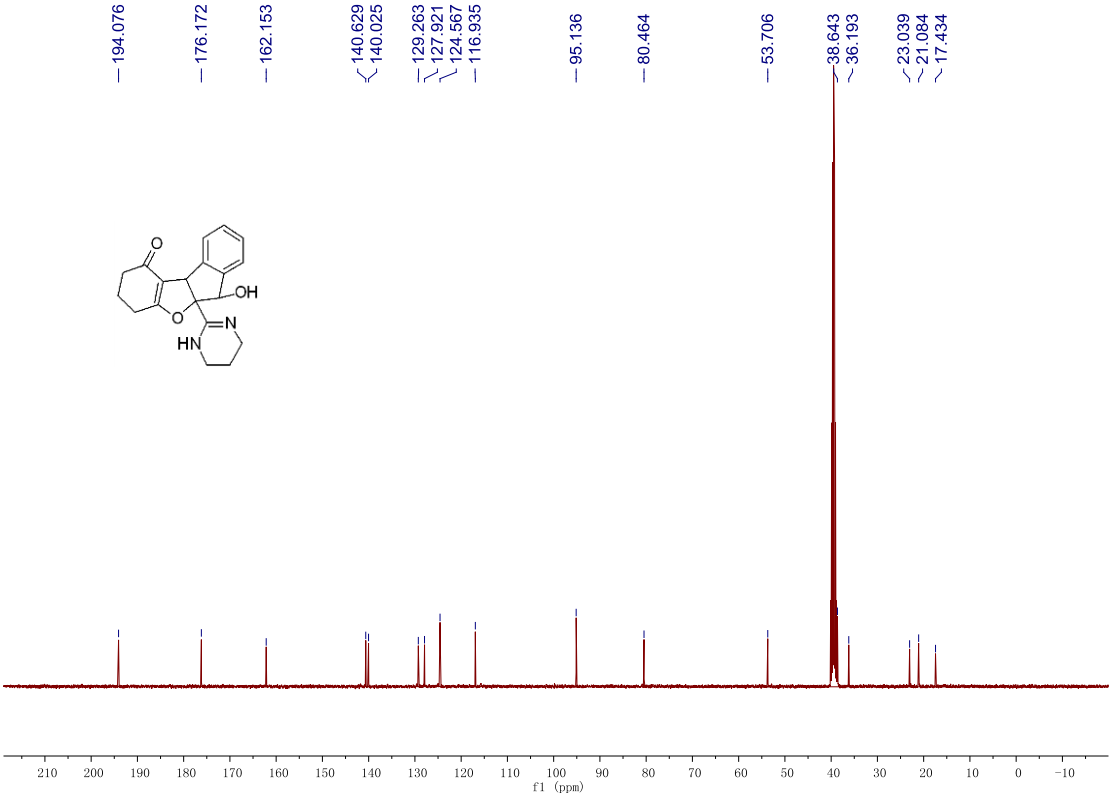


Figure 2. ^{13}C NMR (100 MHz, DMSO) spectra of compound 5a

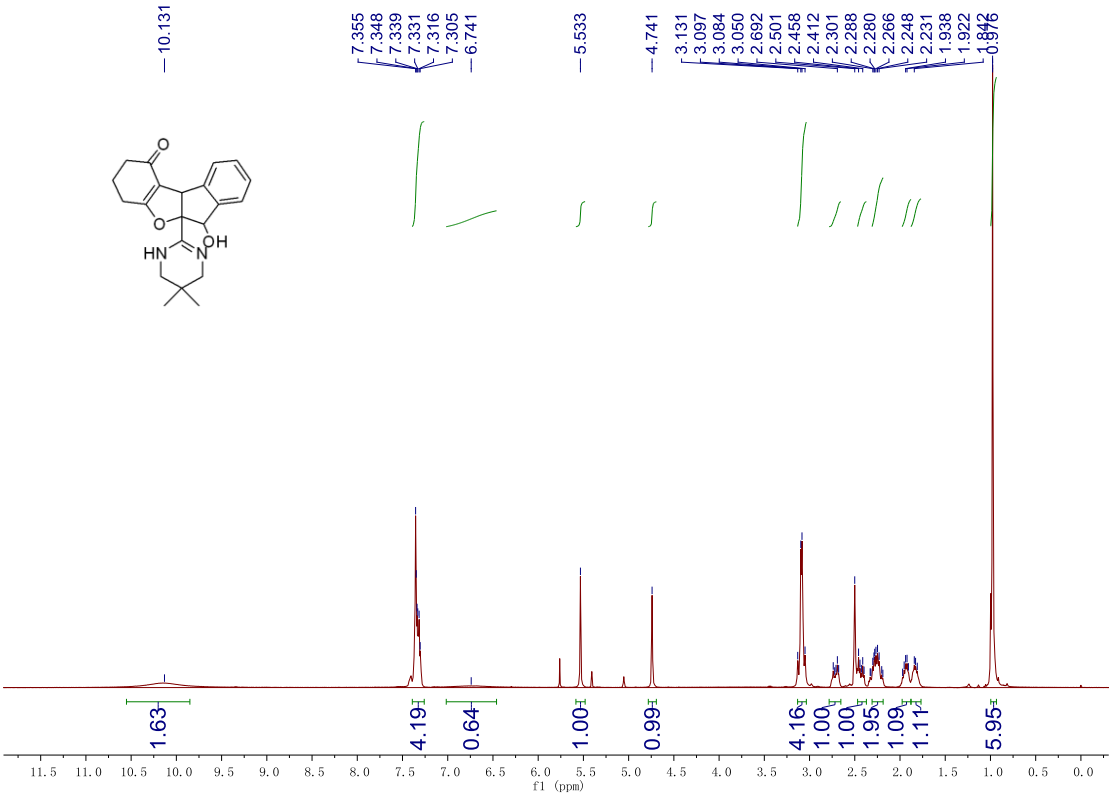


Figure 3. ^{1}H NMR (400 MHz, DMSO) spectra of compound 5b

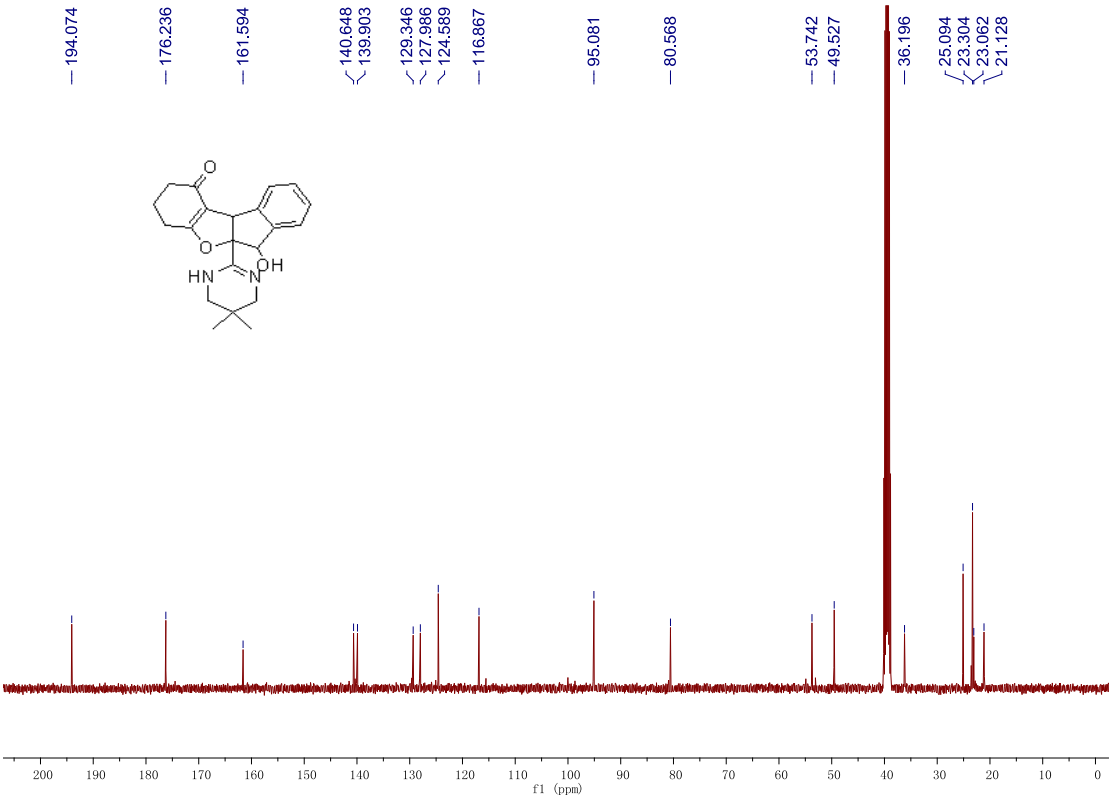


Figure 4. ^{13}C NMR (100 MHz, DMSO) spectra of compound 5b

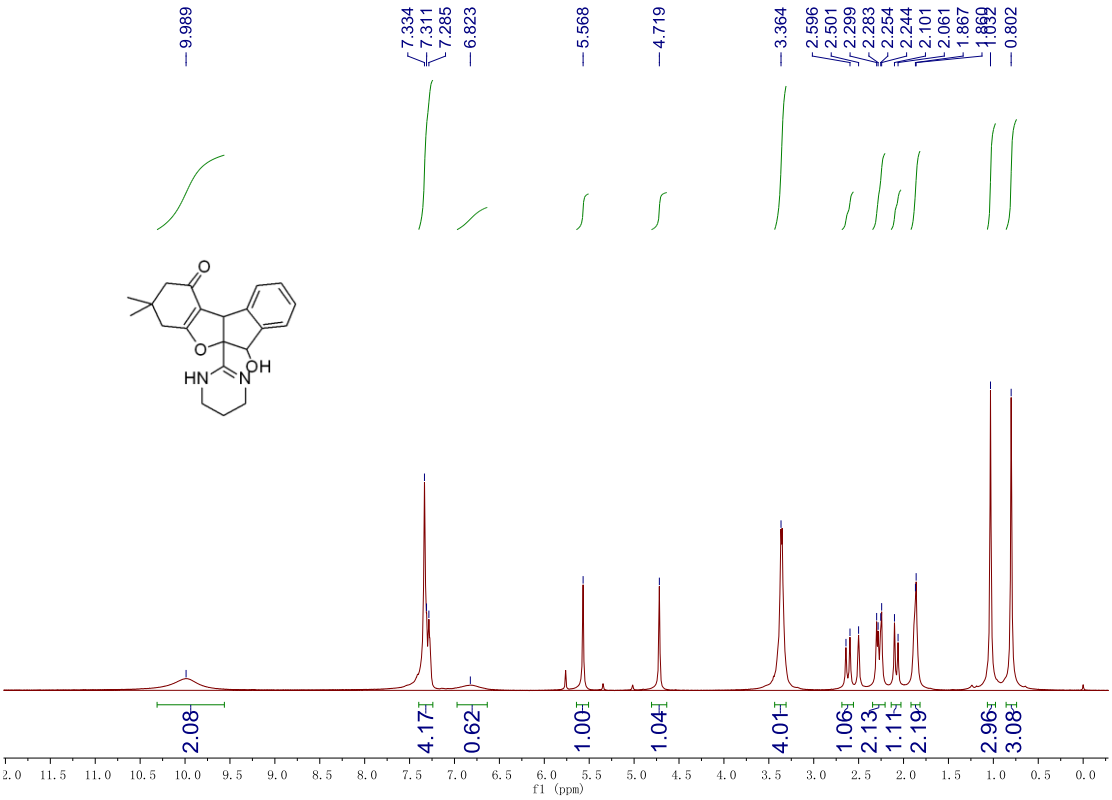


Figure 5. ^{1}H NMR (400 MHz, DMSO) spectra of compound 5c

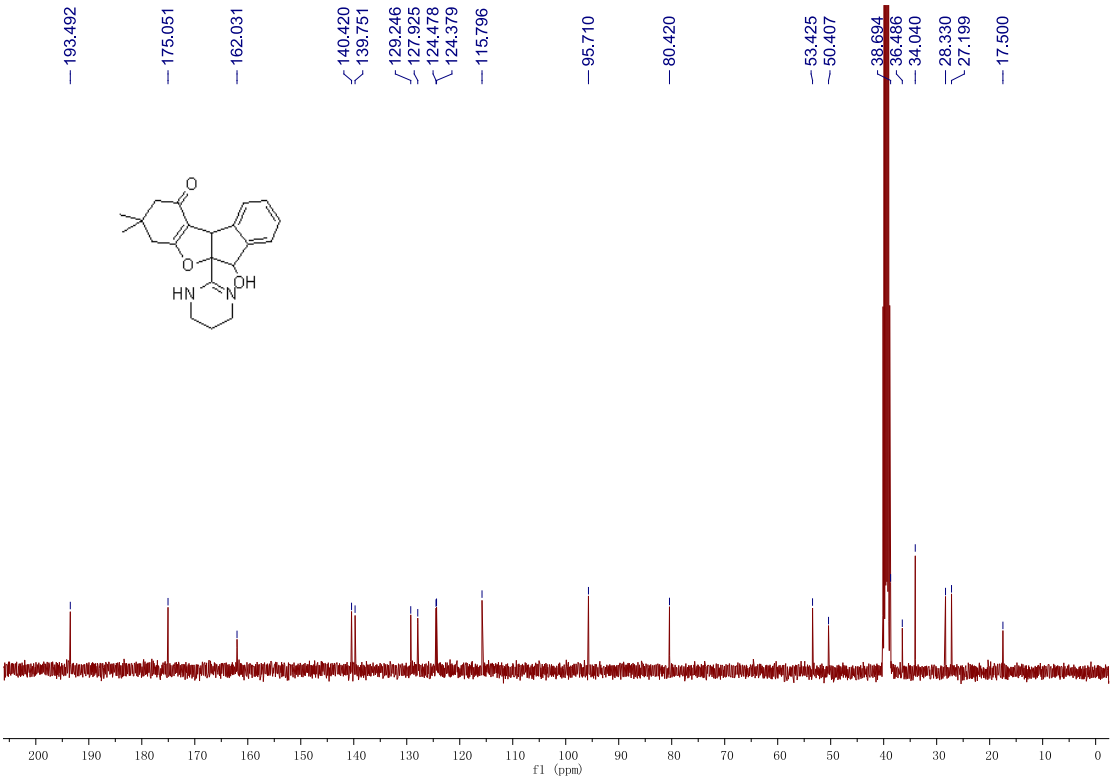


Figure 6. ^{13}C NMR (100 MHz, DMSO) spectra of compound 5c

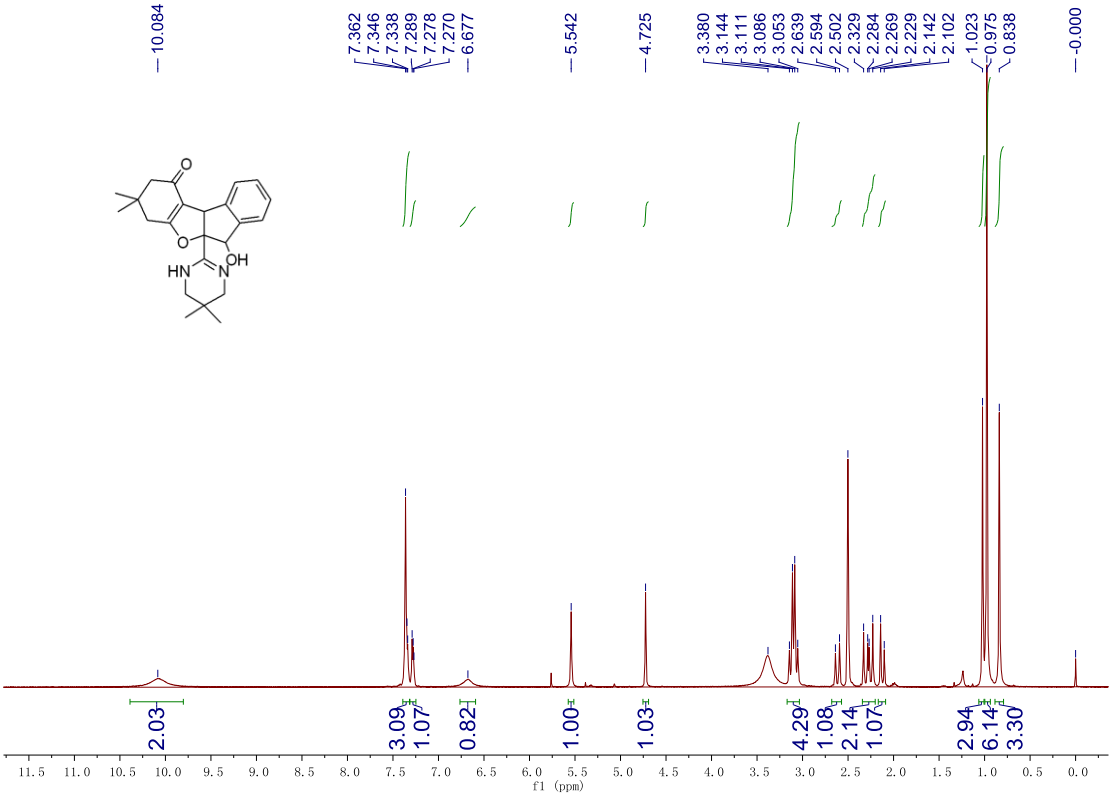


