Supplementary Information

Efficient one-pot Synthesis of the Unexpected Fused Multicyclic Iminosugars by Aza-Diels-Alder Mechanism

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General Considerations:

Solvents were all analytical grade and other reagents were purchased from energy chemical and Bide Pharmatech Ltd. All reactions need to be carried out under nitrogen atmosphere. ^{1}H NMR spectra were measured on Bruker AVANCE 600 MHz and 400 MHz spectrometers. ^{13}C NMR spectra were recorded on Bruker 100 MHz spectrometers with complete proton decoupling. Chemical shifts were reported in ppm from tetramethylsilane in the case of MeOH or DMSO as an internal standard. Melting points were measured on glass slides on an SGW X-4 Melting Point Apparatus. Optical rotations were determined on an SGW-1 automatic polarimeter. Mass Spectra (MS) and High Resolution Mass Spectra (HRMS) were carried out on a FTICR-MS (Ionspec 7.0T) mass spectrometer with electrospray ionization (ESI). Thin-layer chromatography (TLC) was performed on precoated plates (Qingdao GF254) with detection by UV light, Puke (china) silica gel (200-300 mesh) was used for column chromatography.

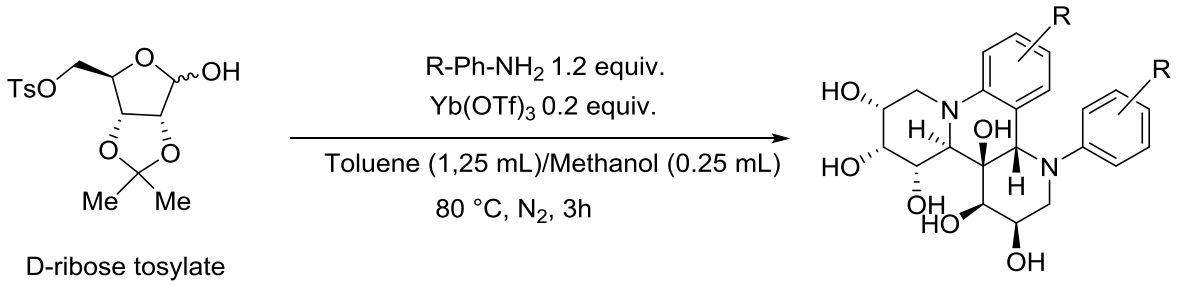
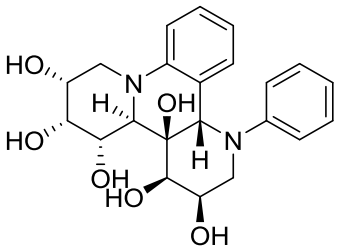


Fig. 1. Synthesis of the complex multicyclic iminosugars using D-ribose tosylate

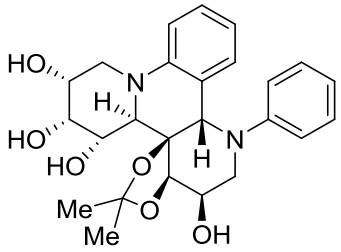
General experimental procedure: D-Ribose tosylate (206 mg, 0.6 mmol), aniline (1.2 equiv.) and $Yb(OTf)_3$ (0.2 equiv.) were added into a 25 mL flask, 1.50 mL toluene and methanol (V:V=5:1) as the mixed solvent. Then the solution was stirred

at the temperature of 80 ^{o}C under N_2 atmosphere for 3h. Upon completion, The mixture was cooled to room temperature, 20 ml of methanol was added to dissolve the solid residue, and the solvent was evaporated in vacuo. The crude product was purified by column chromatography (dichloromethane:methanol V/V = 15:1) to give **5a** as a pale yellow solid accompanied with **5a'**. Compound **5a''** was obtained at room temperature. Control experiments, including gram-level reactions and mechanistic studies, are involved in the reaction system.

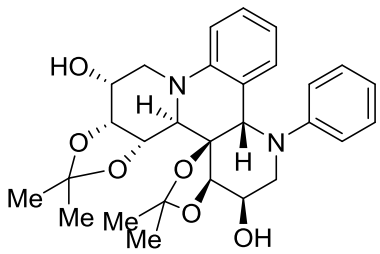
Under similar conditions, different aromatic amines were used as raw materials for the reaction, and the corresponding products were obtained respectively.



(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-1-phenyl-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5a). White solid, yield 89%, m.p. 92.3 - 93.7 ^{o}C, $[\alpha]_D^{25}$ +31.0 (*c* 0.1, CH_3OH); ^{1}H NMR (600 MHz, DMSO-d_6), δ_H (ppm): 7.20 – 7.17 (m, 2H), 7.08 (t, *J* = 7.8 Hz, 1H), 7.05 (d, *J* = 8.4 Hz, 2H), 6.89 – 6.85 (m, 2H), 6.66 (t, *J* = 7.2 Hz, 1H), 6.58 (t, *J* = 7.8 Hz, 1H), 5.93 (s, 1H), 5.27 (d, *J* = 3.0Hz, 1H), 5.23 – 5.17 (m, 2H), 4.91 (d, *J* = 7.8 Hz, 1H), 4.82 (d, *J* = 3.6 Hz, 1H), 4.73 (d, *J* = 6.6 Hz, 1H), 3.91 (d, *J* = 10.8 Hz, 1H), 3.87 –3.83(m, 2H), 3.81 – 3.79 (m, 1H), 3.75– 3.74 (m, 1H), 3.68 (dd, *J* = 13.2, 4.2 Hz, 1H), 3.29 (dd, *J* = 7.8, 3.0 Hz, 1H), 3.07 (dd, *J* = 13.8, 11.4 Hz, 1H), 2.95 (d, *J* = 13.8 Hz, 1H). ^{13}C NMR (100 MHz, DMSO-d_6), δ_C (ppm): 152.2, 144.5, 129.2, 128.5, 126.7, 119.8, 117.1, 116.8, 113.8, 111.8, 73.7, 72.0, 70.2, 68.7, 66.3, 64.9, 60.1, 54.3, 47.1, 46.9. MS (ESI): Calculated for $C_{22}H_{27}N_2O_6$ ($[M+H]^+$) : 415.1864, found: 415.1865.

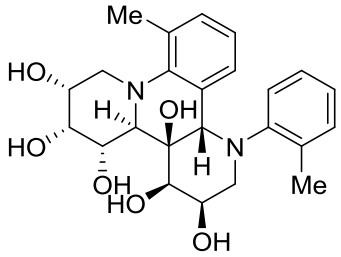


(3*R*,3a*R*,6a*S*,6b*R*,7*S*,8*R*,9*R*,14b*S*)-5,5-dimethyl-1-phenyl-1,3,3a,6b,7,8,9,10,10a,14b-decahydro-2*H*-dibenzo[*f*,*h*][1,3]dioxolo[4,5-*d*]quinoline-3,7,8,9-tetraol (5a'). Yellow solid, yield 5%, m.p. 154.7 - 155.7 ^{o}C, $[\alpha]_D^{25}$ +31.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm):7.22 – 7.18 (m, 1H), 7.09 – 7.05 (m, 1H), 6.90 – 6.85 (m, 2H), 6.65 (t, *J* = 7.2 Hz, 1H), 6.58 (t, *J* = 7.2 Hz, 1H), 5.22 (s, 1H), 4.41 (d, *J* = 2.4 Hz, 1H), 4.02 (d, *J* = 2.4 Hz, 1H), 3.84 – 3.78 (m, 2H), 3.68 (d, *J* = 10.4 Hz, 1H), 3.66 – 3.59 (m, 2H), 3.26 – 3.19 (m, 2H), 3.05 (dd, *J* = 10.0, 7.2 Hz, 1H), 1.48 (s, 3H), 1.20 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 149.7, 143.1, 129.1, 128.7, 127.3, 122.4, 118.5, 116.4, 112.3, 111.3, 111.2, 82.3, 80.5, 72.0, 68.6, 64.9, 64.3, 62.0, 53.8, 44.8, 26.0, 25.9. MS (ESI): Calculated for $C_{25}H_{31}N_2O_6$ ($[M+H]^+$): 455.2177, found: 455.2177.

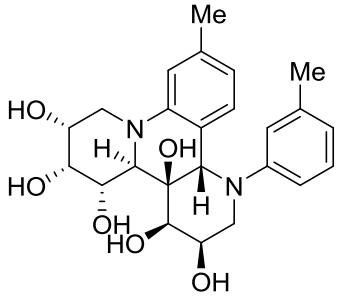


(2*R*,2a*R*,5a*S*,5b*R*,5c*R*,8a*R*,9*R*,11a*S*)-4,4,7,7-tetramethyl-11-phenyl-2,2a,5a,5b,8a,9,11,11a-octahydro-1*H*,10*H*-[1,3]dioxolo[4',5':3,4]pyrido[2,1-*f*]benzo[*h*][1,3]dioxolo[4,5-*d*][1,6]naphthyridine-2,9-diol (5a"). Yellow solid, yield 85%, m.p. 179.7 - 180.7 ^{o}C, $[\alpha]_D^{25}$ +111.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.23 (t, *J* = 7.9 Hz, 2H), 7.09 (d, *J* = 8.1 Hz, 1H), 6.95 – 6.85 (m, 4H), 6.65 (d, *J* = 28.1 Hz, 2H), 5.26 (s, 1H), 4.55 – 4.46 (m, 3H), 4.38 (s, 1H), 4.05 (d, *J* = 11.1 Hz, 1H), 3.98 – 3.91 (m, 1H), 3.66 (s, 1H), 3.48 (d, *J* = 9.1 Hz, 1H), 3.27 (s, 1H), 3.09 (s, 1H), 1.62 (s, 3H), 1.47 (s, 3H), 1.41 (s, 3H), 1.29 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 149.9, 142.6, 129.0, 128.6, 127.2, 118.3, 116.2, 112.2, 111.3,

110.9, 109.8, 82.3, 79.7, 76.4, 73.7, 66.6, 65.1, 62.9, 62.1, 53.8, 45.0, 29.4, 27.8, 24.9. MS (ESI): Calculated for $C_{28}H_{35}N_2O_6$ ($[M+H]^+$): 495.2490, found: 495.2490.

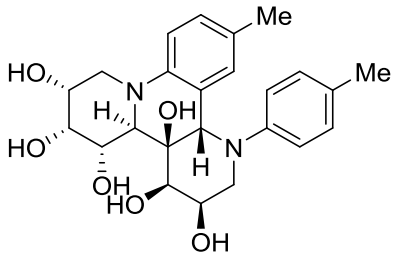


(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-10-methyl-1-(*o*-tolyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5b). Yellow solid, yield 34%, m.p. 114.7 - 115.3 ^oC, $[\alpha]_D^{25}$ +45.0 (*c* 0.1, CH_3OH); ^1H NMR (400 MHz, CD_3OD) , δ_H (ppm)**:** 7.51 (d, *J* = 8.0 Hz, 1H), 7.17 – 7.13 (m, 1H), 6.94 – 6.87 (m, 2H), 6.79 (dd, *J* = 7.2, 2.0 Hz, 1H), 6.23 – 6.19 (m, 2H), 4.97 (s, 1H), 4.27 (d, *J* = 8.4 Hz, 1H), 4.15 (d, *J* = 3.2 Hz, 1H), 4.05 (d, *J* = 9.2 Hz, 2H), 4.00 – 3.98 (m, 1H), 3.96 – 3.93 (m, 1H), 3.48 (dd, *J* = 12.4, 4.4 Hz, 1H), 3.37 (d, *J* = 10.5 Hz, 1H), 3.21 – 3.15 (m, 1H), 2.81 (dd, *J* = 10.8, 5.2 Hz, 1H), 2.23 (s, 3H), 1.93 (s, 3H).^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 145.5, 131.4, 129.8, 125.6, 125.0, 117.6, 74.4, 72.9, 71.2, 69.3, 68.4, 63.1, 57.3, 52.4, 19.6, 17.6. MS (ESI): Calculated for $C_{24}H_{31}N_2O_6$ ($[M+H]^+$): 443.2104, found: 442.2103.

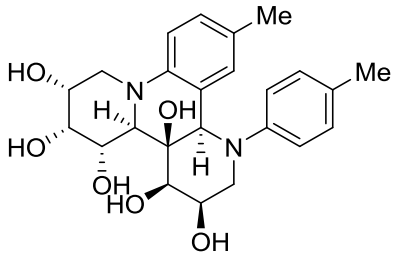


(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-11-methyl-1-(*m*-tolyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5c). Yellow solid, yield 50%, m.p. 140.2 - 142.4 ^oC, $[\alpha]_D^{25}$ +157.0 (*c* 0.1, CH_3OH); ^1H NMR (400 MHz, CD_3OD), δ_H (ppm)**:** 7.02 (t, *J* =8.0 Hz, 1H), 6.87 – 6.81(m, 3H), 6.68 (s, 1H), 6.48 (d, *J* = 7.6Hz, 1H), 6.39 (d, *J* = 8.0 Hz, 1H), 5.24 (s, 1H), 3.99 (d, *J* = 10.8 Hz, 2H), 3.88 – 3.77 (m, 4H), 3.56 – 3.53 (m, 1H), 3.49 (d, *J* = 3.6 Hz, 1H), 3.27 – 3.18 (m, 1H), 3.03 (d, *J* = 14.0 Hz, 1H), 2.22 (s, 3H), 2.17 (s, 3H). ^{13}C NMR

(100 MHz, CD_3OD), δ_C (ppm): 153.8, 145.6, 140.0, 139.8, 130.2, 128.7, 120.0, 119.6, 118.5, 116.2, 113.8, 112.8, 75.1, 73.7, 72.2, 70.0, 68.5, 66.3, 61.9, 56.0, 47.7, 22.0, 21.6. MS (ESI): Calculated for $C_{24}H_{30}N_2NaO_6$ ($[M+Na]^+$): 465.1994, found: 465.1993.

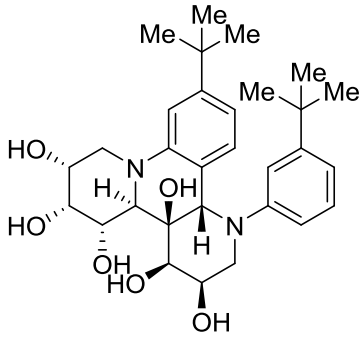


(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-12-methyl-1-(*p*-tolyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5d). Yellow solid, yield 61%, m.p. 105.5 - 107.5 ^oC, $[\alpha]_D^{25}$ +35.0 (*c* 0.1, CH_3OH); ^1H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.05 – 6.98 (m, 4H), 6.93 (dd, *J* = 8.4, 2.0 Hz, 1H), 6.87 (s, 1H), 6.80 (d, *J* = 8.4 Hz, 1H), 5.26 (s, 1H), 4.04 – 3.99 (m, 2H), 3.92 – 3.84 (m, 3H), 3.78 (dd, *J* = 14.0, 4.4 Hz, 1H), 3.60 – 3.55 (m, 1H), 3.54 (d, *J* = 3.2 Hz, 1H), 3.28 – 3.22 (m, 1H), 3.11 (d, *J* = 13.6 Hz, 1H), 2.25 (s, 3H), 2.09 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 150.4, 142.1, 129.5, 129.2, 127.6, 126.9, 126.5, 120.2, 114.3, 112.0, 74.0, 72.4, 71.0, 68.6, 67.3, 64.9, 63.0, 60.9, 54.7, 19.2, 19.1. MS (ESI): Calculated for $C_{24}H_{30}N_2KO_6$ ($[M+K]^+$): 481.2104, found: 481.2105.

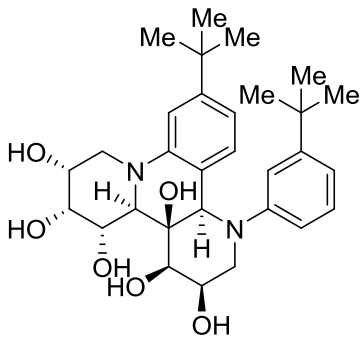


(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*R*)-12-methyl-1-(*p*-tolyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5d-1). Yellow solid, yield 20% m.p. 119.2 - 120.4 ^oC, $[\alpha]_D^{25}$ +49.0 (*c* 0.1, CH3OH); ^1H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.14 (d, *J* = 2.0 Hz, 1H), 7.06 – 7.04 (m, 1H), 6.83 (dd, *J* = 8.4, 4.4 Hz, 3H), 6.26 – 6.24 (m, 2H), 4.89 (s, 1H), 4.13– 4.10 (m, 2H), 3.96 (d, *J* = 2.8 Hz, 1H), 3.73 (dd, *J* = 10.4, 2.8 Hz, 2H), 3.61 – 3.57 (m, 1H), 3.50 (d,

J = 10.4 Hz, 1H), 3.21 – 3.15 (m, 2H), 3.07 – 3.03 (m, 1H), 2.24 (s, 3H), 2.15 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 147.6, 141.4, 131.9, 131.3, 131.2, 130.4, 129.0, 127.5, 124.3, 114.4, 113.7, 81.2, 81.1, 79.6, 74.3, 70.4, 66.2, 56.5, 48.1, 46.7, 20.5, 20.3. MS (ESI): Calculated for $C_{24}H_{31}N_2O_6$ ($[M+H]^+$): 443.2104, found: 443.2105.

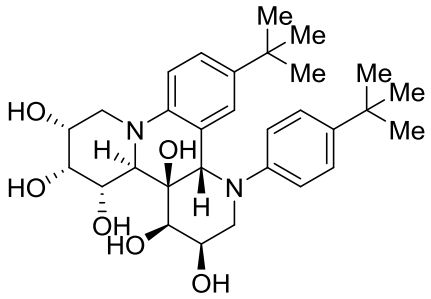


(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-11-(tert-butyl)-1-(3-(tert-butyl)phenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[h]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5e). Yellow solid, yield 52%, m.p. 168.3 - 169.5 ^{o}C, $[\alpha]_D^{25}$ +87.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.15 – 7.09 (m, 2H), 6.97 (d, *J* = 8.4 Hz, 1H), 6.92 – 6.88 (m, 2H), 6.79 – 6.77 (m, 1H), 6.68 (dd, *J* = 8.4, 2.0 Hz, 1H), 5.29 (s, 1H), 4.06 – 4.04 (m, 2H), 3.94 – 3.84 (m, 4H), 3.63–3.59 (m, 1H), 3.56 (d, *J* = 3.2 Hz, 1H), 3.30 – 3.26 (m, 1H), 3.14 (d, *J* = 14.0 Hz, 1H), 1.31 (s, 9H), 1.27 (s, 9H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 153.7, 153.3, 153.2, 145.4, 129.9, 128.5, 118.8, 116.4, 116.1, 113.2, 110.2, 75.2, 73.7, 72.3, 70.1, 68.6, 66.3, 62.2, 56.2, 47.8, 35.6, 35.6, 31.9, 31. MS (ESI): Calculated for $C_{30}H_{43}N_2O_6$ ($[M+H]^+$): 527.3043, found: 527.3043.

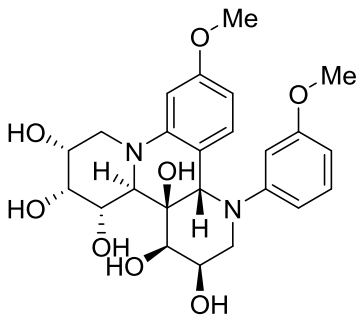


(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*R*)-11-(tert-butyl)-1-(3-(tert-butyl)phenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)

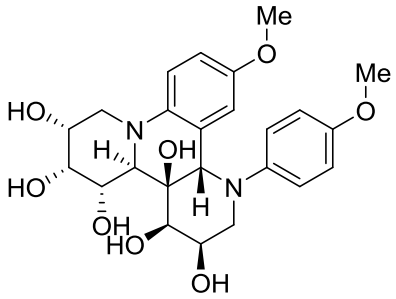
-hexaol (5e-1). Yellow solid, yield 21%, m.p. 140.3 - 141.5 ^{o}C, $[\alpha]_D^{25}$ +30.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.27 (d, *J* = 8.0 Hz, 1H), 6.94 – 6.90 (m, 3H), 6.64 – 6.62 (m, 1H), 6.46 (t, *J* = 2.0 Hz, 1H), 6.08 (dd, *J* = 8.0, 2.0 Hz, 1H), 4.93 (s, 1H), 4.15 – 4.14 (m, 2H), 3.99 (t, *J* = 2.8 Hz, 1H), 3.83 (dd, *J* = 13.6, 4.4 Hz, 1H), 3.74 (dd, *J* = 10.4, 2.8 Hz, 1H), 3.64 – 3.56 (m, 2H), 3.27 – 3.19 (m, 2H), 3.11 (dd, *J* = 13.2, 4.0 Hz, 1H), 1.33 (s, 9H), 1.23 (s, 9H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 153.8, 153.0, 149.7, 143.1, 130.8, 129.5, 121.6, 117.1, 115.5, 111.9, 111.3, 110.5, 81.1, 80.8, 79.5, 74.2, 73.6, 70.5, 66.1, 56.6, 48.0, 46.3, 35.7, 35.4, 31.9, 31.8, 31.8. MS (ESI**):** Calculated for r $C_{30}H_{42}N_2KO_6$ ($[M+K]^+$): 565.4043, found: 565.4044.



(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-12-(tert-butyl)-1-(4-(tert-butyl)phenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5f). Yellow solid, yield 50% m.p. 142.3 - 144.5 ^{o}C, $[\alpha]_D^{25}$ +105.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.30 – 7.27 (m, 2H), 7.14 – 7.11 (m, 2H), 7.07 – 7.04 (m, 2H), 6.81 (d, *J* = 8.4 Hz, 1H), 5.32 (s, 1H), 4.05 – 4.02 (m, 2H), 3.91 (dd, *J* = 10.4, 2.8 Hz, 1H), 3.88 – 3.83 (m, 2H), 3.80 (dd, *J* = 14.0, 4.4 Hz, 1H), 3.60 – 3.55 (m, 2H),3.25 (dd, *J* = 14.0, 11.6 Hz, 1H), 3.11 – 3.08 (m, 1H), 1.30 (s, 9H), 1.09 (s, 9H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 151.7, 143.3, 141.8, 141.8, 127.1, 126.6, 125.6, 120.9, 115.7, 113.0, 75.2, 73.8, 72.2, 69.9, 68.5, 66.3, 64.3, 62.6, 56.0, 47.8, 34.7, 34.6, 32.0. MS (ESI): Calculated for $C_{30}H_{42}N_2NaO_6$ ($[M+Na]^+$): 549.2933, found: 549.2932.

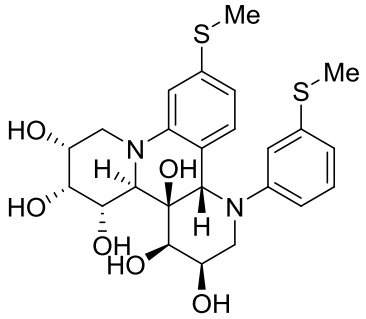


(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-11-methoxy-1-(3-methoxyphenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5g). Yellow solid, yield 57%, m.p. 164.6 - 164.5 ^{o}C, $[\alpha]_D^{25}$ +65.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.11 (t, *J* = 8.0 Hz, 1H), 6.92 (d, *J* = 8.4 Hz, 1H), 6.68 (dd, *J* = 8.4, 2.4 Hz, 1H), 6.62 (t, *J* = 2.4 Hz, 1H), 6.43 (d, *J* = 2.4 Hz, 1H), 6.32 (dd, *J* = 8.4, 2.4 Hz, 1H), 6.24 (dd, *J* = 8.4, 2.4 Hz, 1H), 5.25 (s, 1H), 4.03 (d, *J* = 10.8 Hz, 2H), 3.93 – 3.90 (m, 1H), 3.86 – 3.84 (m, 2H), 3.78 (d, *J* = 4.4 Hz, 1H), 3.76 (s, 3H), 3.73 (s, 3H), 3.61 – 3.59 (m, 1H), 3.54 (d, J = 3.2 Hz, 1H), 3.30 – 3.24 (m, 1H), 3.10 (d, *J* = 13.6 Hz, 1H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 162.4, 162.1, 155.2, 146.9, 131.1, 129.7, 113.7, 108.5, 104.4, 103.7, 102.0, 99.4, 75.1, 73.7, 72.2, 70.1, 68.4, 66.3, 61.9, 55.0, 55.6. MS (ESI): Calculated for $C_{24}H_{30}N_2KO_8$ ($[M+K]^+$): 513.2001, found: 513.2001.

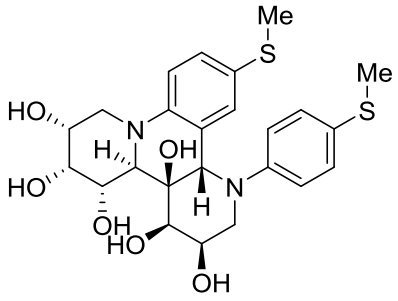


(**3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-12-methoxy-1-(4-methoxyphenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5h)**. Yellow solid, yield 64%, m.p. 142.7 - 144.5 ^{o}C, $[\alpha]_D^{25}$ +70.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.09 – 7.04 (m, 2H), 6.86 – 6.82 (m, 3H), 6.74 – 6.70 (m, 2H), 5.20 (s, 1H), 4.03 (d, *J* = 2.8 Hz, 1H), 3.98 (d, *J* = 10.8 Hz, 1H), 3.89 (dd, *J* = 10.8, 2.8 Hz, 1H), 3.84 – 3.83 (m, 1H), 3.80 – 3.75 (m, 1H), 3.74 (s, 3H), 3.73 – 3.71 (m, 1H), 3.60 – 3.57 (m, 1H), 3.56 (s, 3H), 3.54 (d, *J* = 3.2 Hz, 1H), 3.25

(dd, *J* = 14.0, 11.2 Hz, 1H), 3.15 (dd, *J* = 14.0, 1.6 Hz, 1H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 153.8, 153.7, 148.2, 139.7, 123.1, 117.5, 115.9, 114.4, 113.8, 75.5, 73.8, 72.3, 69.8, 68.6, 66.2, 63.2, 56.2, 56.0, 48.1. MS (ESI): Calculated for $C_{24}H_{30}N_2KO_8$ ($[M+K]^+$): 513.3001, found: 513.3002.

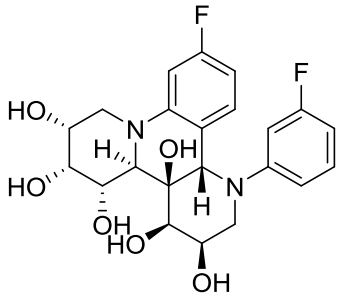


(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-11-(methylthio)-1-(3-(methylthio)phenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5i). Yellow solid, yield 37%, m.p. 159.4 - 160.8 ^{o}C, $[\alpha]_D^{25}$ +65.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.13 (t, *J* = 8.0 Hz, 1H), 6.98 (t, *J* = 2.4 Hz, 1H), 6.94 (d, *J* = 8.0 Hz, 1H), 6.87 (dd, *J* = 8.4, 2.4 Hz, 1H), 6.78 (d, *J* = 1.6 Hz, 1H), 6.63 (dd, *J* = 7.6, 1.6 Hz, 1H), 6.55 (dd, *J* = 8.0, 1.6 Hz, 1H), 5.26 (s, 1H), 4.06 – 4.04 (m, 2H), 3.94 – 3.85 (m, 3H), 3.80 (dd, *J* = 14.0, 4.4 Hz, 1H), 3.60 – 3.56 (m, 1H), 3.53 (d, *J* = 3.2 Hz, 1H), 3.30 – 3.24 (m, 1H), 3.10 (d, *J* = 14.0 Hz, 1H), 2.44 (s, 3H), 2.42 (s, 3H). ^{13}C NMR (101 MHz, MeOD), δ_C (ppm): 154.2, 146.1, 141.0, 140.9, 130.8, 129.1, 118.3, 117.1, 116.8, 113.6, 112.7, 111.0, 75.1, 73.7, 72.2, 70.1, 68.4, 66.3, 62.0, 56.0, 47.9, 15.7, 15.6. MS (ESI): Calculated for $C_{24}H_{31}N_2O_6S_2$($[M+H]^+$): 507.1545, found: 507.1544.

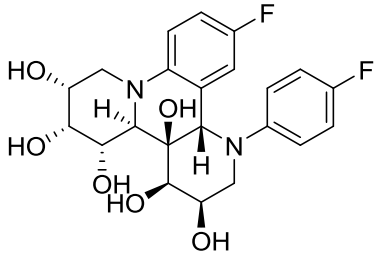


(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-12-(methylthio)-1-(4-(methylthio)phenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5j). Yellow solid, yield 48%, m.p. 158.4 - 160.1 ^{o}C, $[\alpha]_D^{25}$ +157.0 (*c* 0.1,

CH_3OH); ^1H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.24 (d, *J* = 8.4 Hz, 2H), 7.12 – 7.07 (m, 3H), 7.00 (d, *J* = 2.4 Hz, 1H), 6.87 (d, *J* = 8.8 Hz, 1H), 5.29 (s, 1H), 4.05 (d, *J* = 10.4 Hz, 2H), 3.94 – 3.85 (m, 3H), 3.79 (dd, *J* = 14.0, 4.8 Hz, 1H), 3.60 – 3.55 (m, 1H), 3.51 (d, *J* = 3.2 Hz, 1H), 3.30 – 3.23 (m, 1H), 3.10 (d, *J* = 14.0 Hz, 1H), 2.39 (s, 3H), 2.22 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 152.5, 144.3, 132.1, 131.2, 129.2, 127.2, 126.6, 122.2, 116.4, 114.1, 75.1, 73.7, 72.2, 70.0, 68.4, 66.3, 62.3, 56.0, 47.9, 18.6, 18.1. HRMS (ESI, m/z**):** Calculated for r $C_{30}H_{42}N_2KO_6$ ($[M+K]^+$): 565.4043, found: 565.4042.

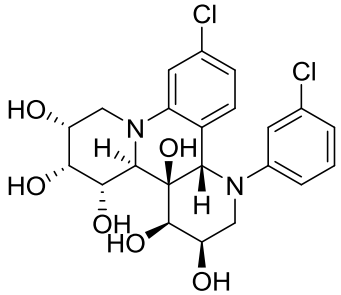


(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-11-fluoro-1-(3-fluorophenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5k). Yellow solid, yield 50%, m.p. 160.4 - 162.1 ^oC, $[\alpha]_D^{25}$ +120.0 (*c* 0.1, CH_3OH); ^1H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.19 (q, *J* = 8.0 Hz, 1H), 6.99 – 6.94 (m, 1H), 6.88 (dd, *J* = 8.4, 2.4 Hz, 1H), 6.85 – 6.80 (m, 1H), 6.66 (dd, *J* = 12.4, 2.4 Hz, 1H), 6.45 – 6.35 (m, 2H), 5.27 (s, 1H), 4.06 (d, *J* = 10.8 Hz, 2H), 3.96 – 3.87 (m, 3H), 3.75 – 3.70 (m, 1H), 3.60 – 3.57 (m, 1H), 3.51 (d, *J* = 3.2 Hz, 1H), 3.28 (d, *J* = 11.2 Hz, 1H), 3.10 (d, *J* = 14.0 Hz, 1H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 166.4, 164.4, 155.7, 147.7, 131.7, 131.6, 130.1, 116.7, 111.0, 105.3(3C), 104.8, 102.4, 102.1, 100.3(2C), 75.0, 73.7, 72.1, 70.1, 68.3, 66.3, 62.0, 55.9, 48.2. MS (ESI): Calculated for $C_{22}H_{24}F_2N_2NaO_6$ ($[M+Na]^+$): 473.1602, found: 473.1603.

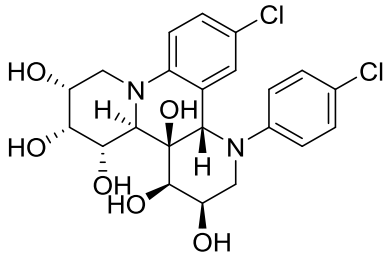


(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-12-fluoro-1-(4-fluorophenyl)-1,3,4,5,6,7,8,13b-oc

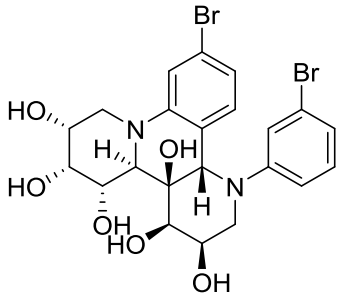
tahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5l). Yellow solid, yield 74%, m.p. 162.8 - 163.7 ^{o}C, $[\alpha]_D^{25}$ +99.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.09 (dd, *J* = 9.2, 4.4 Hz, 2H), 6.97 (t, *J* = 8.4 Hz, 2H), 6.88 (dd, *J* = 6.4, 1.6 Hz, 2H), 6.77 – 6.75 (m, 1H), 5.23 (s, 1H), 4.05 – 4.01 (m, 2H), 3.92 – 3.84 (m, 3H), 3.75 (dd, *J* = 13.6, 4.4 Hz, 1H), 3.59 – 3.55 (m, 1H), 3.51 (d, *J* = 3.2 Hz, 1H), 3.30 – 3.25 (m, 1H), 3.13 (dd, *J* = 14.8, 2.0 Hz, 1H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 158.6, 156.2, 150.3, 142.3, 123.5, 123.4, 117.2, 117.2, 116.7, 116.5, 116.4(2C), 114.7(3C), 75.3, 73.7, 72.2, 69.8, 68.4, 66.2, 62.9, 56.1, 48.12. MS (ESI): Calculated for $C_{22}H_{24}F_2N_2NaO_6$ ($[M+Na]^+$): 473.1602, found: 473.1602.



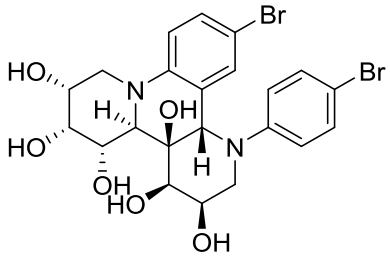
(7*R*,8*R*,9*S*,9a*R*,9b*R*,10*R*,11*R*,13a*S*)-3-chloro-13-(3-chlorophenyl)-7,8,9,9a,11,12,13,13a-octahydro-6*H*-pyrido[1,2-*f*]phenanthridine-7,8,9,9b,10,11(10*H*)-hexaol (5n). Yellow solid, yield 87%, m.p. 126.1 - 128.0 ^{o}C, $[\alpha]_D^{25}$ +90.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.17 (t, *J* = 8.0 Hz, 1H), 7.10 (t, *J* = 2.4 Hz, 1H), 7.01 (dd, *J* = 8.4, 2.4 Hz, 1H), 6.94 (dd, *J* = 8.4, 1.2 Hz, 1H), 6.91 (d, *J* = 1.6 Hz, 1H), 6.70 (dd, *J* = 7.6, 2.0 Hz, 1H), 6.65 (dd, *J* = 8.0, 1.6 Hz, 1H), 5.26 (s, 1H), 4.09 – 4.05 (m, 2H), 3.96 – 3.88 (m, 3H), 3.76 (dd, *J* = 14.0, 4.4 Hz, 1H), 3.57 (dd, *J* = 4.4, 2.8 Hz, 1H), 3.50 (d, *J* = 2.8 Hz, 1H), 3.28 (d, *J* = 11.6 Hz, 1H), 3.10 (d, *J* = 13.6 Hz, 1H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 155.0, 147.2, 136.3, 136.0, 131.5, 129.8, 119.7, 118.9, 118.6, 115.4, 113.8, 113.1, 75.0, 73.6, 72.1, 70.1, 68.3, 66.3, 62.1, 56.0, 48.0. MS (ESI): Calculated for $C_{22}H_{25}Cl_2N_2O_6$ ($[M+H]^+$): 483.1011, found: 483.1011.



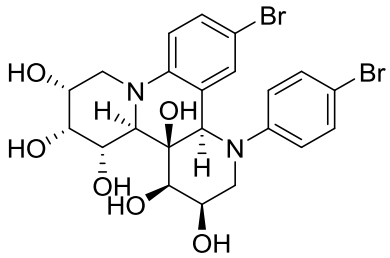
(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-12-chloro-1-(4-chlorophenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5o). Yellow solid, yield 87%, m.p. 126.1 - 128.0 ^{o}C, $[\alpha]_D^{25}$ +90.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.19 – 7.17 (m, 2H), 7.10 – 7.07 (m, 3H), 6.95 (dd, *J* = 2.8, 1.2 Hz, 1H), 6.88 (d, *J* = 8.8 Hz, 1H), 5.27 (s, 1H), 4.07 – 4.03(m, 2H), 3.93 (d, *J* = 2.8 Hz, 1H), 3.91 – 3.87 (m, 2H), 3.77 (dd, *J* = 14.0, 4.4 Hz, 1H), 3.58 – 3.54(m, 1H), 3.49 (d, *J* = 3.2 Hz, 1H), 3.31 – 3.28 (m, 1H), 3.10 (dd, *J* = 14.4, 1.2 Hz, 1H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 152.4, 144.7, 130.1, 129.9, 128.0, 123.9, 123.5, 123.1, 117.0, 114.8, 75.1, 73.6, 72.2, 70.0, 68.3, 66.3, 62.3, 56.0, 48.4, 48.0. MS (ESI): Calculated for $C_{22}H_{25}Cl_2N_2O_6$ ($[M+H]^+$): 483.1011, found: 483.1013.



(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-11-bromo-1-(3-bromophenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5p). Yellow solid, yield 78%, m.p. 183.1 - 184.7 ^{o}C, $[\alpha]_D^{25}$ +99.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.25 (t, *J* = 2.4 Hz, 1H), 7.09 (d, *J* = 7.6 Hz, 1H), 7.07–7.04 (m, 2H), 6.89 – 6.84(m, 2H), 6.78 (dd, *J* = 8.4, 2.0 Hz, 1H), 5.23 (s, 1H), 4.08 – 4.05 (m, 2H), 3.95 – 3.87 (m, 3H), 3.75 (dd, *J* = 14.0, 4.4 Hz, 1H), 3.61 – 3.56 (m, 1H), 3.50 (d, *J* = 3.2 Hz, 1H), 3.30 – 3.26 (m, 1H), 3.09 (d, *J* = 13.2 Hz, 1H). ^{13}C NMR (101 MHz, CD_3OD), δ_C (ppm): 155.1, 147.3, 131.8, 130.1, 124.4, 124.0, 121.9, 121.6, 120.1, 118.3, 116.0, 114.3, 74.9, 72.1, 70.1, 68.3, 66.3, 62.1, 56.0, 48.0. MS (ESI): Calculated for $C_{22}H_{24}Br_2N_2NaO_6$ ($[M+Na]^+$): 592.9891, found: 592.9891.

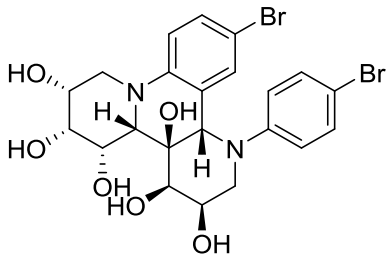


(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-12-bromo-1-(4-bromophenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5q). Yellow solid, yield 85%, m.p. 187.3 - 189.5 ^{o}C, $[\alpha]_D^{25}$ +202.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.33 – 7.30 (m, 2H), 7.22(dd, *J* = 8.8, 2.4 Hz, 1H), 7.08 (dd, *J* = 2.4, 0.8 Hz, 1H), 7.05 – 7.03 (m, 2H), 6.84 (d, *J* = 8.8 Hz, 1H), 5.28 (s, 1H), 4.07 – 4.03 (m, 2H), 3.94 (d, *J* = 2.8 Hz, 1H), 3.92 – 3.88 (m, 2H), 3.77 (dd, *J* = 14.0, 4.4 Hz, 1H), 3.58 – 3.54 (m, 1H), 3.49 (d, *J* = 3.2 Hz, 1H), 3.30 – 3.25 (m, 1H), 3.10 (d, *J* = 14.4 Hz, 1H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 152.8, 145.1, 133.1, 132.8, 130.9, 123.5, 117.4, 115.3, 110.8, 110.5, 75.0, 73.6, 72.1,70.0, 68.3, 66.3, 62.2, 56.0, 48.0. MS (ESI): Calculated for $C_{22}H_{24}Br_2N_2KO_6$ ($[M+K]^+$): 609.0001, found: 609.0002.