Figure 7. ^{1}H NMR (400 MHz, DMSO) spectra of compound 5d

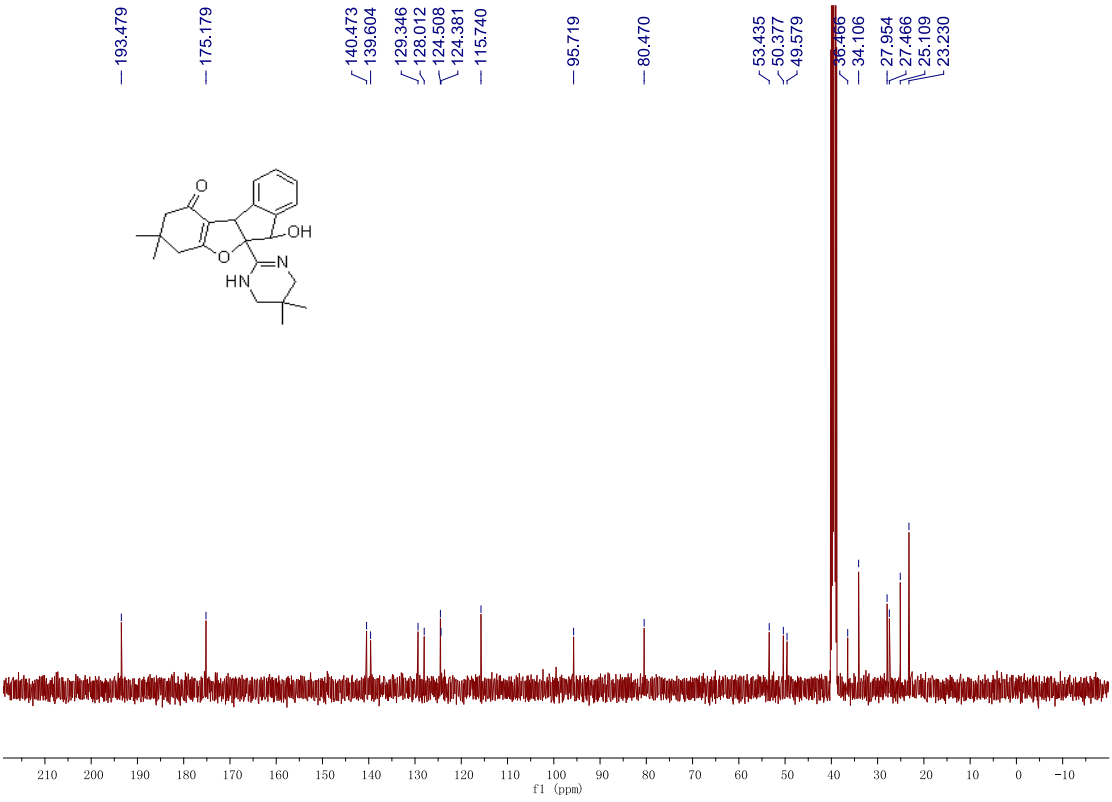


Figure 8. ^{13}C NMR (100 MHz, DMSO) spectra of compound 5d

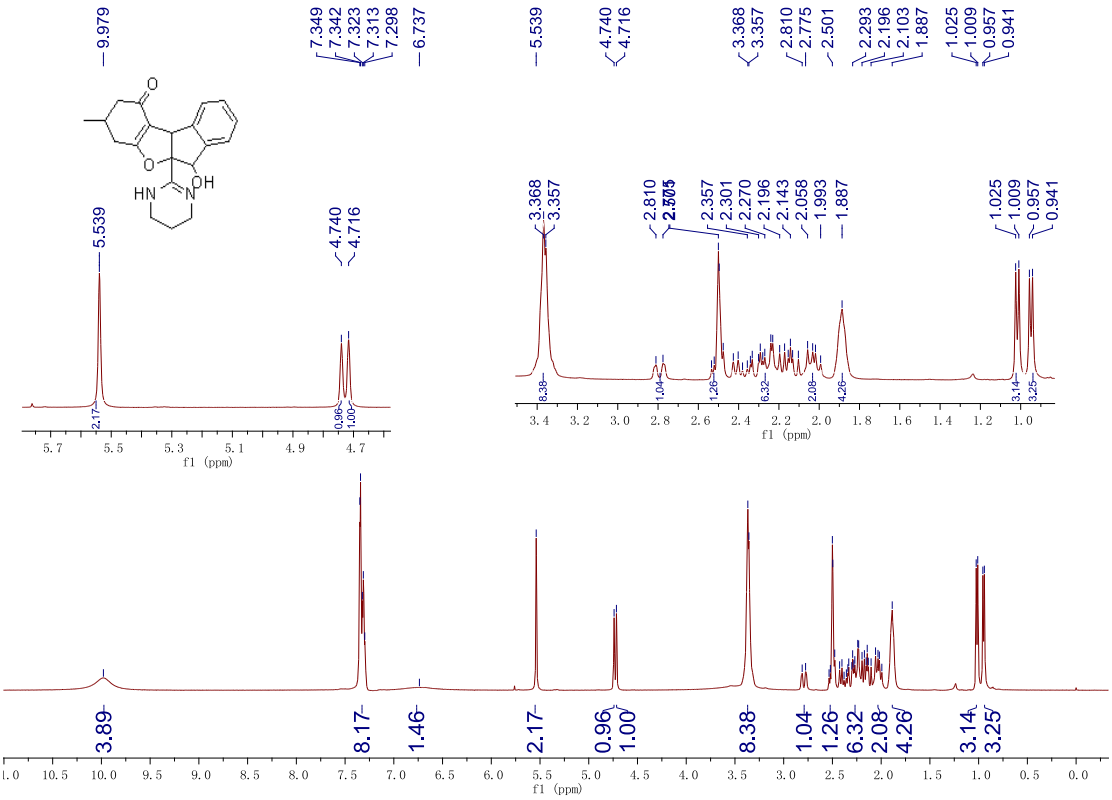


Figure 9. ^{1}H NMR (400 MHz, DMSO) spectra of compound 5e

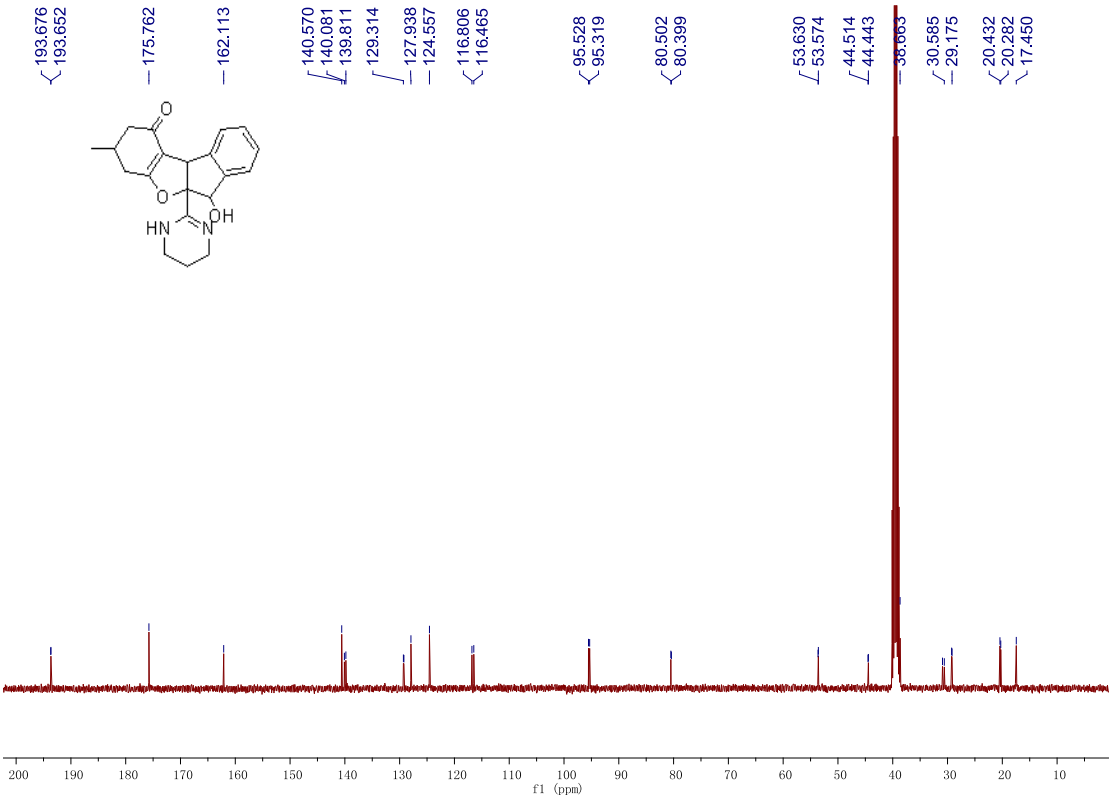


Figure 10. ^{13}C NMR (100 MHz, DMSO) spectra of compound 5e

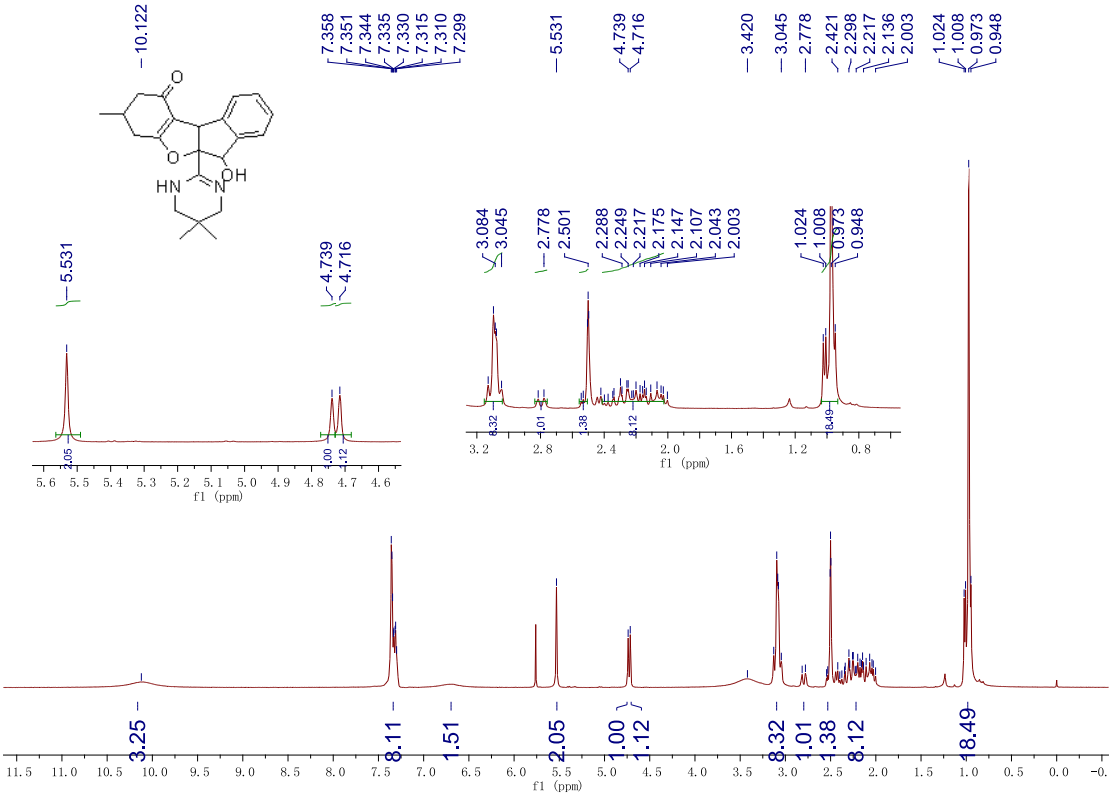


Figure 11. ^{1}H NMR (400 MHz, DMSO) spectra of compound 5f

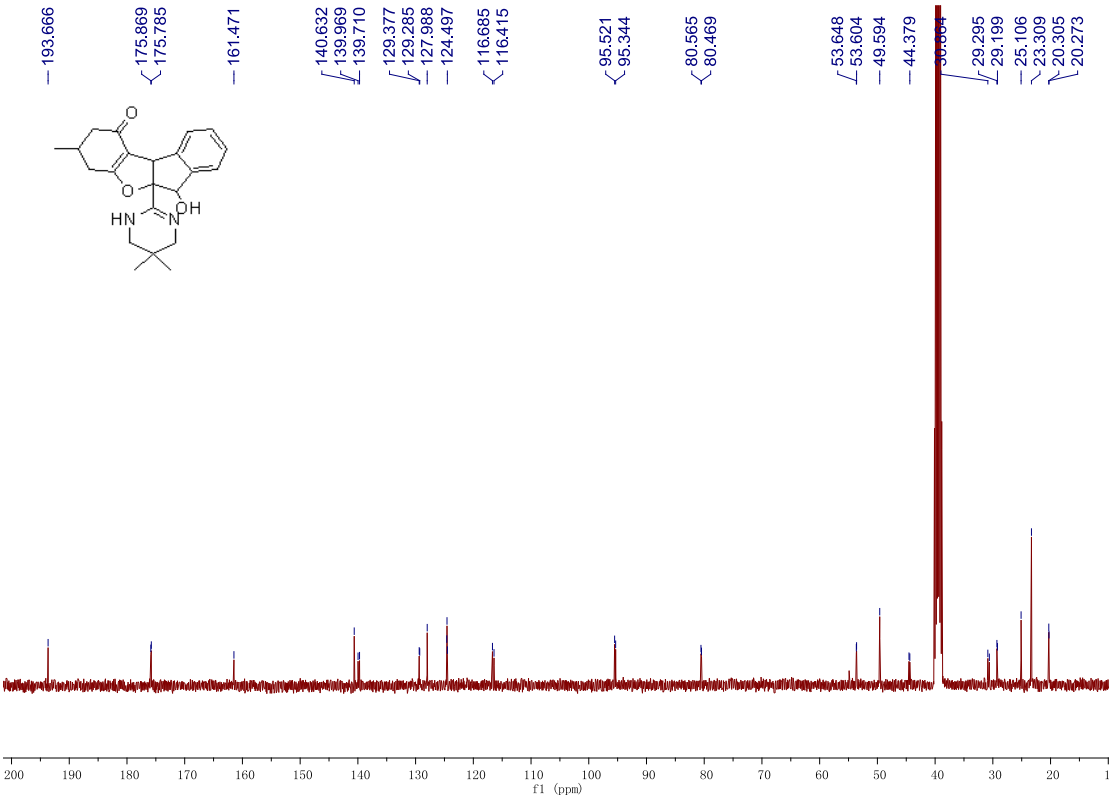


Figure 12. ^{13}C NMR (100 MHz, DMSO) spectra of compound 5f