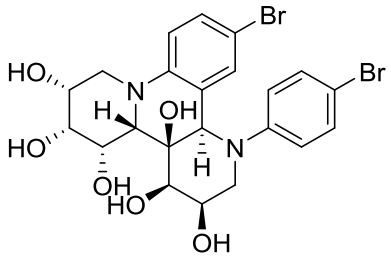


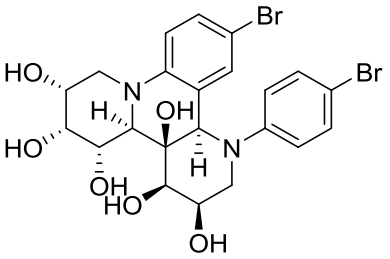
(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*R*)-12-bromo-1-(4-bromophenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5q-1). Yellow solid, yield 6%, m.p. 122.3 - 123.5 ^{o}C, $[\alpha]_D^{25}$ +64.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.41 (d, *J* = 2.4 Hz, 1H), 7.29 (dd, *J* = 8.8, 2.4 Hz, 1H), 7.11 (d, *J* = 8.8 Hz, 2H), 6.84 (d, *J* = 8.8 Hz, 1H), 6.34 (d, *J* = 8.8 Hz, 2H), 4.85 (s, 1H), 4.10 – 4.05 (m, 1H), 3.99 (d, *J* = 8.4 Hz, 2H), 3.73 (dd, *J* = 10.4, 2.8 Hz, 1H), 3.69 – 3.65 (m, 1H), 3.59 – 3.54 (m, 1H), 3.51 (d, *J* = 10.4 Hz, 1H), 3.26 – 3.17 (m, 2H), 3.06 (dd, *J* = 13.2, 4.8 Hz, 1H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 147.8, 141.6, 132.2, 131.8, 131.3, 127.6, 125.4, 114.3, 114.2, 109.9, 107.8,

79.9, 79.1, 77.8, 73.3, 72.2, 69.0, 64.8, 55.2, 46.8, 45.1. MS (ESI): Calculated for $C_{22}H_{24}Br_2N_2NaO_6$ ($[M+Na]^+$): 592.9899, found: 592.9899.

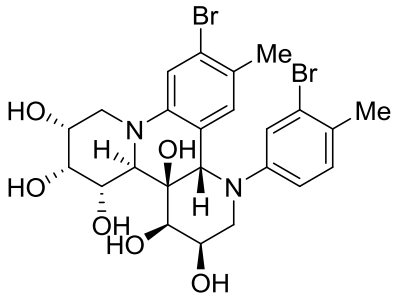


(3*R*,4*R*,4a*R*,4b*S*,5*S*,6*R*,7*R*,13b*S*)-12-bromo-1-(4-bromophenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5q-2). Yellow solid, yield 1%, m.p. 205.6 - 206.5 ^oC, $[\alpha]_D^{25}$+165.0 (*c* 0.1, CH_3OH); ^1H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.32 – 7.29 (m, 2H), 7.25 (dd, *J* = 8.8, 2.4 Hz, 1H), 7.04 – 6.99 (m, 3H), 6.95 (dd, *J* = 2.4, 1.2 Hz, 1H), 5.18 (s, 1H), 4.42 (t, *J* = 2.4 Hz, 1H), 4.07 (dd, *J* = 13.0, 2.8 Hz, 1H), 4.02 (q, *J* = 2.4 Hz, 1H), 3.92 – 3.88 (m, 2H) 3.61 (d, *J* = 3.2 Hz, 1H), 3.54 (d, *J* = 2.8 Hz, 1H), 3.17 – 3.13 (m, 1H), 3.02 (dd, *J* = 13.0, 1.6 Hz, 1H), 2.93 (s, 1H).^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 152.4, 148.6, 133.1, 132.3, 130.0, 126.2, 121.7, 117.6, 113.1, 110.7, 73.6, 71.6, 71.2, 70.8, 70.2, 69.5, 67.1, 65.7, 64.3, 60.2. MS (ESI): Calculated for $C_{22}H_{24}Br_2N_2NaO_6$ ($[M+Na]^+$): 592.9899, found: 592.9895.

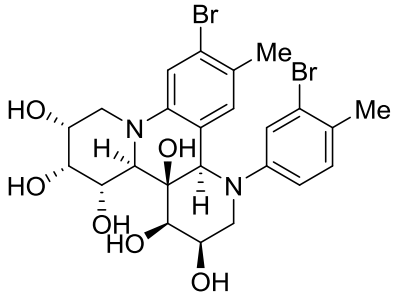




Mixture (5q-3 and 5q-1). ^1H NMR (400 MHz, MeOD), δ_H (ppm): 4.87 (s, 1H), 4.84 (s, 1H). MS (ESI): Calculated for $C_{22}H_{24}Br_2N_2NaO_6$ ($[M+Na]^+$): 592.9899, found: 592.9901.

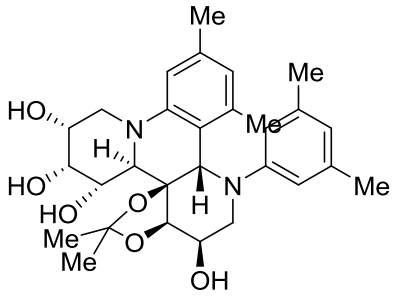


(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-11-bromo-1-(3-bromo-4-methylphenyl)-12-methyl-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5s). Yellow solid, yield 51%, m.p. 173.3 - 173.9 ^{o}C, $[\alpha]_D^{25}$ +67.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.29 (d, *J* = 2.8 Hz, 1H), 7.11 – 7.08 (m, 2H), 7.00 (dd, *J* = 8.8, 2.8 Hz,, 1H), 6.88 (s, 1H), 5.16 (s, 1H), 4.05 – 4.01 (m, 2H), 3.90 (dd, *J* = 10.4, 2.8 Hz, 1H), 3.87 – 3.83 (m, 2H), 3.70 (dd, *J* = 13.6, 4.0 Hz, 1H), 3.58 – 3.56 (m, 1H), 3.50 (d, *J* = 3.2 Hz, 1H), 3.30 – 3.24 (m, 1H), 3.11 – 3.07 (m, 1H), 2.27 (s, 3H), 2.14 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 151.7, 143.8, 130.9, 129.0, 126.5, 126.2, 125.1, 124.7, 119.5, 117.8, 115.5, 113.6, 73.8, 72.3, 70.8, 68.6, 67.0, 64.9, 60.8, 54.6, 46.7, 20.6, 20.4. MS (ESI): Calculated for $C_{24}H_{28}Br_2N_2NaO_6$ ($[M+Na]^+$): 621.0204, found: 620.0204.

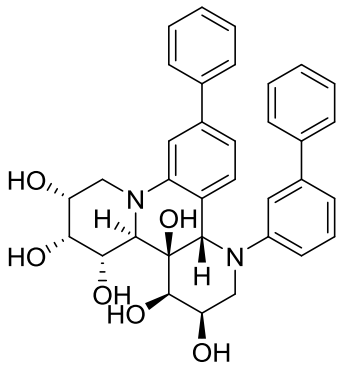


(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*R*)-11-bromo-1-(3-bromo-4-methylphenyl)-12-methyl-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5s-1). Yellow solid, yield 26%, m.p. 173.3 - 173.9 ^{o}C, $[\alpha]_D^{25}$ +12.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.18 (s, 1H), 7.09 (s, 1H), 6.91 (d, *J* = 8.4 Hz, 1H), 6.52 (d, *J* = 2.4 Hz, 1H), 6.26 (dd, *J* = 8.4, 2.4 Hz, 1H), 4.83 (s, 1H), 4.07– 4.03 (m, 2H), 3.98 (t, *J* = 3.2 Hz, 1H), 3.72 (dd, *J* = 10.4, 2.8 Hz, 1H), 3.65 (dd, *J* = 13.2, 4.8 Hz, 1H), 3.57 (t, *J* = 3.6 Hz, 1H), 3.49 (d, *J* = 10.4 Hz, 1H), 3.21 (dd, *J* = 13.2, 3.2 Hz, 2H), 3.05 (dd, *J* = 13.2, 3.6 Hz, 1H), 2.26 (s, 3H),

2.19 (s, 3H). ^{13}C NMR (400 MHz, CD_3OD), δ_C (ppm): 148.1, 141.7, 131.6, 130.5, 127.2, 125.3, 124.8, 124.5, 122.7, 116.0, 115.7, 111.9, 80.1, 79.2, 78.0, 72.9, 72.2, 69.1, 64.8, 63.0, 55.1, 53.4, 44.7, 29.4, 20.4. MS (ESI): Calculated for $C_{24}H_{28}Br_2N_2KO_6$ ($[M+K]^+$): 637.1314, found: 637.1314.

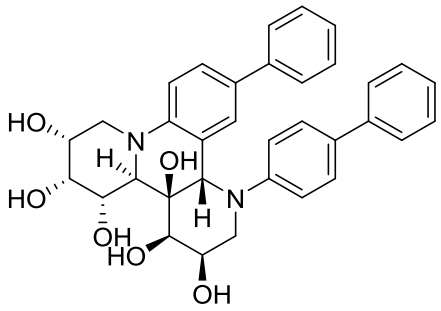


(2*R*,3*R*,4*S*,4a*R*,4b*R*,7a*R*,8*R*,10a*S*)-10-(3,5-dimethylphenyl)-6,6,11,13-tetramethyl-2,3,4,4a,7a,8,10,10a-octahydro-1*H*,9*H*-benzo[*h*][1,3]dioxolo[4,5-d]pyrido[2,1-*f*][1,6]naphthyridine-2,3,4,8-tetraol (5t'). Yellow solid, yield 80%, m.p. 119.3 - 120.9 ^{o}C, $[\alpha]_D^{25}$ +48.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 6.63 (s, 1H), 6.50 (s, 1H), 6.28 (s, 1H), 6.17 (s, 2H), 5.17 (d, *J* = 2.0 Hz, 1H), 4.97 (s, 1H), 4.19 – 4.15 (m, 1H), 4.01 (d, *J* = 2.8 Hz, 1H), 3.89 (dd, *J* = 9.6, 2.8 Hz, 1H), 3.72 – 3.66 (m, 2H), 3.42 (d, *J* = 9.6 Hz, 1H), 3.12 – 3.02 (m, 2H), 2.86 (dd, *J* = 13.2, 7.2 Hz, 1H), 2.35 (s, 3H), 2.23 (s, 3H), 2.16 (s, 6H), 1.55 (s, 3H), 1.52 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 149.5, 146.3, 140.9, 140.3, 139.5, 123.3, 120.5, 118.5, 115.2, 112.8, 112.4, 91.2, 89.2, 83.1, 78.7, 73.0, 69.8, 66.8, 57.0, 47.3, 28.7, 28.2, 21.8, 21.7, 19.7. MS (ESI): Calculated for $C_{29}H_{38}N_2KO_6$ ($[M+K]^+$): 549.2730, found: 549.2731.

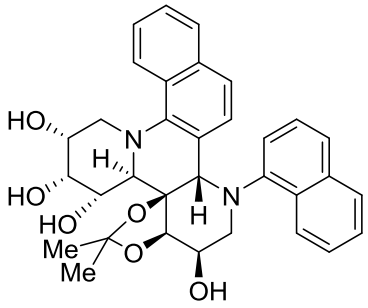


(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-1-([1,1'-biphenyl]-3-yl)-11-phenyl-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hex

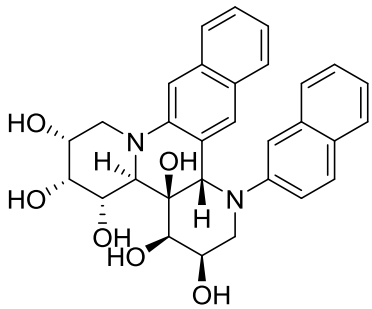
aol (5u). Yellow solid, yield 78%, m.p. 182.1 - 184.0 °C, $[\alpha]_D^{25}$ +309.0 (*c* 0.1, CH_3OH); ^1H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.49 (dd, *J* = 12.0, 8.0 Hz, 4H), 7.38 – 7.32 (m, 6H), 7.26 (t, *J* = 7.2 Hz, 2H), 7.22 (d, *J* = 7.6 Hz, 1H), 7.17 (dd, *J* = 8.8, 6.0 Hz, 3H), 6.92 (d, *J* = 9.2 Hz, 1H), 5.37 (s, 1H), 4.10 (d, *J* = 2.8 Hz, 1H), 4.04 (d, *J* = 10.8 Hz, 1H), 4.00 – 3.94 (m, 2H), 3.90 (d, *J* = 3.6 Hz, 1H), 3.85 (dd, *J* = 13.6, 4.4 Hz, 1H), 3.67 – 3.65 (m, 1H), 3.60 (d, *J* = 3.2 Hz, 1H), 3.30 – 3.22 (m, 2H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 152.1, 144.0, 141.1, 140.7, 131.5, 131.2, 129.0, 129.0, 128.3, 128.0, 126.7, 126.6, 126.4, 126.2, 120.3, 115.4, 113.0, 74.4, 72.5, 71.1, 69.1, 67.6, 65.4, 61.6, 55.1, 47.9, 47.1. MS (ESI): Calculated for $C_{33}H_{34}N_2NaO_6$ ($[M+Na]^+$): 589.2417, found: 589.2415.



(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-1-([1,1'-biphenyl]-4-yl)-12-phenyl-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5v). Yellow solid, yield 49%, m.p. 168.5 - 169.9 °C, $[\alpha]_D^{25}$ +102.0 (*c* 0.1, CH_3OH); ^1H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.58 – 7.56 (m, 3H), 7.53 – 7.51 (m, 2H), 7.39 – 7.35 (m, 4H), 7.30 – 7.27 (m, 3H), 7.18 (d, *J* = 8.0 Hz, 1H), 7.11 (dd, *J* = 8.4, 2.4 Hz, 1H), 7.06 (d, *J* = 1.6 Hz, 1H), 6.97 (d, *J* = 7.2 Hz, 1H), 6.87 (dd, *J* = 8.0, 1.6 Hz, 1H), 5.40 (s, 1H), 4.08 – 4.01 (m, 4H), 3.96 (dd, *J* = 16.0, 2.8 Hz, 1H), 3.92 (d, *J* = 4.0 Hz, 1H), 3.72 – 3.67 (m, 1H), 3.63 (d, *J* = 3.2 Hz, 1H), 3.45 – 3.32 (m, 1H), 3.26 (d, *J* = 14.8 Hz, 1H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 153.3, 145.3, 143.3, 143.0, 142.4, 141.9, 130.4, 129.2, 129.2, 128.9, 127.9, 127.8, 127.6, 119.5, 117.8, 117.6, 114.2, 113.9, 111.5, 74.5, 72.9, 71.4, 69.5, 67.9, 65.7, 61.6, 55.5, 49.0, 47.4. MS (ESI): Calculated for $C_{33}H_{34}N_2NaO_6$ ($[M+Na]^+$): 589.2417, found: 589.2416.

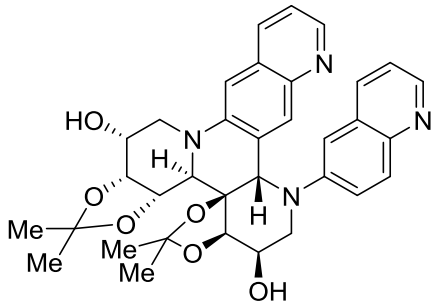


(3a*R*,4*R*,6a*S*,15*R*,16*R*,17*S*,17a*R*,17b*R*)-2,2-dimethyl-6-(naphthalen-1-yl)-3a,4,6,6a,15,16,17,17a-octahydro-5*H*,14*H*-[1,3]dioxolo[4,5-d]naphtho[1,2-*h*]pyrido[2,1-*f*][1,6]naphthyridine-4,15,16,17-tetraol (5w'). Yellow solid, yield 70%, m.p. 128.5 - 129.9 ^{o}C, $[\alpha]_D^{25}$+144.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, $CDCl_3$) , δ_H (ppm): 8.55 (d, *J* = 8.4 Hz, 1H), 7.81 (d, *J* = 8.0 Hz, 1H), 7.67 (d, *J* = 8.4 Hz, 1H), 7.64 – 7.57 (m, 2H), 7.54 (d, *J* = 7.6 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 1H), 7.31 – 7.28 (m, 2H), 7.25 (d, *J* = 6.8 Hz, 1H), 7.19 (d, *J* = 8.0 Hz, 1H), 6.93 (t, *J* = 7.6 Hz, 1H), 6.53 (d, *J* = 7.6 Hz, 1H), 5.29 (s, 1H), 5.08 (s, 1H), 4.72 (s, 2H), 4.64 – 4.60 (m, 2H), 4.54 (t, *J* = 6.0 Hz, 1H), 4.34 – 4.27 (m, 2H), 4.10 (s, 1H), 3.74 – 3.71 (m, 1H), 3.67 (s, 1H), 3.45 – 3.32 (m, 2H), 3.23 (d, *J* = 12.8 Hz, 1H), 1.59 (s, 3H), 1.42 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$), δ_C (ppm): 143.1, 142.8, 134.4, 134.2, 128.5, 128.3, 126.6, 126.5, 126.4, 126.1, 125.8, 125.0, 124.9, 124.8, 124.1, 123.9, 120.1, 118.3, 116.1, 105.0, 91.6, 88.3, 82.6, 82.0, 70.4, 69.7, 68.1, 62.4, 55.1, 46.4, 28.6, 28.2. MS (ESI): Calculated for $C_{33}H_{34}N_2KO_6$ ($[M+K]^+$): 555.2417, found: 555.2415.



(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,15b*S*)-1-(naphthalen-2-yl)-1,3,4,5,6,7,8,15b-octahydro-2H-naphtho[2,3-*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5x). Yellow solid, yield 68%, m.p. 147.5 - 147.9 ^{o}C, $[\alpha]_D^{25}$ +70.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 8.08 (d, *J* = 8.8 Hz, 1H), 7.77 (dd, *J* = 14.0, 9.2 Hz, 2H), 7.50 (d, *J* = 8.0 Hz, 1H), 7.45 – 7.42 (m, 1H), 7.38 (d, *J* = 8.4 Hz, 1H), 7.32

– 7.28 (m, 3H), 7.23 – 7.21 (m, 1H), 7.05 (t, *J* = 7.6 Hz, 1H), 6.46 (d, *J* = 2.0 Hz, 1H), 6.06 (dd, *J* = 8.8, 2.4 Hz, 1H), 5.53 (s, 1H), 4.29 (d, *J* = 8.4 Hz, 1H), 4.25 – 4.22 (m, 1H), 3.97 – 3.92 (m, 2H), 3.77 (dd, *J* = 10.4, 2.4 Hz, 1H), 3.68 (d, *J* = 10.0 Hz, 1H), 3.61 – 3.59 (m, 1H), 3.54 – 3.50 (m, 1H), 3.25 – 3.15 (m, 2H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 147.5, 141.7, 136.6, 134.6, 131.5, 130.7, 129.6, 129.3, 129.1, 128.8, 128.4, 127.9, 126.9, 125.2, 123.9, 122.5, 119.0, 115.9, 114.6, 105.3, 80.8, 79.9, 79.5, 74.5, 73.5, 69.8, 67.1, 64.3, 56.2, 45.9. MS (ESI): Calculated for $C_{30}H_{31}N_2O_6$ ($[M+H]^+$): 515.2140, found: 515.2142.



(3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,15b*S*)-1-(quinolin-6-yl)-1,3,4,5,6,7,8,15b-octahydro-2*H*-pyrido[2,1-*f*]quinolino[6,7-*h*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5y"). Yellow solid, yield 60%, m.p. 106.3 - 107.9 ^{o}C, $[\alpha]_D^{25}$ -5.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 8.56 (dd, *J* = 4.4, 1.6 Hz, 1H), 8.50 (d, *J* = 8.4 Hz, 1H), 8.42 (dd, *J* = 4.4, 1.6 Hz, 1H), 7.98 (dd, *J* = 8.4, 1.6 Hz, 1H), 7.88 (d, *J* = 9.2 Hz, 1H), 7.69 (d, *J* = 9.2 Hz, 1H), 7.53 (d, *J* = 9.6 Hz, 1H), 7.47 (dd, J = 8.4, 4.0 Hz, 1H), 7.29 (dd, *J* = 8.4, 4.4 Hz, 1H), 7.20 (dd, *J* = 9.2, 2.4 Hz, 1H), 6.77 (d, *J* = 2.8 Hz, 1H), 5.12 – 5.11 (m, 2H), 4.78 (t, *J* = 7.2 Hz, 1H), 4.57 – 4.53 (m, 1H), 4.49 (dd, *J* = 6.8, 3.6 Hz, 1H), 4.17 – 4.15 (m, 1H), 3.81 (dd, *J* = 12.0, 3.6 Hz, 1H), 3.60 (s, 1H), 3.47 (dd, *J* = 13.6, 6.0 Hz, 1H), 3.41 – 3.35 (m, 3H), 1.53 (s, 3H), 1.51 (s, 3H), 1.47 (s, 3H), 1.35 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 148.2, 147.4, 146.1, 145.7, 143.3, 143.3, 135.9, 133.4, 131.9, 131.1, 130.9, 129.4, 123.5, 123.2, 122.5, 121.5, 116.5, 110.8, 110.6, 103.5, 87.4, 86.7, 82.6, 76.9, 76.0, 74.3, 66.5, 56.7, 50.3, 49.0, 46.8, 29.1, 27.6, 27.5, 25.3. MS (ESI): Calculated for $C_{34}H_{37}N_4O_6$ ($[M+H]^+$): 596.2417, found: 597.2415.

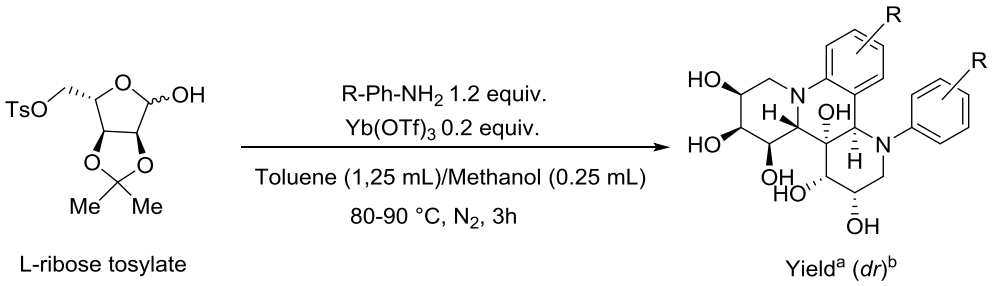
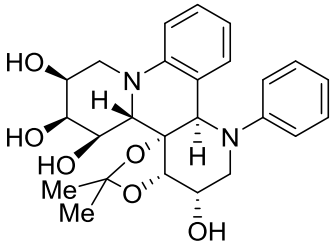


Fig. 2. Synthesis of the complex multicyclic iminosugars using L-ribose tosylate

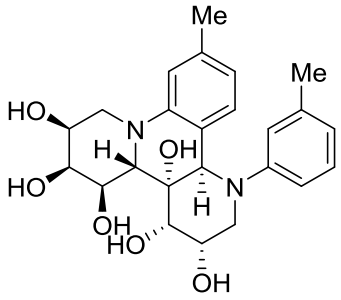
General experimental procedure 2: L-Ribose tosylate (206 mg, 0.6 mmol), aniline (1.2 equiv.) and $Yb(OTf)_3$ (0.2 equiv.) were added into a 25 mL flask, 1.50 mL toluene and methanol (V:V=5:1) as the mixed solvent. Then the solution was stirred at the temperature of 80 – 90 ^oC under N_2 atmosphere for 3 h. Upon completion, The mixture was cooled to room temperature, 20 ml of methanol was added to dissolve the solid residue, and the solvent was evaporated in vacuo. The crude product was purified by column chromatography (dichloromethane:methanol V/V = 15:1) to give **6a'** as a pale yellow solid.

Under similar conditions, different aromatic amines were used as raw materials for the reaction, and the corresponding products were obtained respectively.

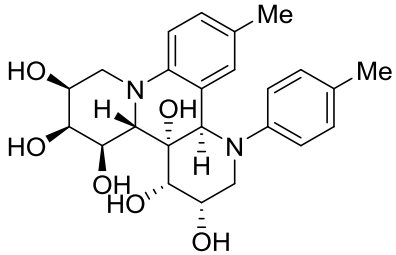


(2*S*,3*R*,4*S*,4a*R*,4b*R*,7a*R*,8*S*,10a*S*)-6,6-dimethyl-10-phenyl-2,3,4,4a,7a,8,10,10a-octahydro-1*H*,9*H*-benzo[*h*][1,3]dioxolo[4,5-d]pyrido[2,1-*f*][1,6]naphthyridine-2,3,4,8-tetraol (6a'). Yellow solid, yield 69%, m.p. 123.5 - 124.9 ^oC, $[\alpha]_D^{25}$ -33.0 (*c* 0.1, CH_3OH); ^1H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.24 (t, *J* = 7.6 Hz, 2H), 7.12 (t, *J* = 8.0 Hz, 1H), 6.95 – 6.89 (m, 4H), 6.70 (t, *J* = 7.6 Hz, 1H), 6.63 (t, *J* = 7.6 Hz, 1H), 5.26 (s, 1H), 4.44 (d, *J* = 2.4 Hz, 1H), 4.06 (d, *J* = 2.8 Hz, 1H), 3.88 – 3.82 (m, 2H), 6.72 (d, *J* = 14.4 Hz, 1H), 3.70 – 3.63 (m, 2H), 3.28 – 3.23 (m, 2H), 3.09 (dd, *J* = 10.0, 6.8 Hz, 1H), 1.52 (s, 3H), 1.24 (s, 3H). ^{13}C NMR (101 MHz, CD_3OD), δ_C (ppm): 151.1, 144.5, 130.4, 130.0, 128.6, 123.7, 119.9, 117.7, 113.6, 112.6, 112.5, 83.7, 81.9,

73.4, 69.9, 66.2, 65.6, 64.3, 63.4, 55.1, 46.1, 27.3, 27.2. MS (ESI): Calculated for $C_{24}H_{27}N_2KO_6$ ($[M+K]^+$): 478.1869, found: 478.1870.

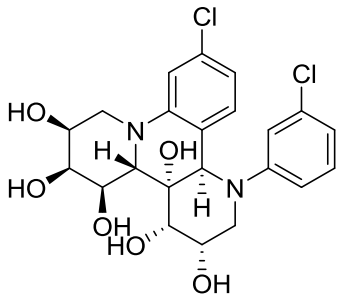


(3*S*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*S*,13b*S*)-11-methyl-1-(m-tolyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (6c). Yellow solid, yield 56%, m.p. 170.5 - 171.9 ^oC, $[\alpha]_D^{25}$ -156.0 (*c* 0.1, CH_3OH); ^1H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.09 (t, *J* = 8.0 Hz, 1H), 6.91 – 6.86 (m, 3H), 6.74 (s, 1H), 6.55 (d, *J* = 7.6 Hz, 1H), 6.46 (d, *J* = 8.0 Hz, 1H), 5.29 (s, 1H), 4.03 (d, *J* = 10.4 Hz, 2H), 3.93 – 3.90 (m, 1H), 3.88 – 3.81 (m, 3H), 3.57 (d, *J* = 3.6 Hz, 1H), 3.54 (d, *J* = 3.2 Hz, 1H), 3.29 – 3.23 (m, 1H), 3.10 (d, *J* = 14.0 Hz, 1H), 2.28 (s, 3H), 2.24 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 153.9, 145.7, 140.1, 139.8, 130.2, 128.7, 112.0, 119.6, 118.5, 116.2, 113.8, 112.8, 75.1, 73.8, 72.2, 70.0, 68.5, 66.3, 64.3, 61.9, 56.0,, 47.8, 21.9, 21.6. MS (ESI): Calculated for $C_{24}H_{30}N_2KO_6$ ($[M+K]^+$): 478.1869, found: 478.1869.

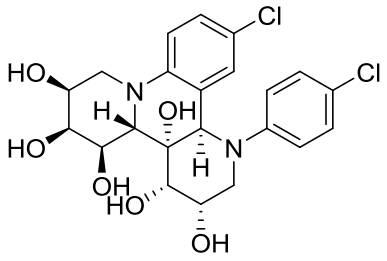


(3*S*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*S*,13b*S*)-12-methyl-1-(p-tolyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (6d). Yellow solid, yield 78%, m.p. 179.5 - 180.2 ^oC, $[\alpha]_D^{25}$ -38.0 (*c* 0.1, CH_3OH); ^1H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.03 – 6.97 (m, 4H), 6.92 (dd, *J* = 8.4, 2.0 Hz, 1H), 6.87 (d, *J* = 2.4 Hz, 1H), 6.79 (d, *J* = 8.8 Hz, 1H), 5.25 (s, 1H), 4.03 – 3.99 (m, 2H), 3.90 – 3.82 (m, 3H), 3.78 (dd, *J* = 14.0, 4.4 Hz, 1H), 3.59 – 3.55 (m, 1H), 3.53 (d, *J* = 2.8 Hz, 1H), 3.25 (dd, *J* = 14.0, 11.6 Hz, 1H), 3.10 (d, *J* = 13.2 Hz, 1H), 2.23 (s,

3H), 2.08 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 151.7, 143.5, 130.8, 130.5, 129.0, 128.3, 127.9, 121.5, 115.6, 113.4, 75.2, 73.8, 72.3, 69.9, 68.5, 66.2, 62.2, 56.00, 47.9, 20.5, 20.4. MS (ESI): Calculated for $C_{24}H_{30}N_2NaO_6$ ($[M+Na]^+$): 462.1869, found: 462.1869.

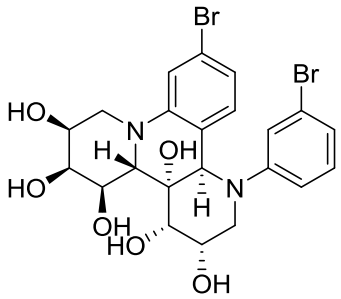


(3*S*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*S*,13b*S*)-11-chloro-1-(3-chlorophenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[h]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (6n). Yellow solid, yield 77%, m.p. 162.5 - 163.1 ^oC, $[\alpha]_D^{25}$ -92.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.17 (t, *J* = 8.0 Hz, 1H), 7.10 (d, *J* = 2.4 Hz, 1H), 7.02 (dd, *J* = 8.4, 2.4 Hz, 1H), 6.96 – 6.92 (m, 2H), 6.72 – 6.64 (m, 2H), 5.26 (s, 1H), 4.08 – 4.05 (m, 2H), 3.96 – 3.88 (m, 3H), 3.76 (dd, *J* = 13.6, 4.4 Hz, 1H), 3.62 – 3.57 (m, 2H), 3.51 (d, *J* = 3.2 Hz, 1H), 3.09 (d, *J* = 13.6 Hz, 1H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 155.0, 147.1, 136.2, 131.6, 129.9, 119.7, 118.9, 118.6, 115.4, 113.8, 113.1, 74.8, 73.7, 72.0, 70.0, 68.2, 66.2, 62.0, 56.0. MS (ESI): Calculated for $C_{22}H_{24}Cl_2N_2KO_6$ ($[M+K]^+$): 521.1011, found: 521.1011.

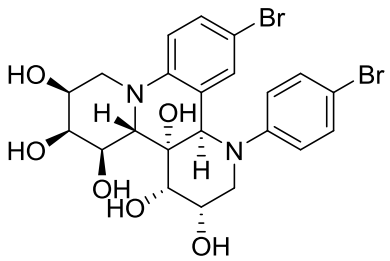


(3*S*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*S*,13b*S*)-12-chloro-1-(4-chlorophenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (6o). Yellow solid, yield 76%, m.p. 157.8 - 158.9 ^oC, $[\alpha]_D^{25}$ -90.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.20 – 7.18 (m, 2H), 7.10 – 7.08 (m, 3H), 6.95 (d, *J* = 2.4 Hz, 1H), 6.89 (d, *J* = 8.8 Hz, 1H), 5.27 (s, 1H), 4.05 (d, *J* = 10.4 Hz, 2H), 3.94 (d, *J* = 2.8 Hz, 1H), 3.91 – 3.87 (m, 2H), 3.78 (dd, *J* = 14.0, 4.4 Hz, 1H), 3.59 –

3.54 (m, 1H), 3.49 (d, *J* = 3.2 Hz, 1H), 3.29 – 3.25 (m, 1H), 3.10 (d, *J* = 14.4 Hz, 1H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 152.4, 144.7, 130.1, 129.9, 128.0, 123.8, 123.5, 123.1, 117.0, 114.9, 75.0, 73.7, 72.1, 69.9, 68.3, 66.2, 64.3, 62.3, 56.0, 48.0. MS (ESI): Calculated for $C_{22}H_{24}Cl_2N_2NaO_6$ ($[M+Na]^+$): 505.1011, found: 505.1010.

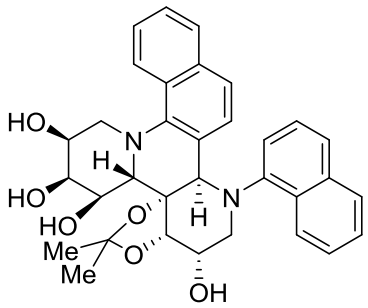


(3*S*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*S*,13b*S*)-11-bromo-1-(3-bromophenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (6p). Yellow solid, yield 68%, m.p. 160.0 - 161.3 ^oC, $[\alpha]_D^{25}$ -100.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.25 (d, *J* = 2.4 Hz, 1H), 7.09 (d, *J* = 8.0 Hz, 1H), 7.07 – 7.04 (m, 2H), 6.87 (d, *J* = 8.4 Hz, 1H), 6.85 – 6.83 (m, 1H), 6.78 (dd, *J* = 8.0, 1.6 Hz, 1H), 5.22 (s, 1H), 4.06 (d, *J* = 10.8 Hz, 2H), 3.95 – 3.87 (m, 3H), 3.75 (dd, *J* = 13.6, 4.4 Hz, 1H), 3.60 – 3.55 (m, 1H), 3.49 (d, *J* = 2.8 Hz, 1H), 3.30 – 3.26 (m, 1H), 3.11 – 3.06 (m, 1H). ^{13}C NMR (101 MHz, CD_3OD), δ_C (ppm): 155.1, 147.3, 131.8, 130.1, 124.4, 124.0, 121.9, 121.6, 120.1, 118.3, 116.0, 114.3, 74.9, 73.6, 72.0, 70.0, 68.2, 66.3, 62.1, 56.0, 48.0. MS (ESI): Calculated for $C_{22}H_{25}Br_2N_2O_6$ ($[M+H]^+$): 571.0001, found: 571.0002.



(3*S*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*S*,13b*S*)-12-bromo-1-(4-bromophenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (6q). Yellow solid, yield 82%, m.p. 159.8 - 160.3 ^oC, $[\alpha]_D^{25}$ -200.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.32 – 7.30 (m, 2H), 7.22 (dd, *J* = 8.8, 2.4 Hz, 1H), 7.08 (d, *J* = 2.4 Hz, 1H), 7.05 – 7.03 (m, 2H), 6.84 (d, *J* = 9.2 Hz, 1H), 5.28

(s, 1H), 4.05 (d, *J* = 10.4 Hz, 2H), 3.93 (d, *J* = 2.8 Hz, 1H), 3.92 – 3.87 (m, 2H), 3.77 (dd, *J* = 14.0, 4.4 Hz, 1H), 3.56 (dt, *J* = 11.2, 4.4, 2.4 Hz, 1H), 3.49 (d, *J* = 3.6 Hz, 1H), 3.28 – 3.25 (m, 1H), 3.09 (d, *J* = 14.0 Hz, 1H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 152.8, 145.1, 133.1, 132.8, 130.9, 123.5, 117.4, 115.3, 110.8, 110.4, 745.0, 73.6, 72.1, 69.9, 68.3, 66.2, 62.2, 56.0, 48.0. MS (ESI): Calculated for $C_{22}H_{25}Br_2N_2O_6$ ($[M+H]^+$): 571.0001, found: 571.0001.



(3a*R*,4*S*,6a*S*,15*S*,16*R*,17*S*,17a*R*,17b*R*)-2,2-dimethyl-6-(naphthalen-1-yl)-3a,4,6,6a, 15,16,17,17a-octahydro-5*H*,14*H*-[1,3]dioxolo[4,5-d]naphtho[1,2-*h*]pyrido[2,1-*f*][1, 6]naphthyridine-4,15,16,17-tetraol (6w'). Yellow solid, yield 52%, m.p. 128.8 - 129.9 ^{o}C, $[\alpha]_D^{25}$ -145.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 8.57 (d, *J* = 8.4 Hz, 1H), 7.81 – 7.79 (m, 1H), 7.65 (d, *J* = 8.0 Hz, 1H), 7.59 – 7.49 (m, 5H), 7.28 (dd, *J* = 8.0, 6.8 Hz, 1H), 7.22 (t, *J* = 8.0 Hz, 1H), 7.12 (d, *J* = 8.4 Hz, 1H), 7.00 – 6.96 (m, 1H), 6.58 (d, *J* = 7.2 Hz, 1H), 5.04 (s, 1H), 4.71 (d, *J* = 3.2 Hz, 1H), 4.62 – 4.59 (m, 1H), 4.32 – 4.31 (m, 1H), 4.27 (t, *J* = 3.6 Hz, 1H), 4.00 – 3.98 (m, 1H), 3.67 (dd, *J* = 12.8, 3.2 Hz, 1H), 3.57 (s, 1H), 3.45 – 3.36 (m, 2H), 3.19 (d, *J* = 12.4 Hz, 1H), 1.61 (s, 3H), 1.50 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 144.7, 144.3, 135.8, 135.7, 131.1, 129.5, 129.4, 129.2, 127.5, 127.4, 127.0, 126.5, 125.9, 125.5, 125.4, 125.2, 121.5, 118.6, 117.1, 105.5, 92.3, 89.4, 83.5, 83.0, 71.800, 71.101, 68.9, 63.8, 56.9,, 47.4, 28.9, 28.4. MS (ESI): Calculated for $C_{33}H_{34}N_2NaO_6$ ($[M+Na]^+$): 577.2417 found: 577.2416.

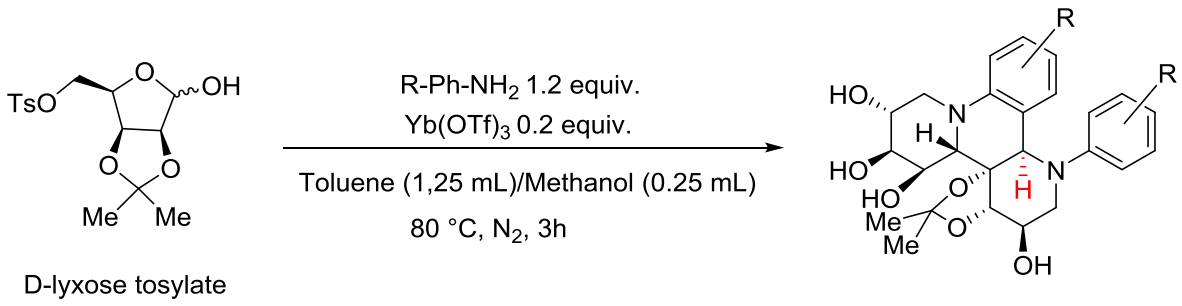
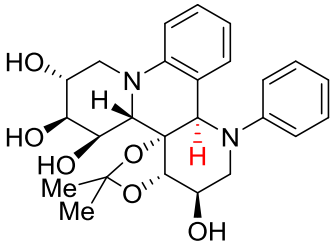


Fig. 3. Synthesis of the complex multicyclic iminosugars using D-lyxose tosylate

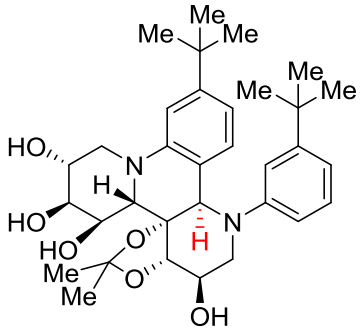
General experimental procedure 3: L-Lyxose tosylate (206 mg, 0.6 mmol), aniline (1.2 equiv.) and $Yb(OTf)_3$ (0.2 equiv.) were added into a 25 mL flask, 1.50 mL toluene and methanol (V:V=5:1) as the mixed solvent. Then the solution was stirred at the temperature of 80 ^oC under N_2 atmosphere for 3h. Upon completion, The mixture was cooled to room temperature, 20 ml of methanol was added to dissolve the solid residue, and the solvent was evaporated in vacuo. The crude product was purified by column chromatography (dichloromethane:methanol V/V = 15:1) to give **7a-1'** as a pale yellow solid.

Under similar conditions, different aromatic amines were used as raw materials for the reaction, and the corresponding products were obtained respectively.

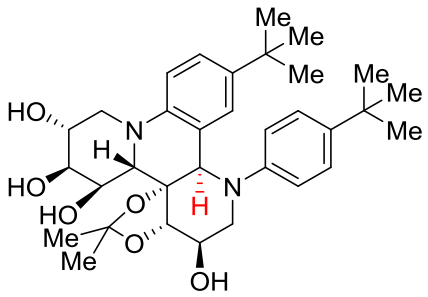


(2*R*,3*S*,4*R*,4a*S*,4b*S*,7a*S*,8*R*,10a*R*)-6,6-dimethyl-10-phenyl-2,3,4,4a,7a,8,10,10a-octahydro-1*H*,9*H*-benzo[*h*][1,3]dioxolo[4,5-d]pyrido[2,1-*f*][1,6]naphthyridine-2,3,4,8-tetraol (7a-1'). Yellow solid, yield 74%, m.p. 84.4 - 85.9 ^oC, $[\alpha]_D^{25}$ -40.0 (*c* 0.1, CH_3OH); ^1H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.35 (dd, *J* = 7.6, 1.6 Hz, 1H), 7.16 – 7.12 (m, 1H), 7.10 – 7.06 (m, 2H), 6.95 (d, *J* = 8.4 Hz, 1H), 6.82 (t, *J* = 7.6 Hz, 1H), 6.66 (*J* = 8.0 Hz, 2H), 6.61 (t, *J* = 7.2 Hz, 1H), 4.89 (d, *J* = 3.2 Hz, 1H), 4.86 (s, 1H), 4.35 (dd, *J* = 8.0, 3.2 Hz, 1H), 4.00 (dt, *J* = 4.8, 2.4 Hz, 1H), 3.96 (dd, *J* = 4.8,

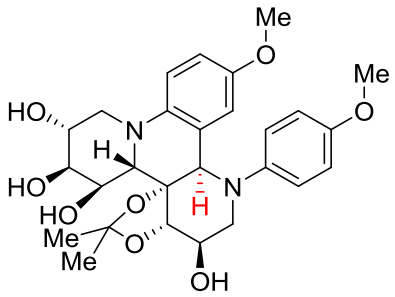
2.8 Hz, 1H), 3.86 (td, *J* = 6.4, 3.6 Hz, 1H), 3.64 – 3.61 (m, 1H), 3.52 (dd, *J* = 13.6, 5.6 Hz, 1H), 3.42 (dd, *J* = 13.2, 6.8 Hz, 1H), 3.24 (dd, *J* = 13.2, 2.8 Hz, 1H), 3.22 – 3.19 (m, 1H), 1.62 (s, 3H), 1.58 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 149.9, 149.1, 131.1, 130.0, 129.6, 128.9, 124., 120.6, 118.4, 115.8, 115.6, 114.3, 95.1, 87.8, 81.4, 79.3, 72.8, 71.1, 68.0, 61.2, 50.5, 49.0, 44.0, 28.3, 28.3. MS (ESI): Calculated for $C_{25}H_{31}N_2O_6$ ($[M+H]^+$): 455.2104, found: 455.2105.



(2*R*,3*S*,4*R*,4a*S*,4b*S*,7a*S*,8*R*,10a*R*)-13-(tert-butyl)-10-(3-(tert-butyl)phenyl)-6,6-dimethyl-2,3,4,4a,7a,8,10,10a-octahydro-1*H*,9*H*-benzo[*h*][1,3]dioxolo[4,5-d]pyrido[2,1-*f*][1,6]naphthyridine-2,3,4,8-tetraol (7e-1'). Yellow solid, yield 80%, m.p. 88.1 - 90.1 ^{o}C, $[\alpha]_D^{25}$ -25.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.26 (d, *J* = 8.0 Hz, 1H), 7.02 (t, *J* = 7.6 Hz, 1H), 6.99 (s, 1H), 6.89 (dd, *J* = 8.0, 1.6 Hz, 1H), 6.74 (t, *J* = 2.4 Hz, 1H), 6.70 – 6.67 (m, 1H), 6.48 (dd, *J* = 8.0, 2.4 Hz, 1H), 4.85 (s, 1H), 4.83 (d, *J* = 3.2 Hz, 1H), 4.33 (dd, *J* = 7.6, 3.2 Hz, 1H), 4.03 – 4.00 (m, 1H), 3.96 (dd, *J* = 5.2, 2.8 Hz, 1H), 3.88 – 3.84 (m, 1H), 3.61 – 3.57 (m, 1H), 3.57 – 3.52 (m, 1H), 3.42 (dd, *J* = 13.6, 6.8 Hz, 1H), 3.28 – 3.25 (m, 1H), 3.19 (d, *J* = 7.2 Hz, 1H), 1.62 (s, 3H), 1.57 (s, 3H), 1.28 (s, 9H), 1.26 (s, 9H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 153.1, 152.6, 149.6, 148.6, 129.7, 128.5, 121.8, 118.3, 115.8, 113.4, 112.0, 111.7, 95.2, 87.9, 81.4, 79.3, 73.1, 71.2, 68.3, 61.7, 51.0, 44.2, 35.7, 35.4, 31.9, 31.8, 28.3, 28.1, 28.0. MS (ESI): Calculated for $C_{33}H_{46}N_2NaO_6$ ($[M+Na]^+$): 589.3356, found: 589.3357.

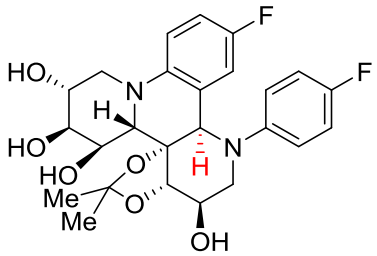


(2*R*,3*S*,4*R*,4a*S*,4b*S*,7a*S*,8*R*,10a*R*)-12-(tert-butyl)-10-(4-(tert-butyl)phenyl)-6,6-di methyl-2,3,4,4a,7a,8,10,10a-octahydro-1*H*,9*H*-benzo[*h*][1,3]dioxolo[4,5-d]pyrido[2,1-*f*][1,6]naphthyridine-2,3,4,8-tetraol (7f-1'). Yellow solid, yield 78%, m.p. 107.1 - 108.5 ^{o}C, $[\alpha]_D^{25}$ -25.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.37 (d, *J* = 2.4 Hz, 1H), 7.17 (dd, *J* = 8.4, 2.4 Hz, 1H), 7.14 – 7.12 (m, 2H), 6.87 (d, *J* = 8.8 Hz, 1H), 6.64 – 6.62 (m, 2H), 4.86 (s, 1H), 4.84 (s, 1H), 4.37 (dd, *J* = 7.6, 3.2Hz, 1H), 4.01 – 3.95 (m, 2H), 3.89 (ddd, *J* = 7.2, 5.2, 3.6 Hz, 1H), 3.55 (dd, *J* = 13.6, 4.4 Hz, 2H), 3.48 – 3.42 (m, 1H), 3.23 – 3.20 (m, 1H), 3.10 (d, *J* = 7.6 Hz, 1H), 1.62 (s, 3H), 1.57 (s, 3H), 1.23 (s, 18H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 147.2, 146.8, 143.6, 141.3, 131.0, 126.8, 126.5, 125.2, 123.8, 115.7, 115.5, 114.4, 95.4, 87.8, 81.6, 79.0, 72.8, 70.9, 67.9, 61.5, 50.7, 4.19, 3.83, 34.6, 32.0, 32.0, 31.9, 28.4, 28.3. MS (ESI): Calculated for $C_{33}H_{46}N_2NaO_6$ ($[M+Na]^+$): 589.3356, found: 589.3356.



(2*R*,3*S*,4*R*,4a*S*,4b*S*,7a*S*,8*R*,10a*R*)-12-methoxy-10-(4-methoxyphenyl)-6,6-dimethy l-2,3,4,4a,7a,8,10,10a-octahydro-1*H*,9*H*-benzo[*h*][1,3]dioxolo[4,5-d]pyrido[2,1-*f*][1,6]naphthyridine-2,3,4,8-tetraol (7h-1'). Yellow solid, yield 68%, m.p. 94.1 - 95.5 ^{o}C, $[\alpha]_D^{25}$ -22.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 6.96 (d, *J* = 2.8 Hz, 1H), 6.90 (d, *J* = 8.8 Hz, 1H), 6.76 – 6.69 (m, 5H), 4.82 (s, 1H), 4.76 (d, *J* = 3.2 Hz, 1H), 4.36 (dd, *J* = 6.4, 2.8 Hz, 1H), 4.02 – 3.94 (m, 2H), 3.88 (t, *J* = 2.4 Hz, 1H), 3.69 (d, *J* = 2.0 Hz, 6H), 3.48 (dd, *J* = 13.2, 4.4 Hz, 1H), 3.42 (dd, *J* = 13.6, 7.2

Hz, 1H), 3.36 (dd, *J* = 12.4, 4.0 Hz, 1H), 3.17 (dd, *J* = 12.4, 3.2 Hz, 1H), 3.00 (d, *J* = 6.4 Hz, 1H), 1.61 (s, 3H), 1.56 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 155.6, 154.0, 143.7, 143.2, 127.1, 118.3, 116.4, 115.9, 115.7, 115.6, 112.6, 96.0, 88.1, 82.2, 79.6, 72.9, 70.7, 68.2, 62.7, 56.1, 56.1, 56.0, 52.1, 45.4, 28.3, 28.2. MS (ESI): Calculated for $C_{27}H_{34}N_2KO_8$ ($[M+K]^+$): 553.2315, found: 553.2315.



(2*R*,3*S*,4*R*,4a*S*,4b*S*,7a*S*,8*R*,10a*R*)-12-fluoro-10-(4-fluorophenyl)-6,6-dimethyl-2,3,4,4a,7a,8,10,10a-octahydro-1*H*,9*H*-benzo[*h*][1,3]dioxolo[4,5-d]pyrido[2,1-*f*][1,6]naphthyridine-2,3,4,8-tetraol (7l-1'). Yellow solid, yield 58%, m.p. 87.6 - 89.5 ^{o}C, $[\alpha]_D^{25}$ -33.0 (*c* 0.1, CH_3OH); ^{1}H NMR (400 MHz, CD_3OD), δ_H (ppm): 7.12 (dd, *J* = 9.2, 2.8 Hz, 1H), 6.94 (dd, *J* = 9.2, 4.8 Hz, 1H), 6.90 (dd, *J* = 8.0, 2.8 Hz, 1H), 6.85 (t, *J* = 8.8 Hz, 2H), 6.69 – 6.66(m, 2H), 4.82 – 4.80 (m, 2H), 4.38 (dd, *J* = 7.2, 2.8 Hz, 1H), 3.99 (ddd, *J* = 16.4, 5.2, 2.4 Hz, 2.0H), 3.85 (ddd, *J* = 8.0, 5.6, 2.8 Hz, 1H), 3.52 – 3.39 (m, 3H), 3.21 (dd, *J* = 12.8, 3.2 Hz, 1H), 3.05 (d, *J* = 7.2 Hz, 1H), 1.61 (s, 3H), 1.57 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD), δ_C (ppm): 159.9, 158.4, 157.5, 156.10 146.4, 145.8 127.3, 117.6(2C), 116.4(2C), 116.0(3C), 115.5(2C), 114.3(2C), 96.0, 88.0, 81.9, 79.8, 72.8, 70.8, 67.9, 62.3, 51.3, 44.7, 28.3. MS (ESI): Calculated for $C_{25}H_{28}F_2N_2NaO_6$ ($[M+Na]^+$):513.1915, found: 513.1914.