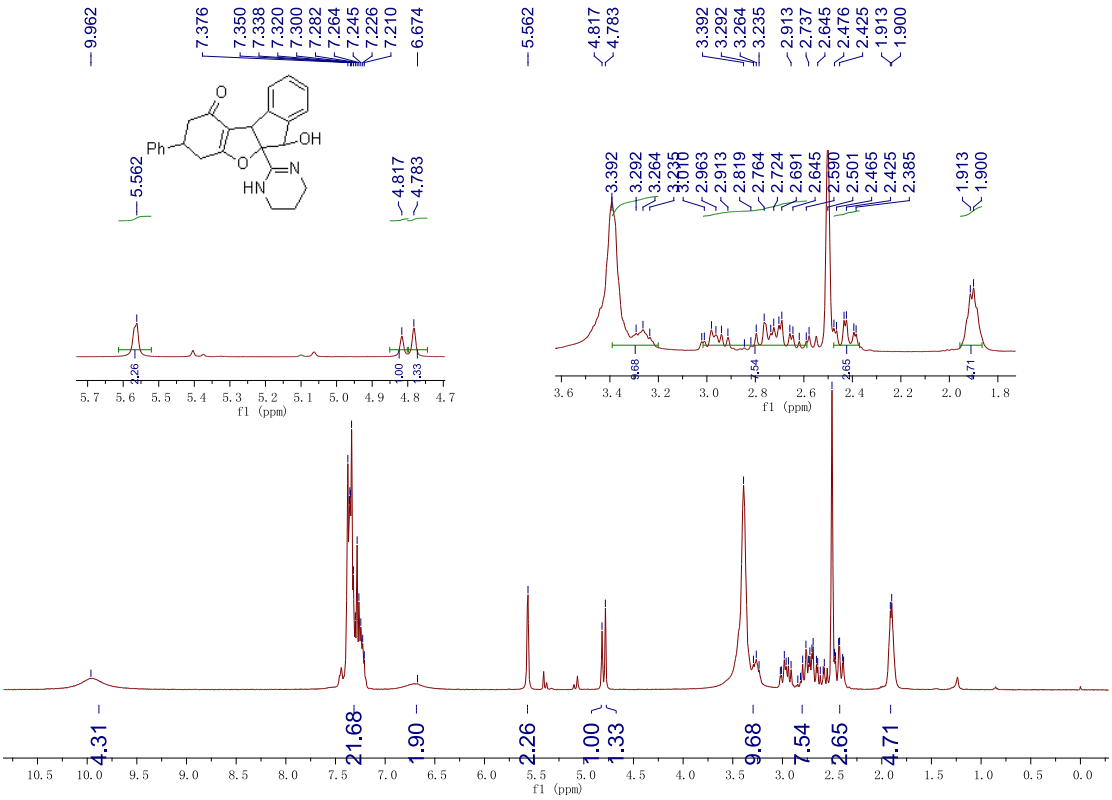


Figure 13. ^{1}H NMR (400 MHz, DMSO) spectra of compound 5g

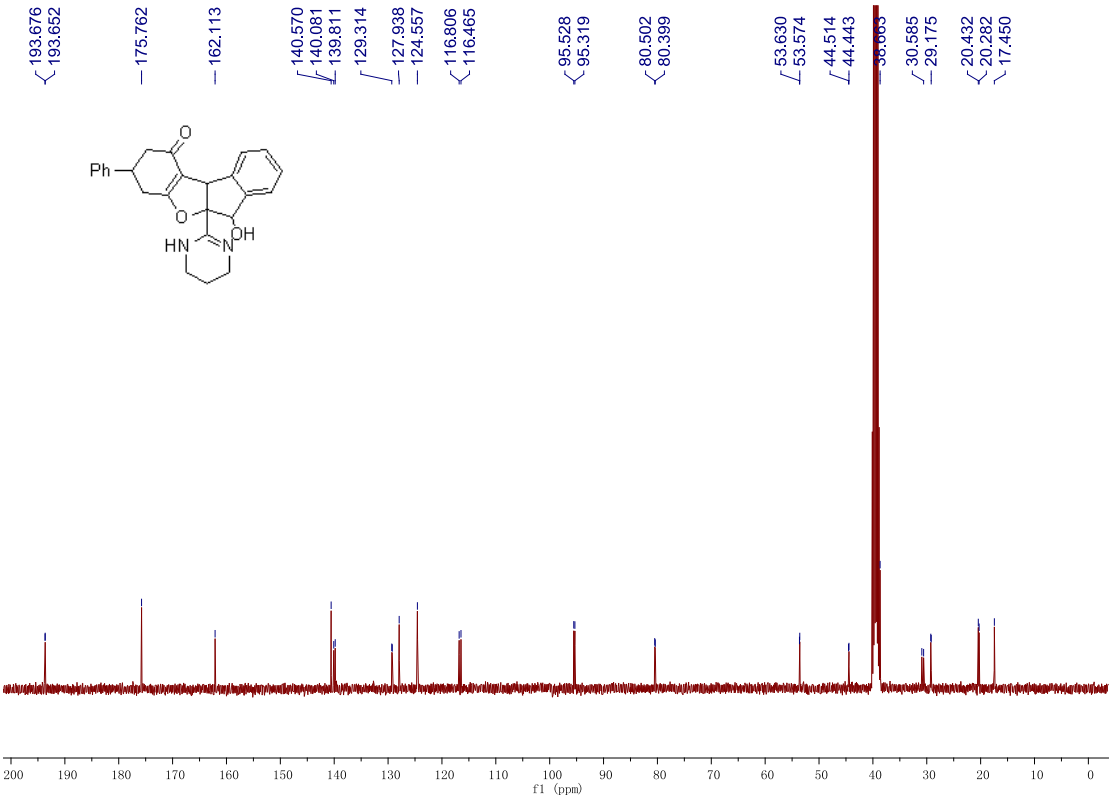


Figure 14. ^{13}C NMR (100 MHz, DMSO) spectra of compound 5g

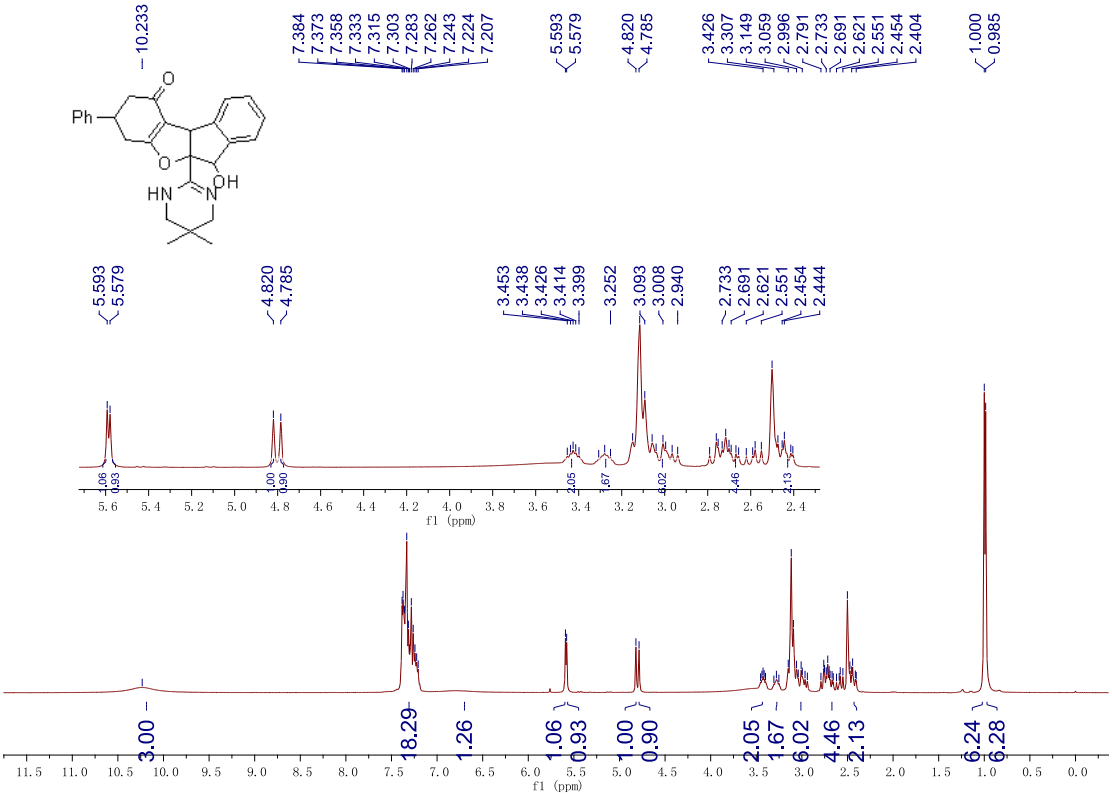


Figure 15. ^{1}H NMR (400 MHz, DMSO) spectra of compound 5h

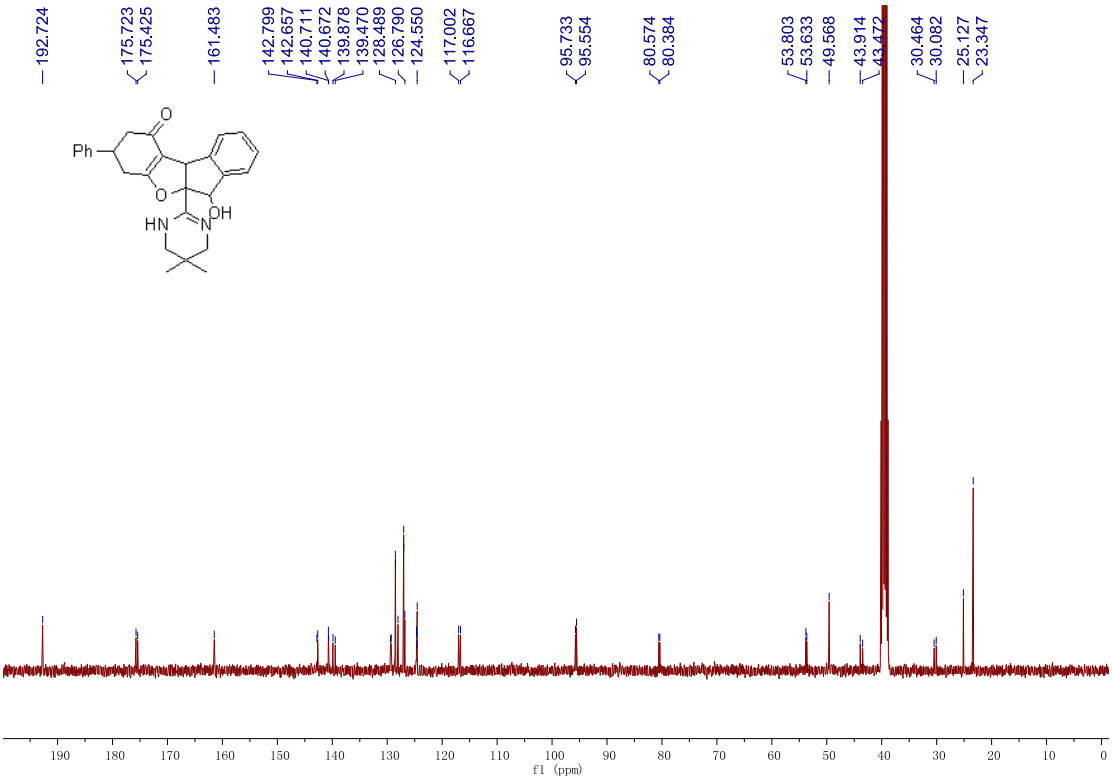


Figure 16. ^{13}C NMR (100 MHz, DMSO) spectra of compound 5h

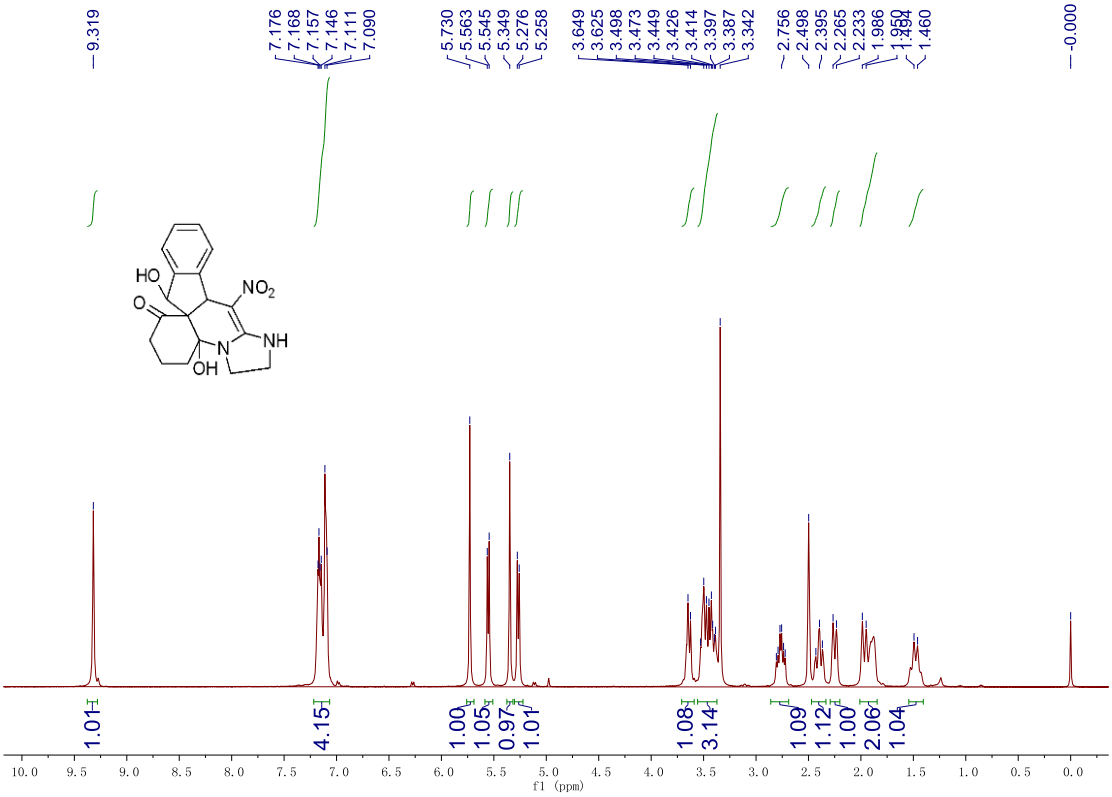


Figure 17. ^{1}H NMR (400 MHz, DMSO) spectra of compound 6a