Fig S1:NMR spectra of the newly synthesized compounds

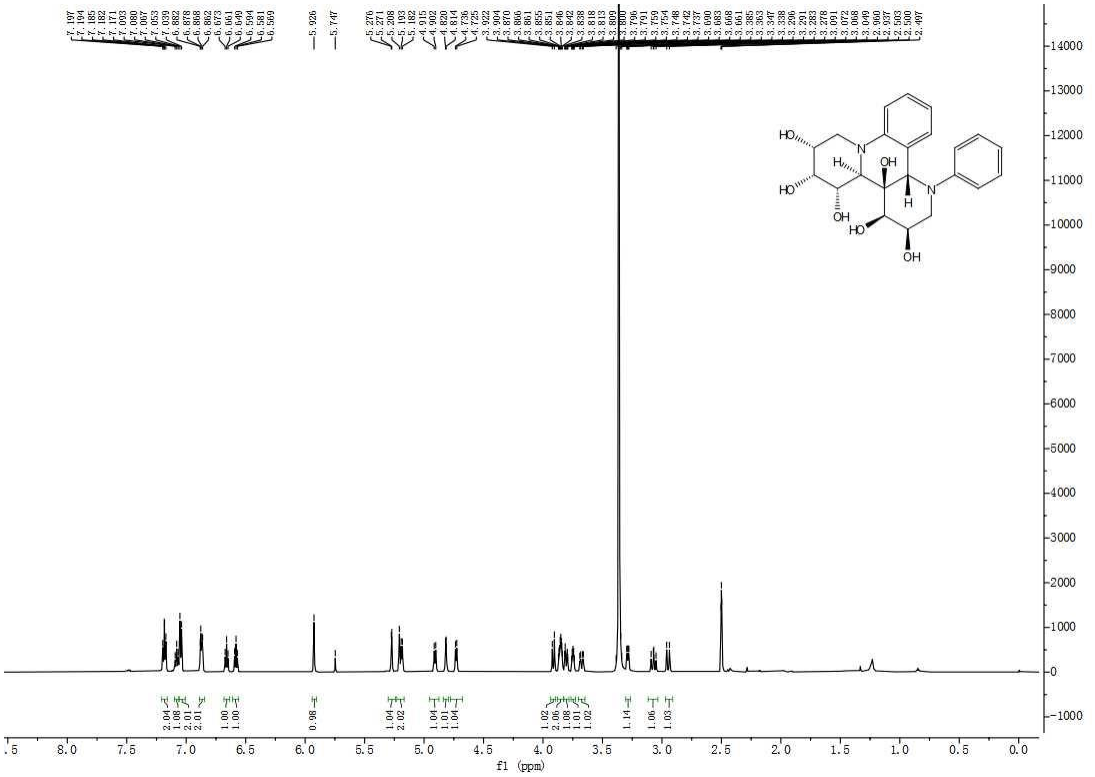


Fig1. ^{1}H NMR of compound **5a**

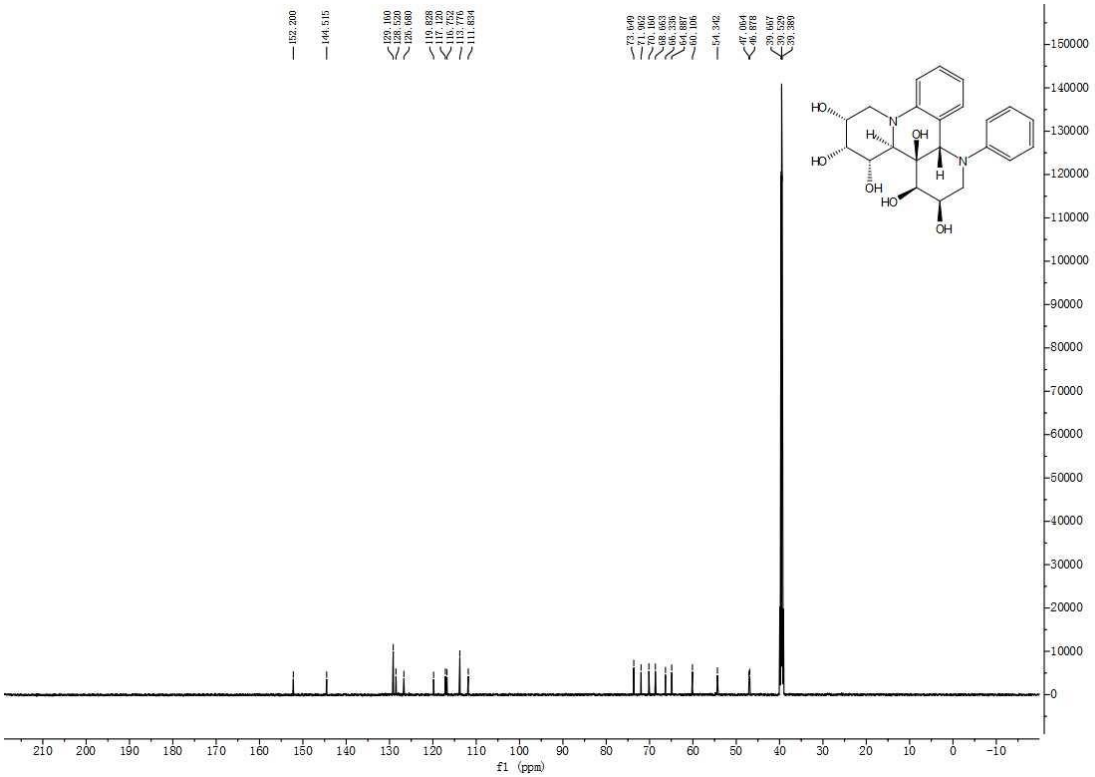


Fig.2 ^{13}C NMR of compound **5a**

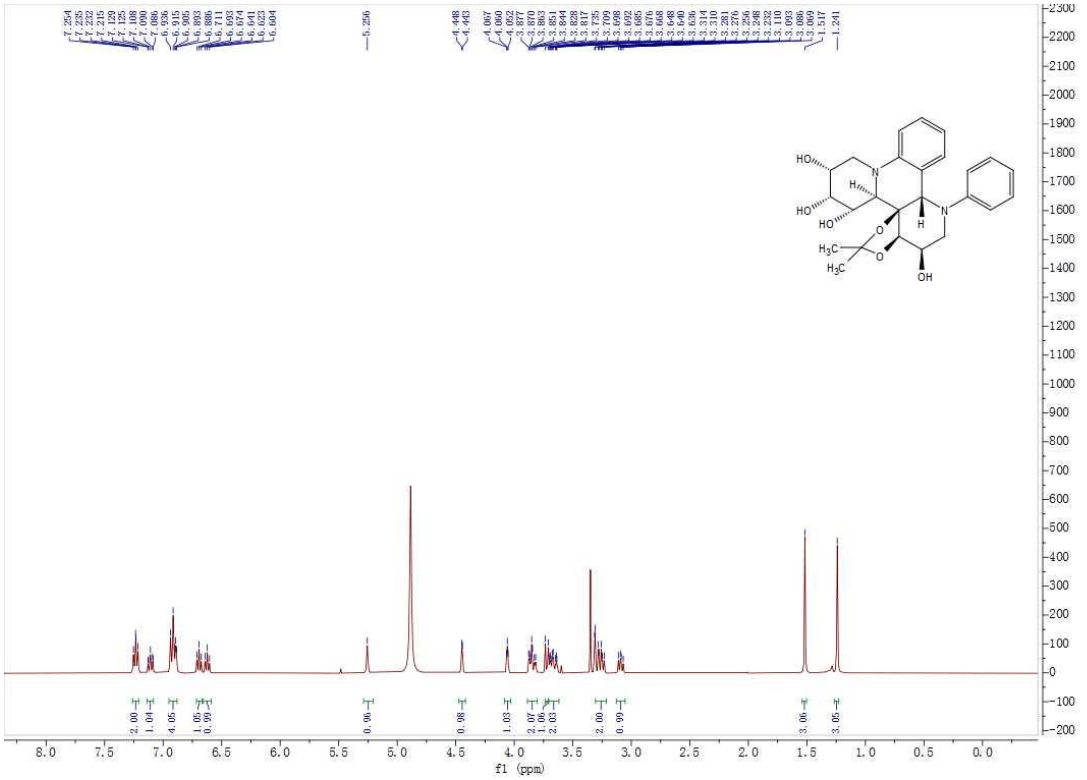


Fig.3 ^{1}H NMR of compound **5a'**

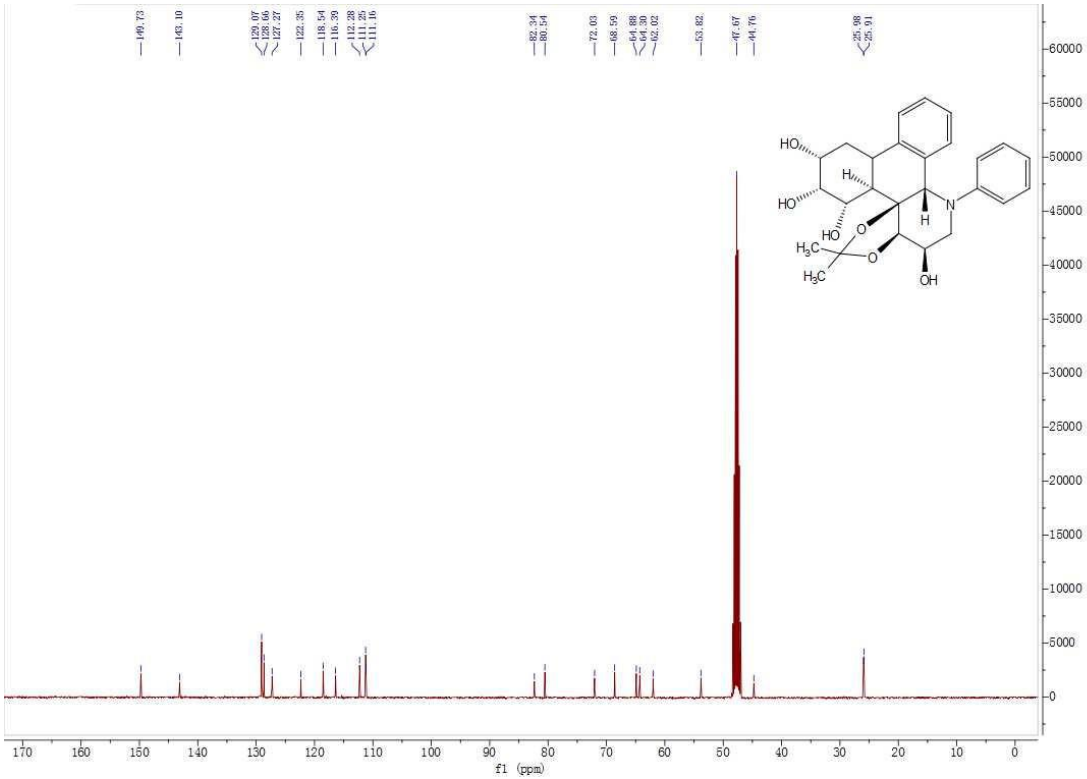


Fig.4 ^{13}C NMR of compound **5a'**

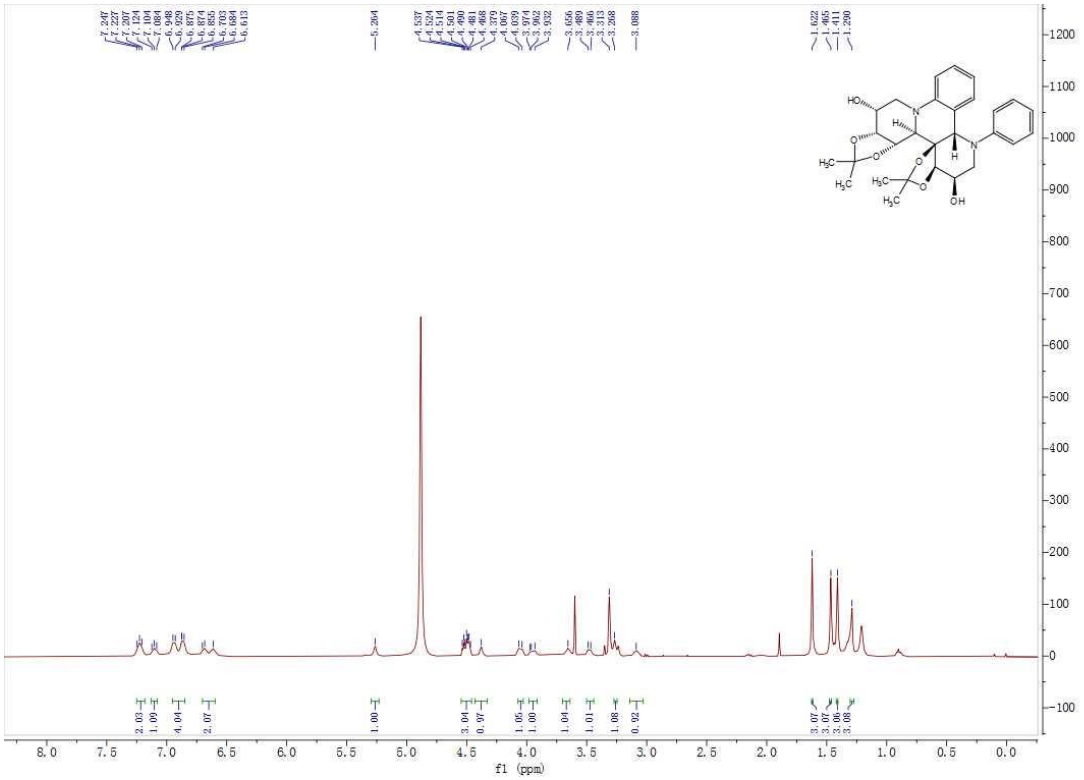


Fig.5 ^{1}H NMR of compound **5a"**

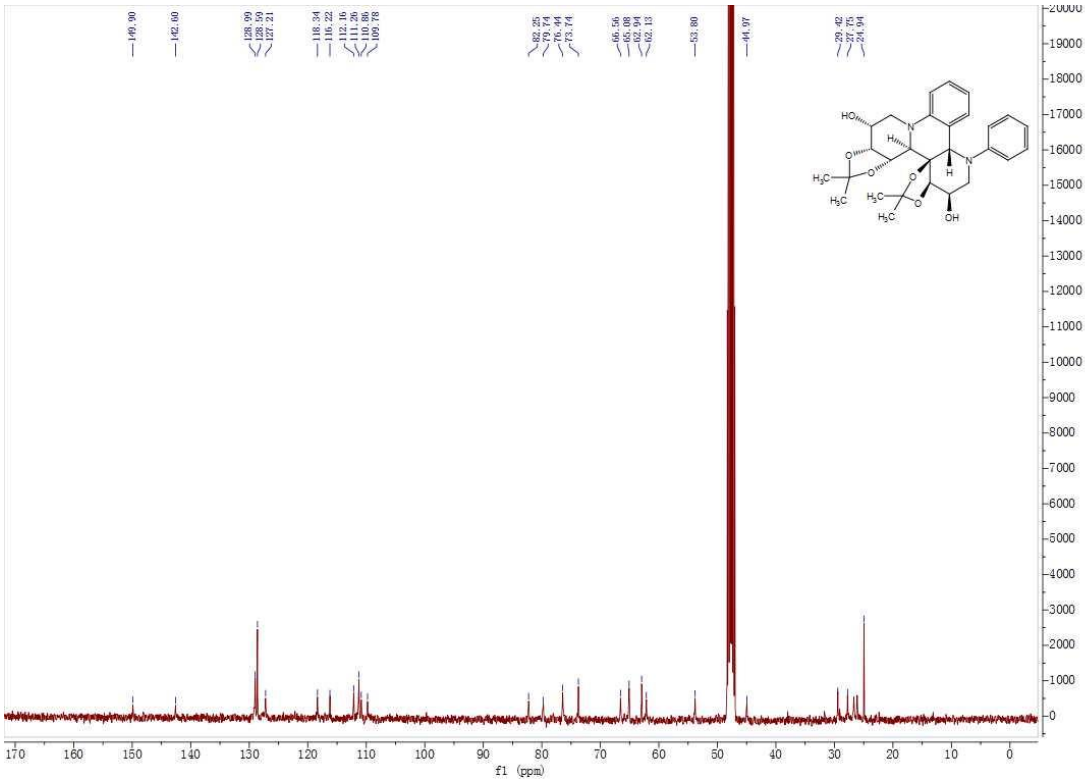


Fig.6 ^{13}C NMR of compound **5a"**

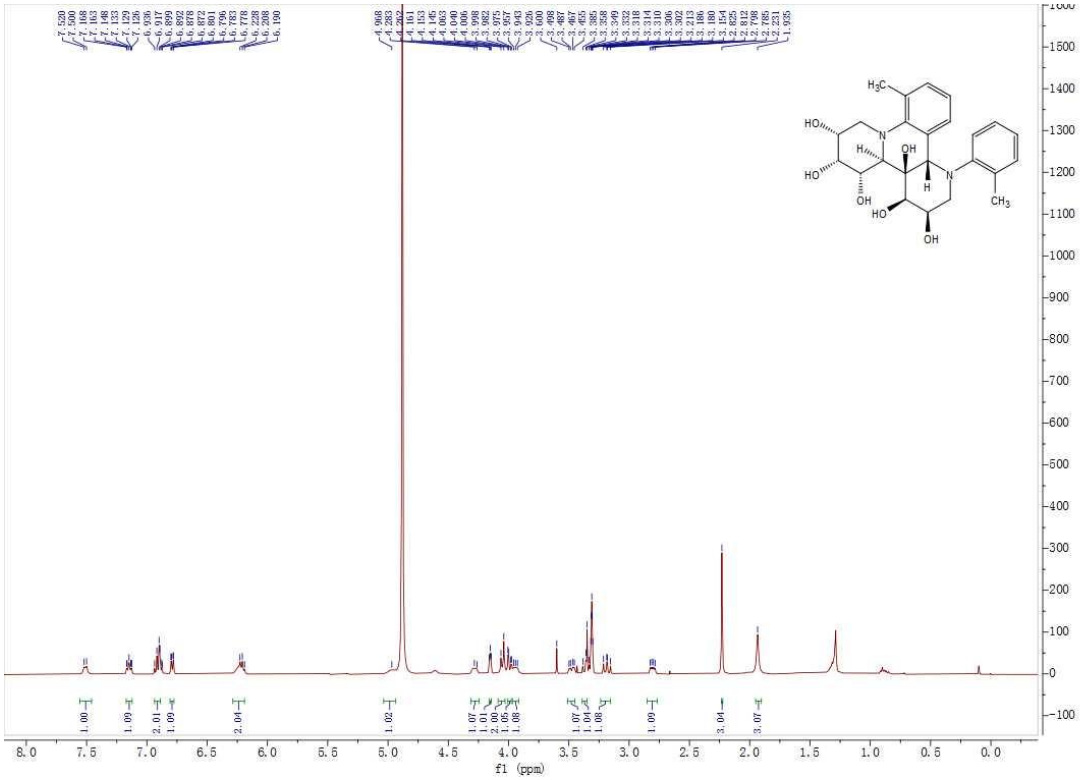


Fig.7 ^{1}H NMR of compound **5b**

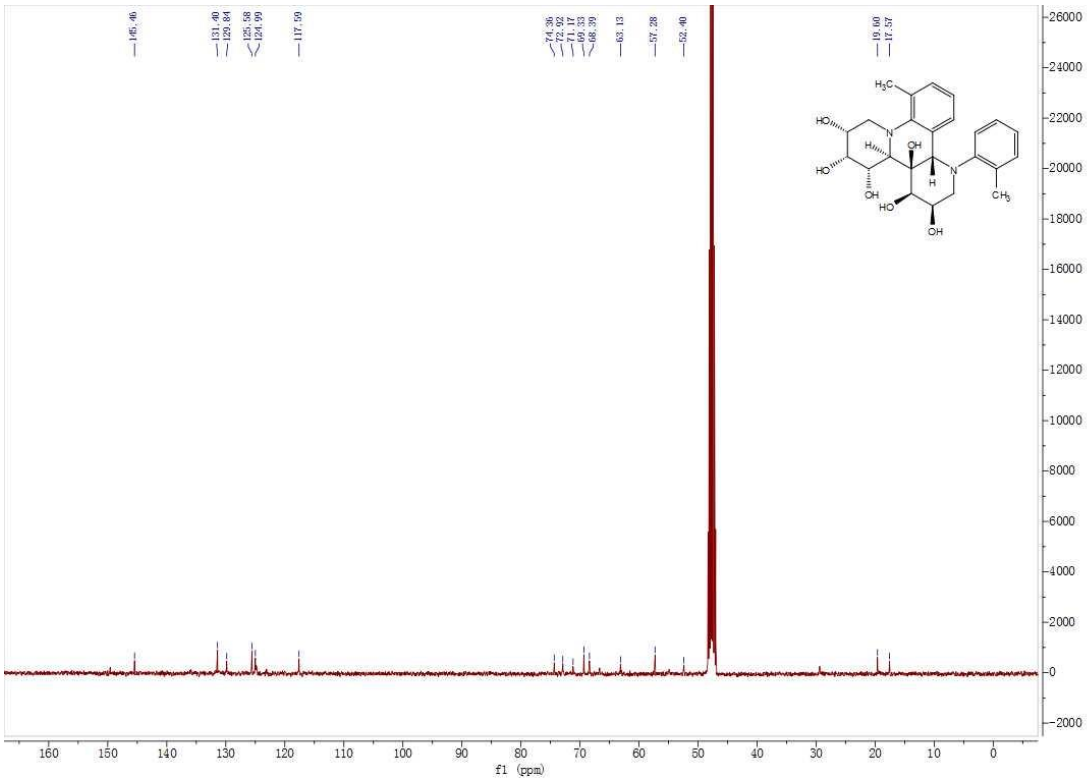


Fig.8 ^{13}C NMR of compound **5b**

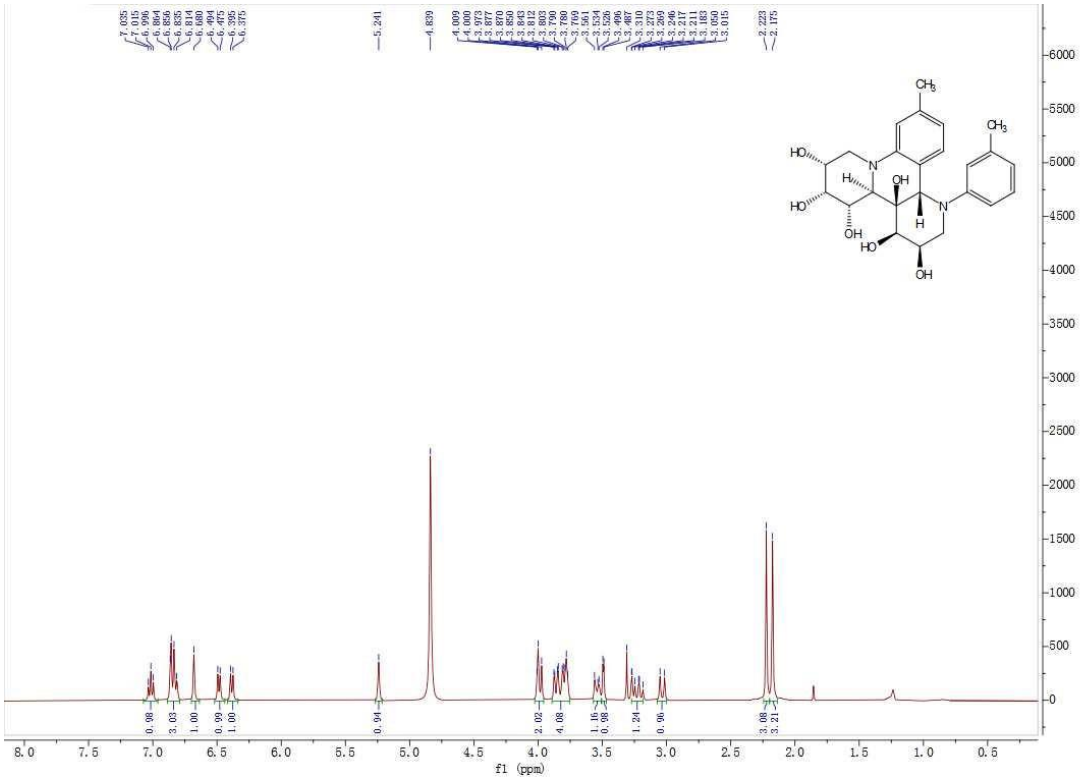


Fig.9 ^{1}H NMR of compound **5c**

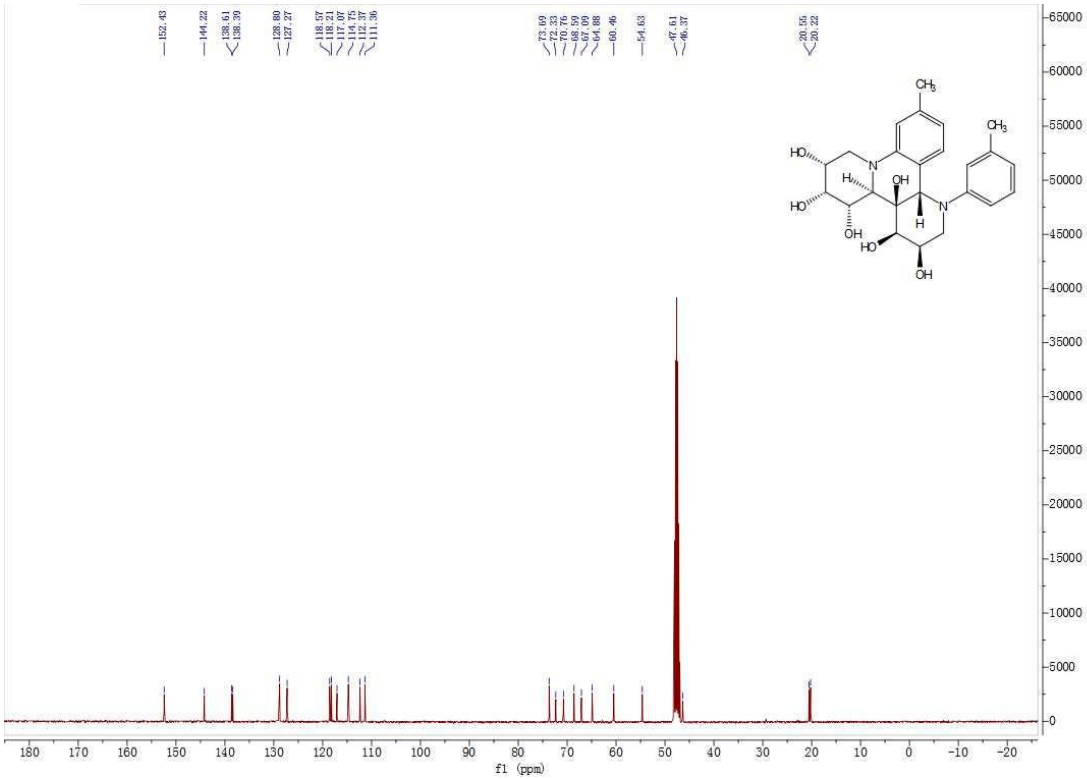


Fig.10 ^{13}C NMR of compound **5c**

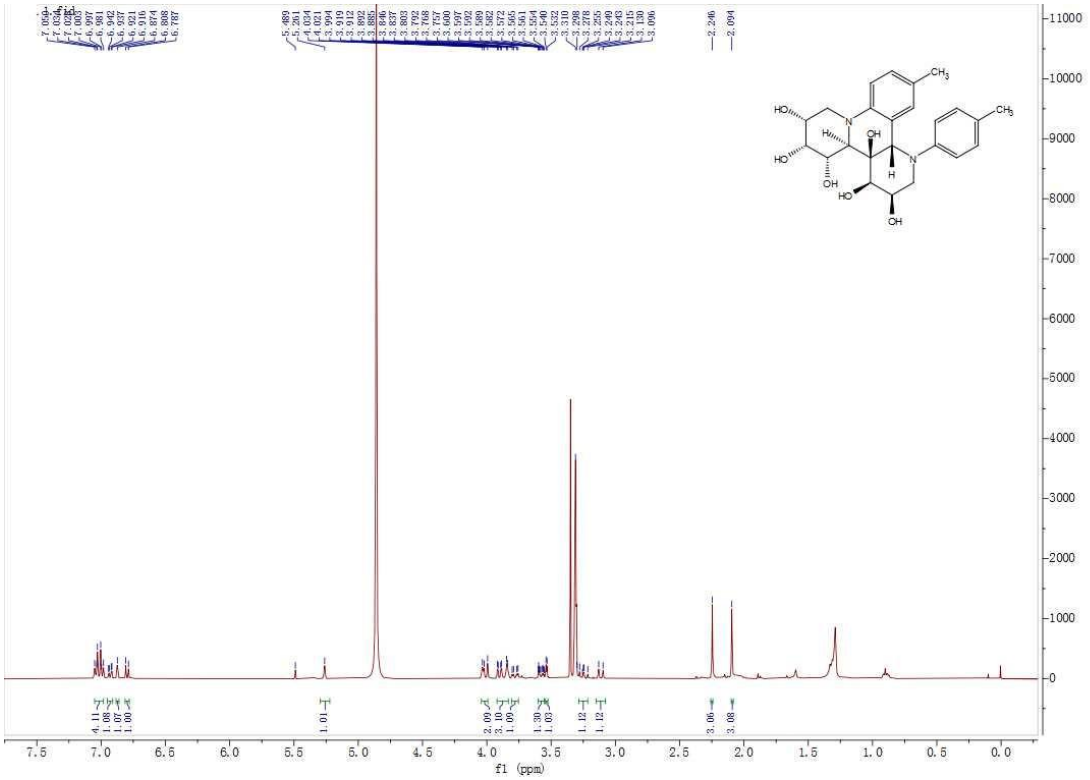


Fig.11 ^{1}H NMR of compound **5d**

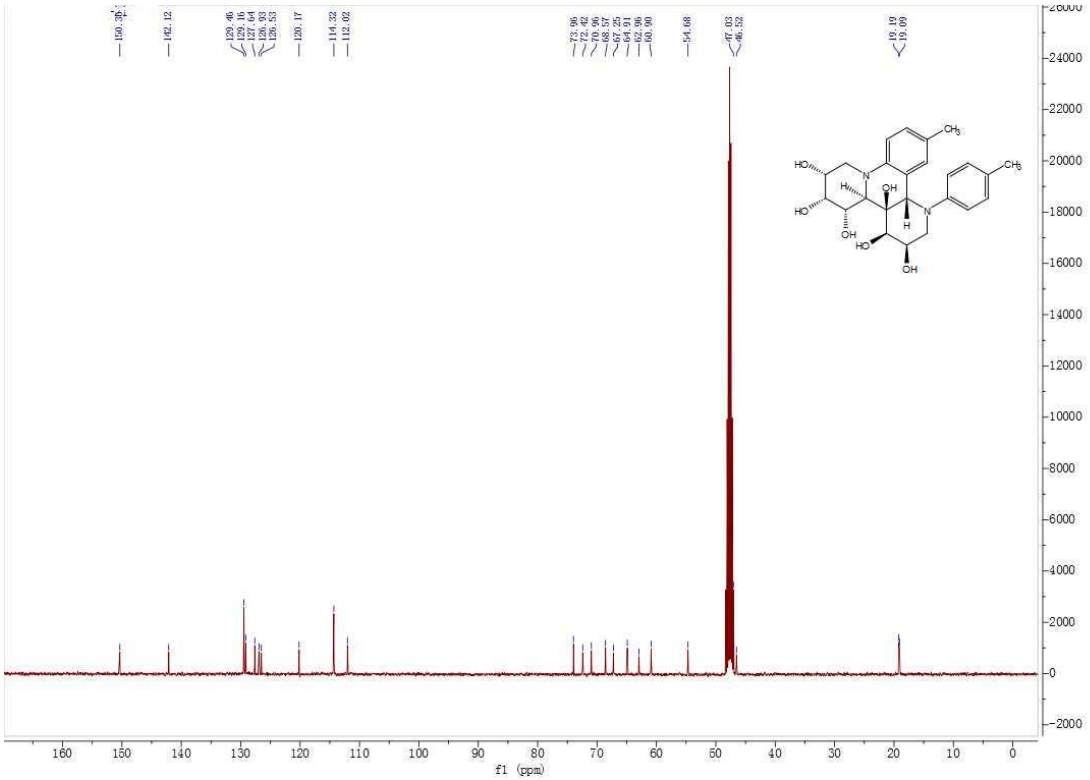


Fig.12 ^{13}C NMR of compound **5d**

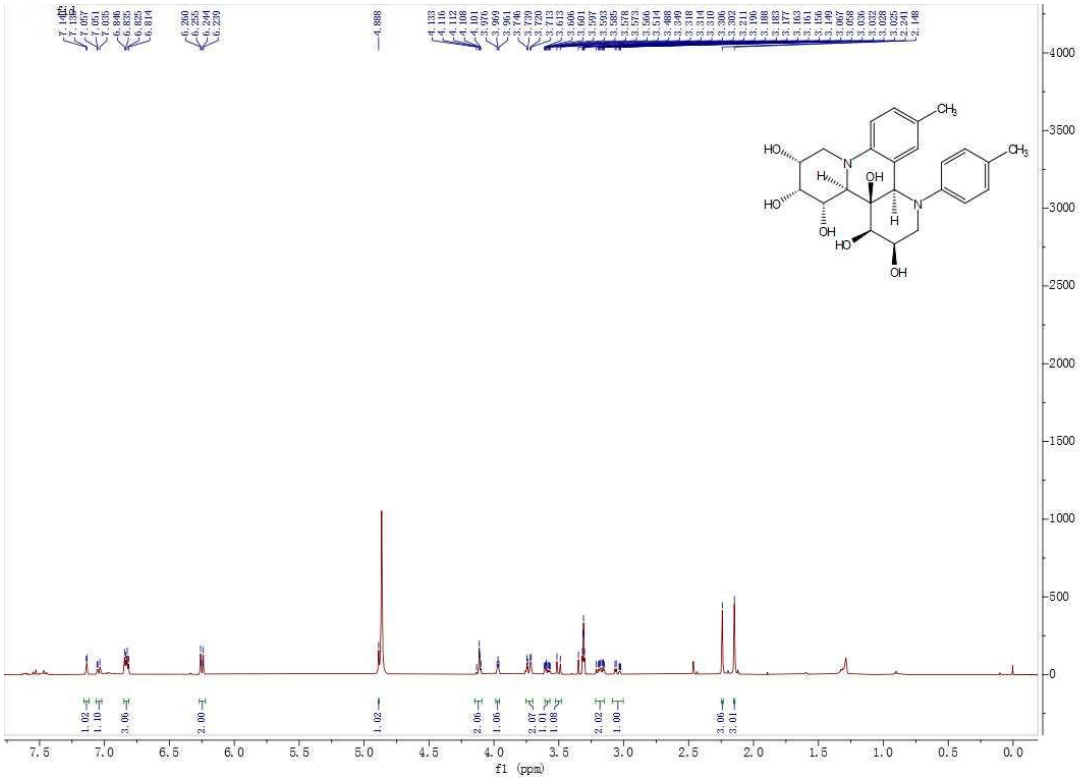


Fig.13 ^{1}H NMR of compound **5d-1**

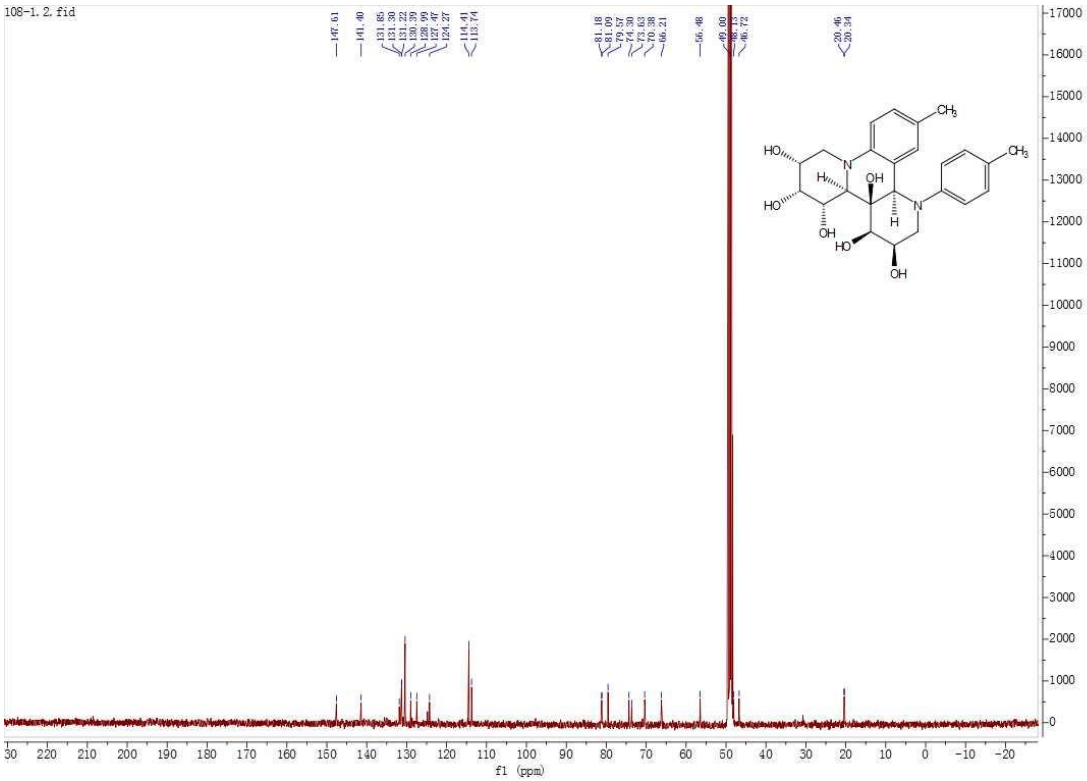


Fig.14 ^{13}C NMR of compound **5d-1**

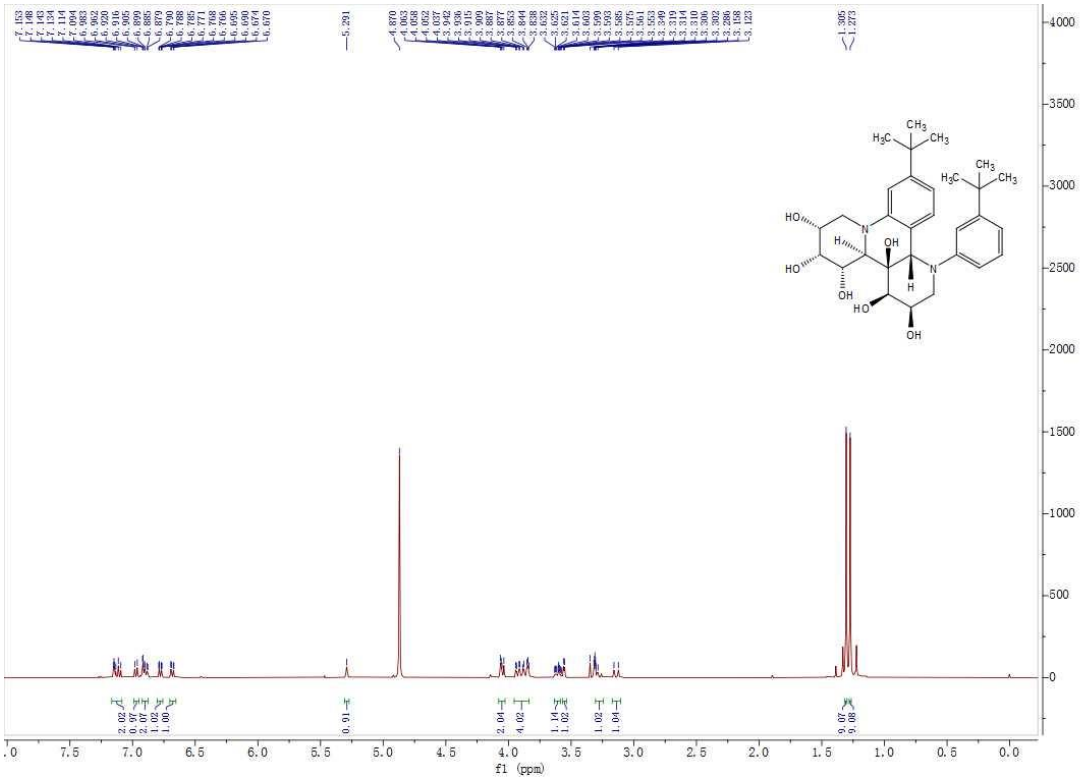


Fig.15 ^{1}H NMR of compound **5e**

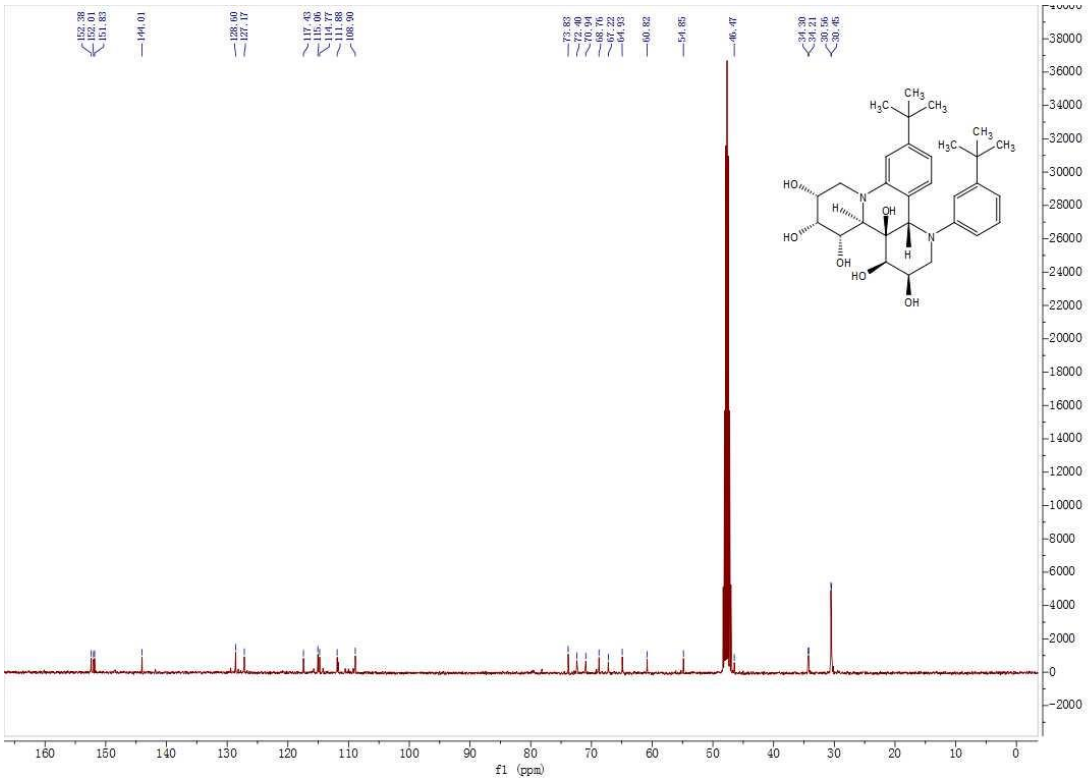


Fig.16 ^{13}C NMR of compound **5e**

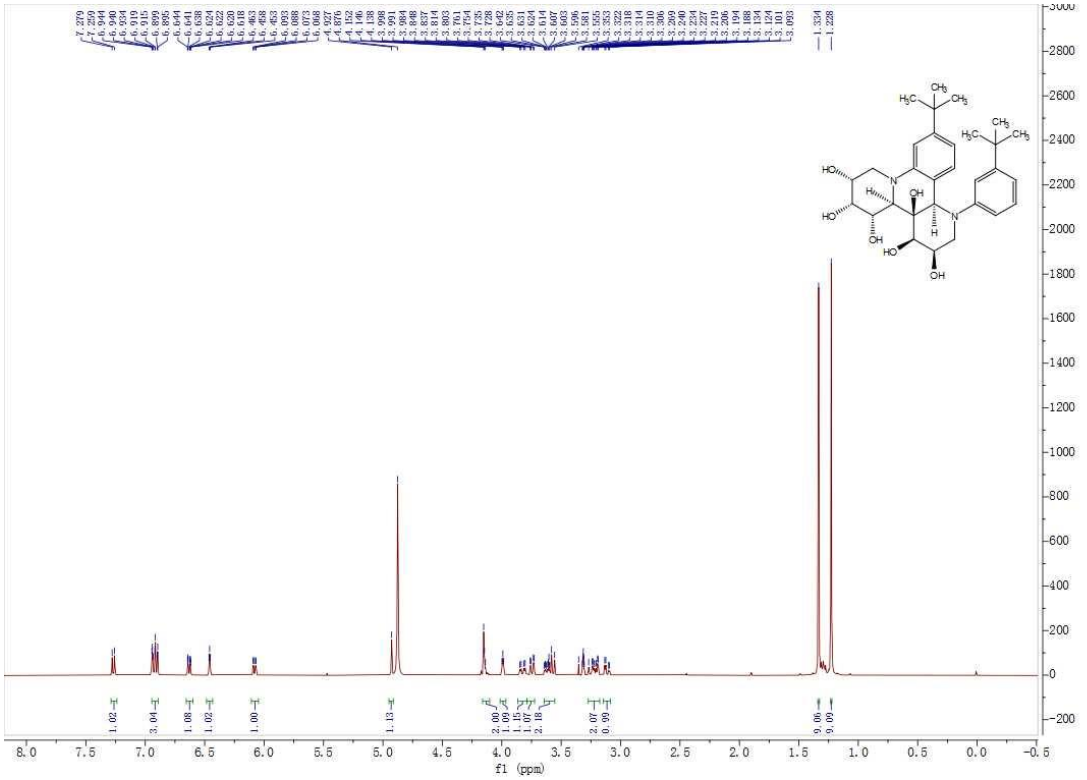


Fig.17 ^{1}H NMR of compound **5e-1**

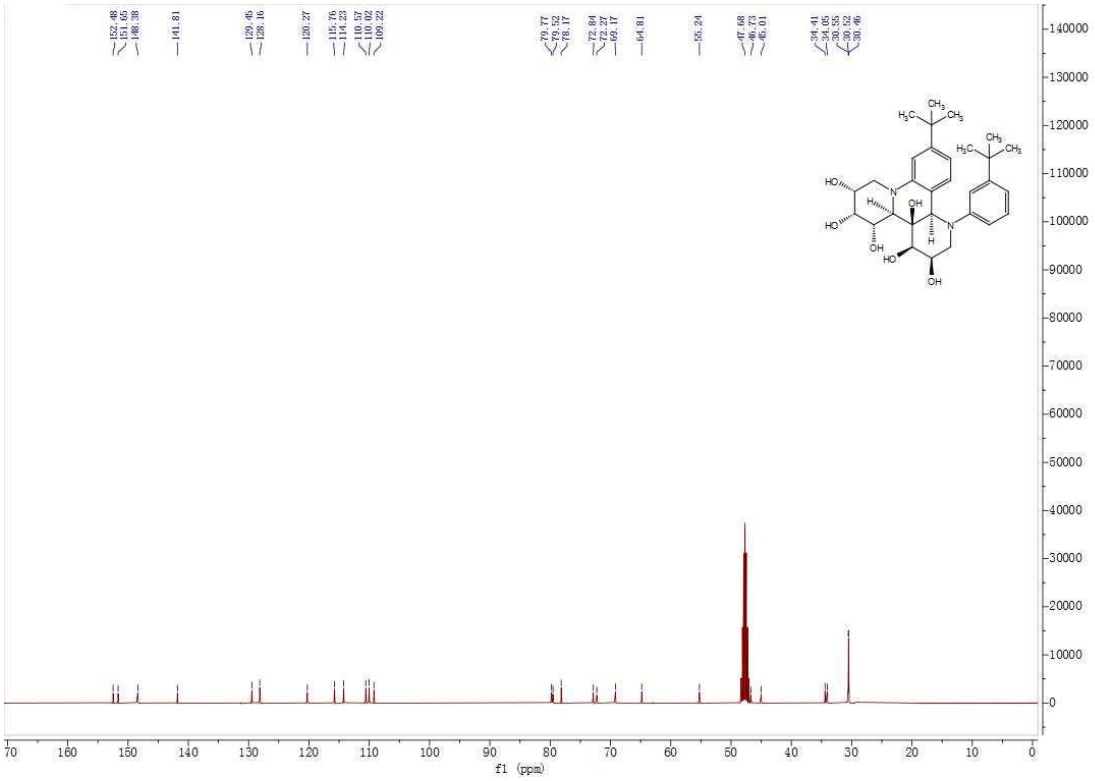


Fig.18 ^{13}C NMR of compound **5e-1**

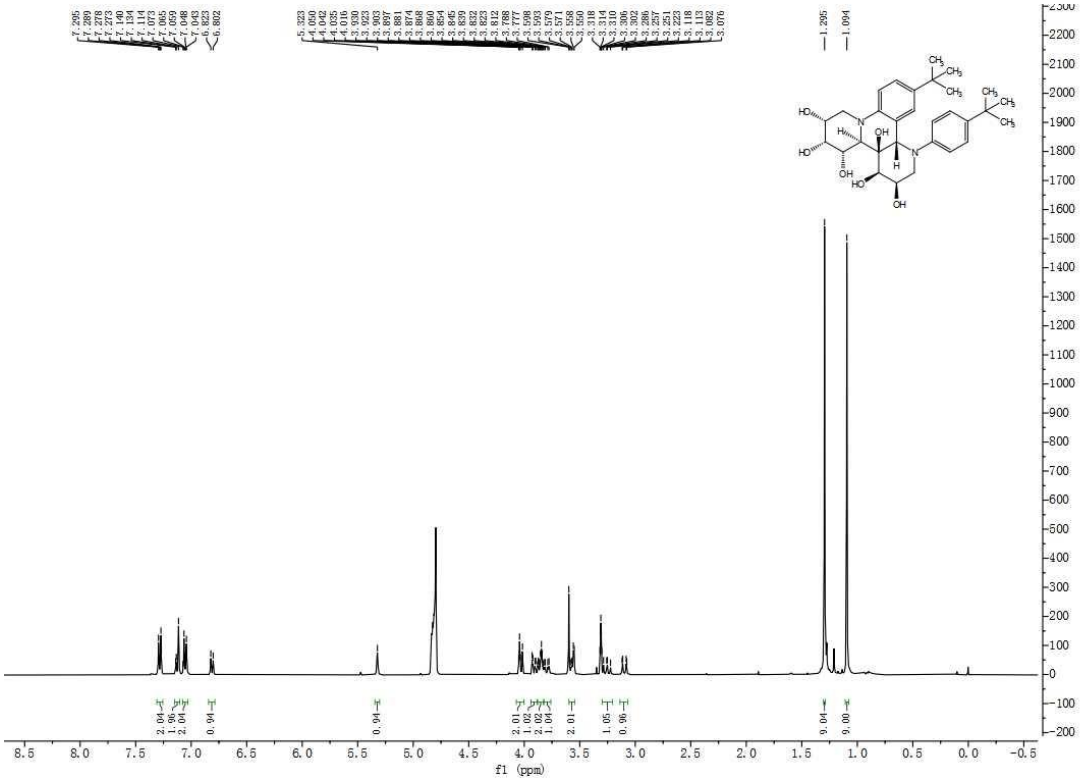


Fig.19 ^{1}H NMR of compound **5f**

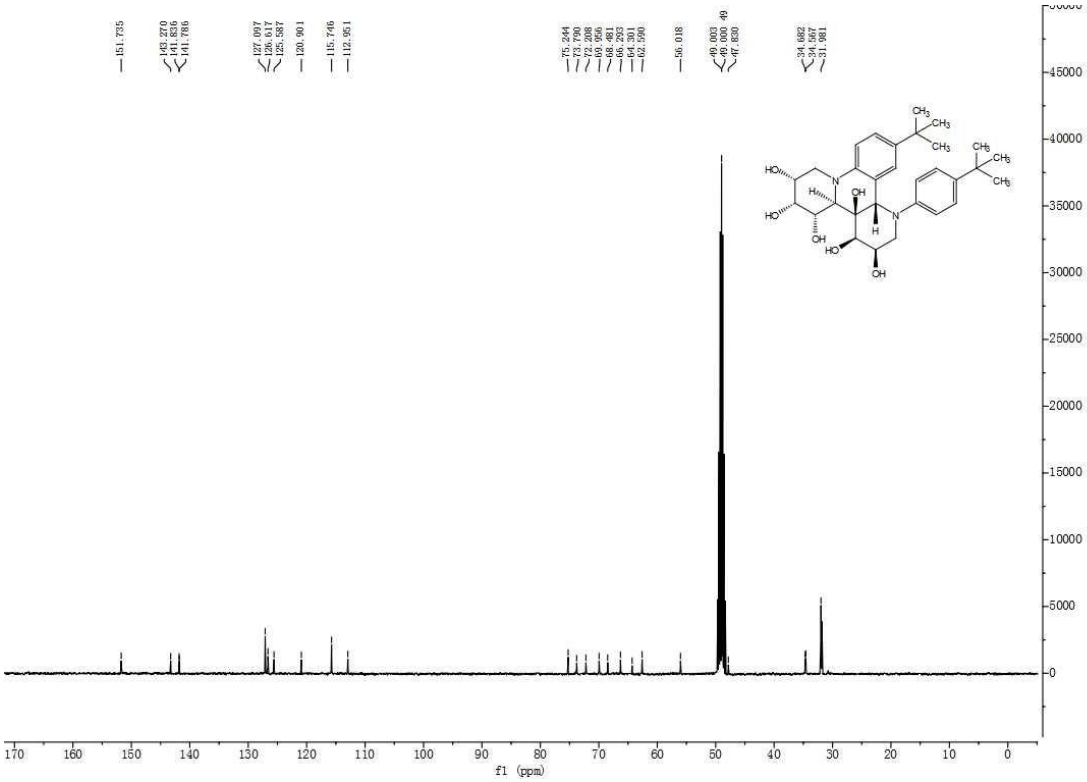


Fig.20 ^{13}C NMR of compound **5f**

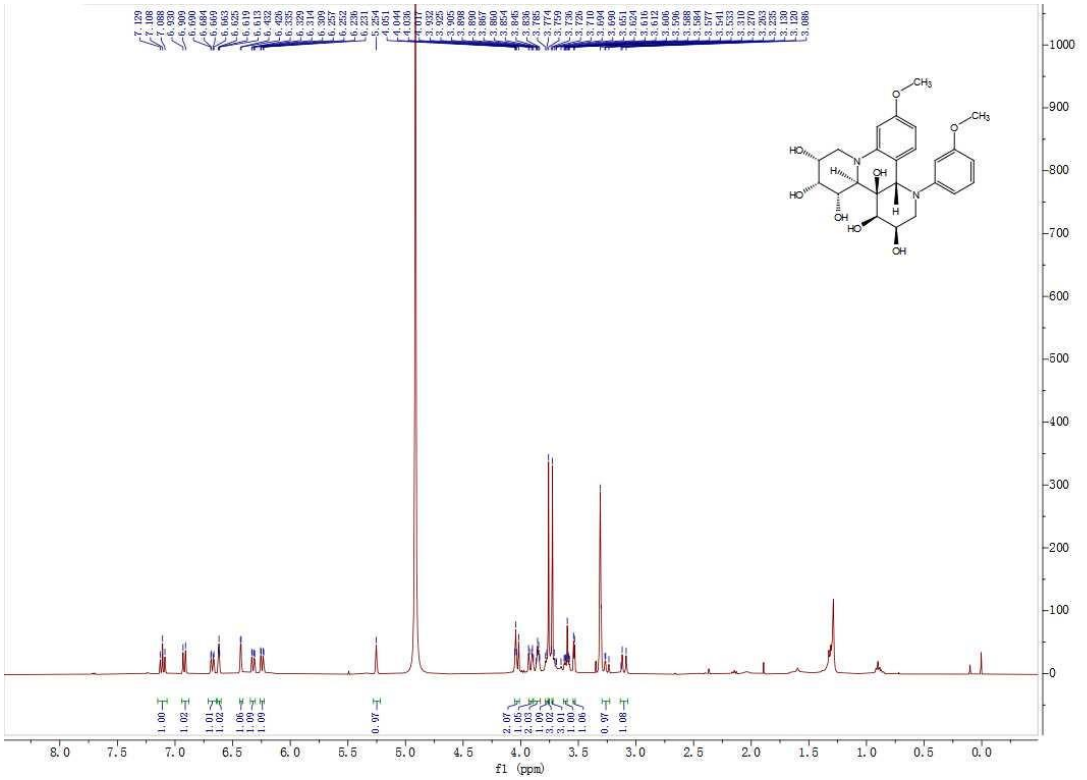


Fig.21 ^{1}H NMR of compound **5g**

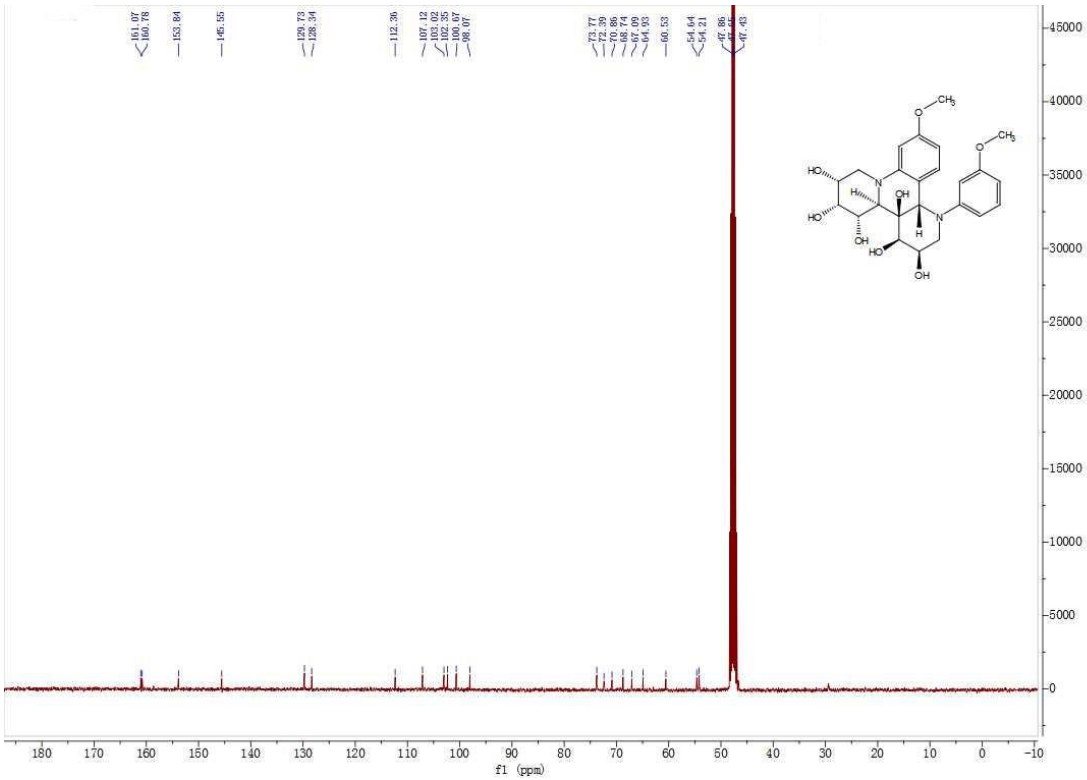


Fig.22 ^{13}C NMR of compound **5g**

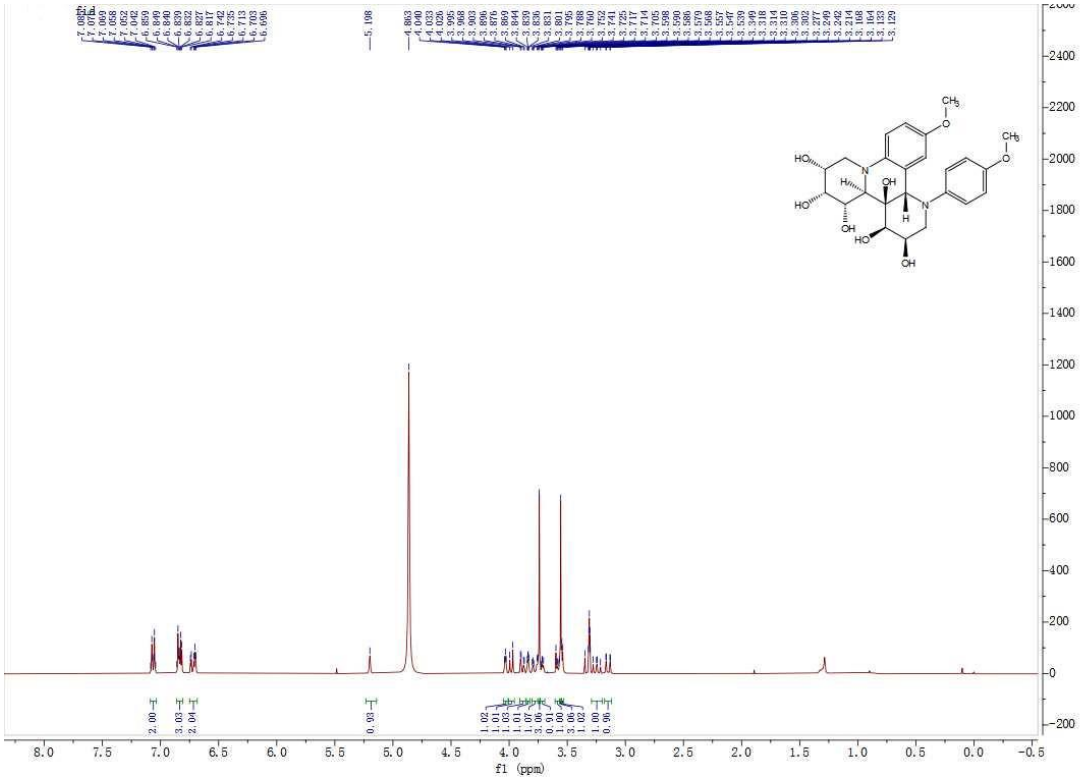


Fig.23 ^{1}H NMR of compound **5h**

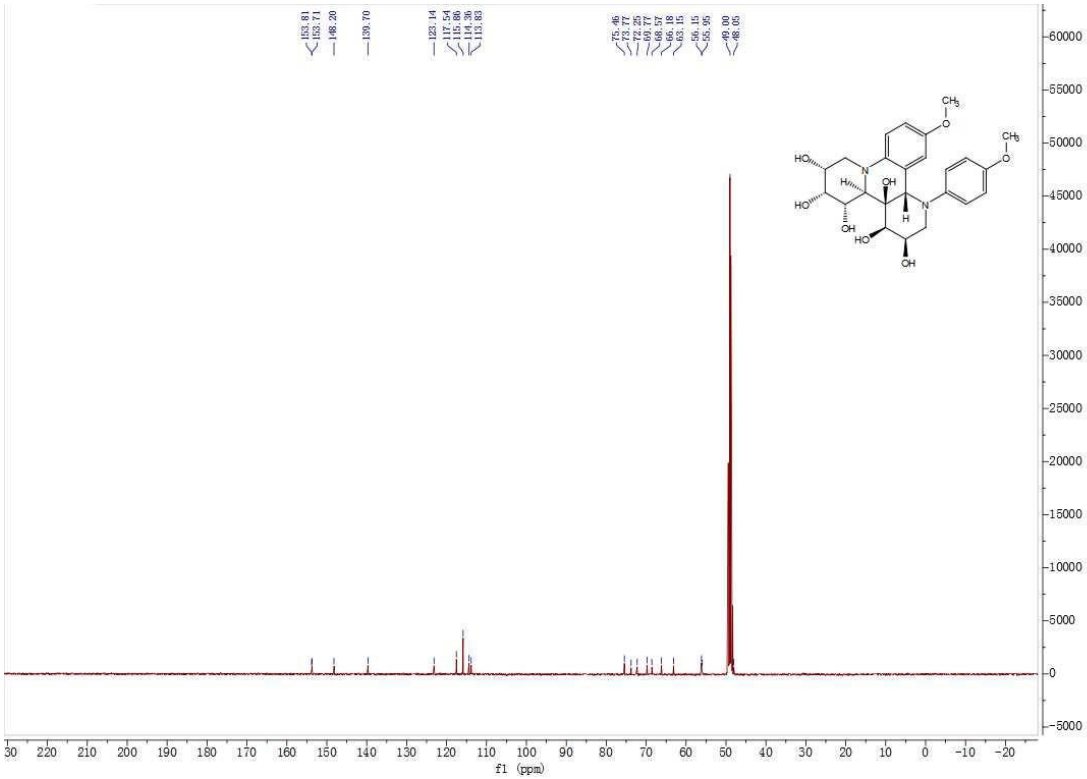


Fig.24 ^{13}C NMR of compound **5h**

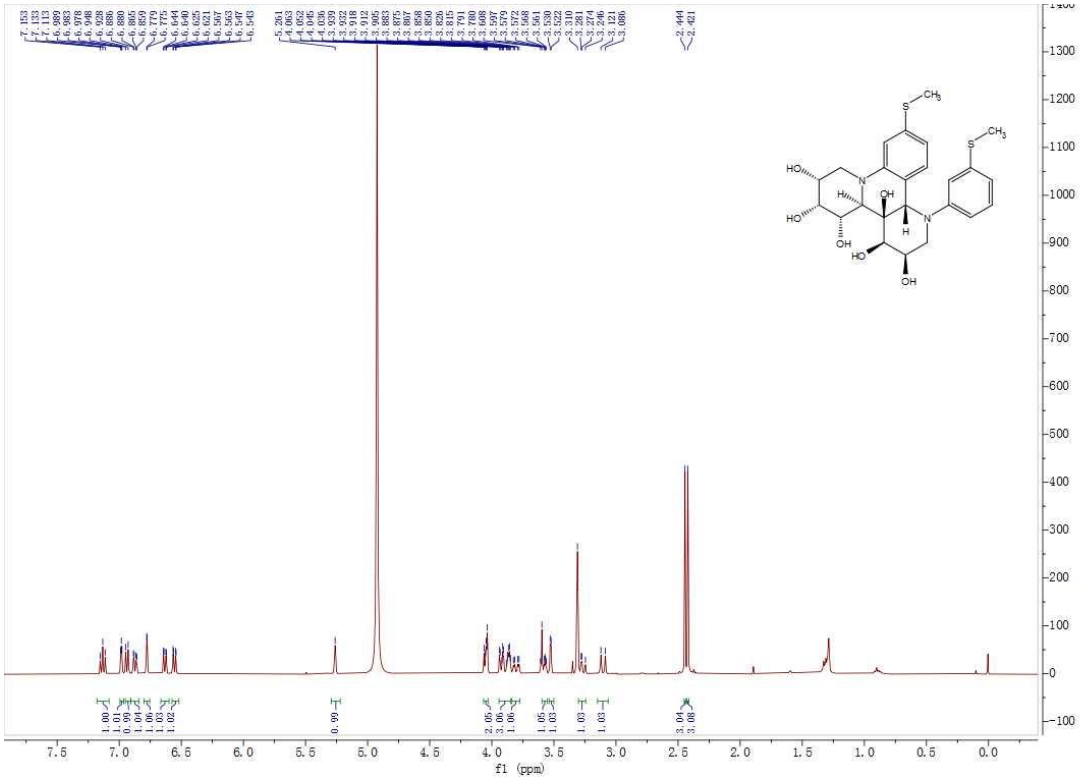


Fig.25 ^{1}H NMR of compound **5i**

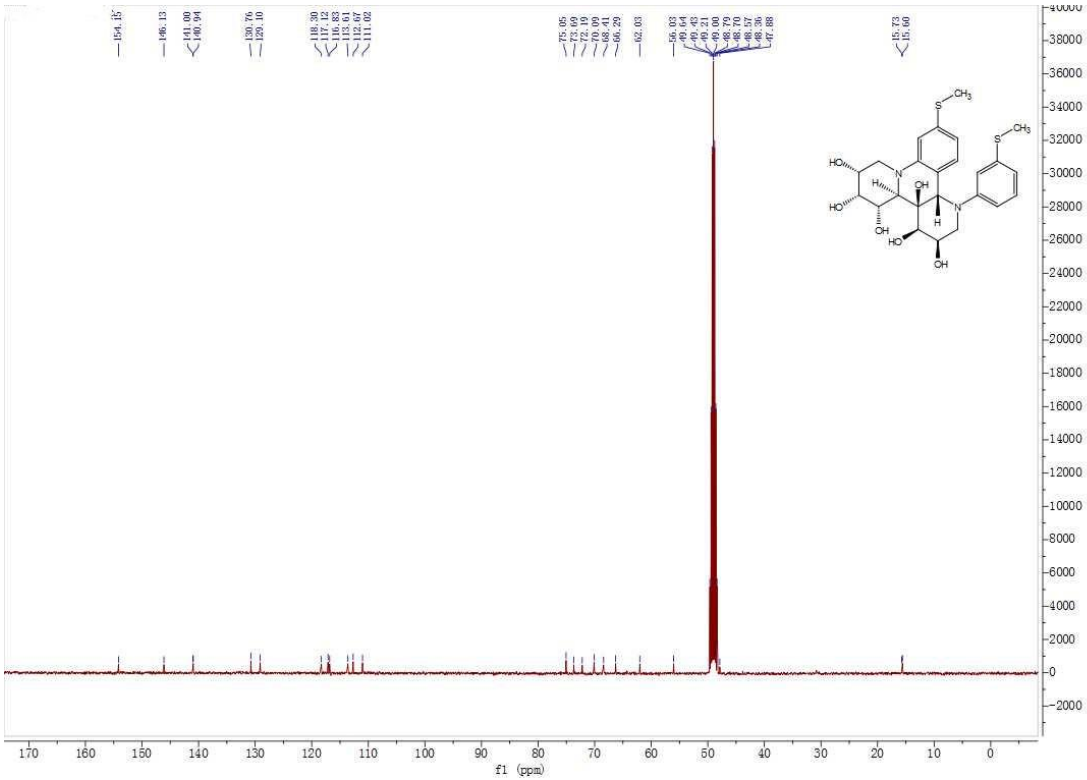


Fig.26 ^{13}C NMR of compound **5i**

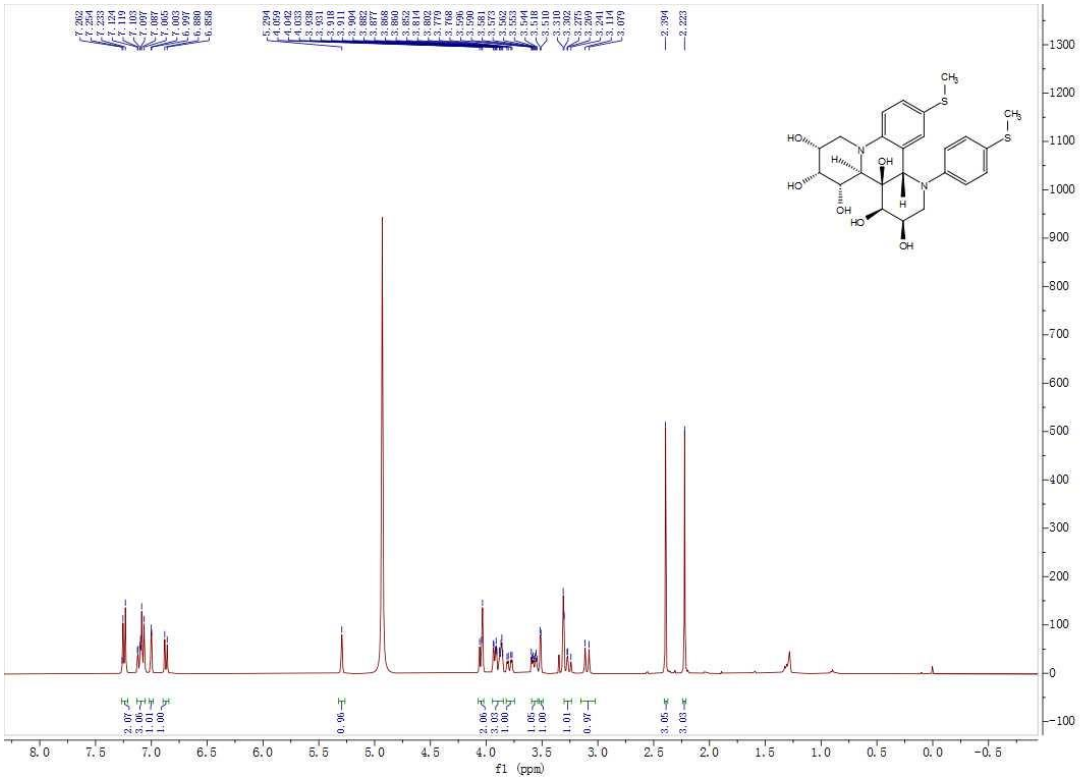


Fig.27 ^{1}H NMR of compound **5j**

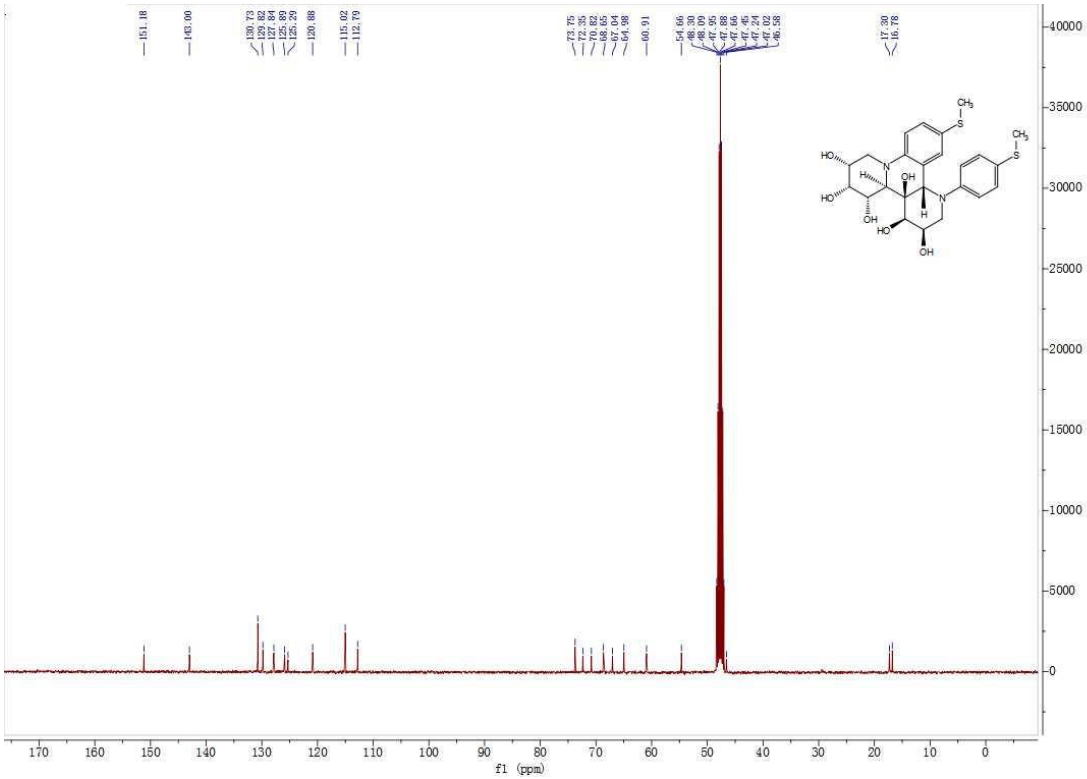


Fig.28 ^{13}C NMR of compound **5j**

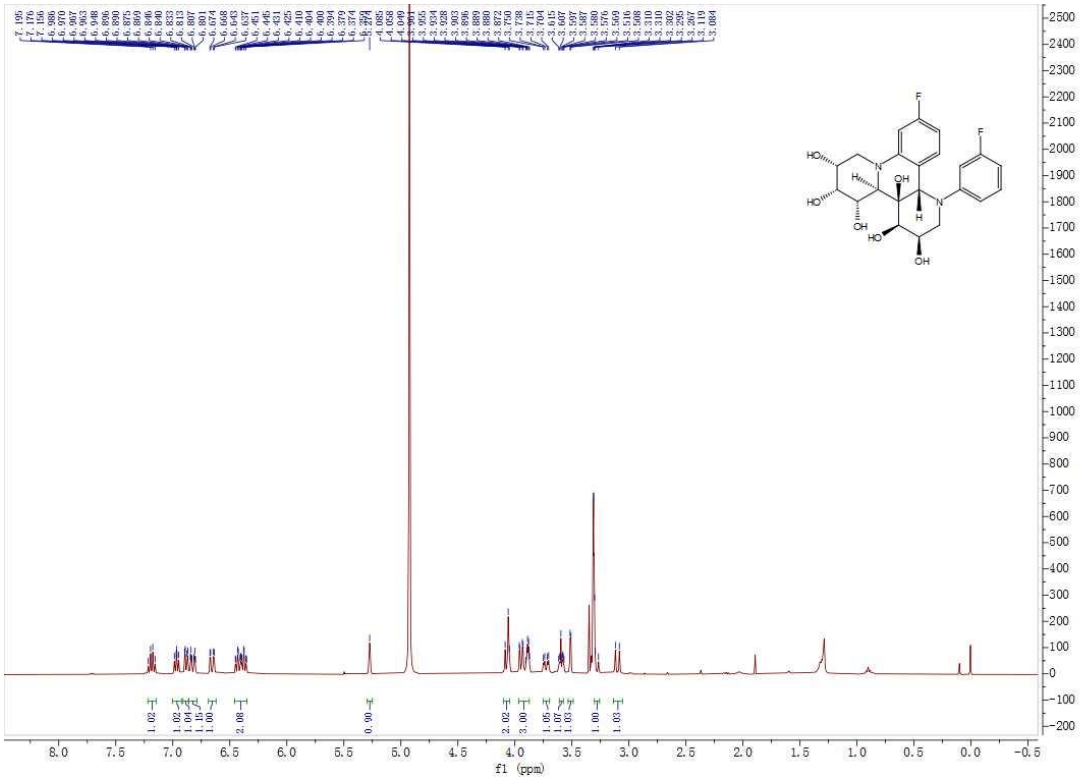


Fig.29 ^{1}H NMR of compound **5k**

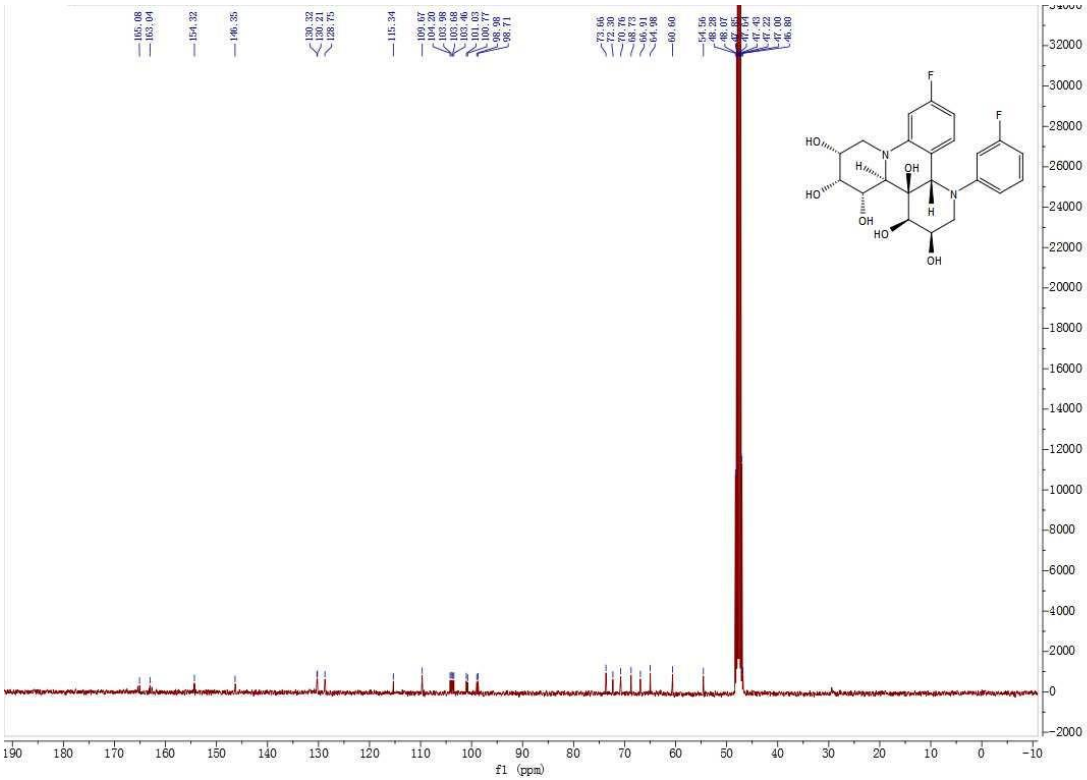


Fig.30 ^{13}C NMR of compound **5k**

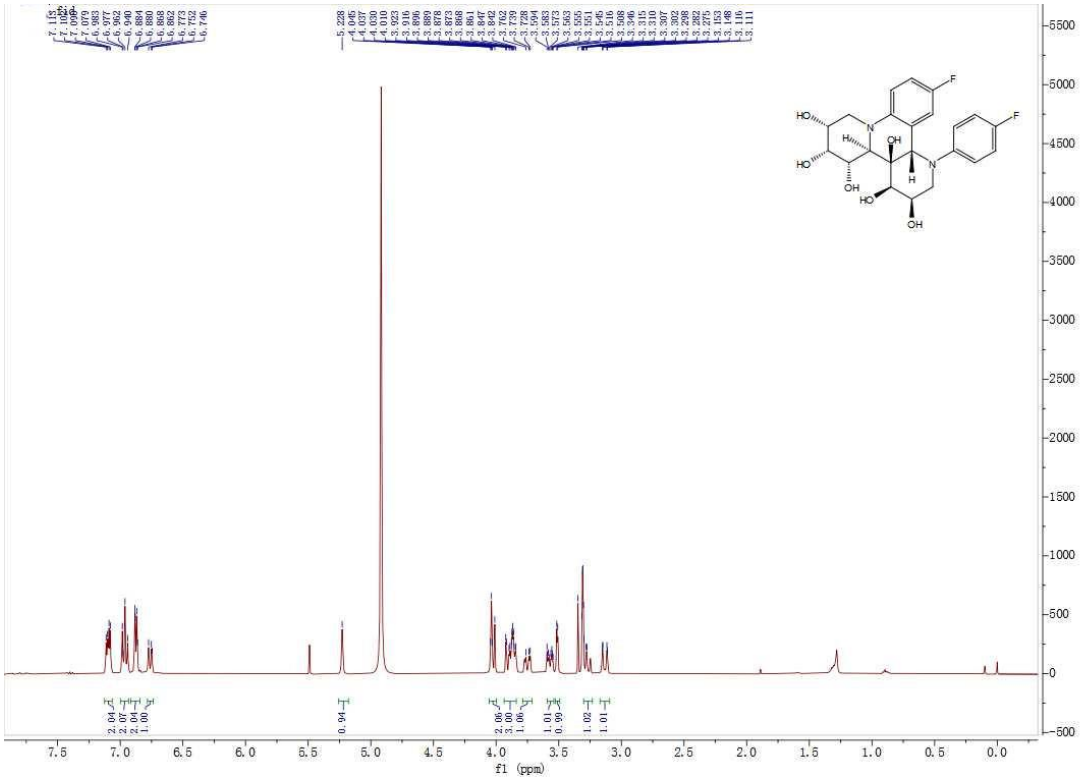


Fig.31 ^{1}H NMR of compound **5l**

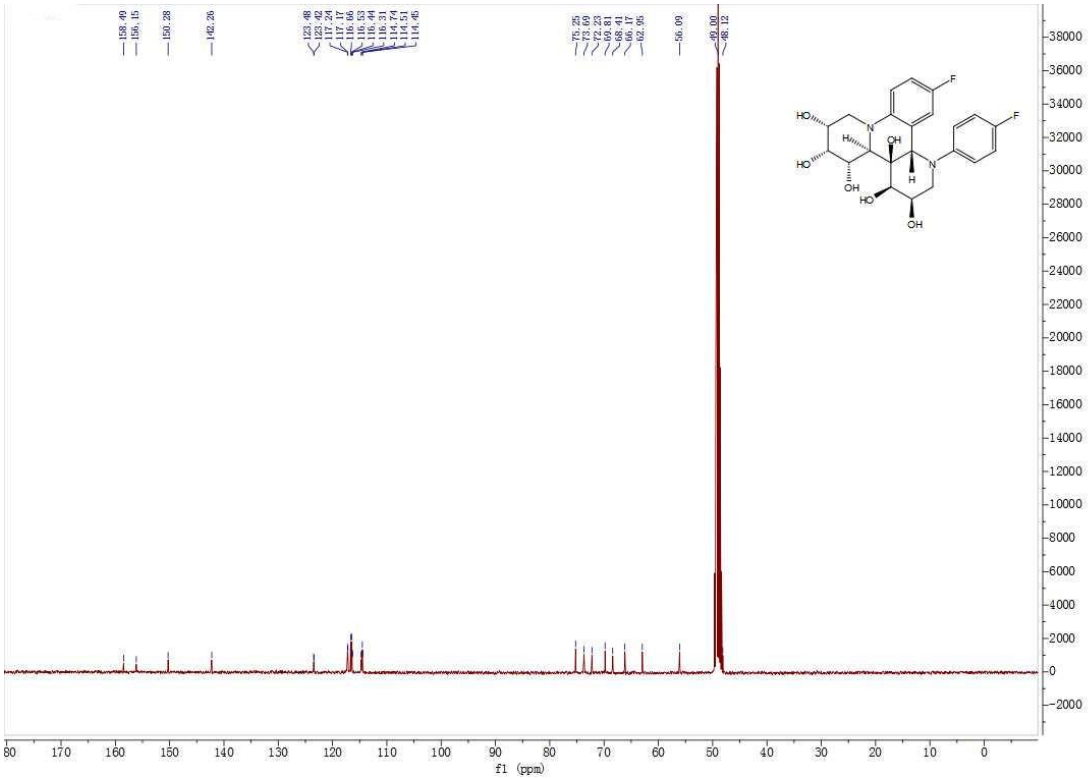


Fig.32 ^{13}C NMR of compound **5l**

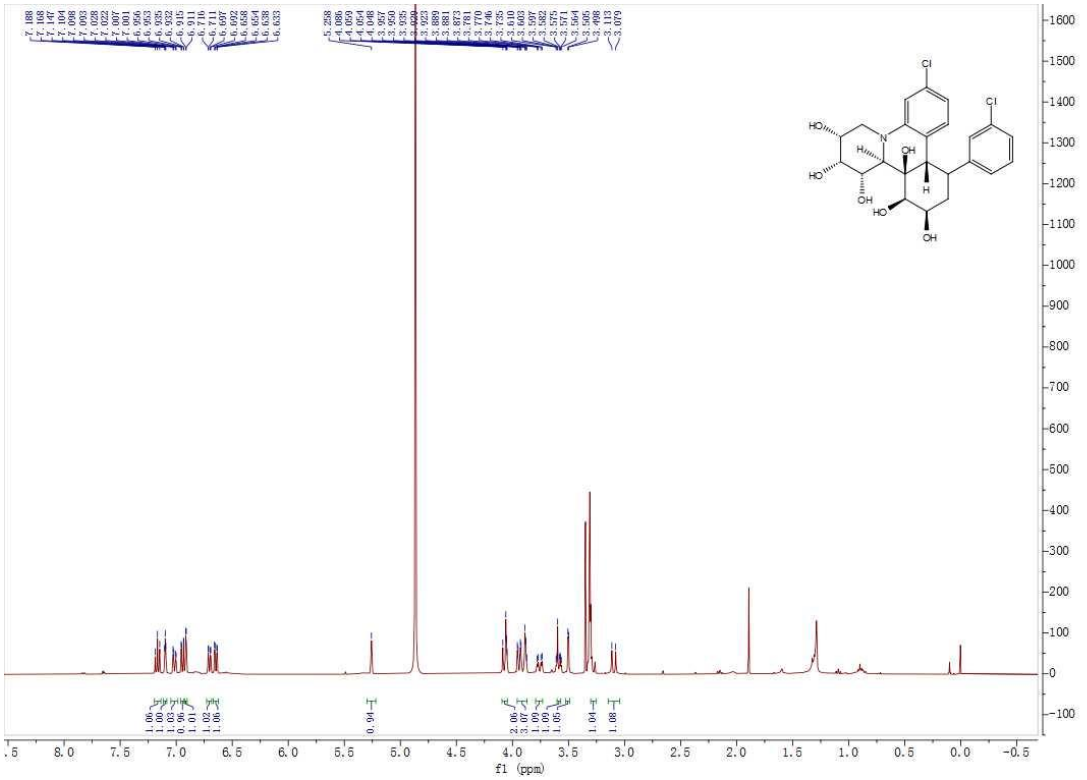


Fig.33 ^{1}H NMR of compound **5n**

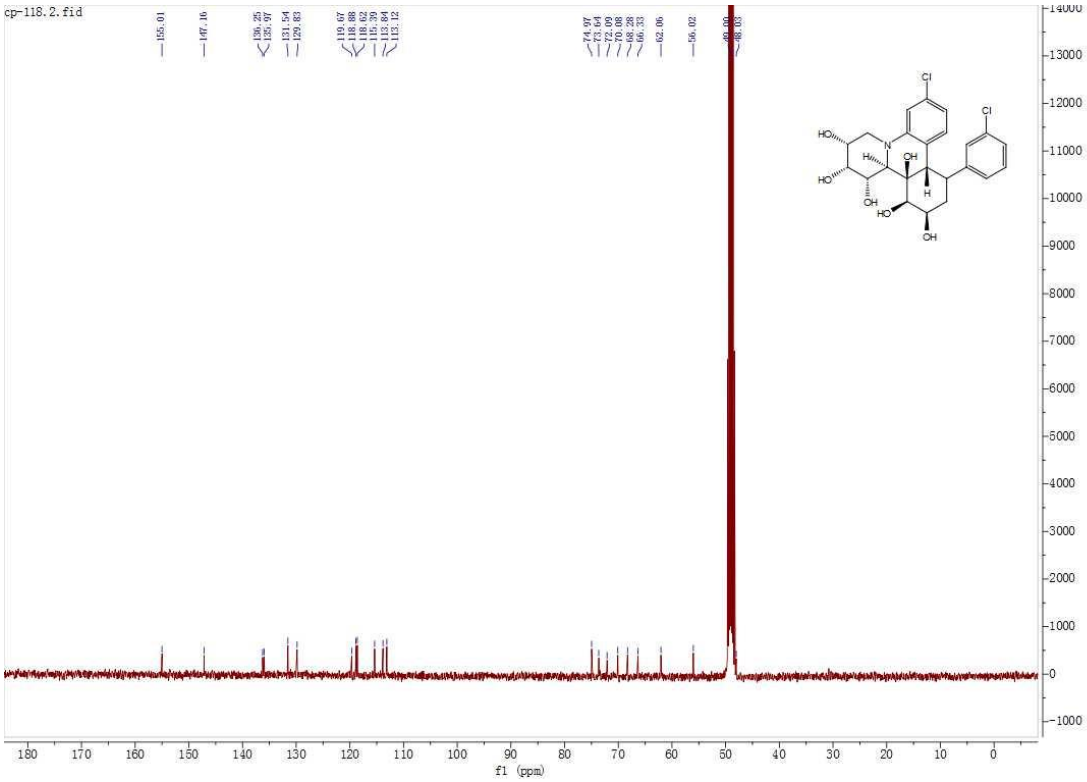


Fig.34 ^{13}C NMR of compound **5n**

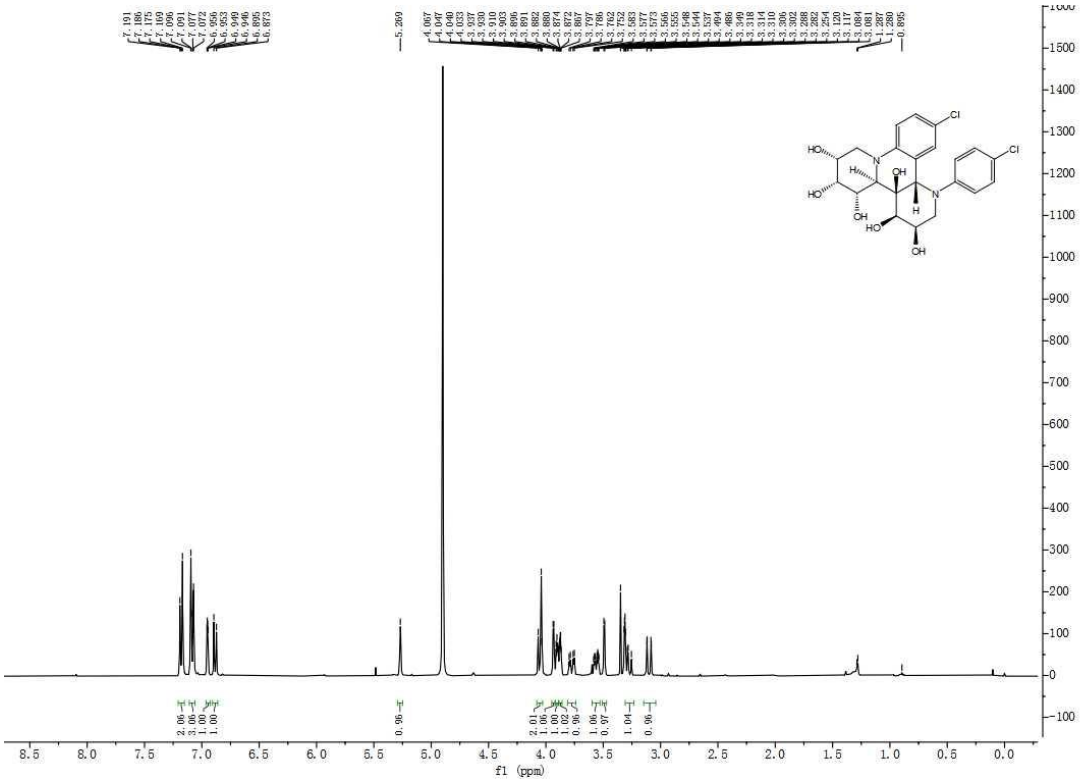