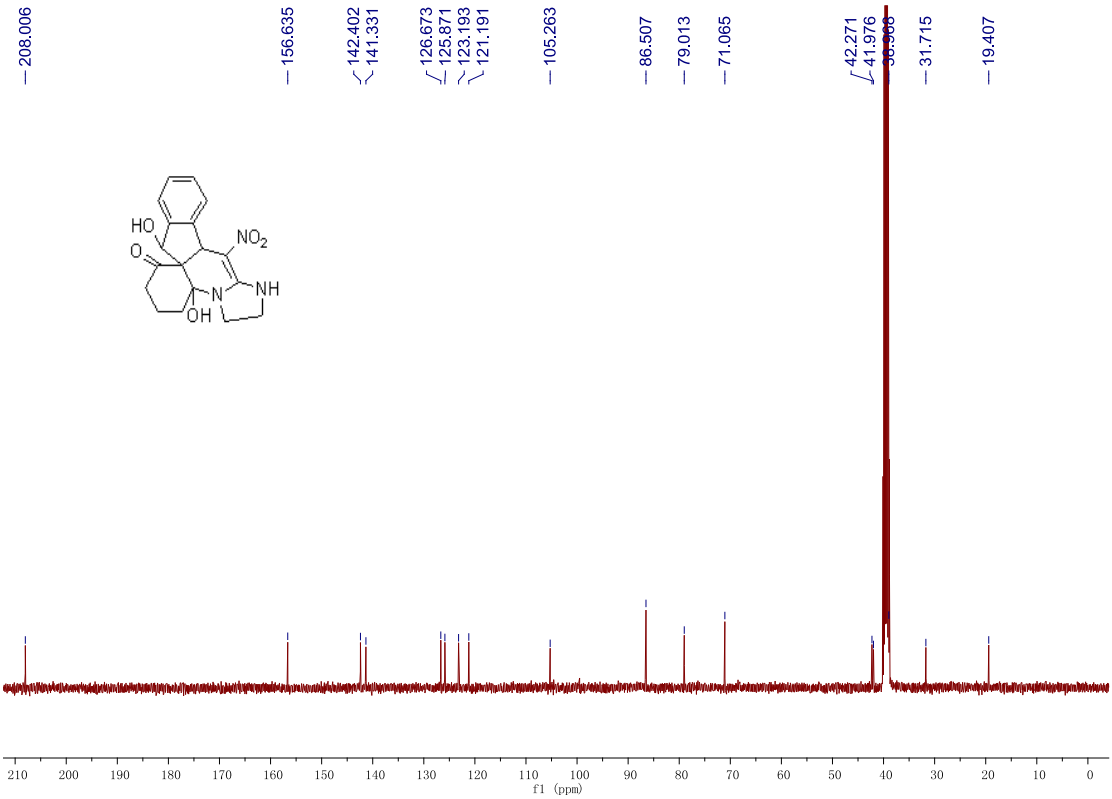


Figure 18. ^{13}C NMR (100 MHz, DMSO) spectra of compound 6a

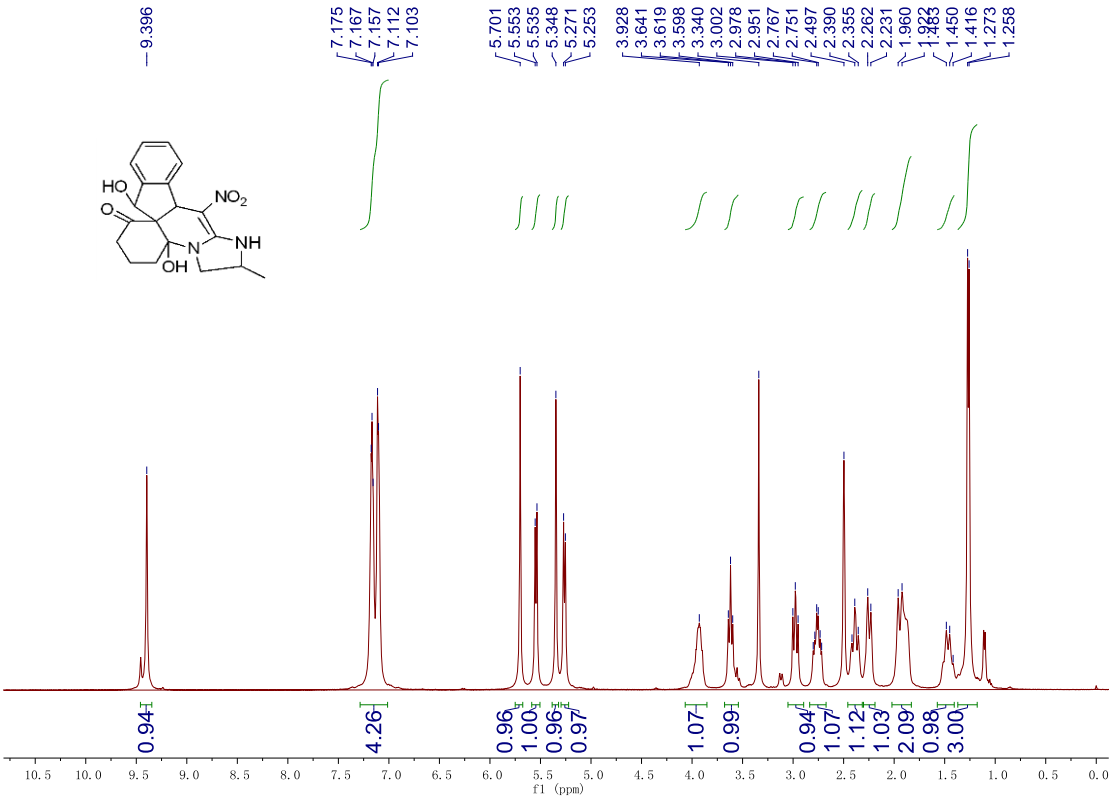


Figure 19. ^{1}H NMR (400 MHz, DMSO) spectra of compound 6b

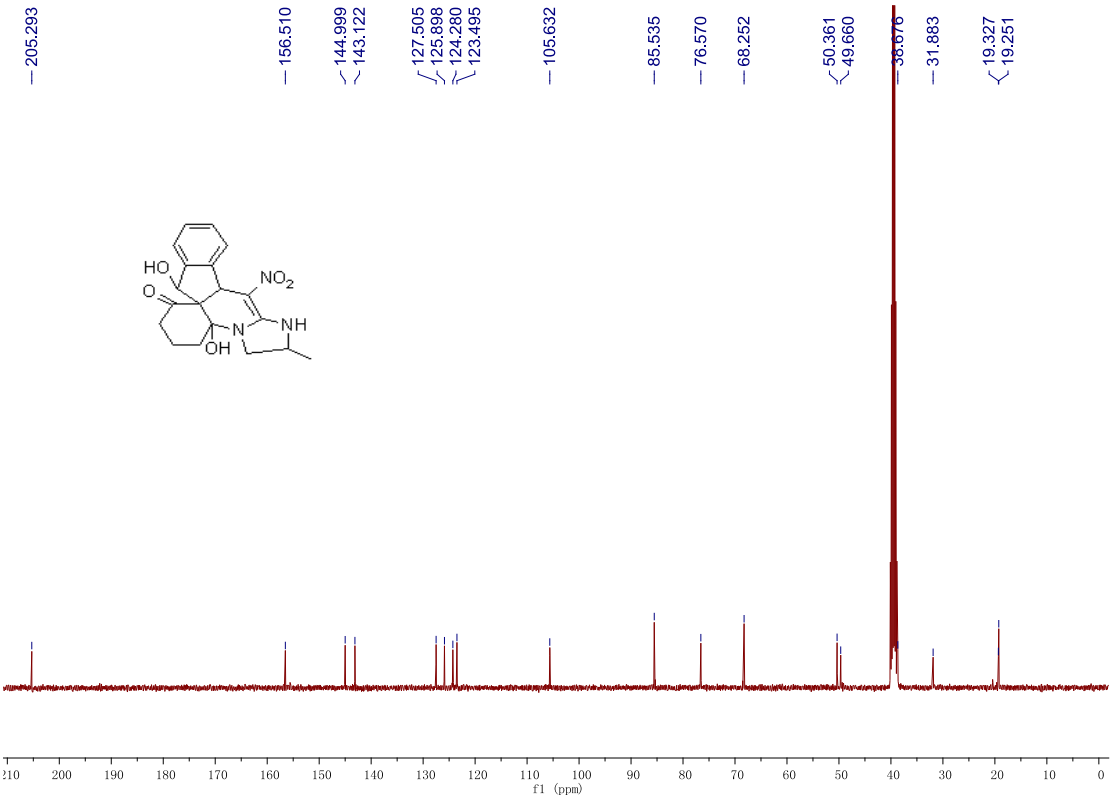


Figure 20. ^{13}C NMR (100 MHz, DMSO) spectra of compound 6b

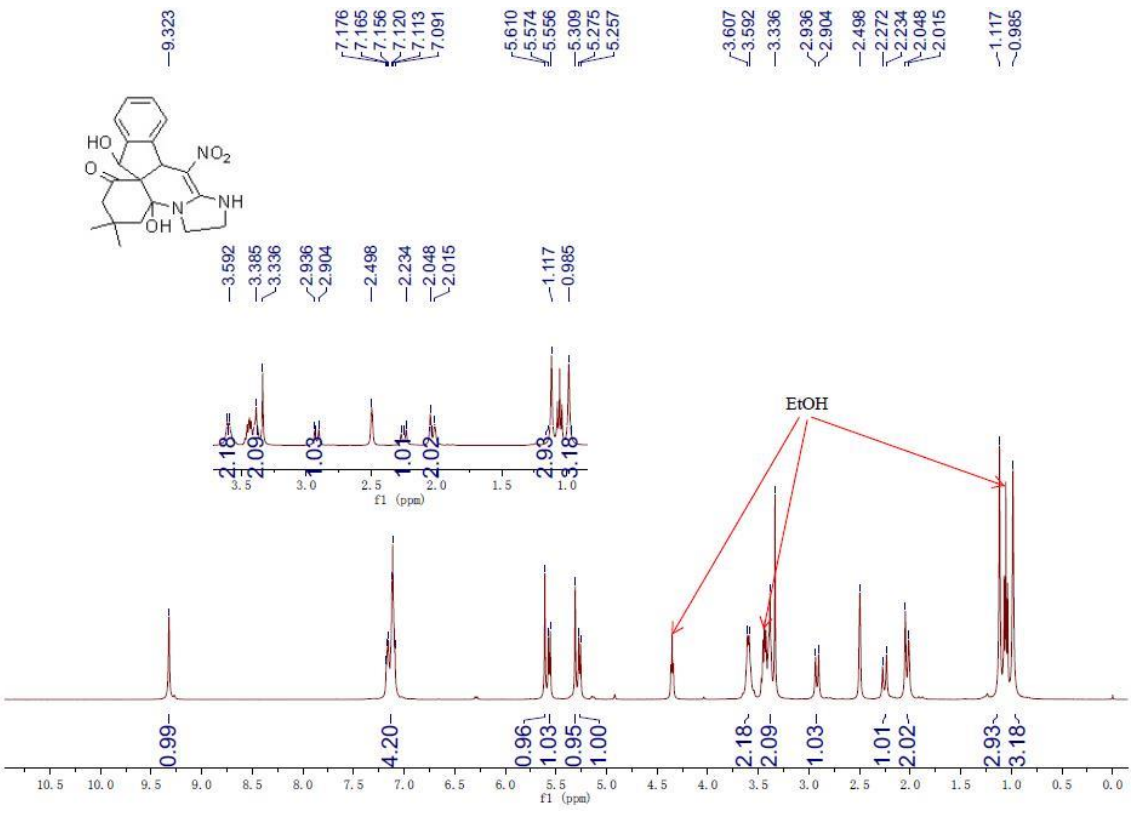


Figure 21. ^{1}H NMR (400 MHz, DMSO) spectra of compound 6c

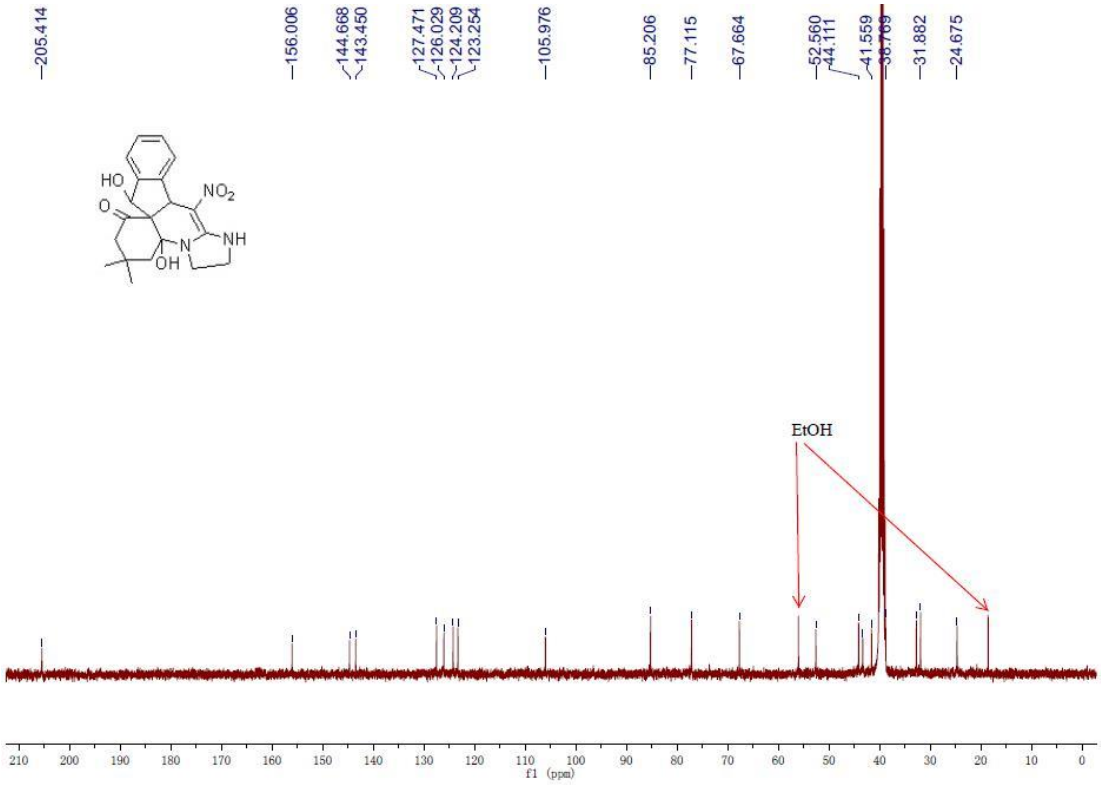


Figure 22. ^{13}C NMR (100 MHz, DMSO) spectra of compound 6c

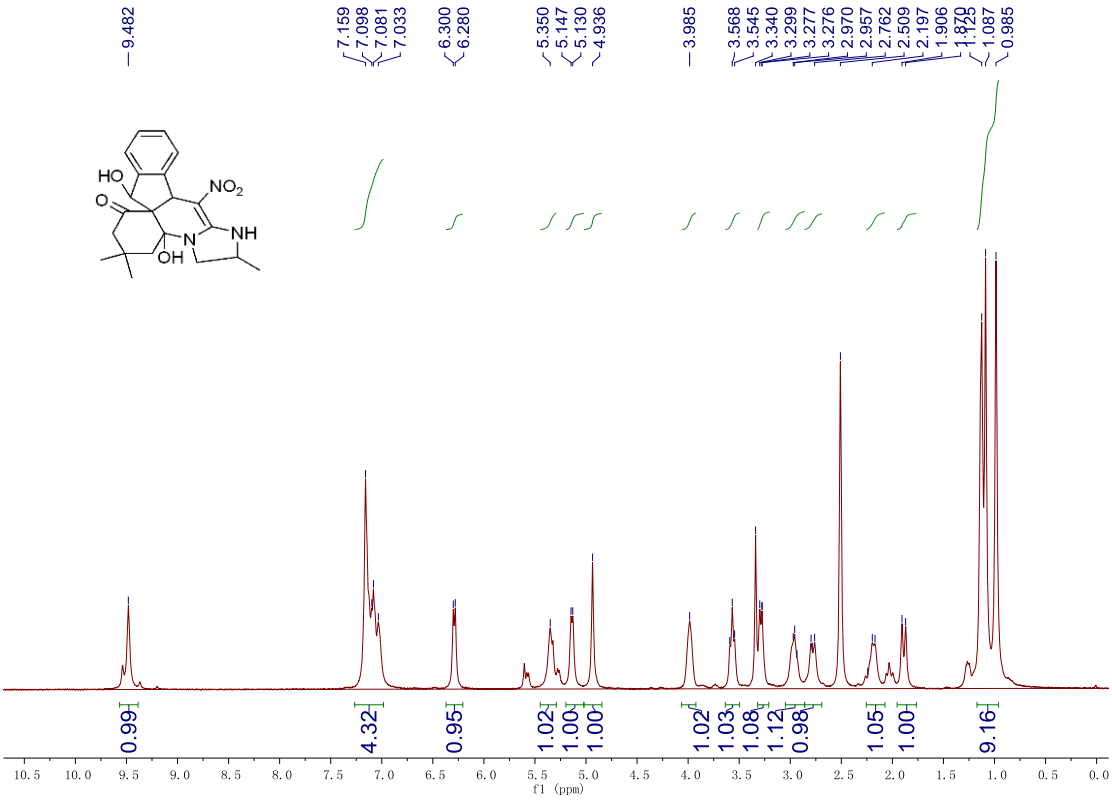