Fig.35 ^{1}H NMR of compound **5o**

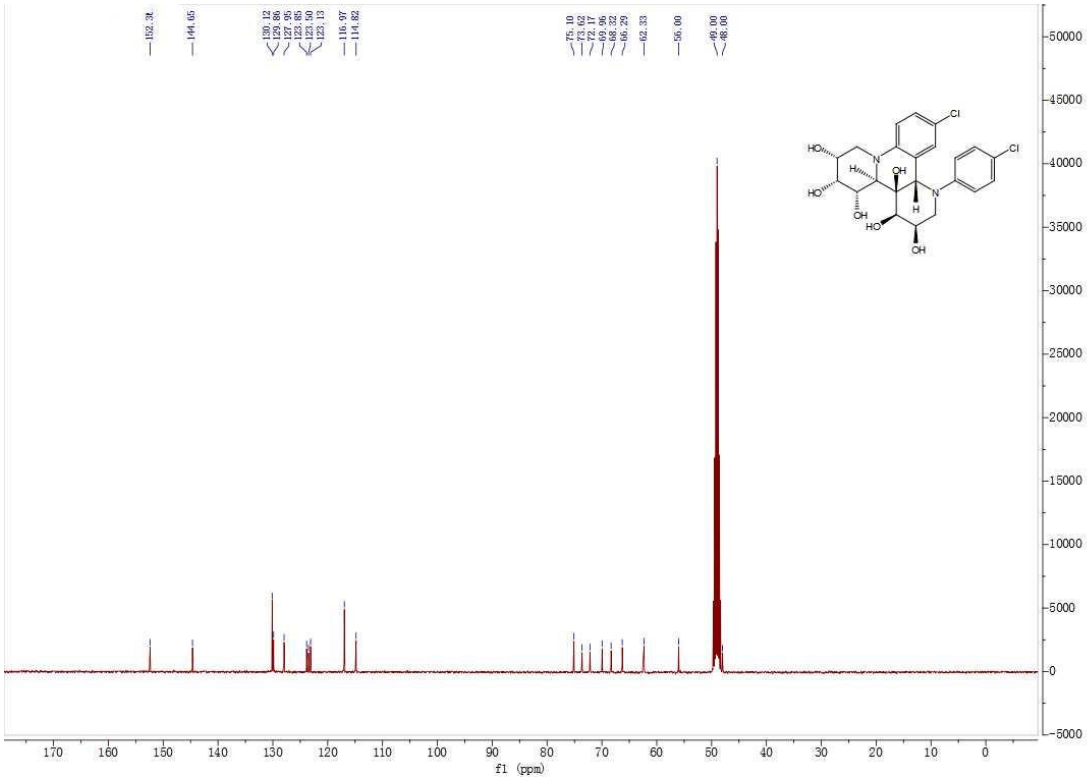


Fig.36 ^{13}C NMR of compound **5o**

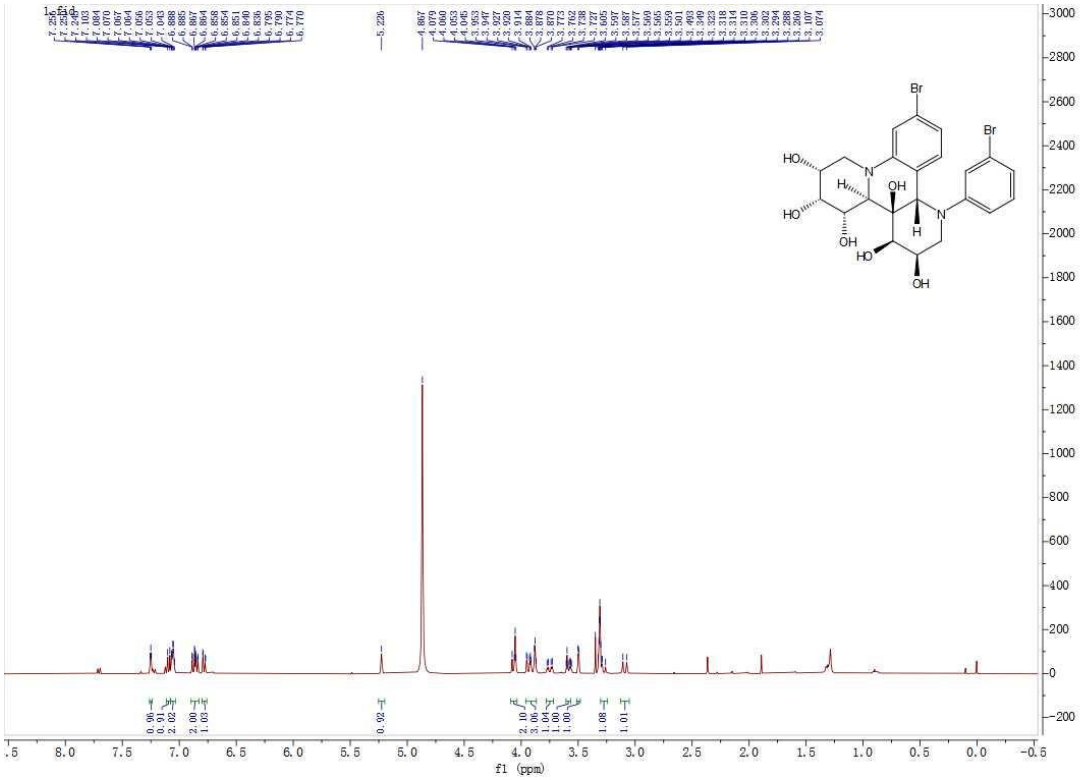


Fig.37 ^{1}H NMR of compound **5p**

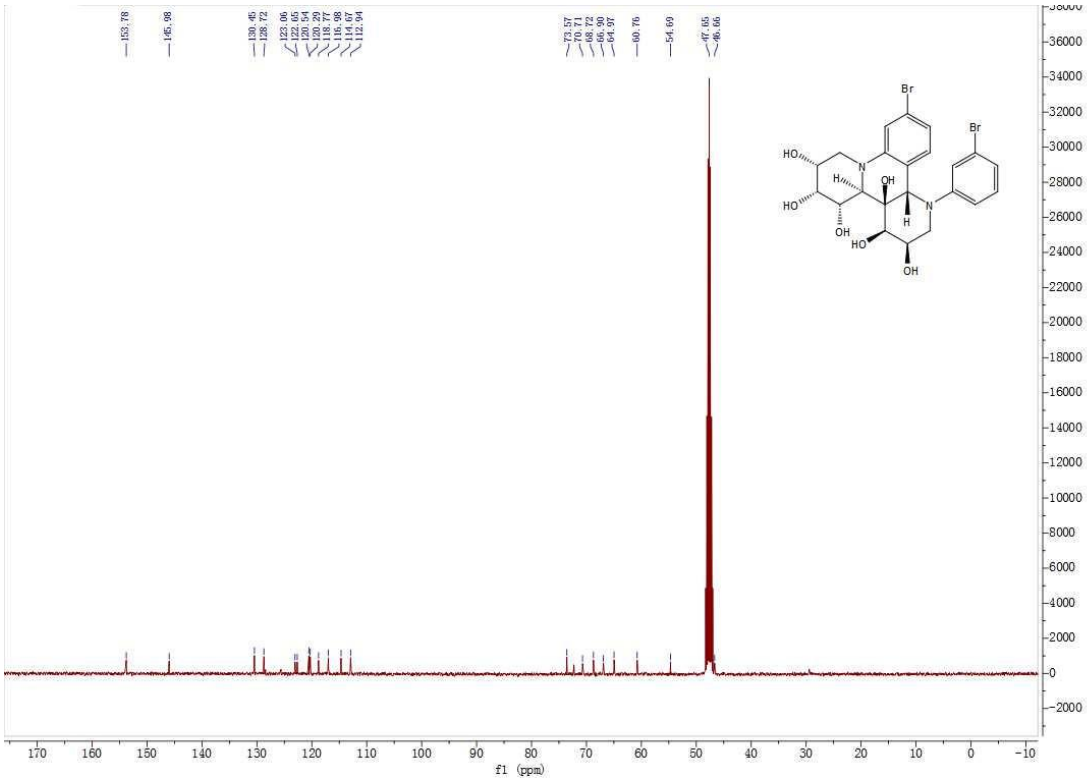


Fig.38 ^{13}C NMR of compound **5p**

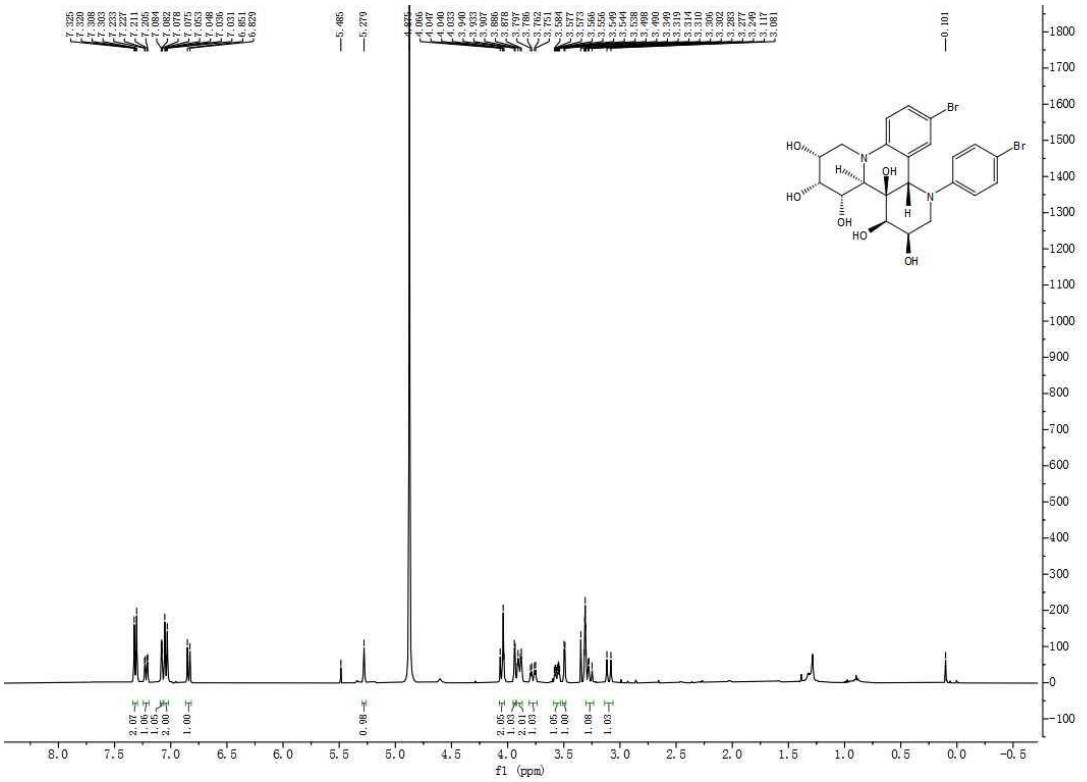


Fig.39 ^{1}H NMR of compound **5q**

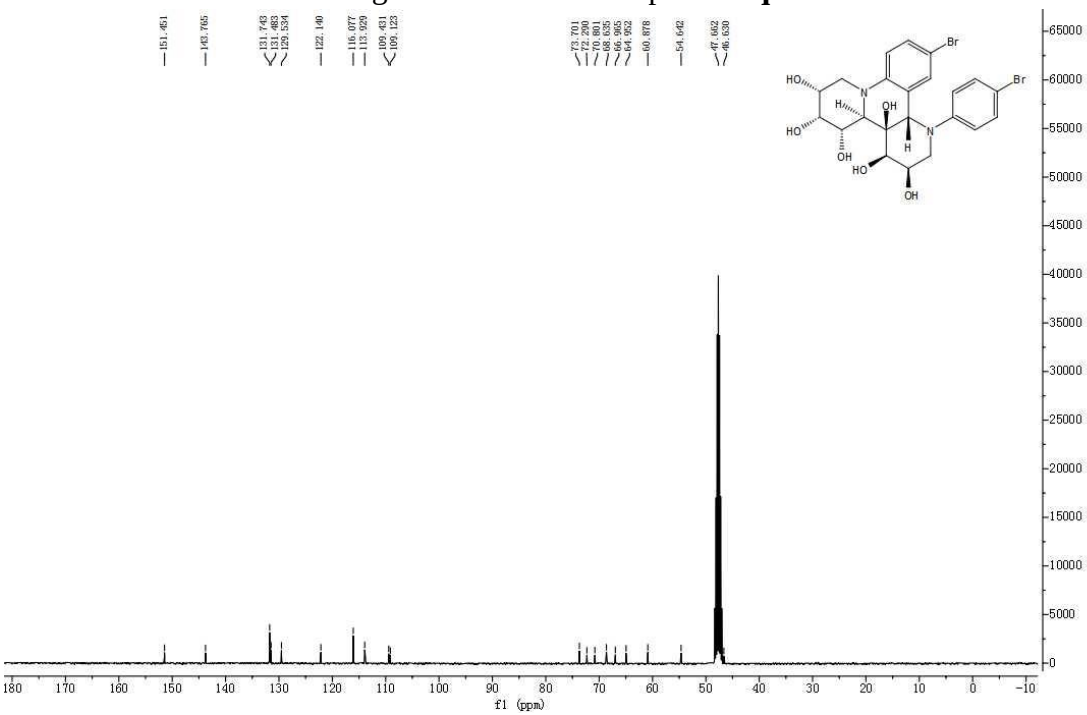


Fig.40 ^{13}C NMR of compound **5q**

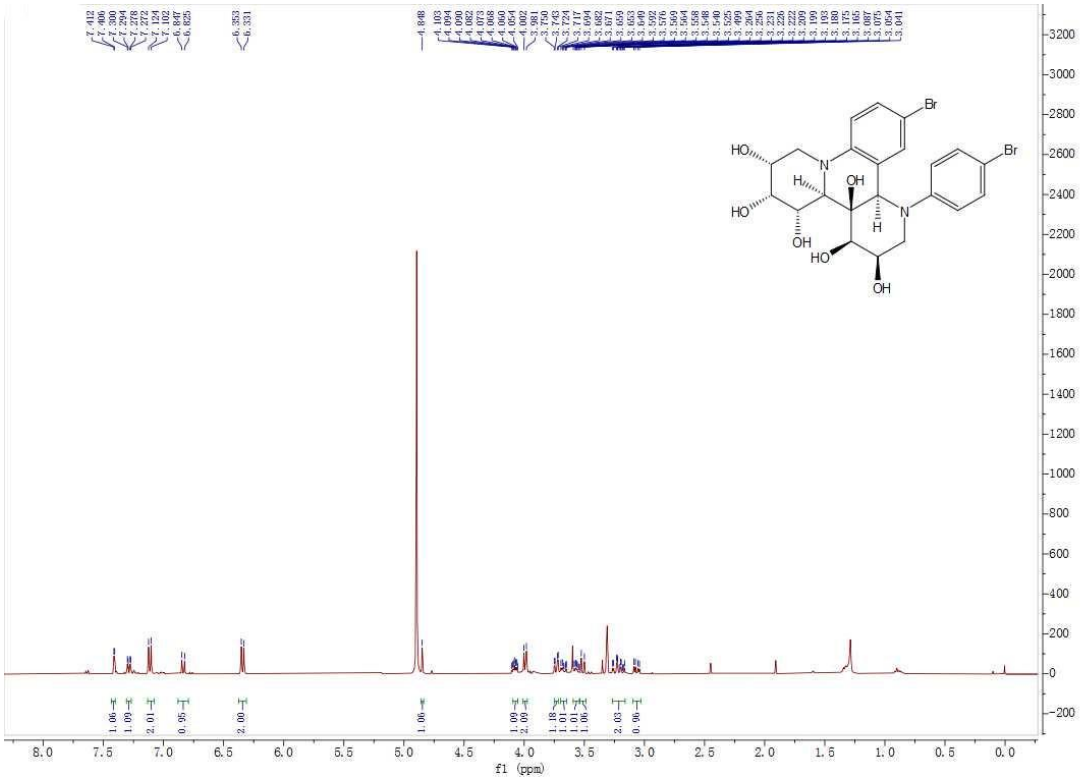


Fig.41 ^{1}H NMR of compound **5q-1**

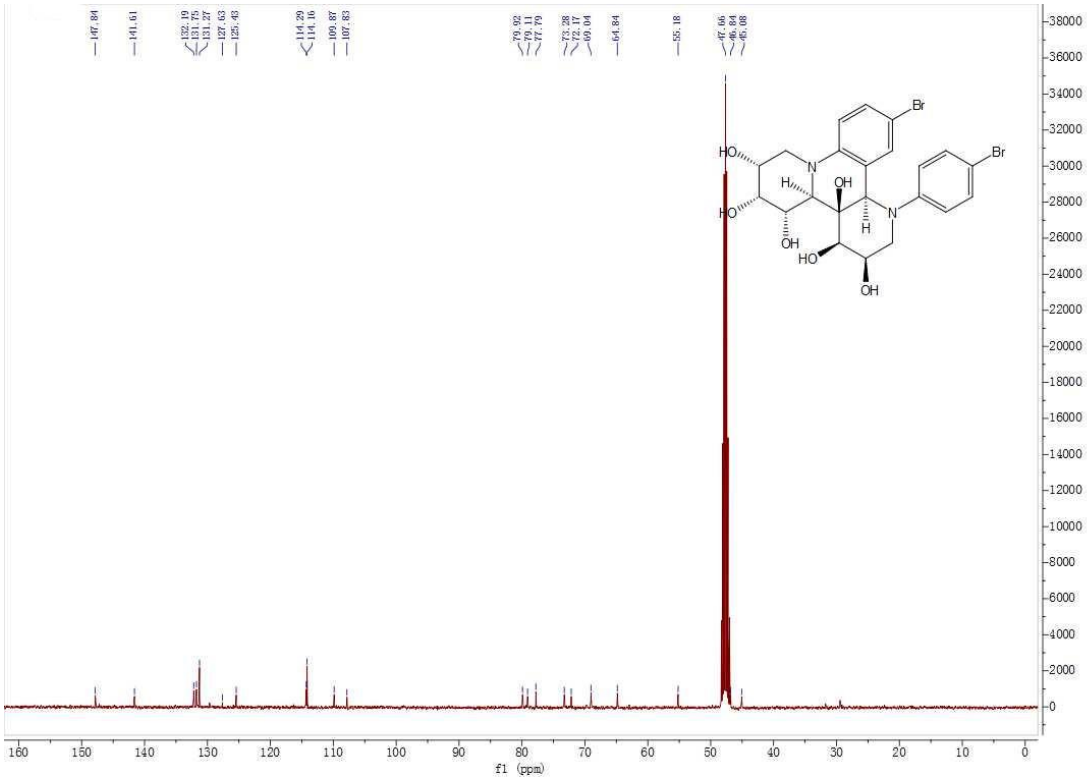


Fig.42 ^{13}C NMR of compound **5q-1**

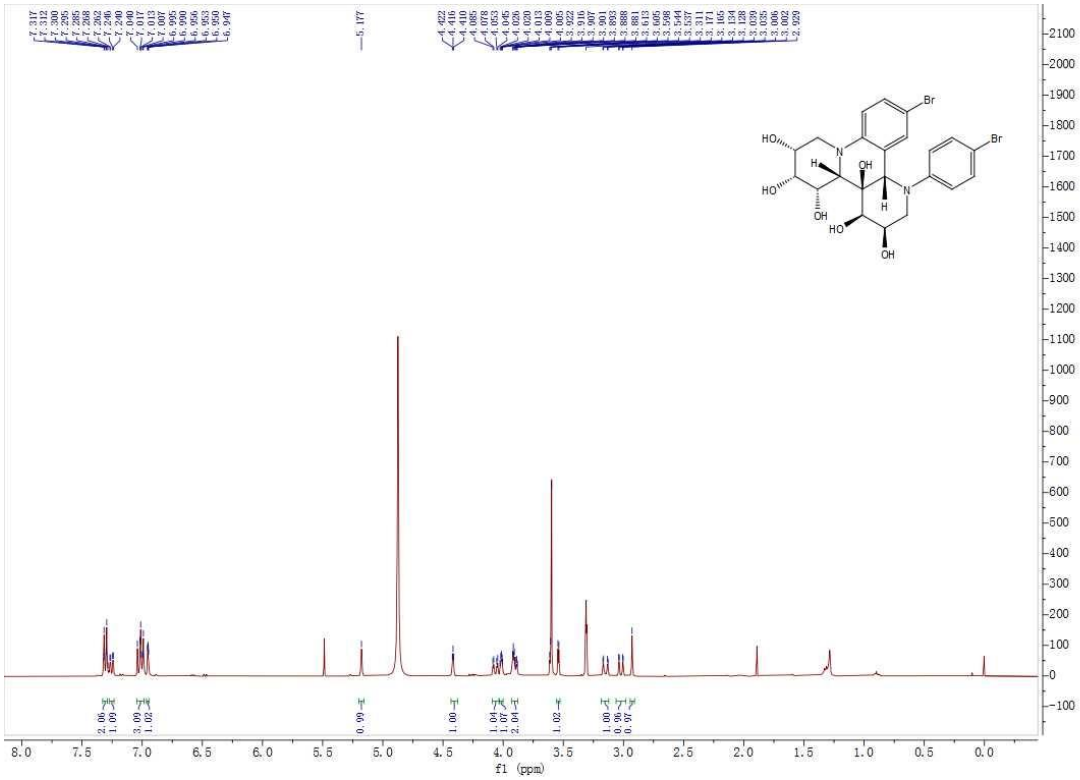


Fig.43 ^{1}H NMR of compound **5q-2**

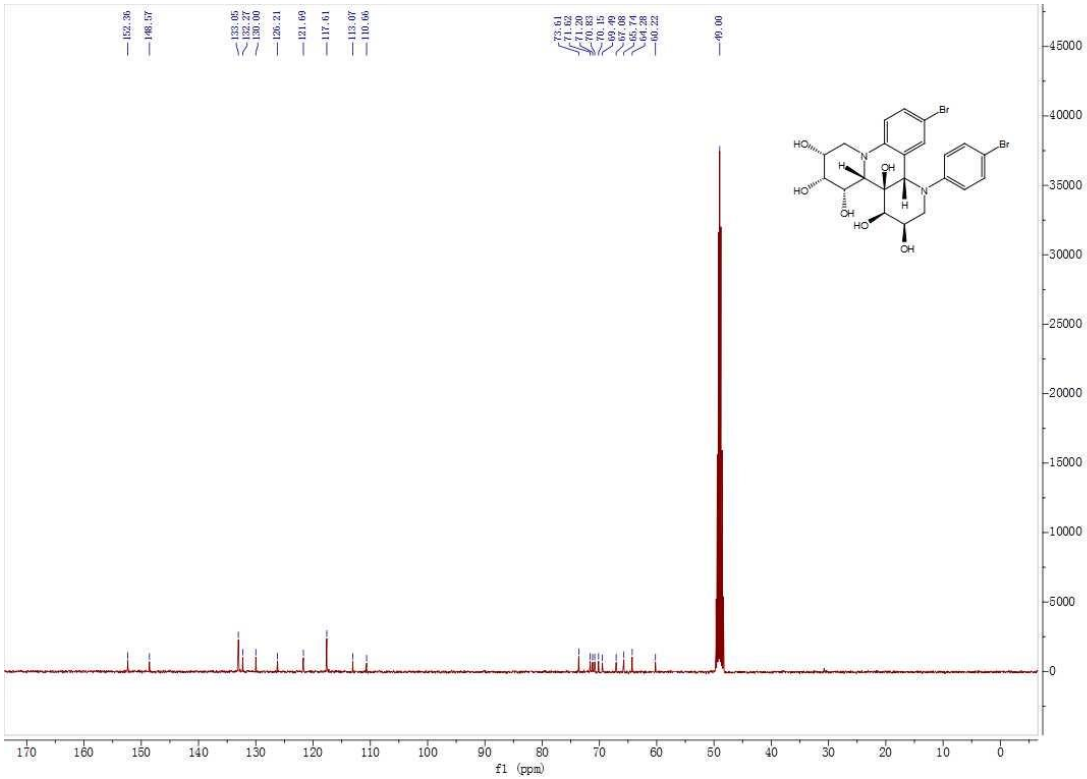


Fig.44 ^{13}C NMR of compound **5q-2**

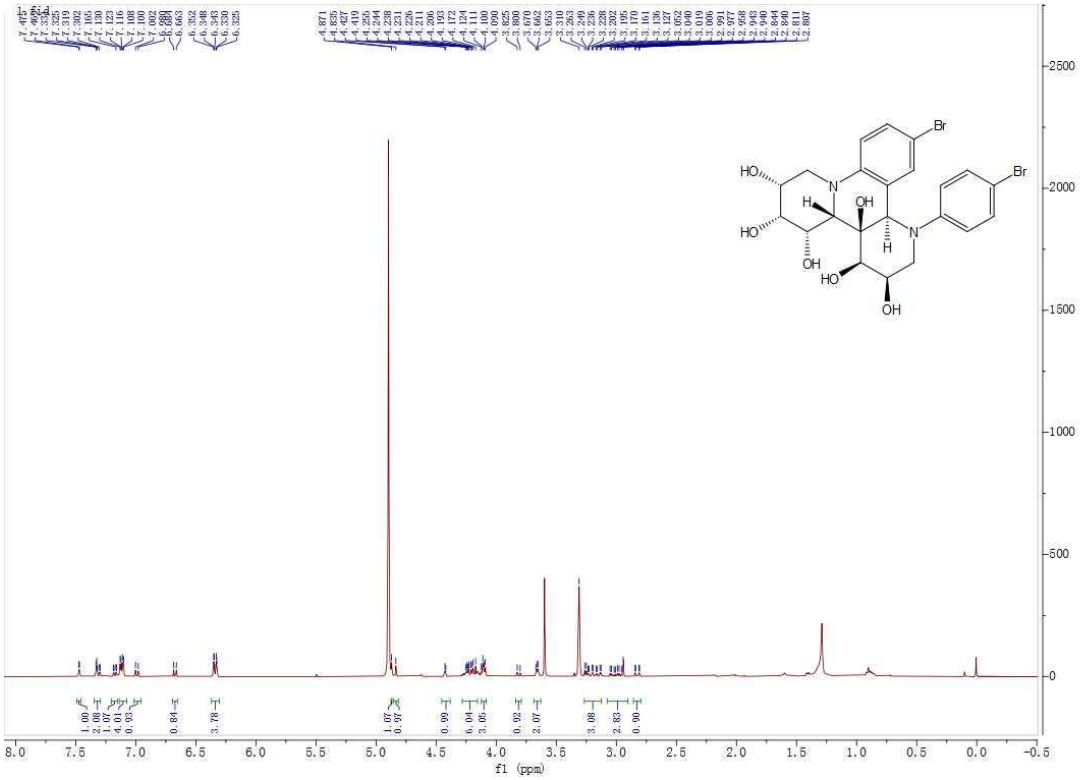


Fig.45 ^{1}H NMR of mixed compounds **5q-1** and **5q-3**

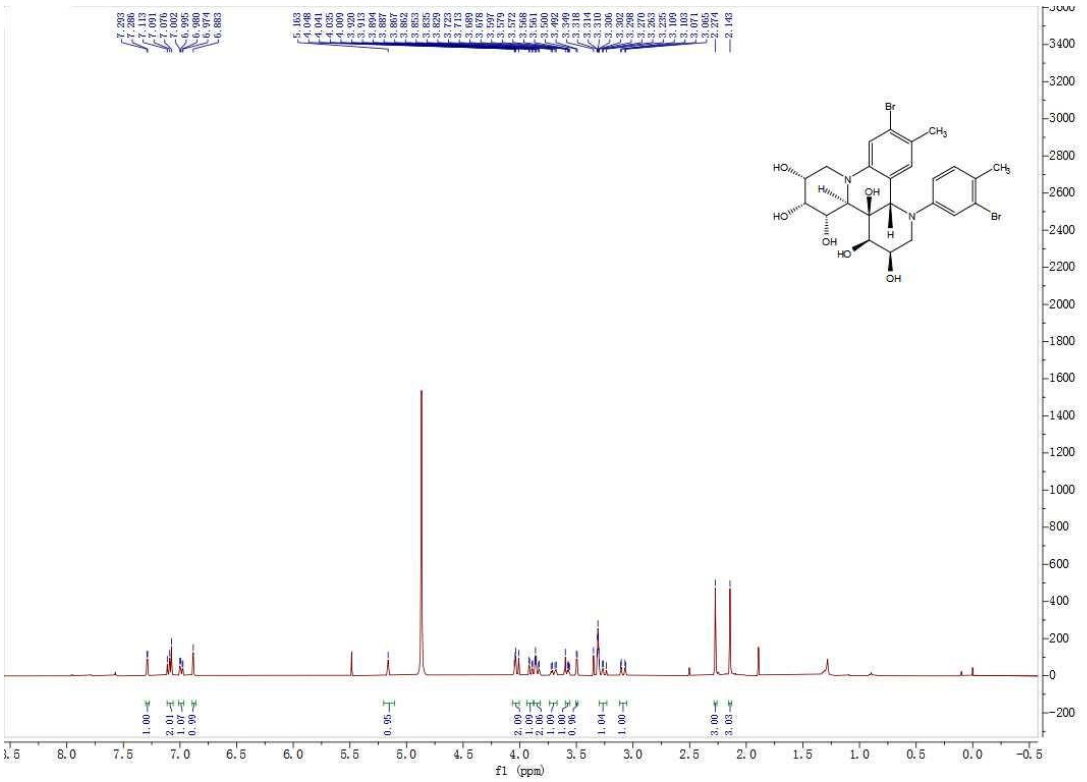


Fig.46 ^{1}H NMR of compound **5s**

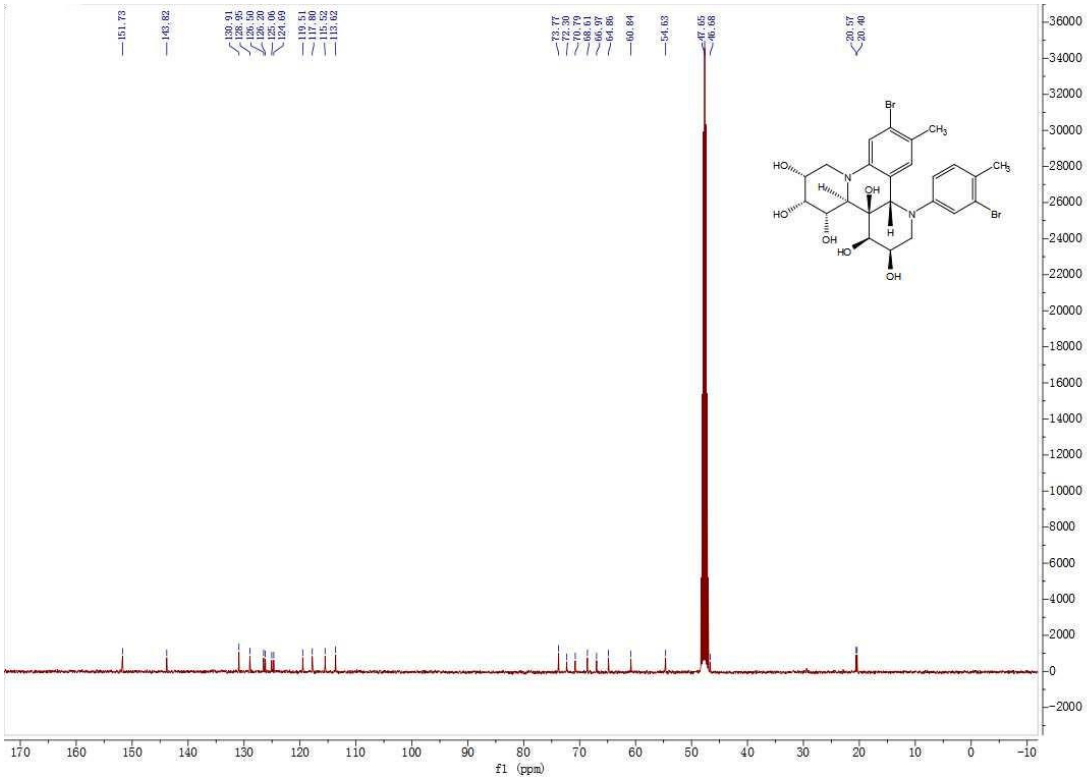


Fig.47 ^{13}C NMR of compound **5s**

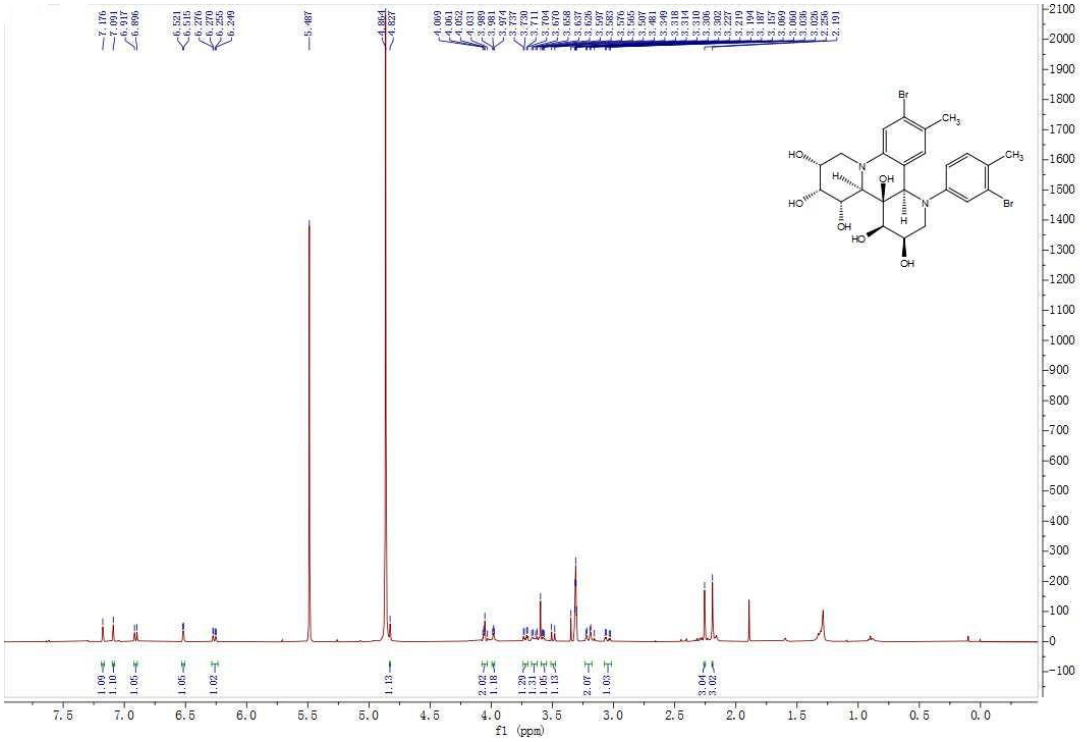


Fig.48 ^{1}H NMR of compound **5s-1**

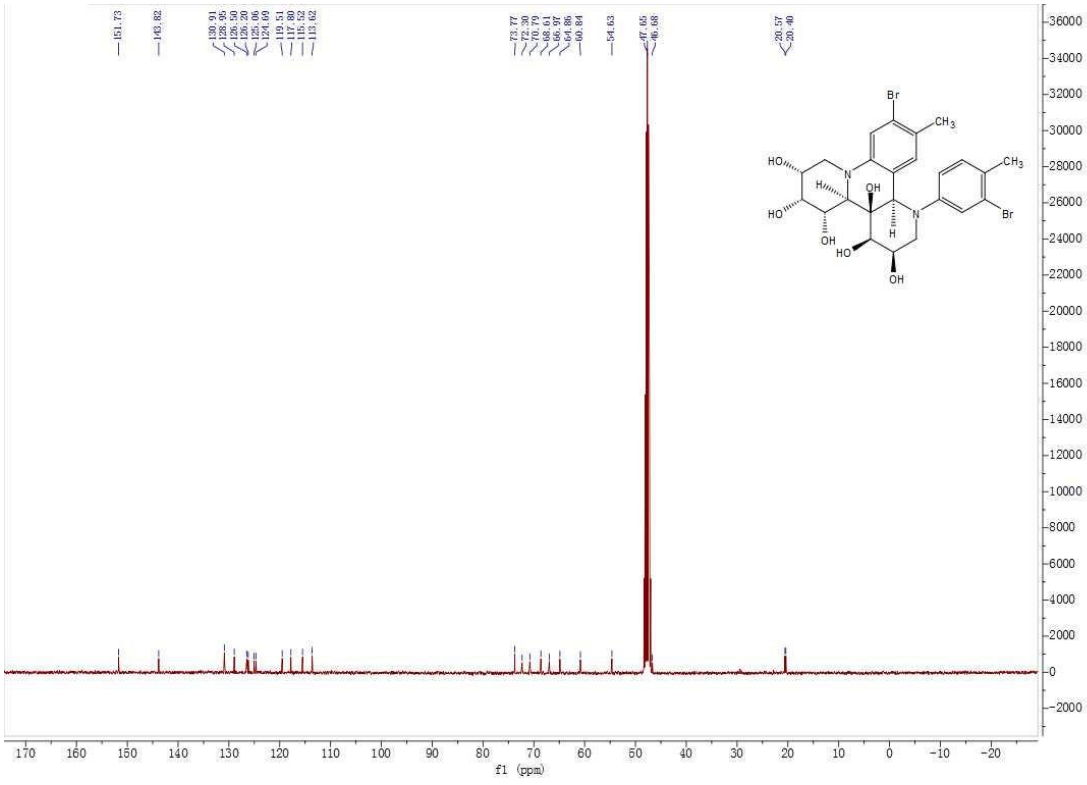


Fig.49 ^{13}C NMR of compound **5s-1**

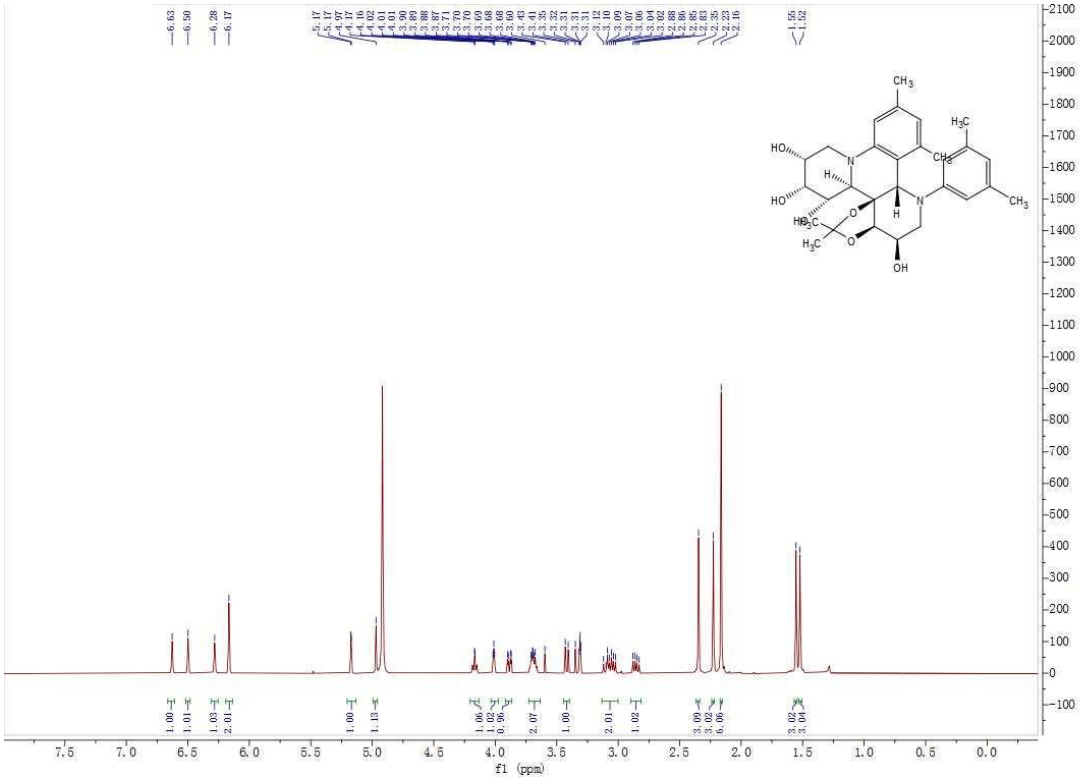


Fig.50 ^{1}H NMR of compound **5t'**

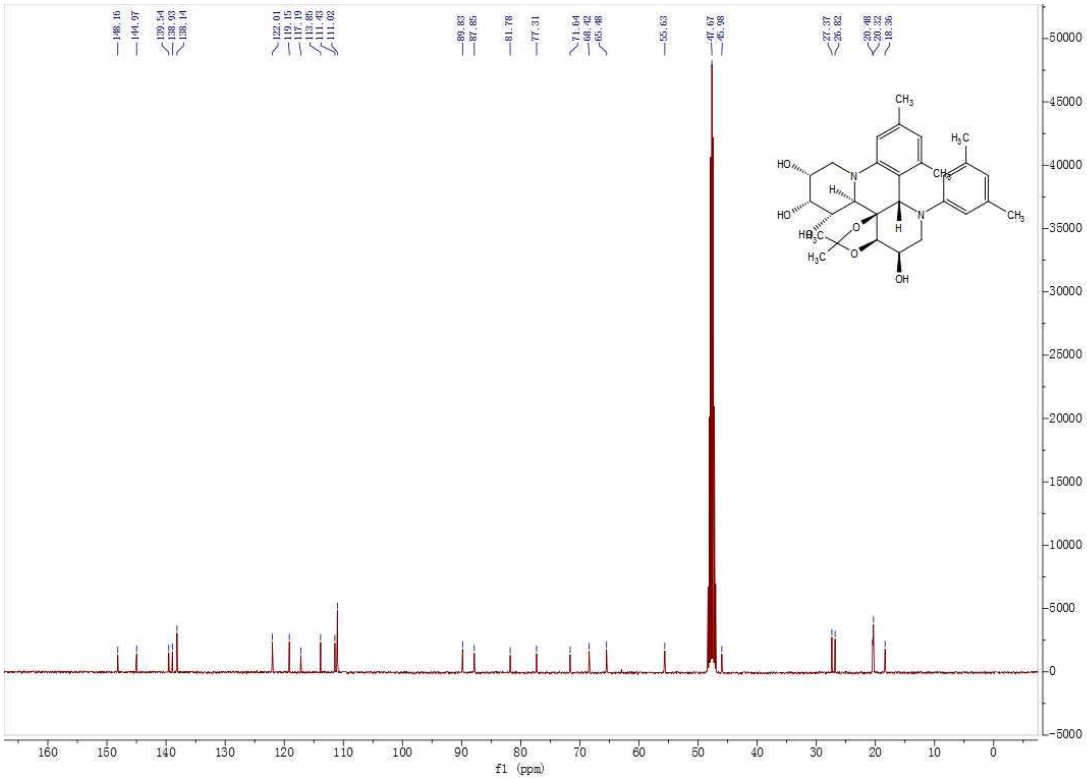


Fig.51 ^{13}C NMR of compound **5t'**

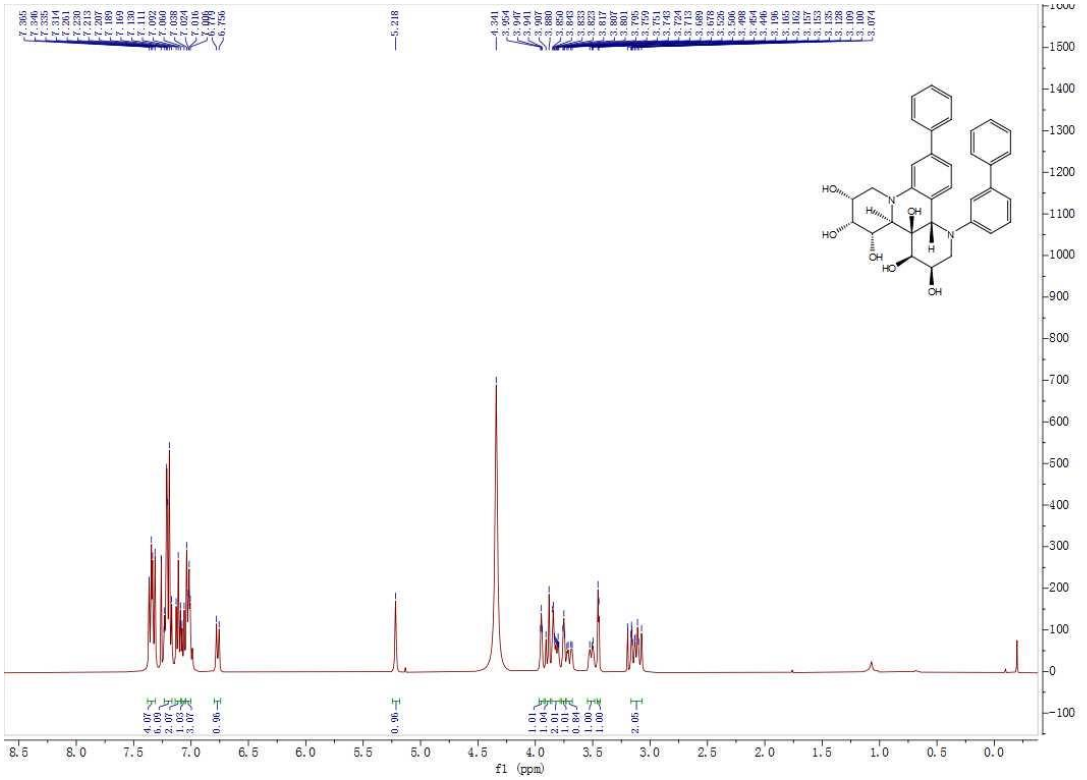