Figure 23. ^{1}H NMR (400 MHz, DMSO) spectra of compound 6d

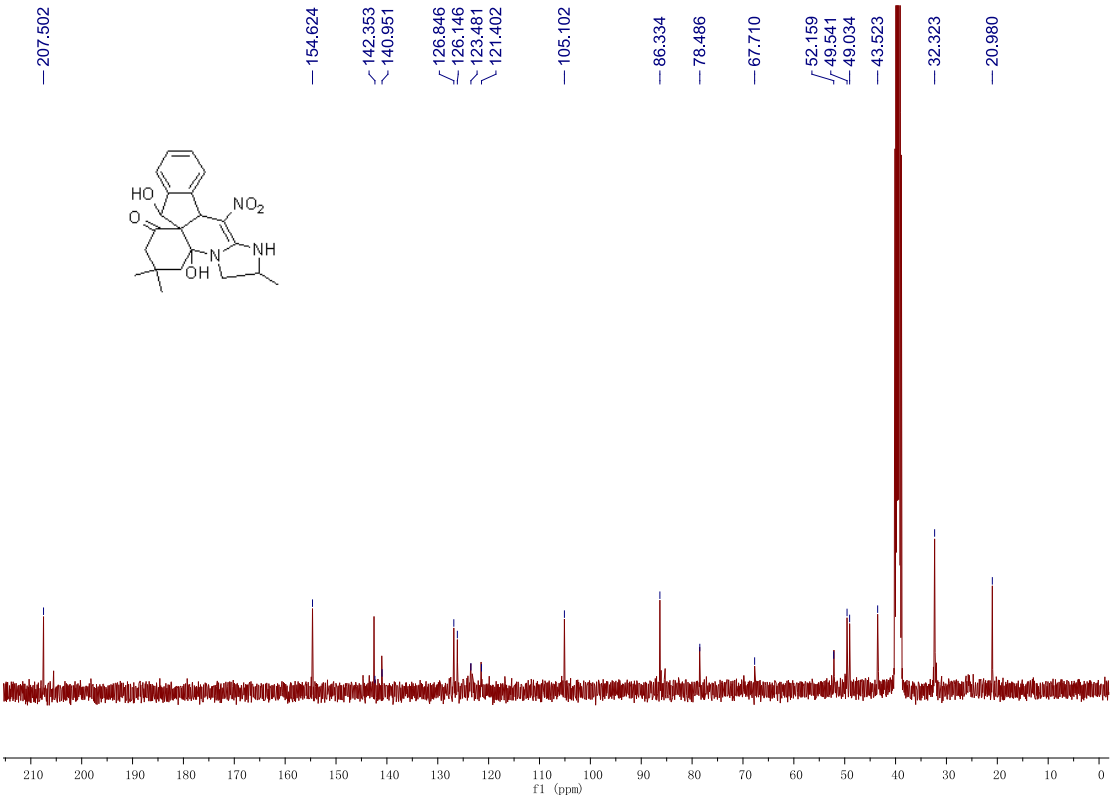


Figure 24. ^{13}C NMR (100 MHz, DMSO) spectra of compound 6d

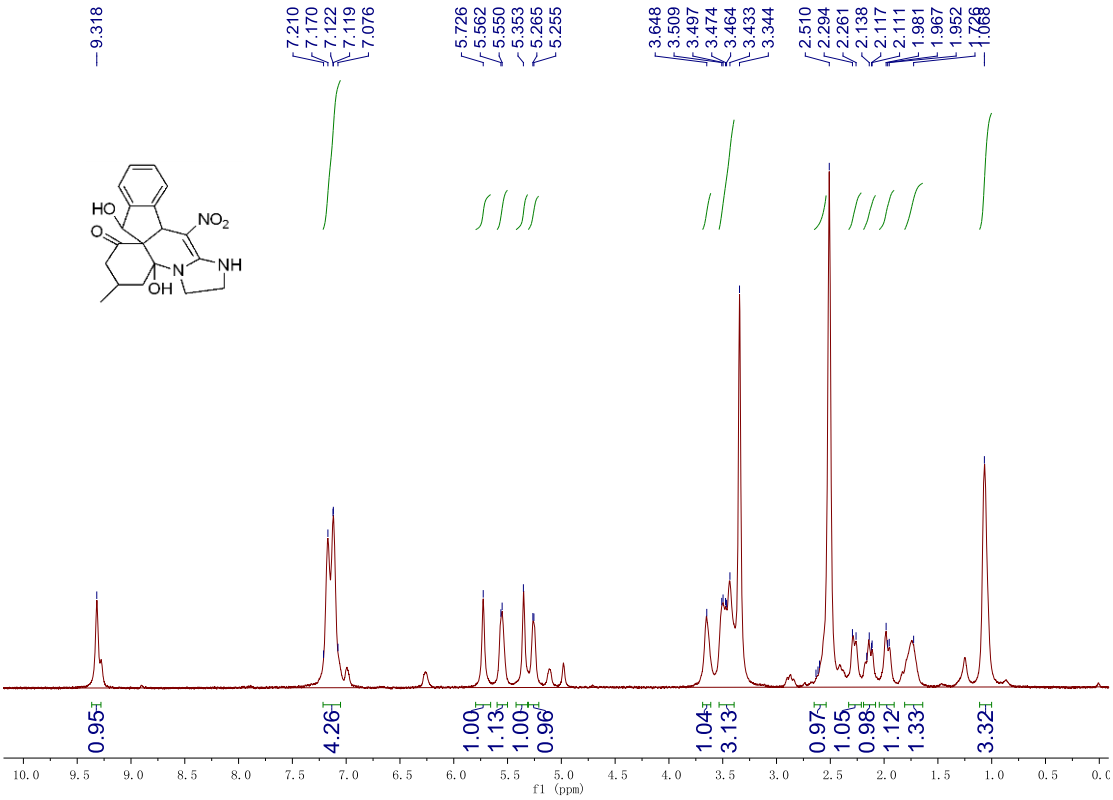


Figure 25. ^{1}H NMR (400 MHz, DMSO) spectra of compound 6e

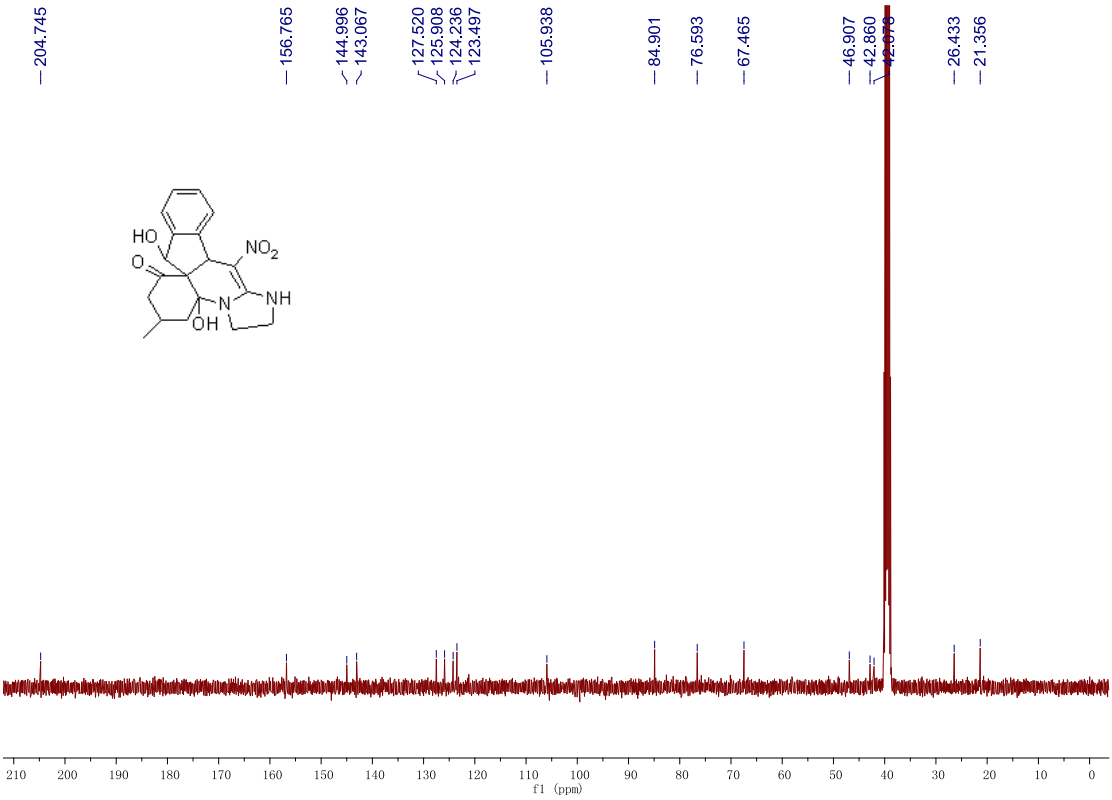


Figure 26. ^{13}C NMR (100 MHz, DMSO) spectra of compound 6e

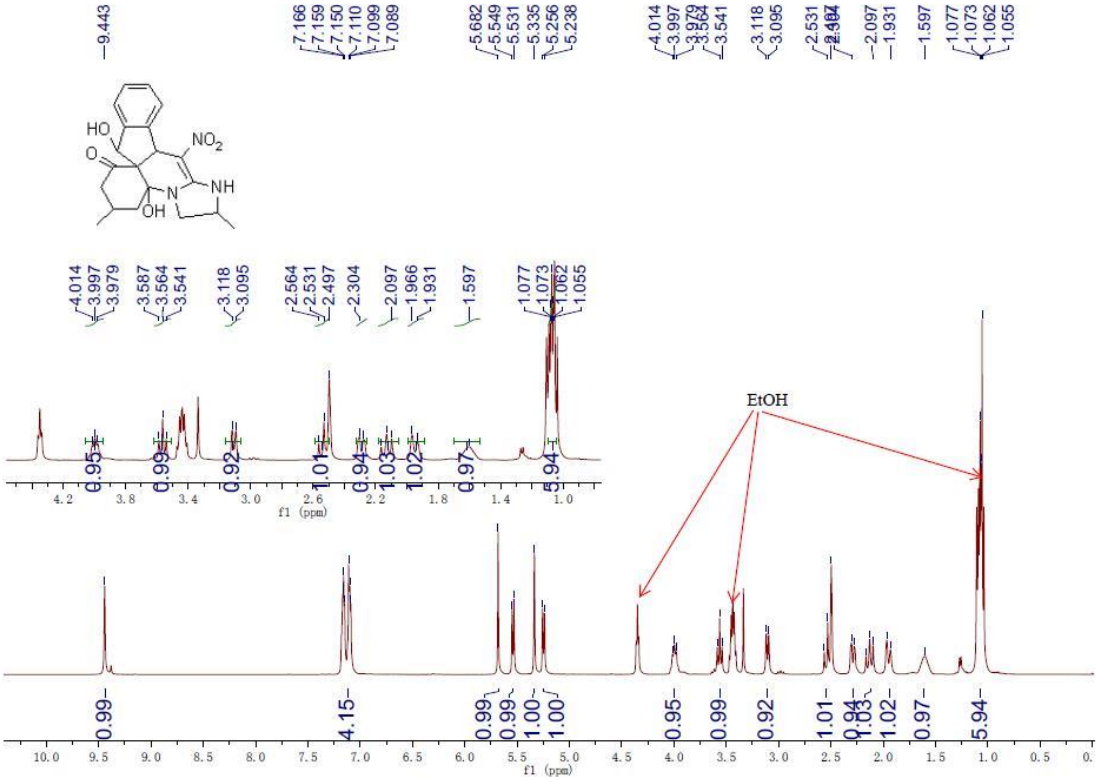


Figure 27. ^{1}H NMR (400 MHz, DMSO) spectra of compound 6f

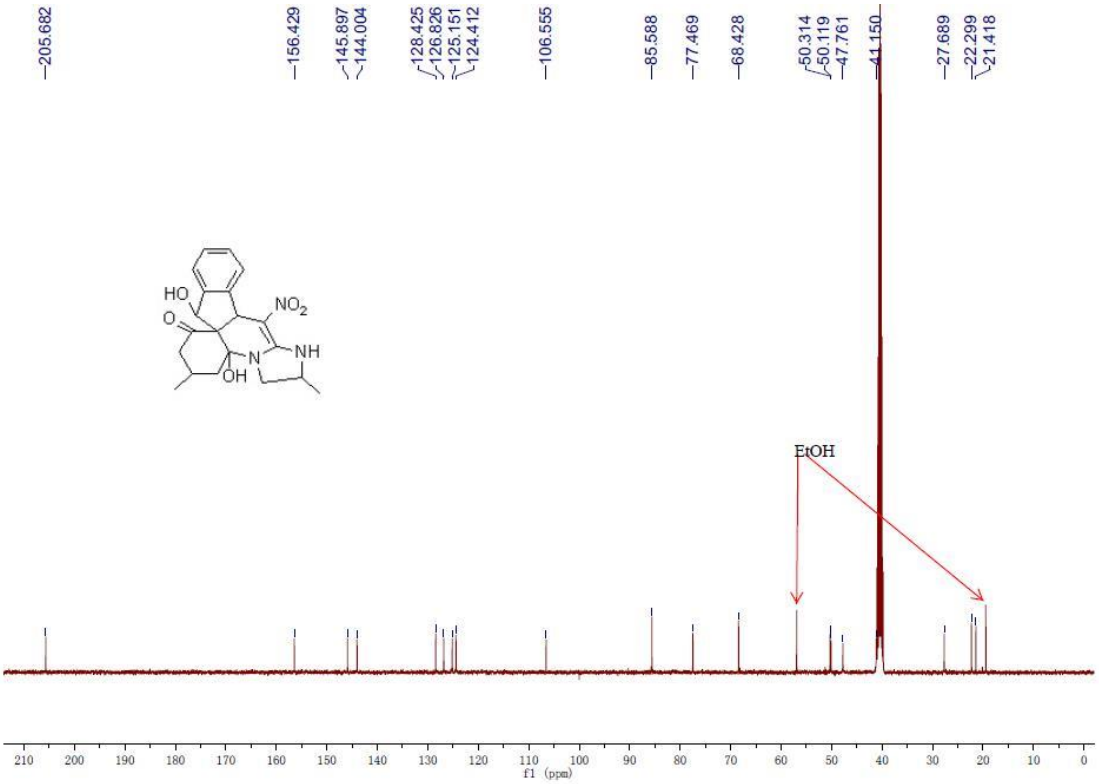


Figure 28. ^{13}C NMR (100 MHz, DMSO) spectra of compound 6f