Fig.52 ^{1}H NMR of compound **5u**

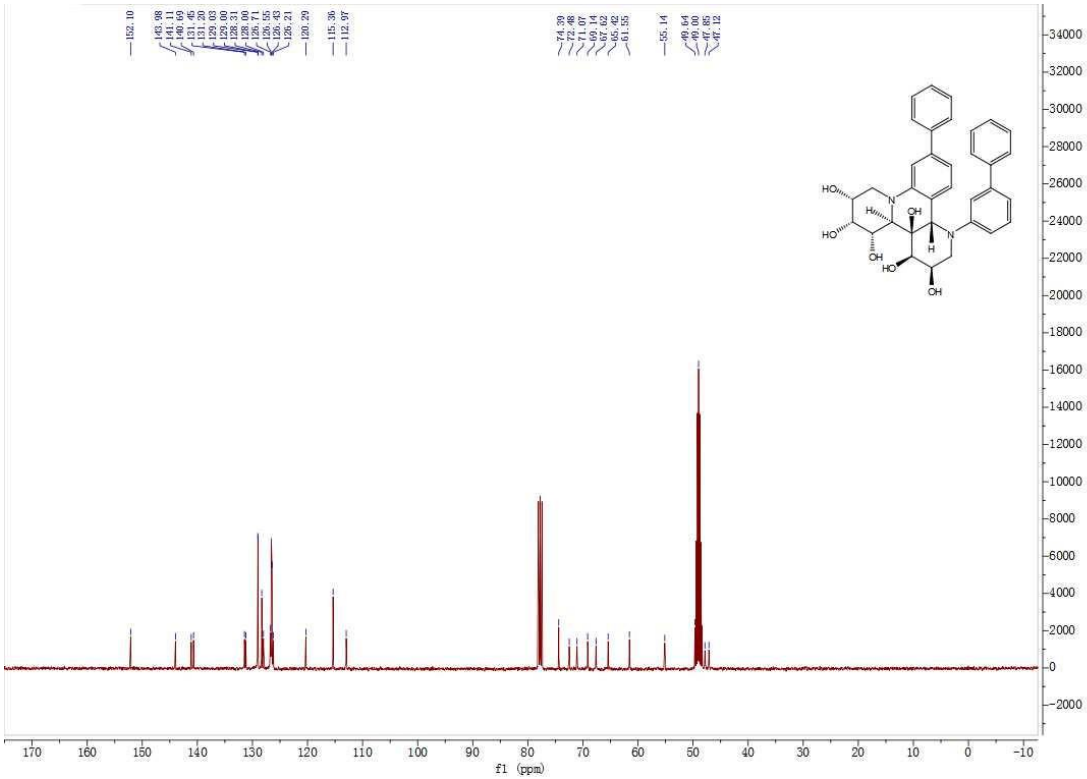


Fig.53 ^{13}C NMR of compound **5u**

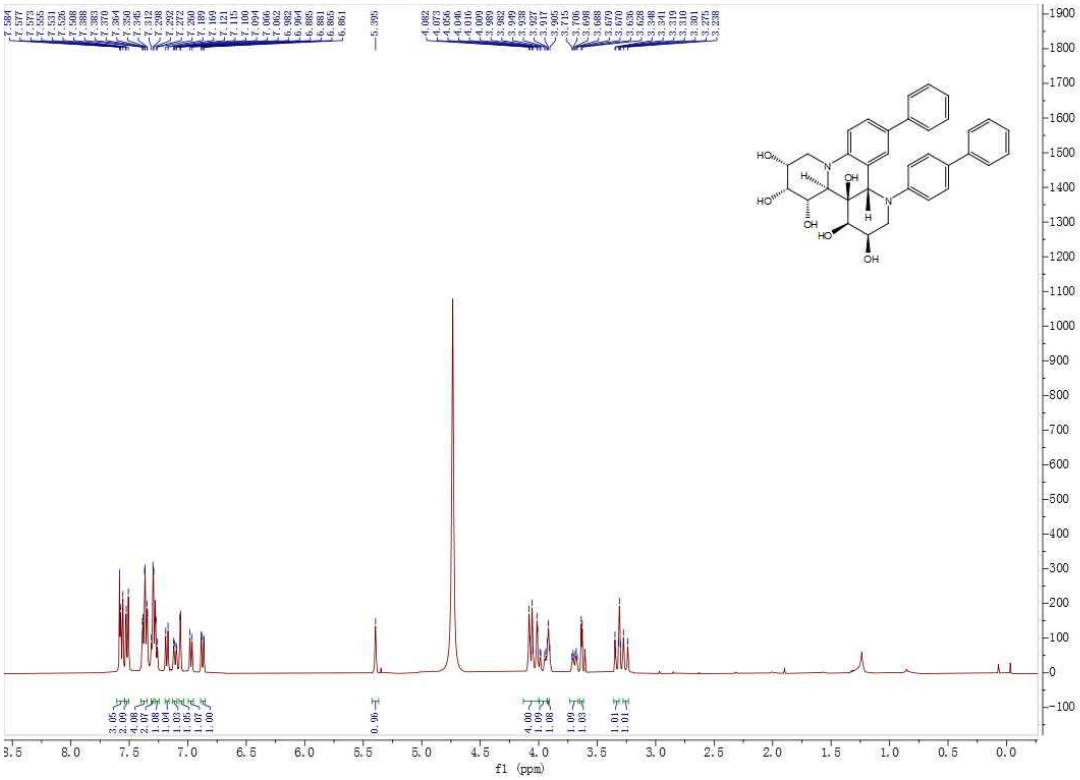


Fig.54 ^{1}H NMR of compound **5v**

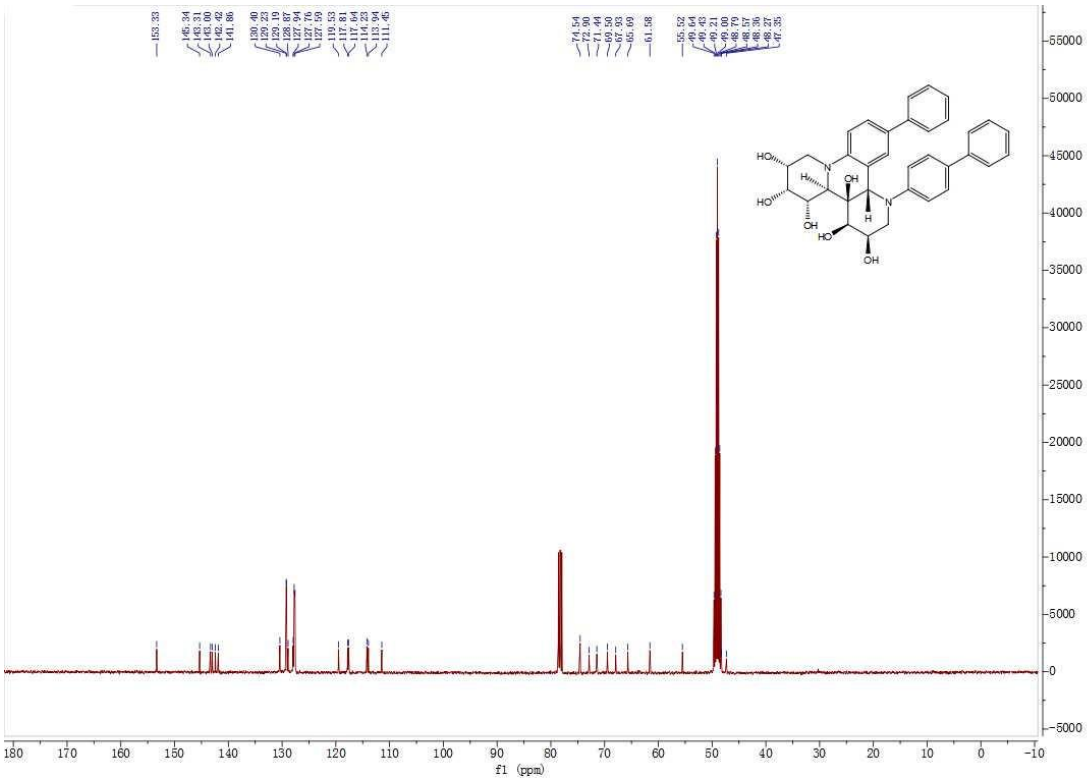


Fig.55 ^{13}C NMR of compound **5v**

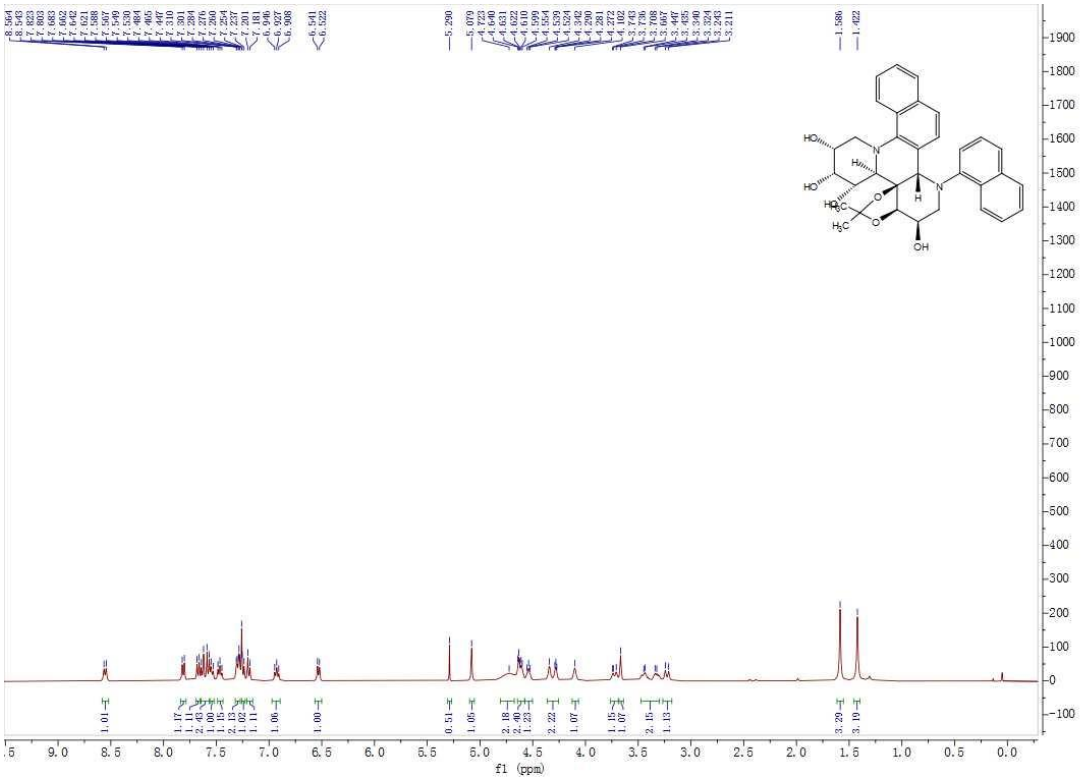


Fig.56 ^{1}H NMR of compound **5w'**

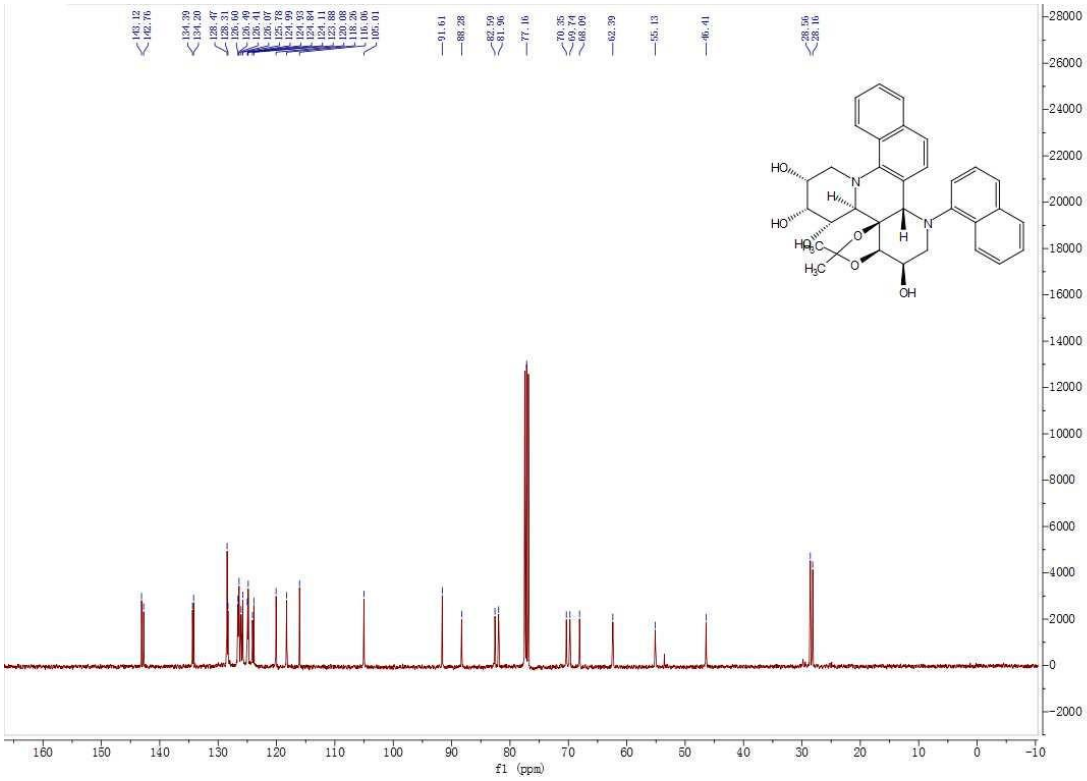


Fig.57 ^{13}C NMR of compound **5w'**

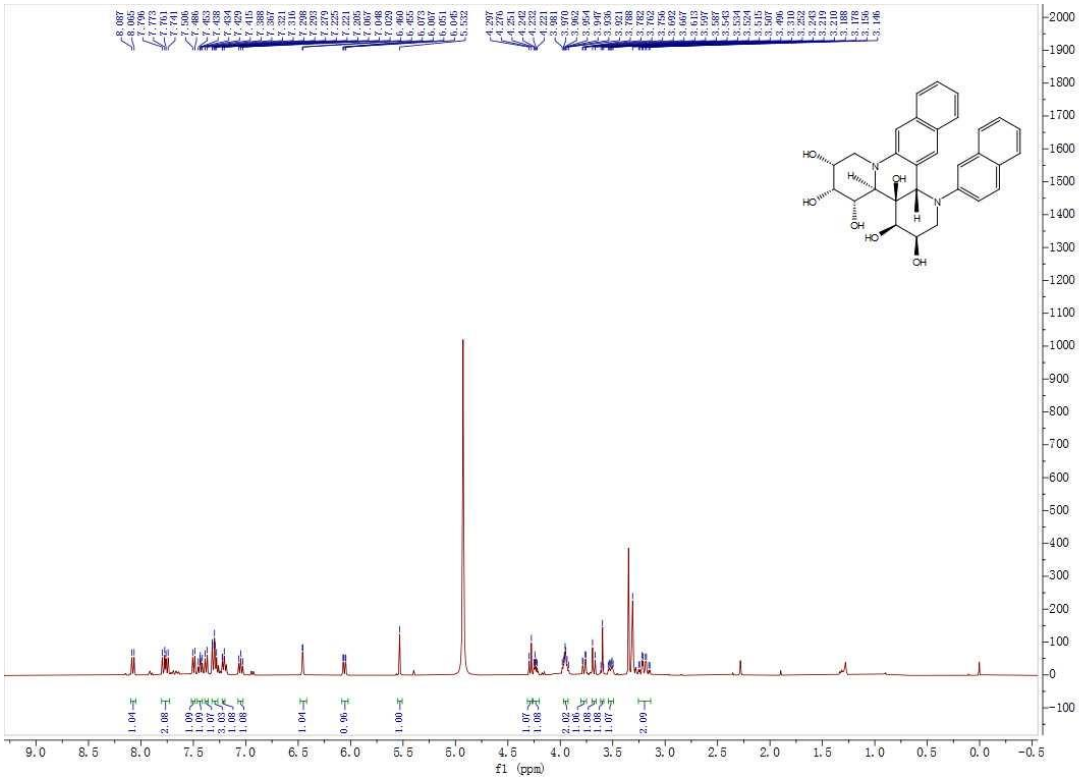


Fig.58 ^{1}H NMR of compound **5x**

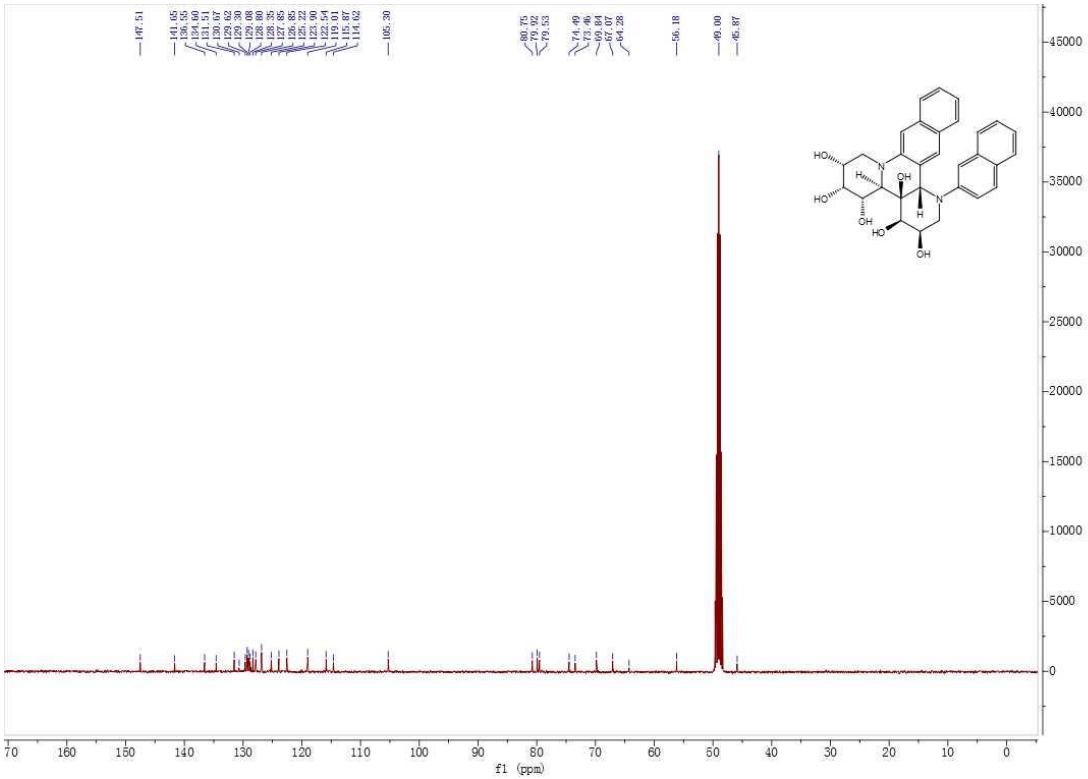


Fig.59 ^{13}C NMR of compound **5x**

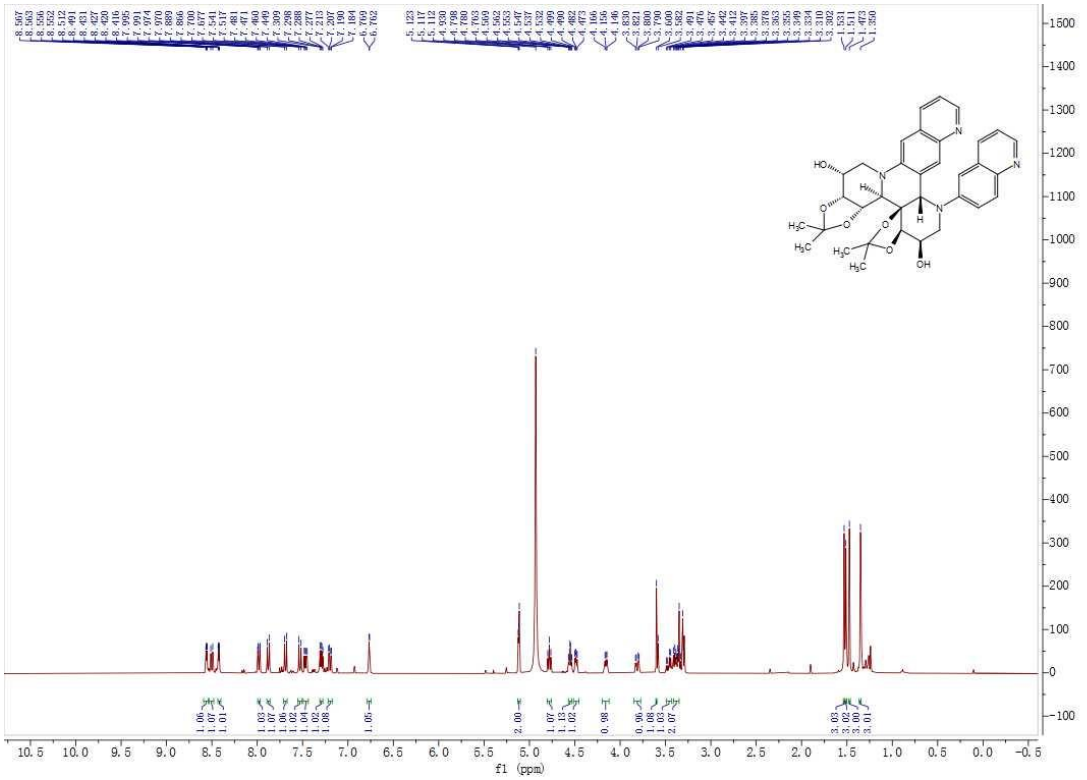


Fig.60 ^{1}H NMR of compound **5y"**

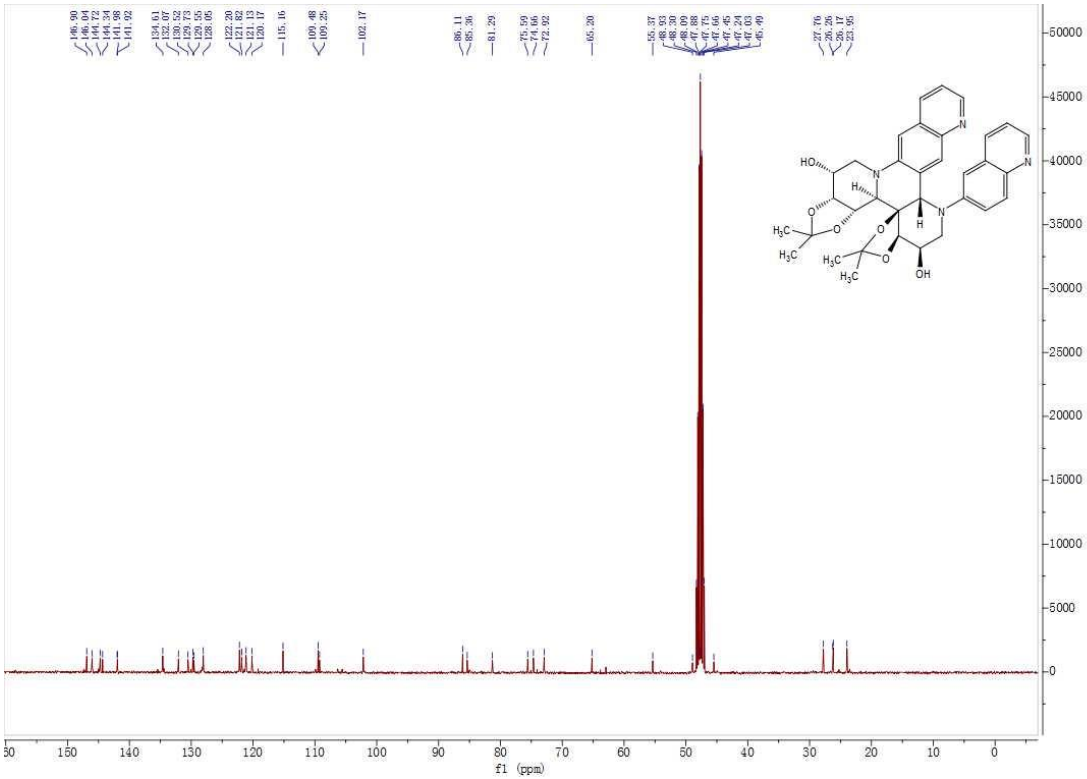


Fig.61 ^{13}C NMR of compound **5y"**

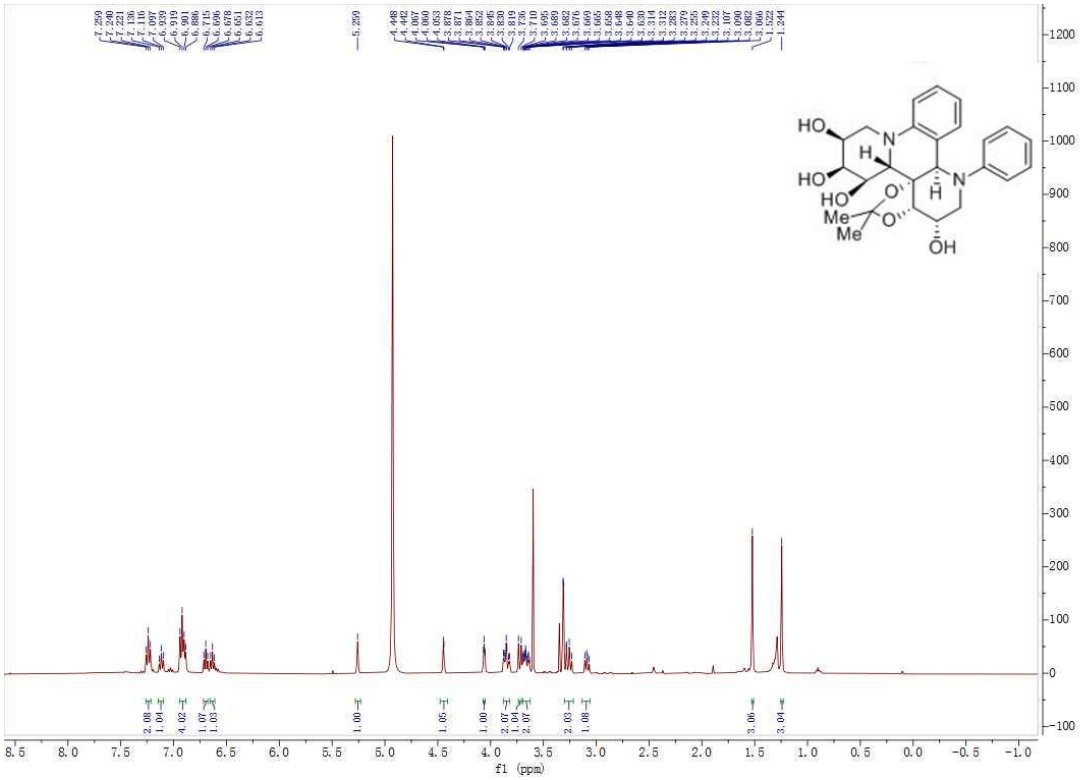


Fig.62 ^{1}H NMR of compound **6a'**

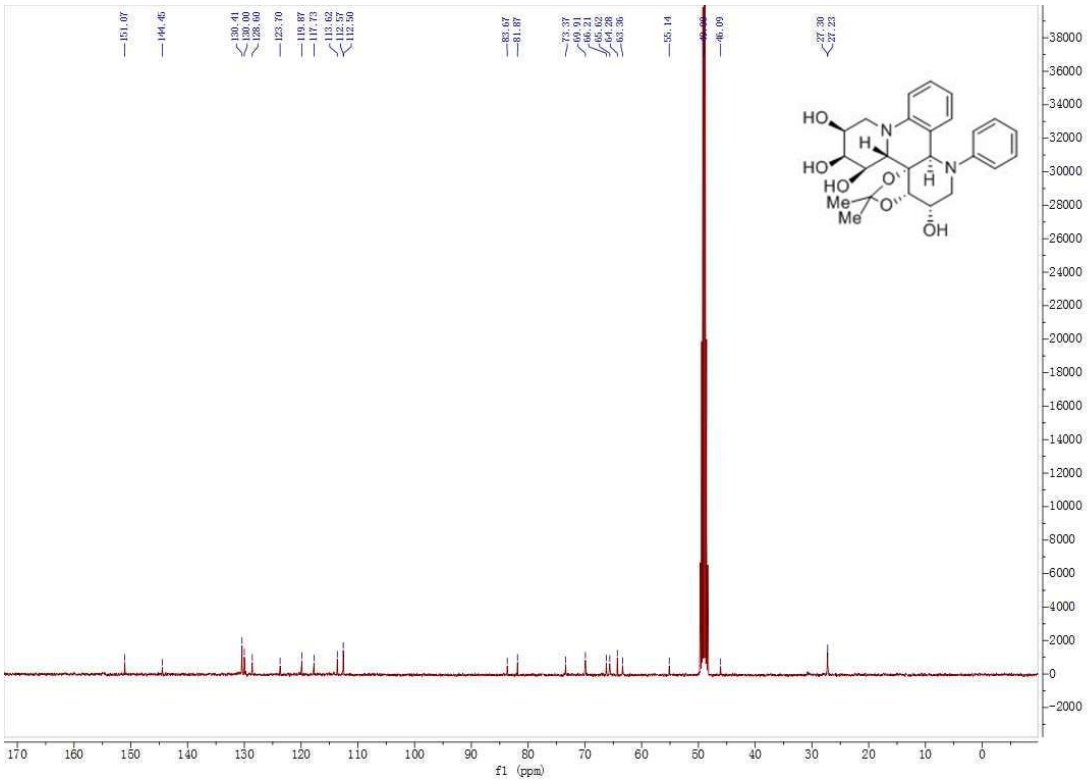


Fig.63 ^{13}C NMR of compound **6a'**

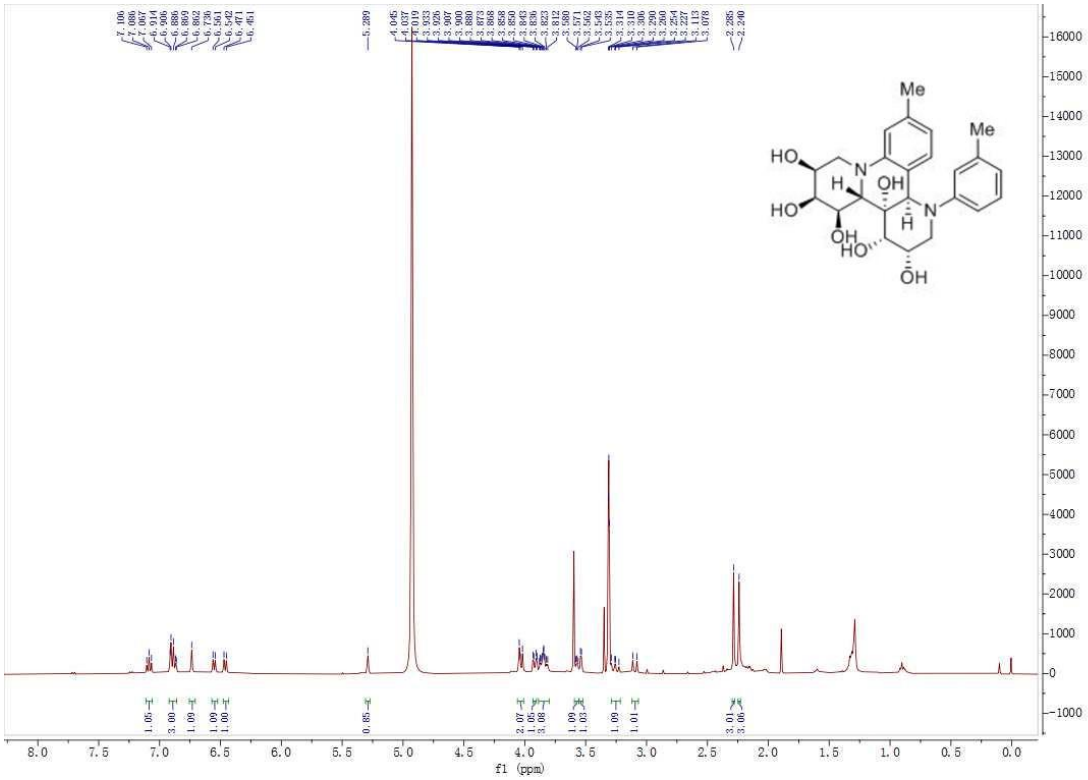


Fig.64 ^{1}H NMR of compound **6c**

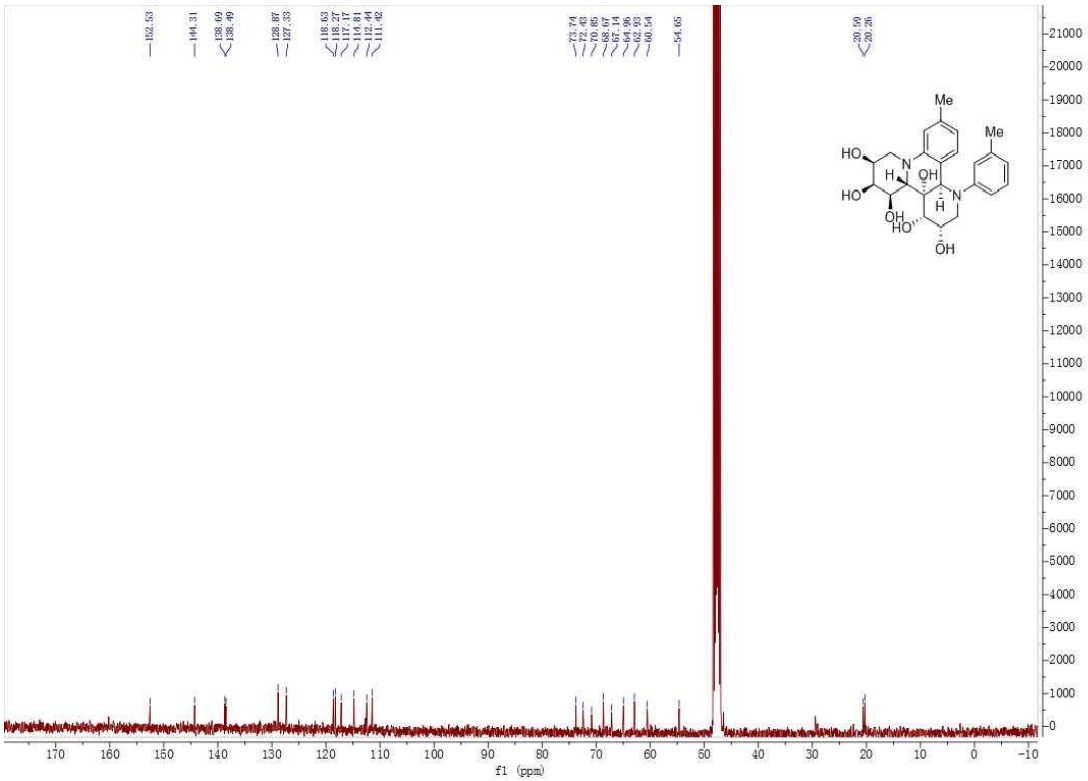


Fig.65 ^{13}C NMR of compound **6c**

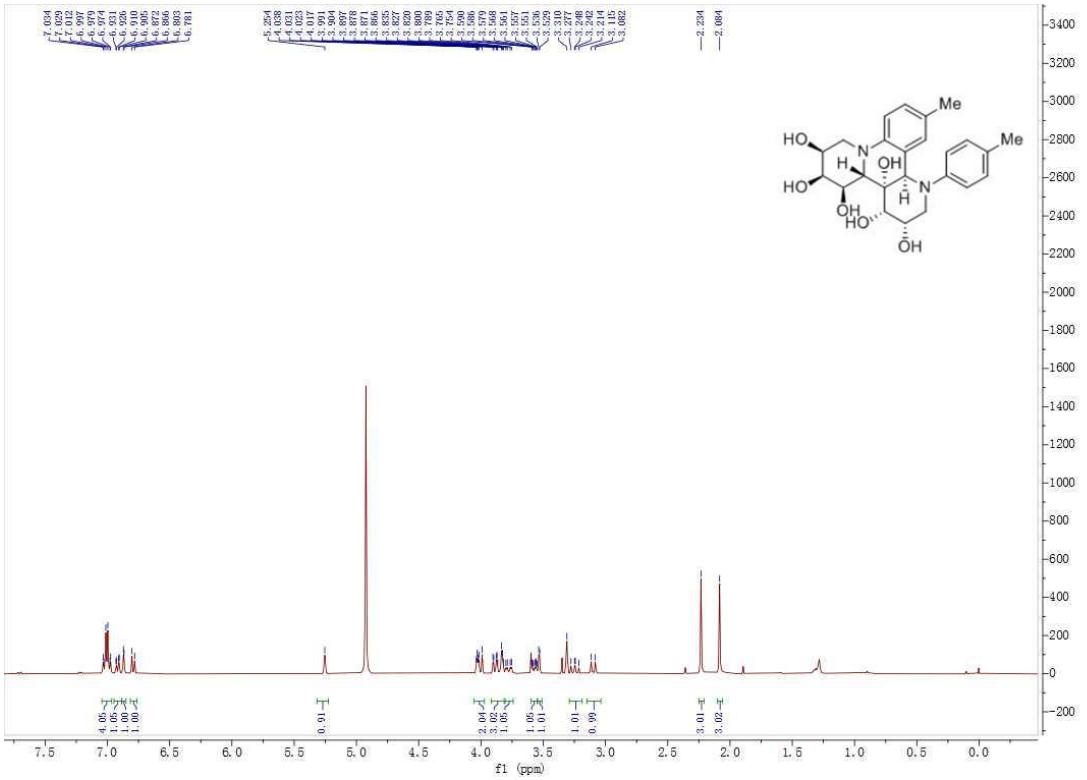


Fig.66 ^{1}H NMR of compound **6d**

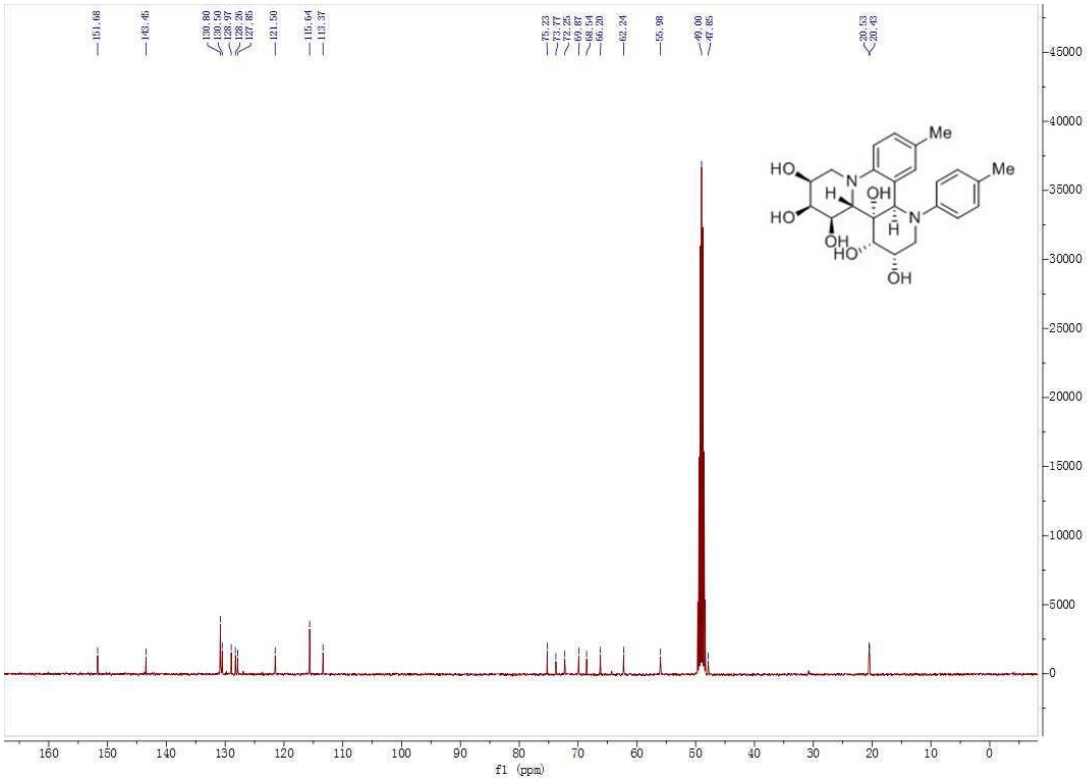


Fig.67 ^{13}C NMR of compound **6d**

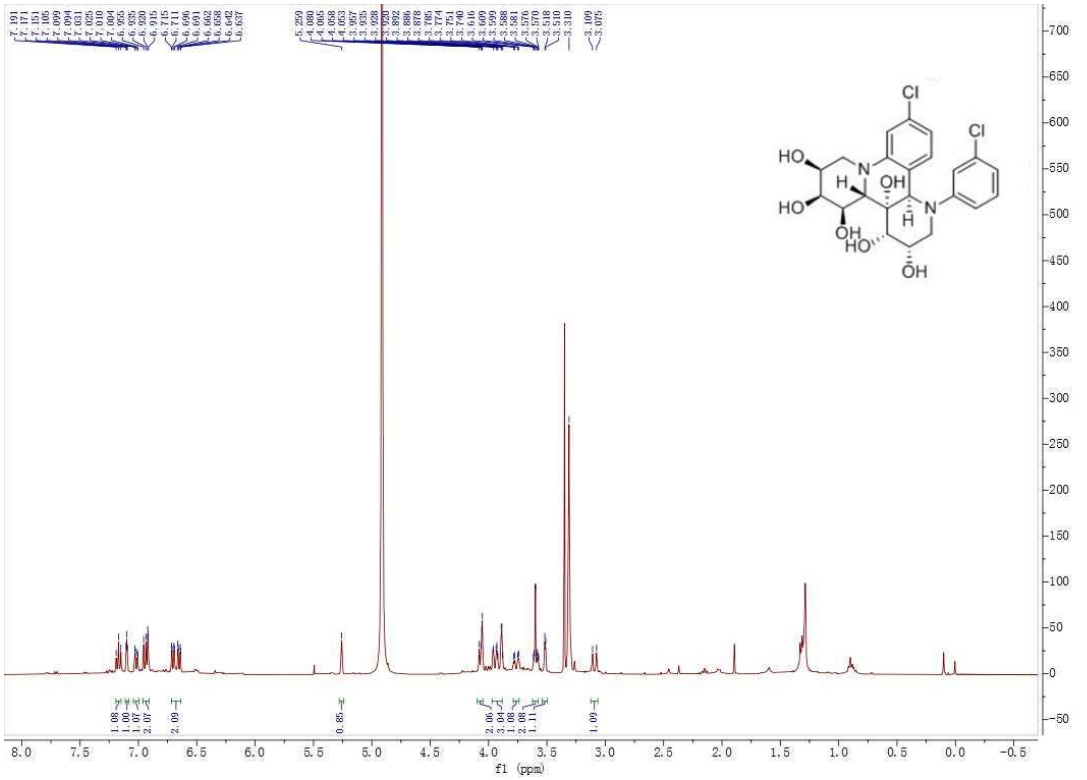


Fig.68 ^{1}H NMR of compound **6n**

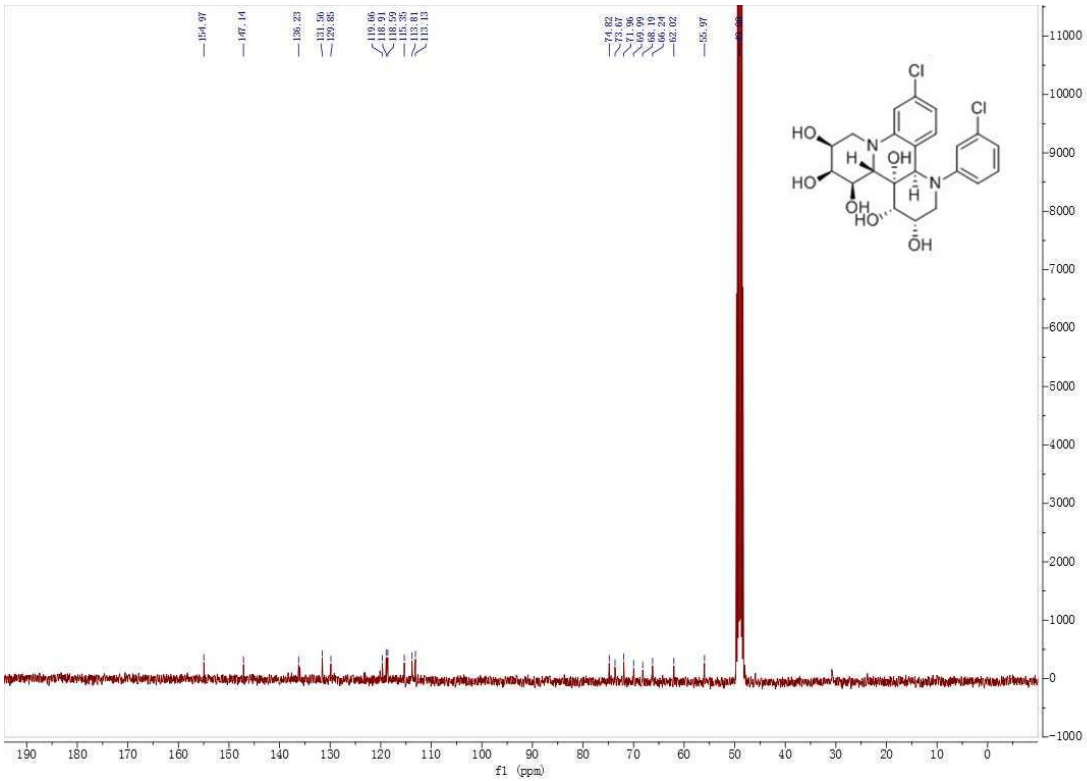


Fig.69 ^{13}C NMR of compound **6n**