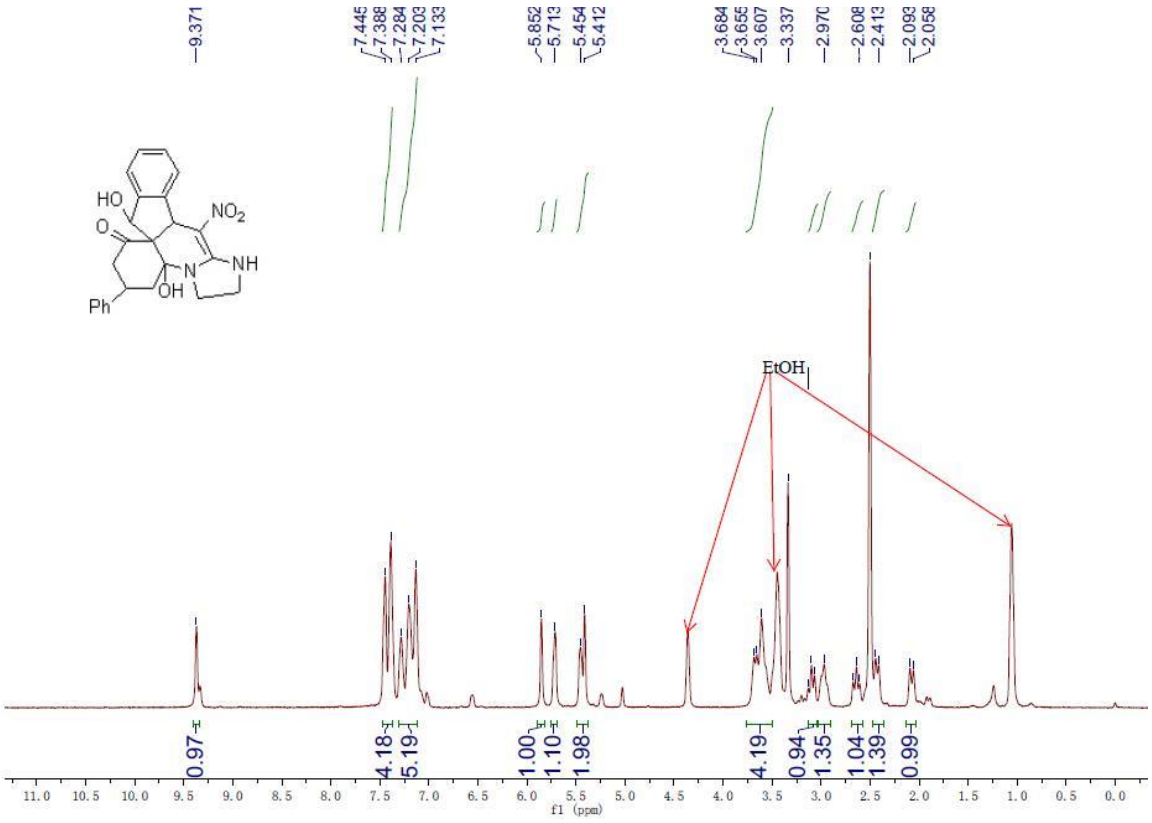


Figure 29. ^{1}H NMR (400 MHz, DMSO) spectra of compound 6g

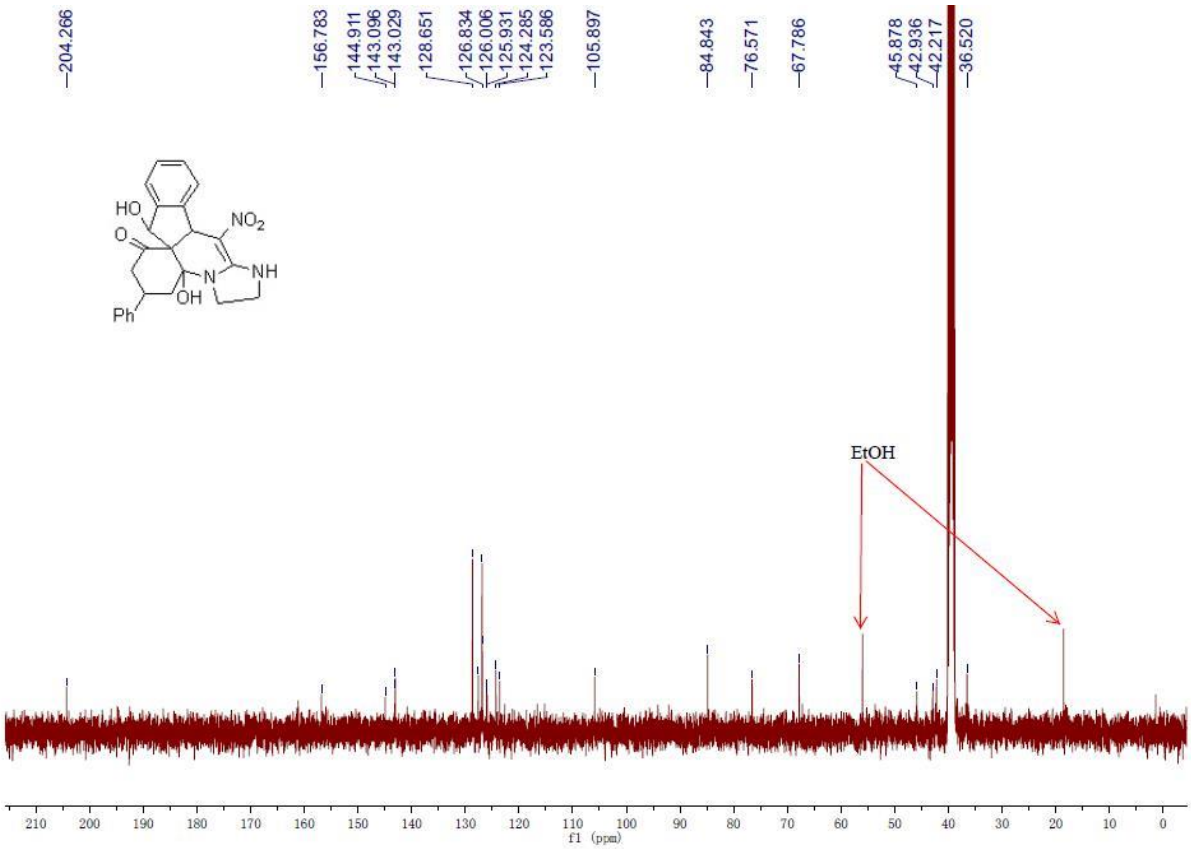


Figure 30. ^{13}C NMR (100 MHz, DMSO) spectra of compound 6g

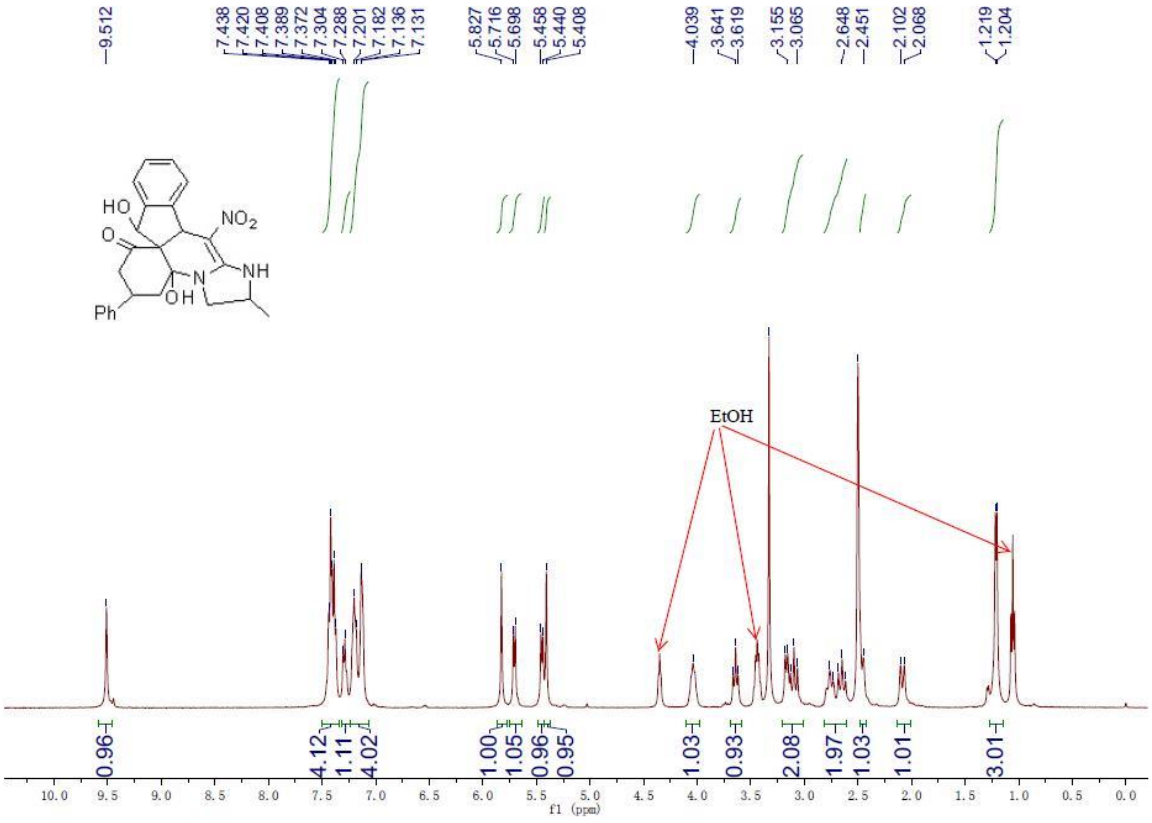


Figure 31. ^{1}H NMR (400 MHz, DMSO) spectra of compound 6h

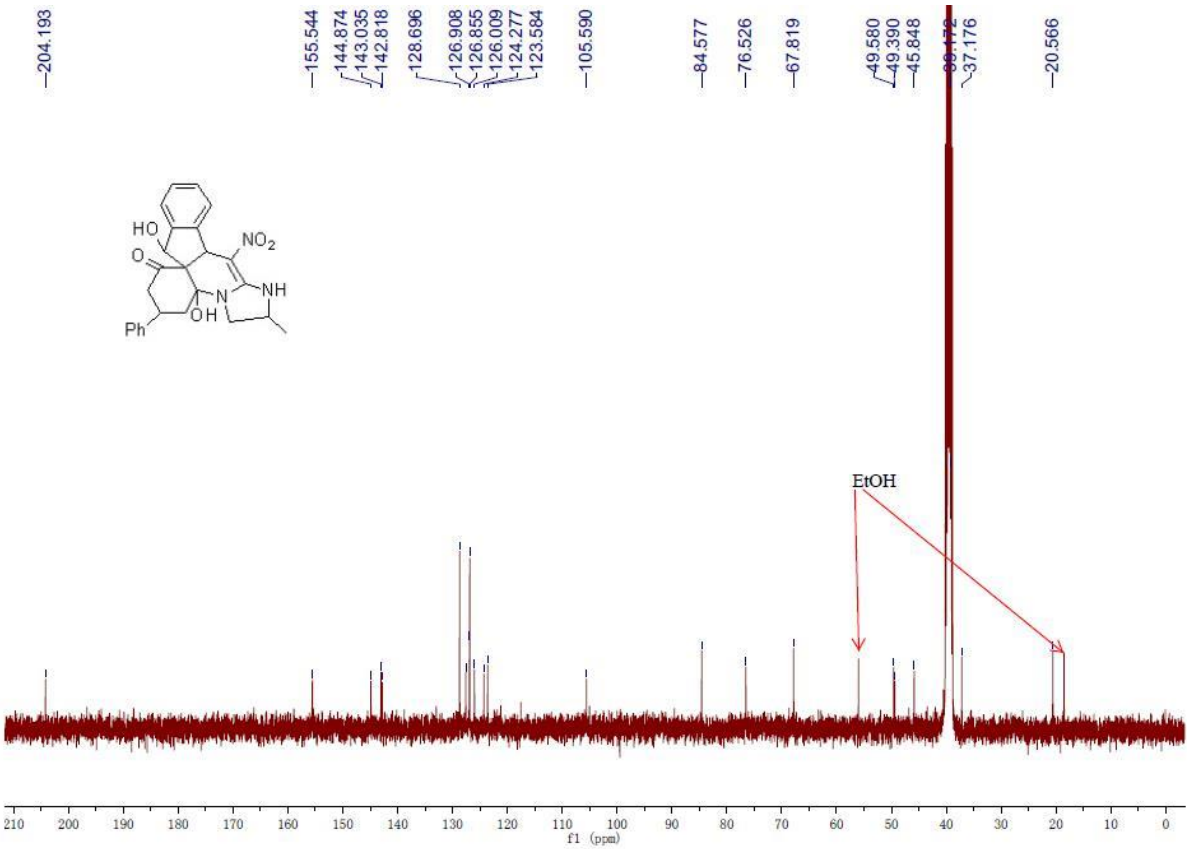


Figure 32. ^{13}C NMR (100 MHz, DMSO) spectra of compound 6h

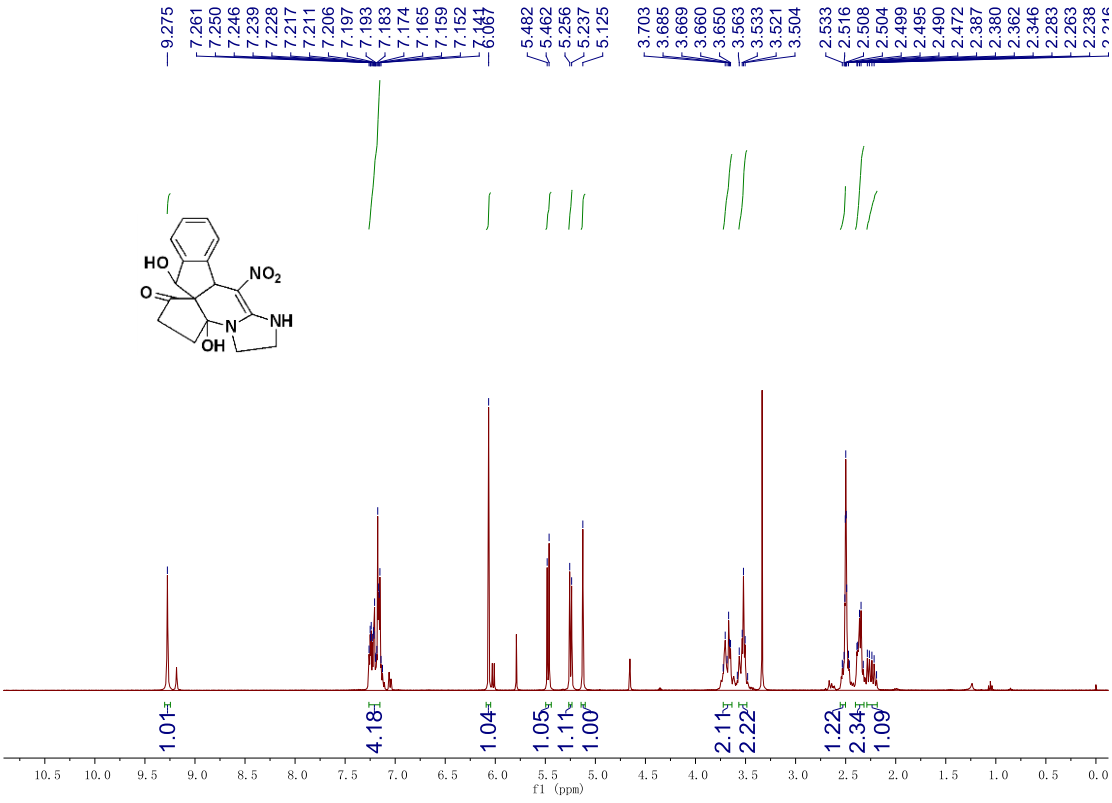


Figure 33. ^{1}H NMR (400 MHz, DMSO) spectra of compound 6i

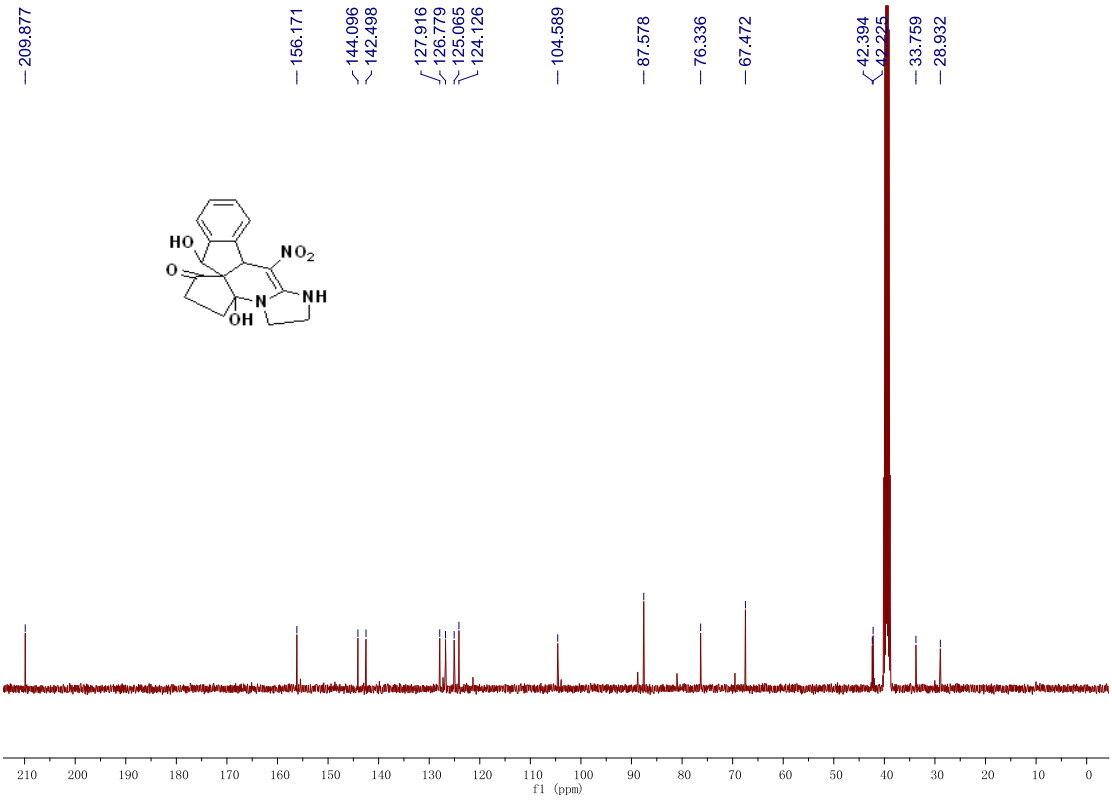


Figure 34. ^{1}H NMR (400 MHz, DMSO) spectra of compound 6i

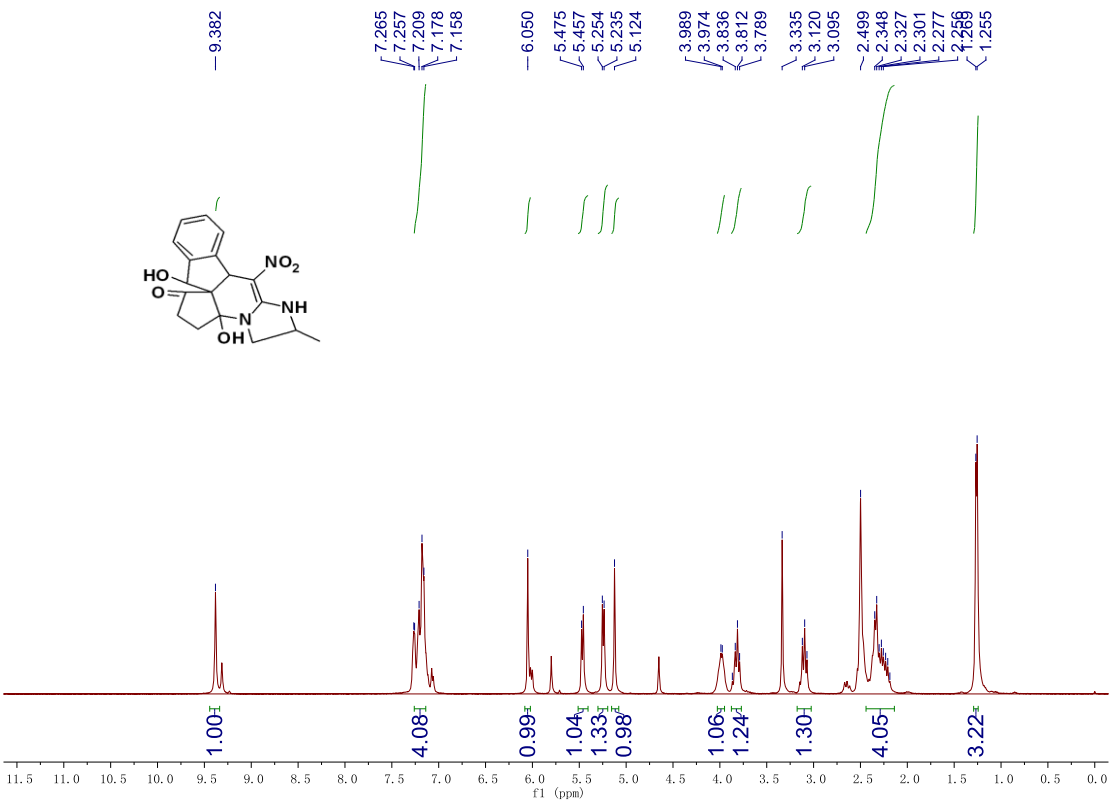


Figure 35. ^{1}H NMR (400 MHz, DMSO) spectra of compound 6j

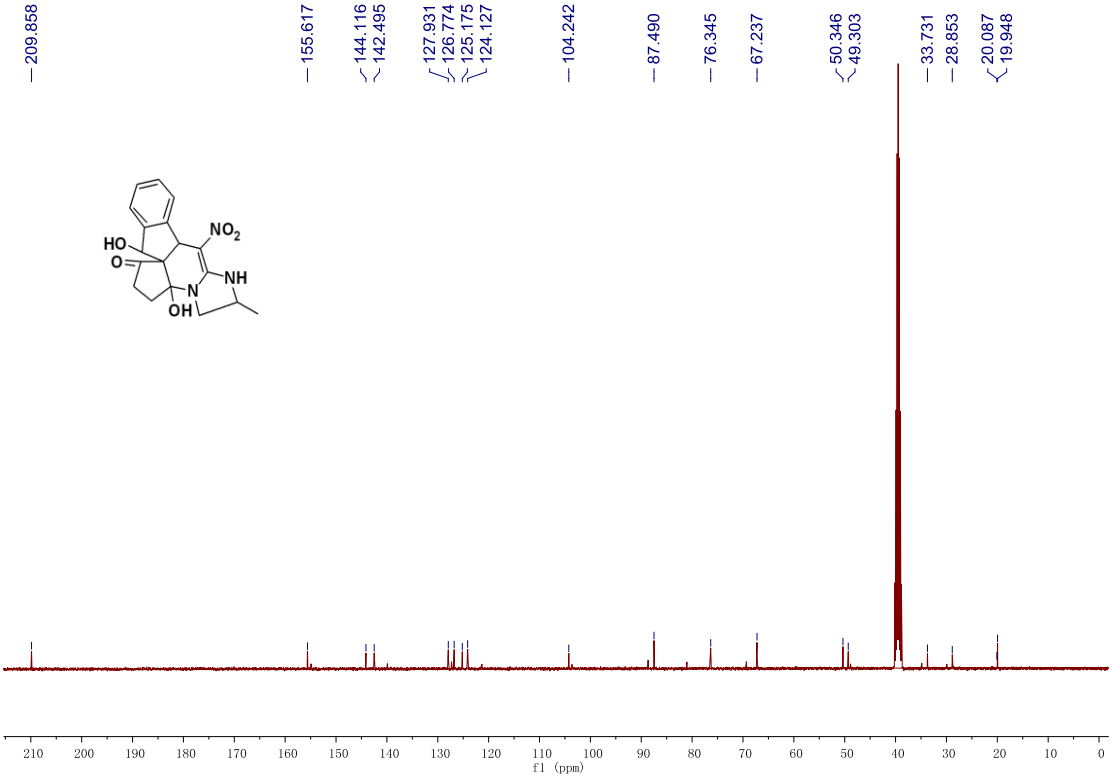


Figure 36. ^{1}H NMR (400 MHz, DMSO) spectra of compound 6j

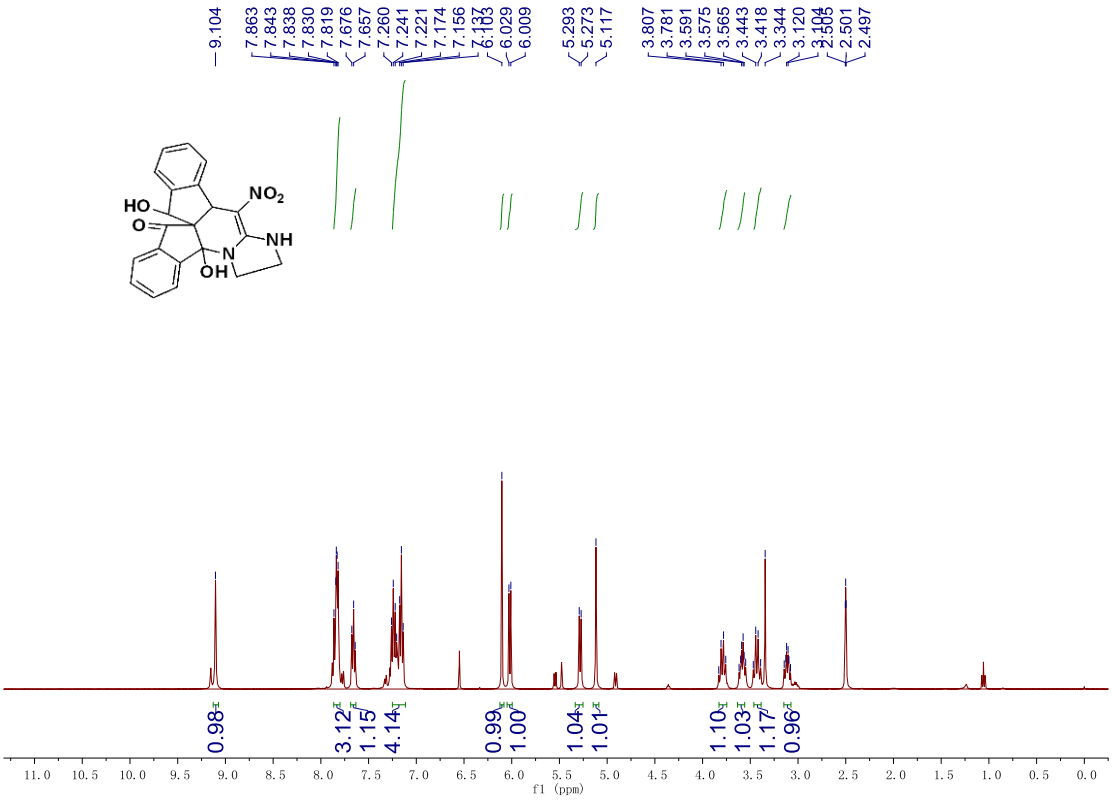


Figure 37. ^{1}H NMR (400 MHz, DMSO) spectra of compound 8a

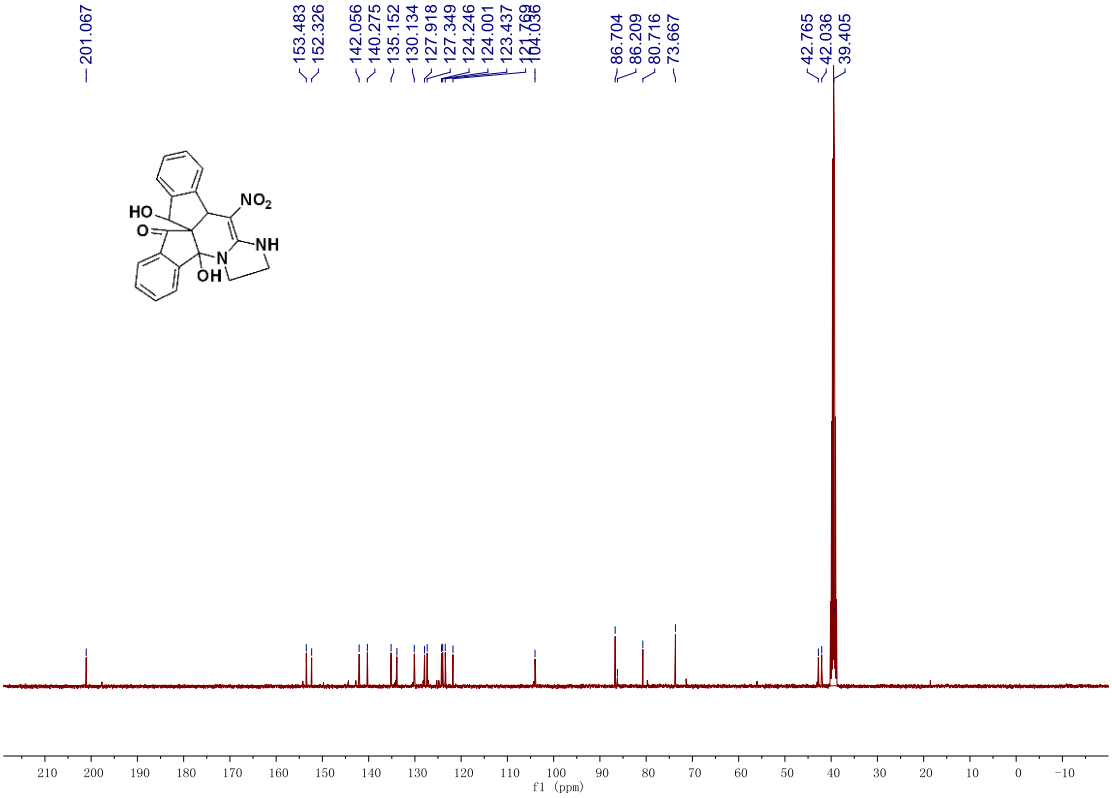


Figure 38. ^{1}H NMR (400 MHz, DMSO) spectra of compound 8a

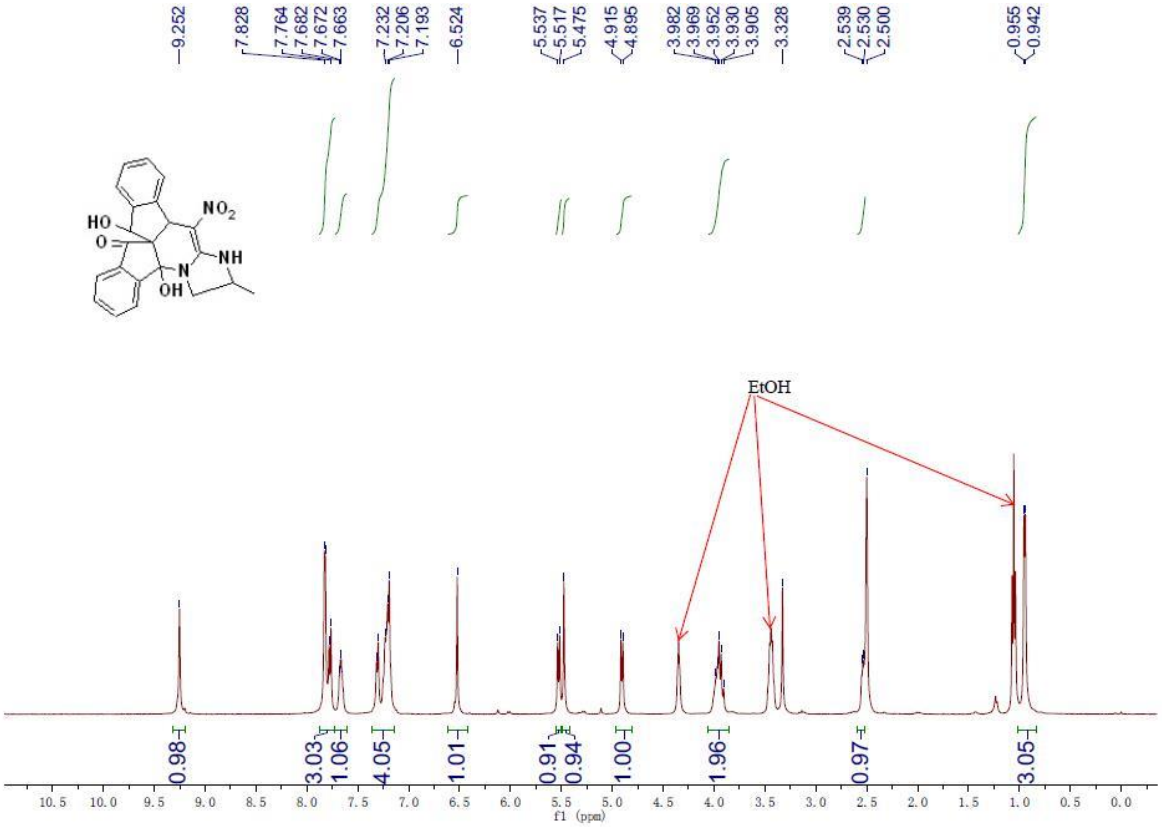


Figure 39. ^{1}H NMR (400 MHz, DMSO) spectra of compound 8b

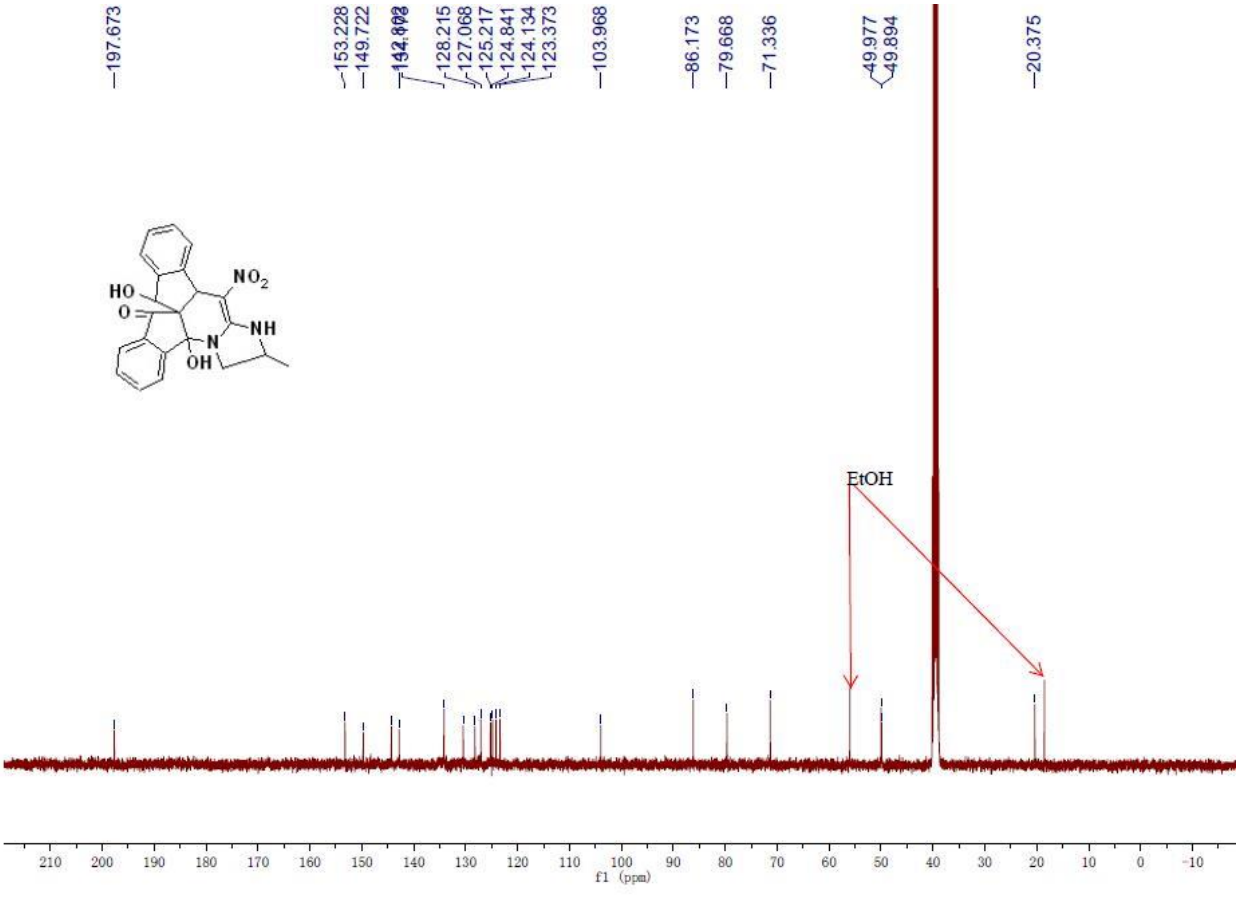


Figure 40. ^{1}H NMR (400 MHz, DMSO) spectra of compound 8b

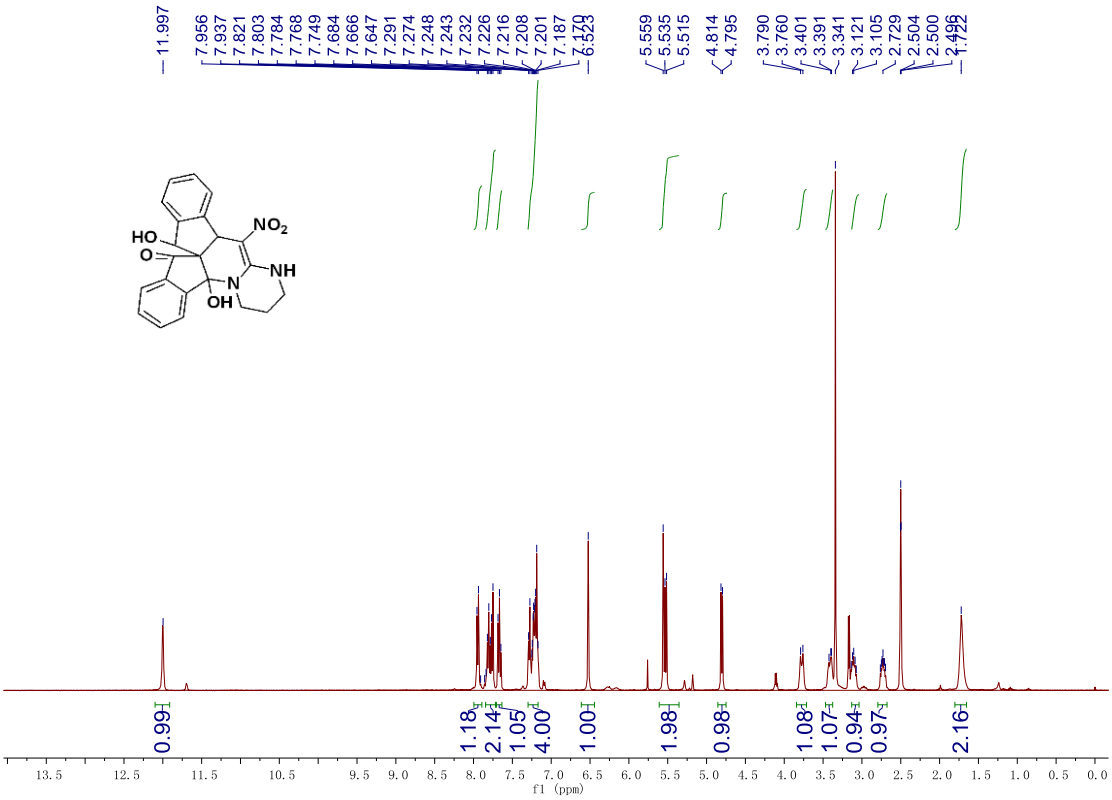


Figure 41. ^{1}H NMR (400 MHz, DMSO) spectra of compound 8c

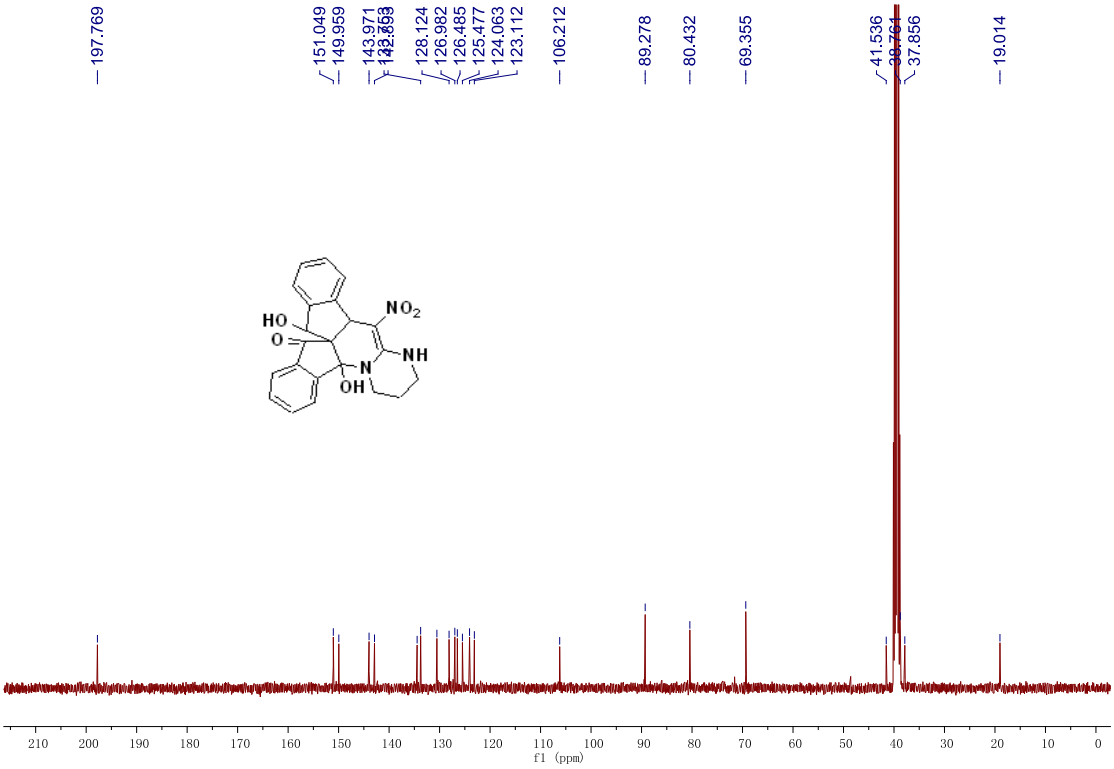


Figure 42. ^{1}H NMR (400 MHz, DMSO) spectra of compound 8c

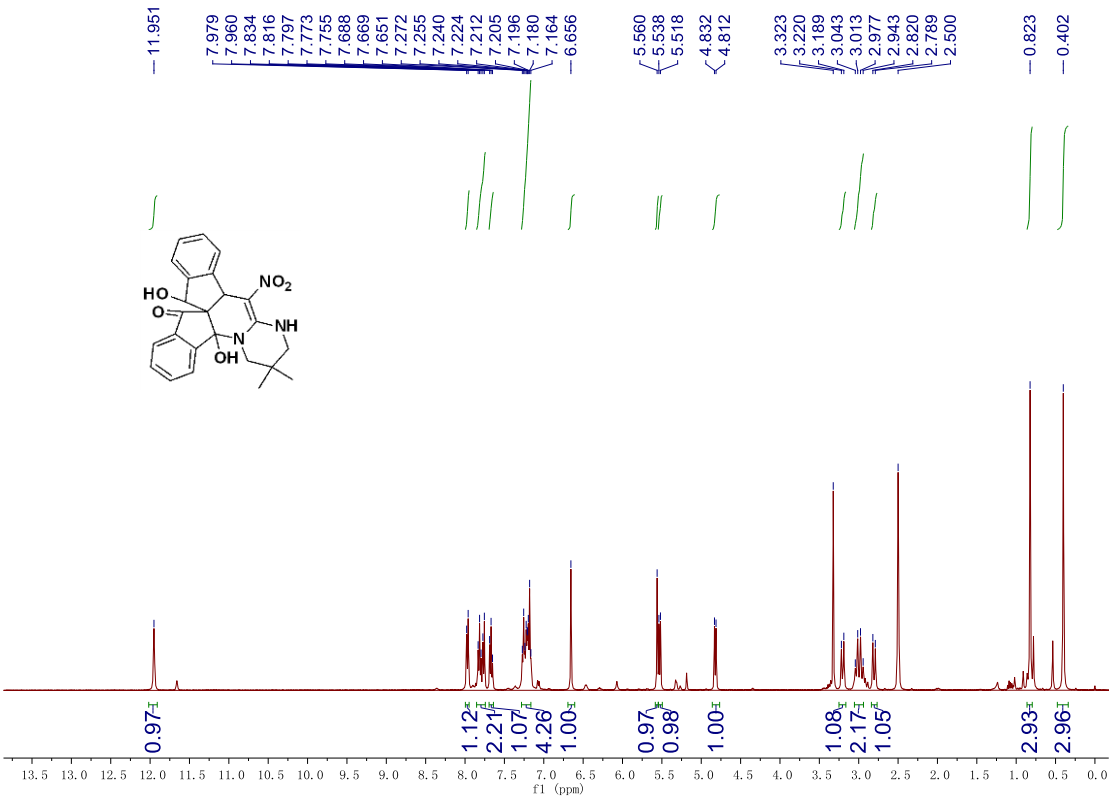


Figure 43. ^{1}H NMR (400 MHz, DMSO) spectra of compound 8d

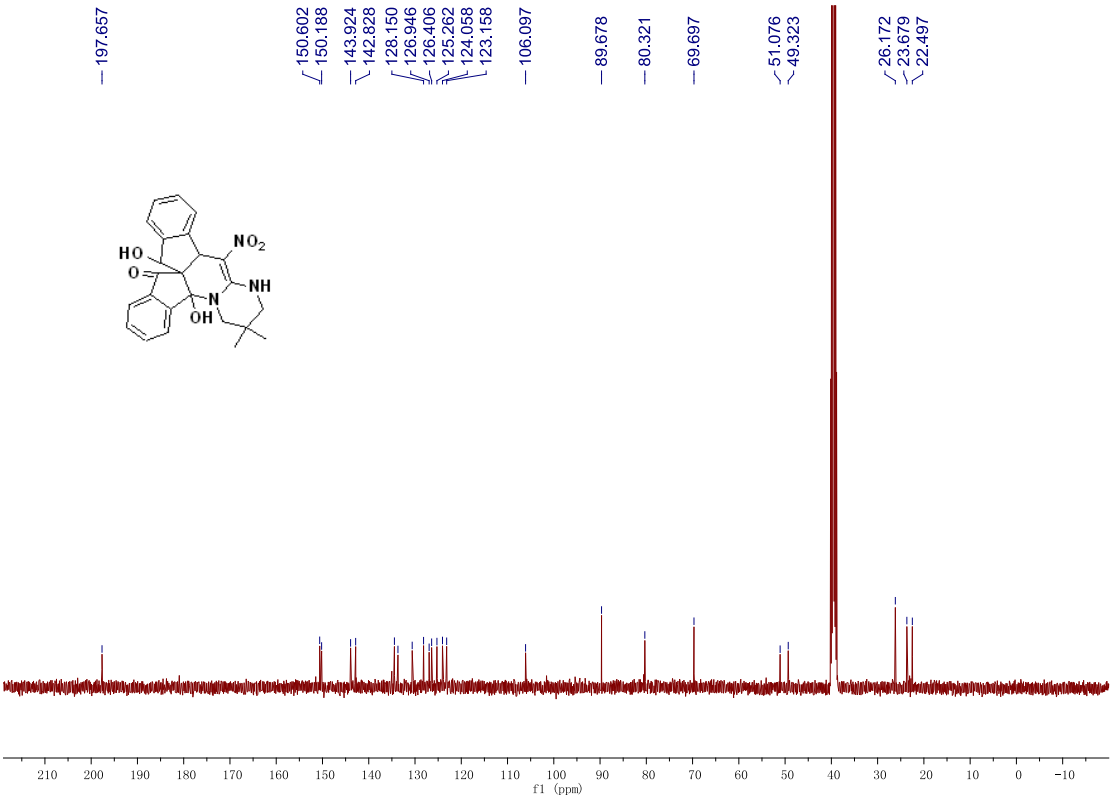


Figure 44. ^{1}H NMR (400 MHz, DMSO) spectra of compound 8d