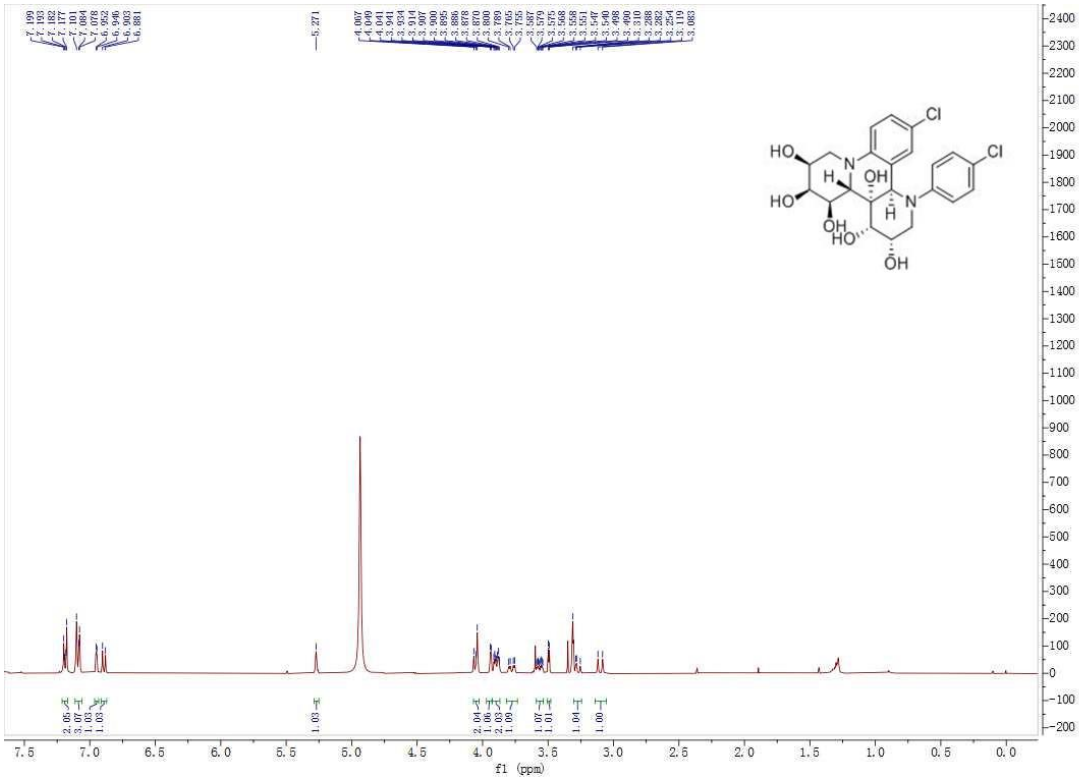


Fig.70 ^{1}H NMR of compound **6o**

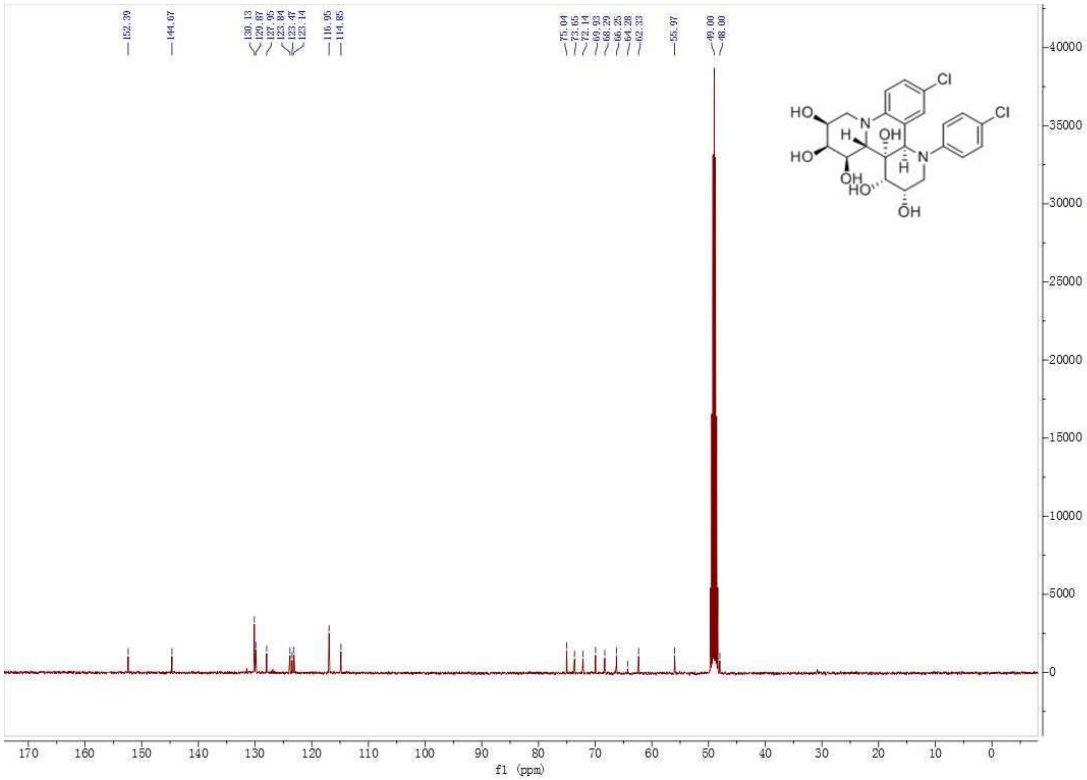


Fig.71 ^{13}C NMR of compound **6o**

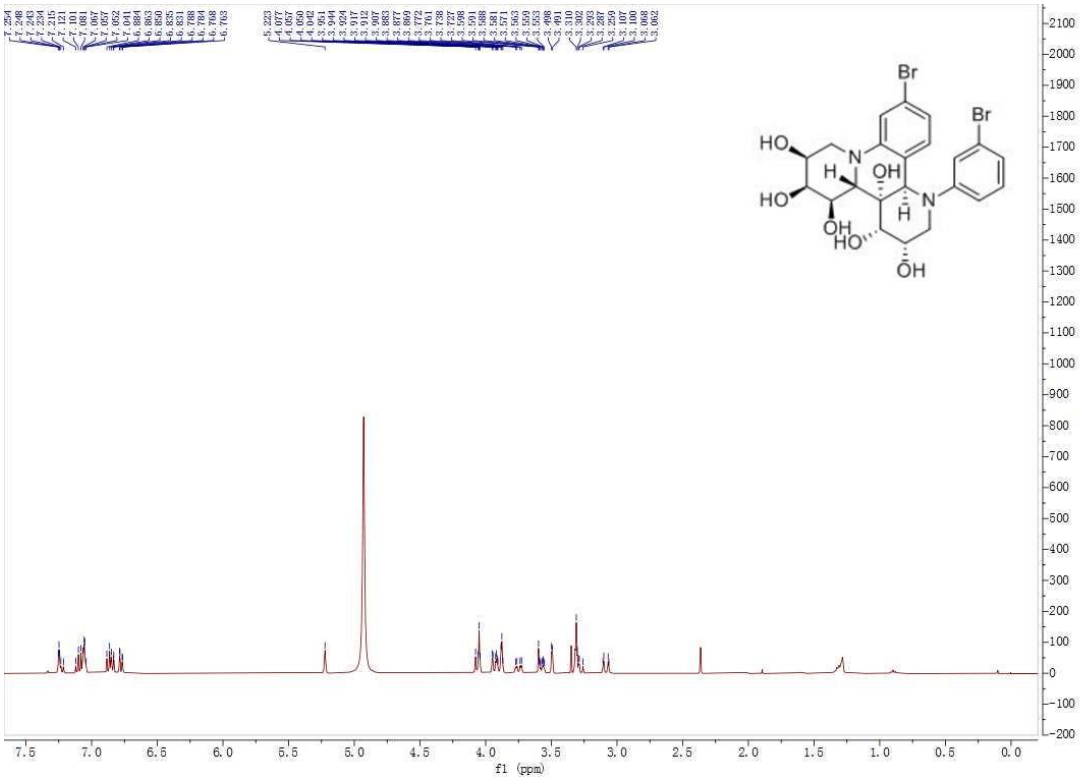


Fig.72 ^{1}H NMR of compound **6p**

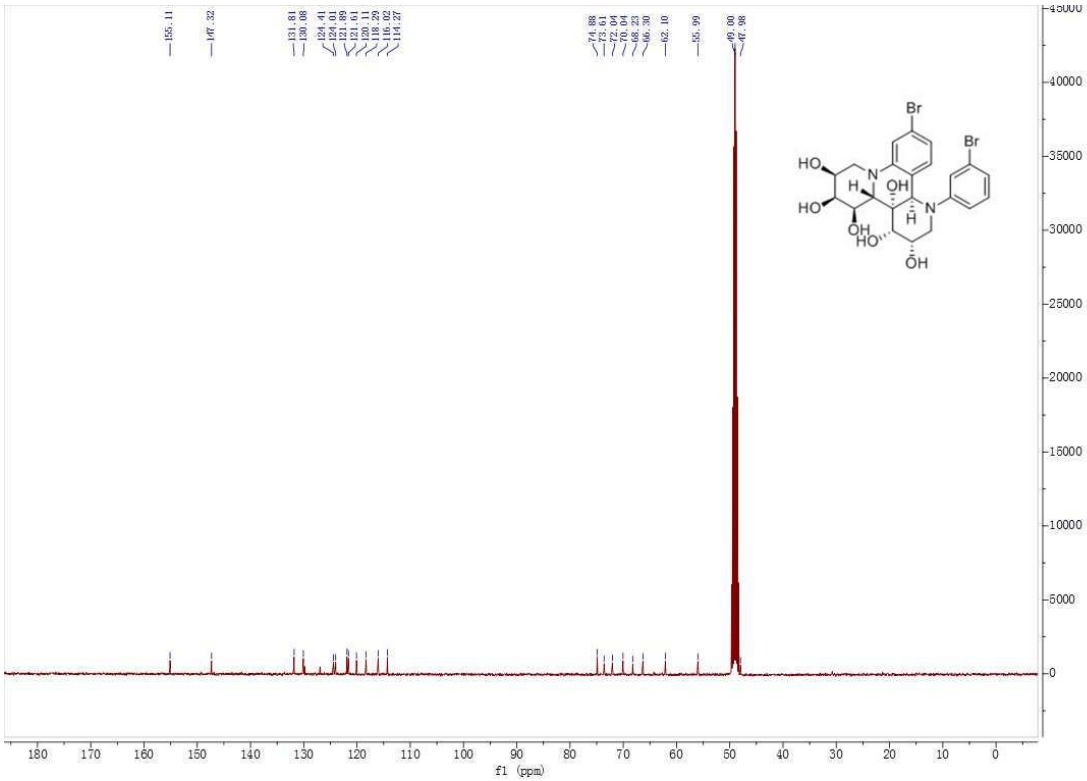


Fig.73 ^{13}C NMR of compound **6p**

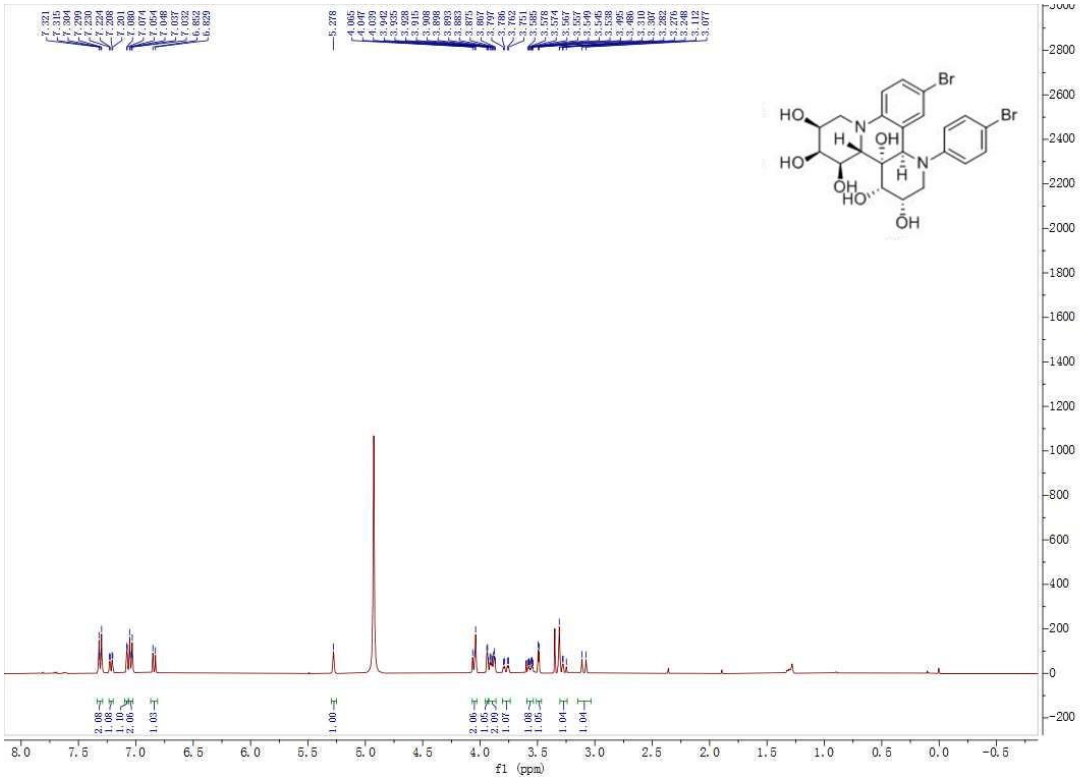


Fig.74 ^{1}H NMR of compound **6q**

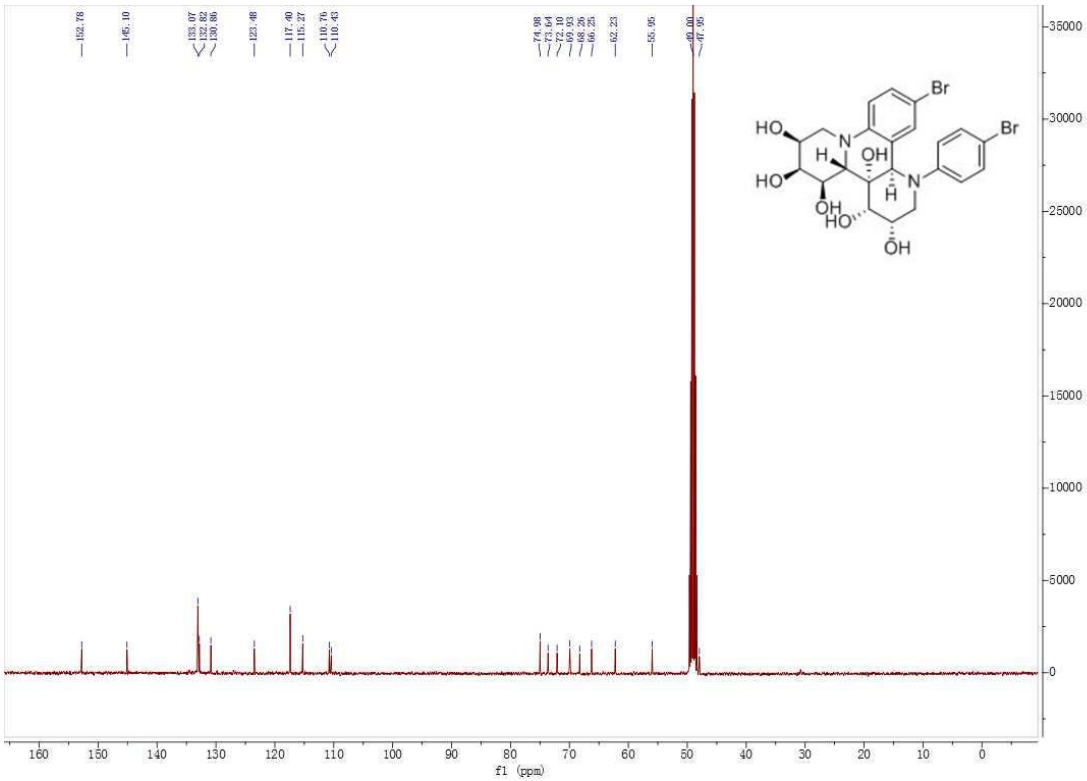


Fig.75 ^{13}C NMR of compound **6q**

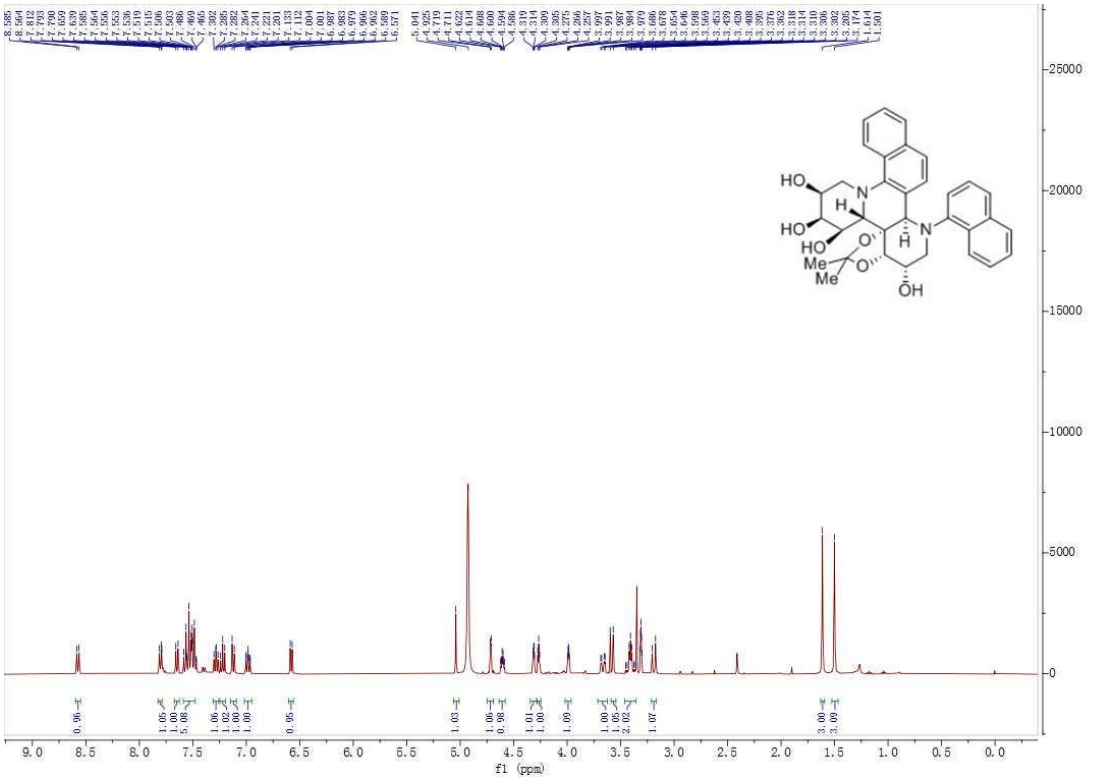


Fig.76 ^{1}H NMR of compound **6w'**

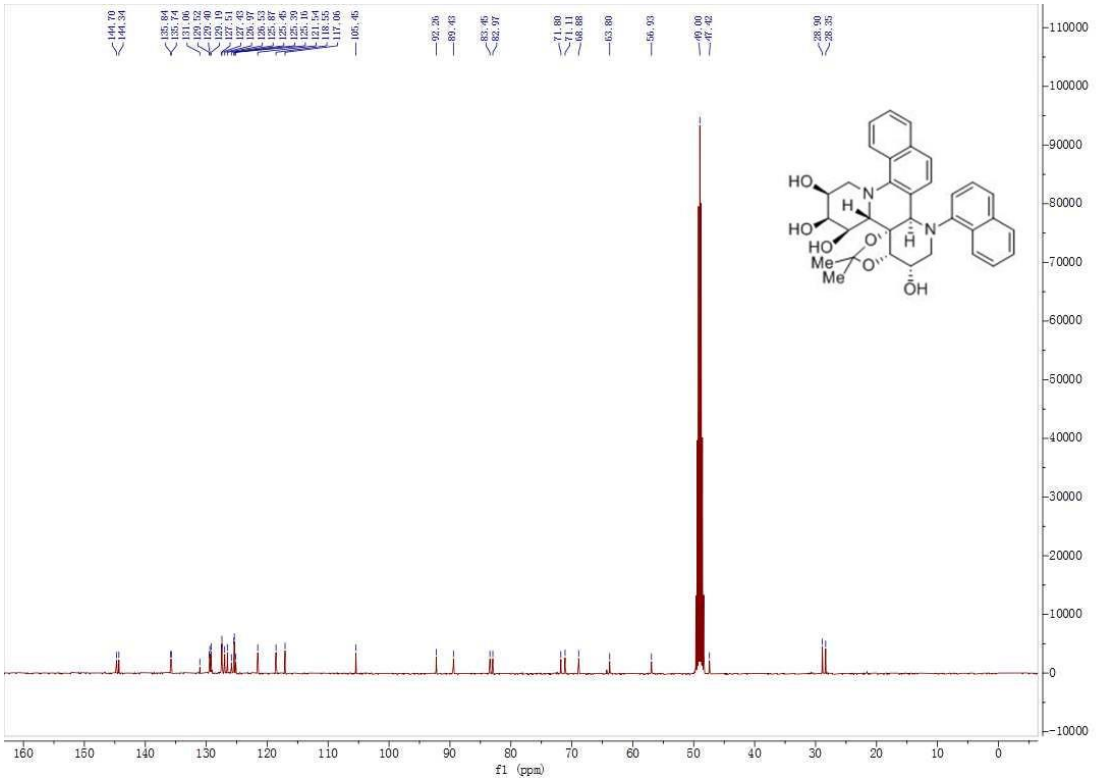


Fig.77 ^{13}C NMR of compound **6w'**

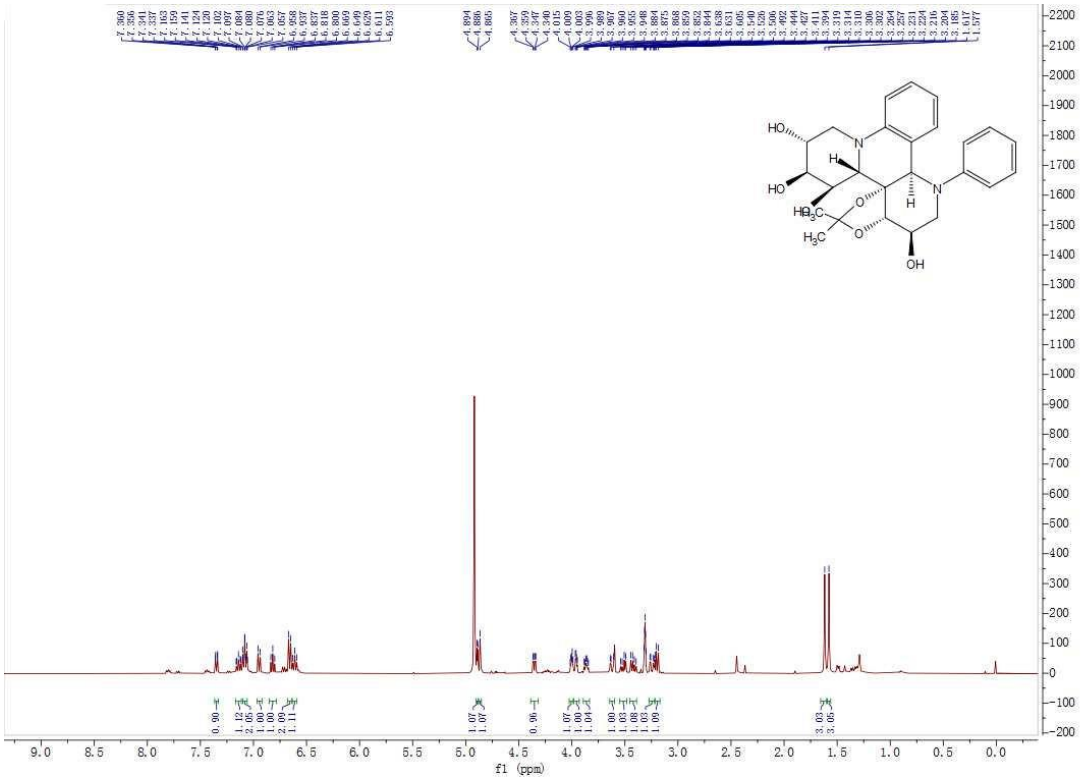


Fig.78 ^{1}H NMR of compound **7a-1'**

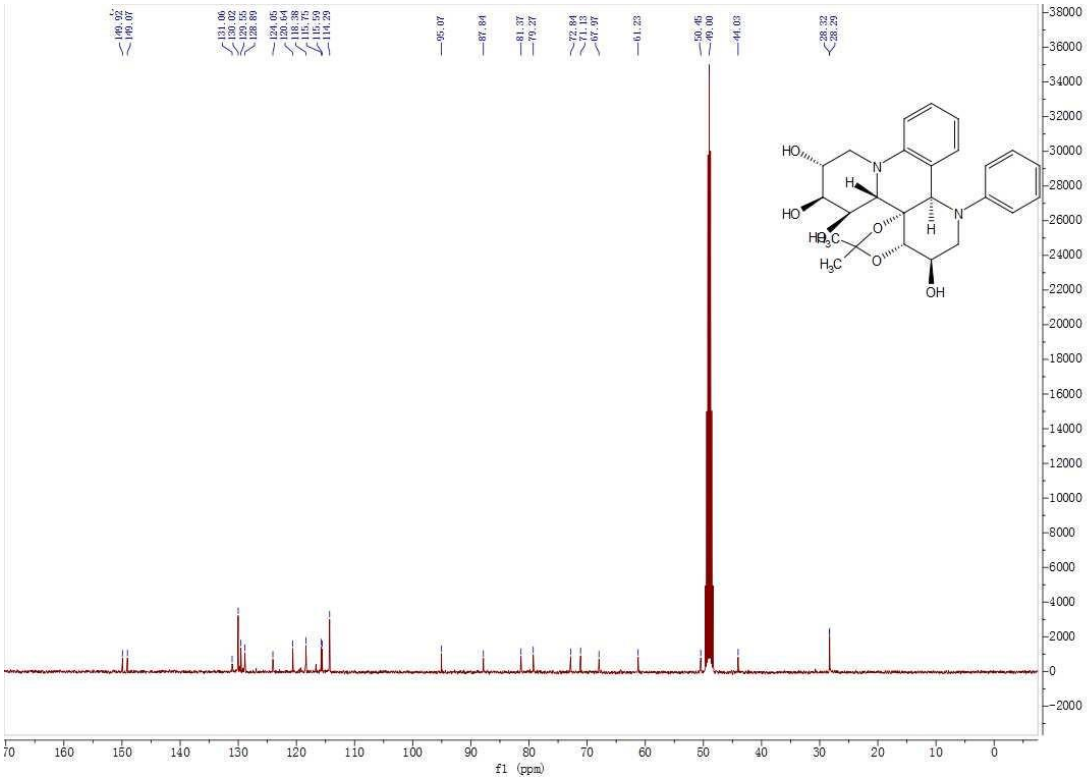


Fig.79 ^{13}C NMR of compound **7a-1'**

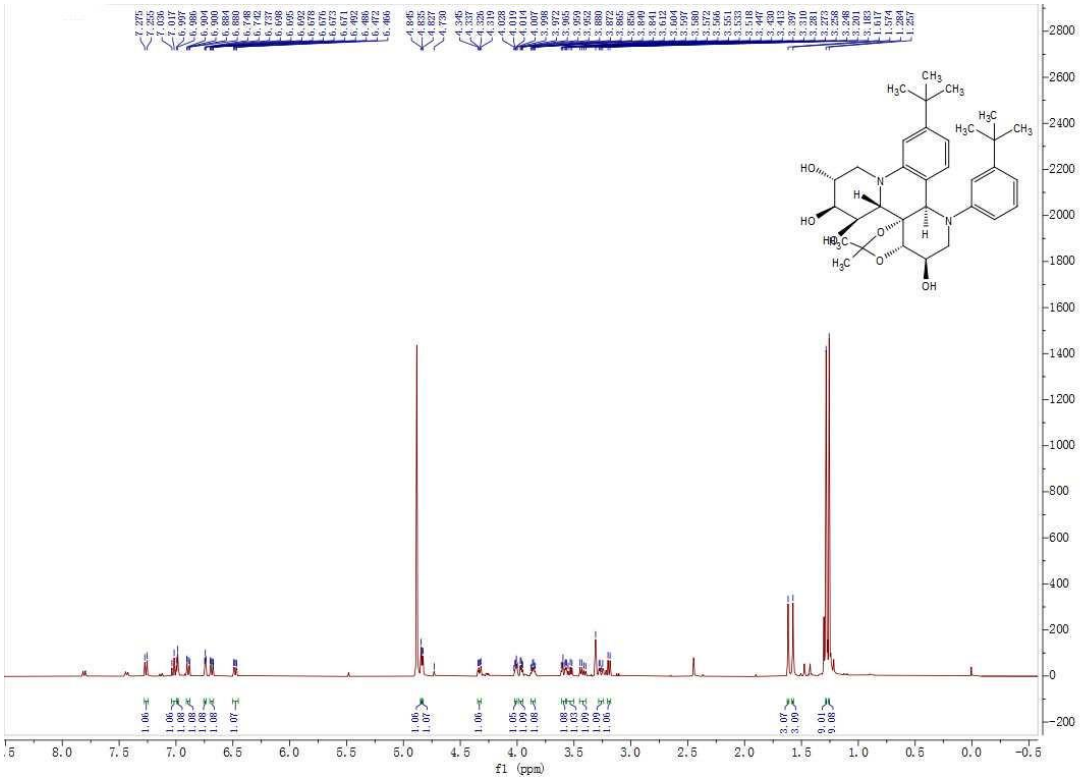


Fig.80 ^{1}H NMR of compound **7e-1'**

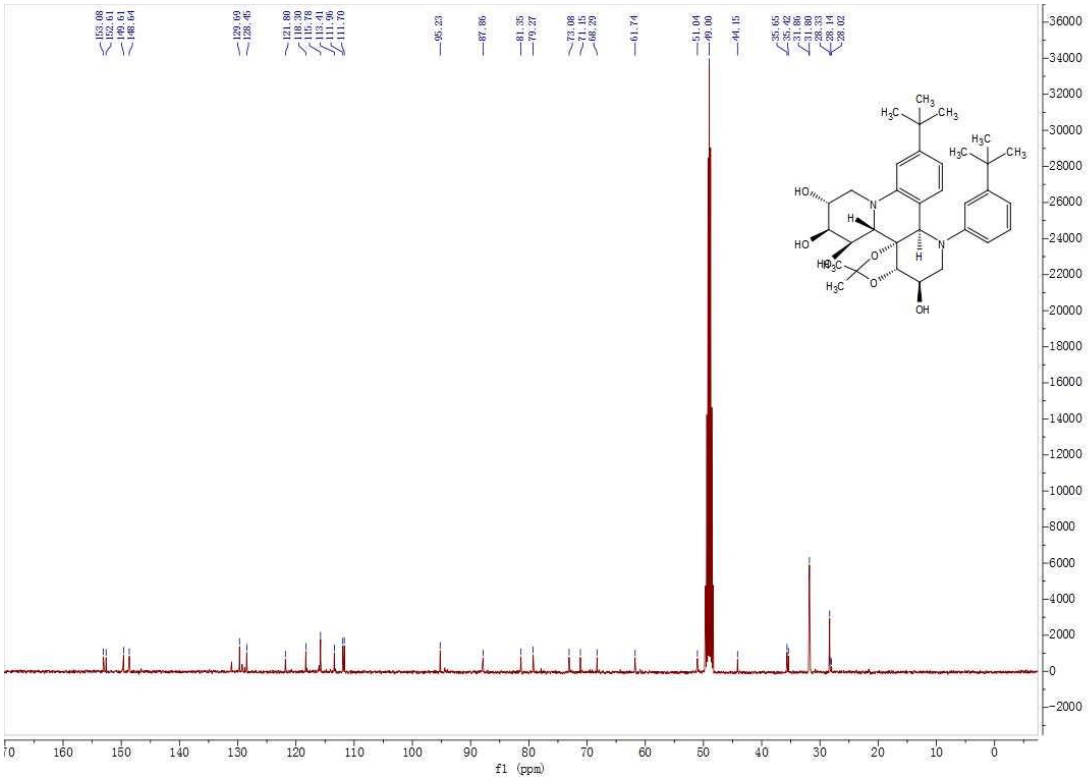


Fig.81 ^{13}C NMR of compound **7e-1'**

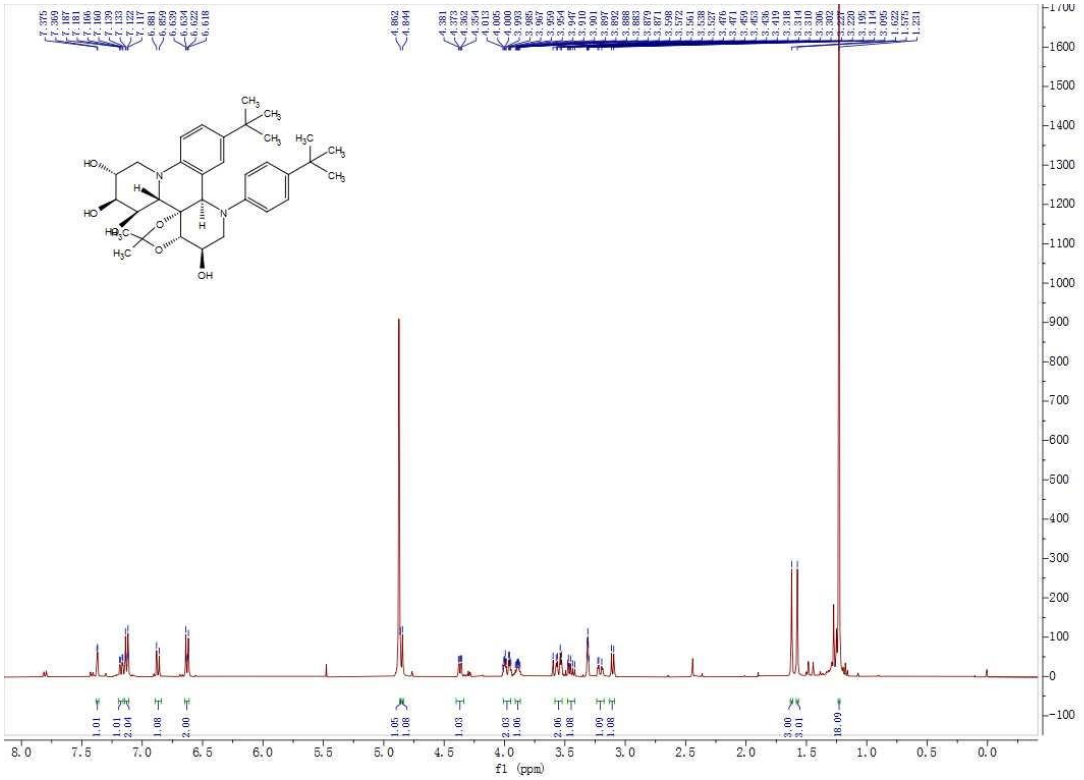


Fig.82 ^{1}H NMR of compound **7f-1'**

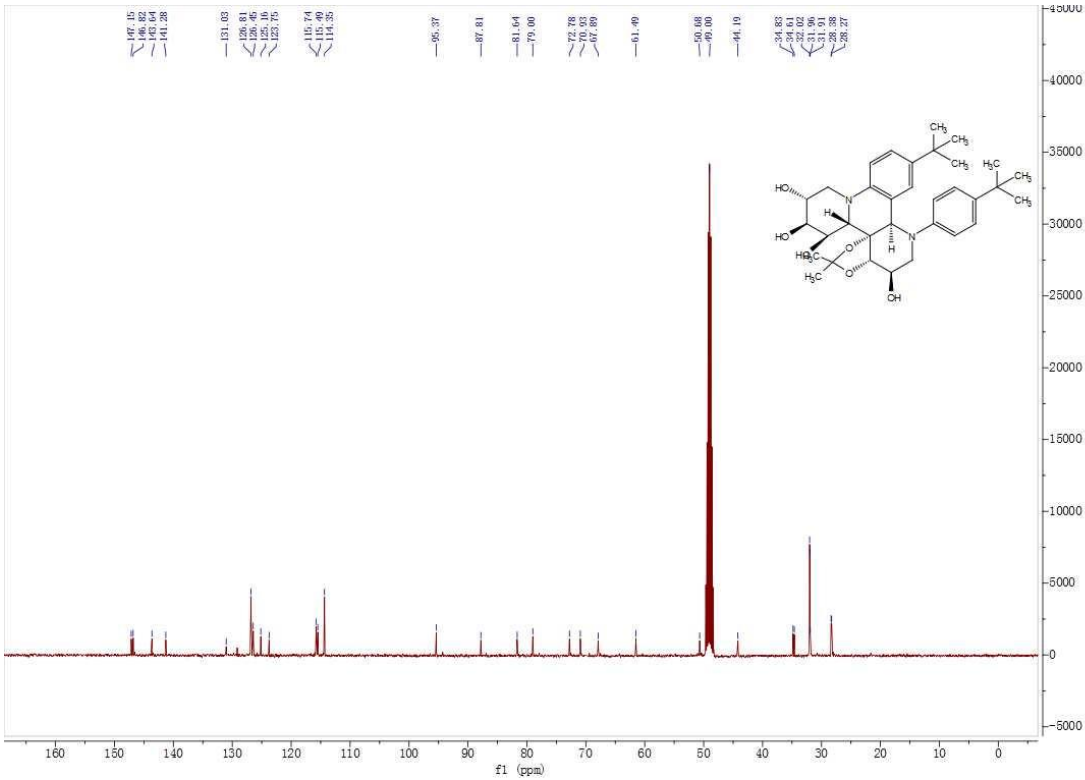


Fig.83 ^{13}C NMR of compound **7f-1'**

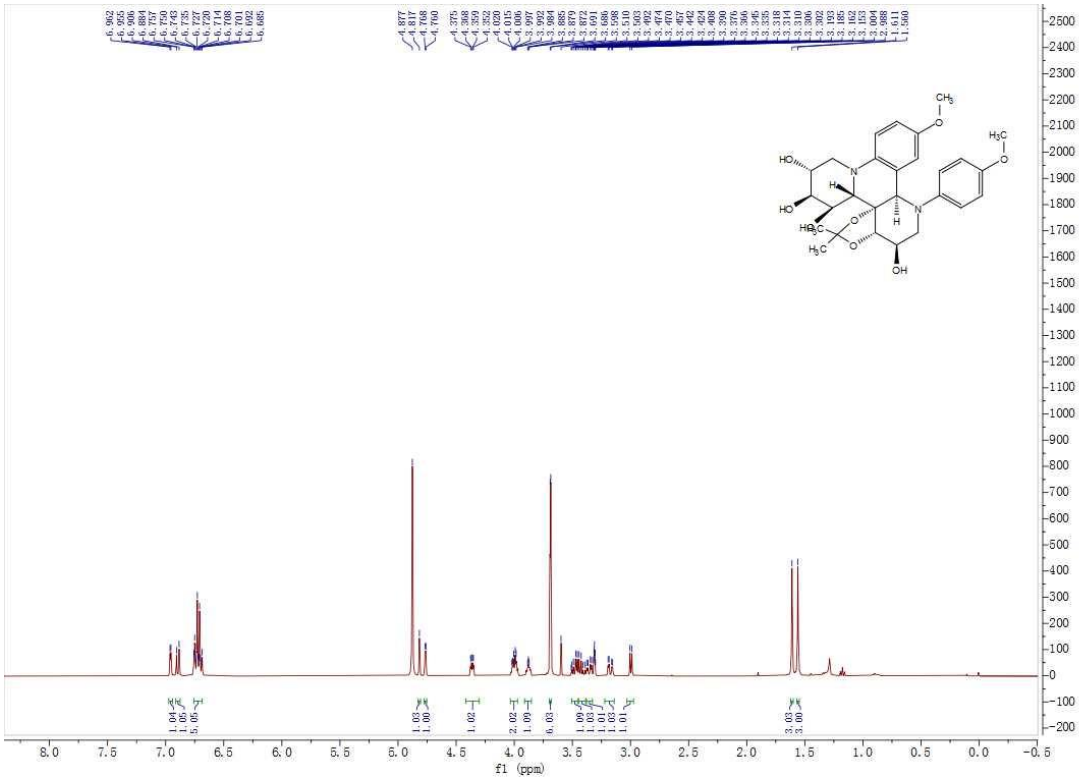


Fig.84 ^{1}H NMR of compound **7h-1'**

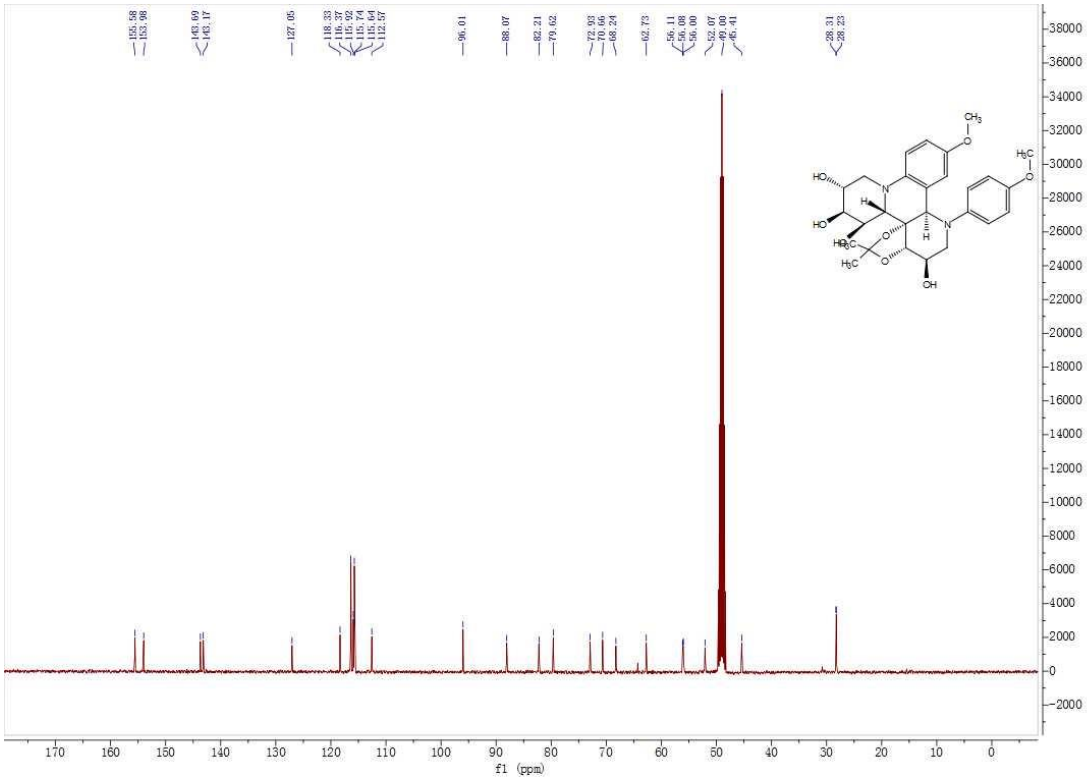


Fig.85 ^{13}C NMR of compound **7h-1'**

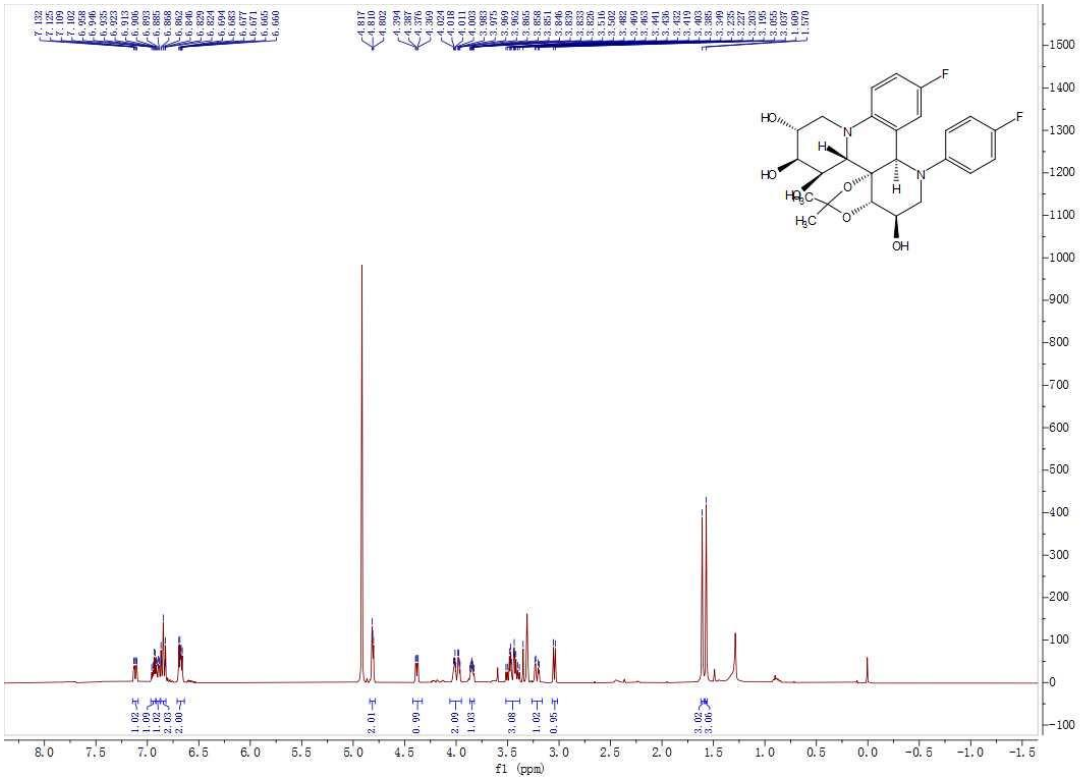


Fig.86 ^{1}H NMR of compound **7l-1'**

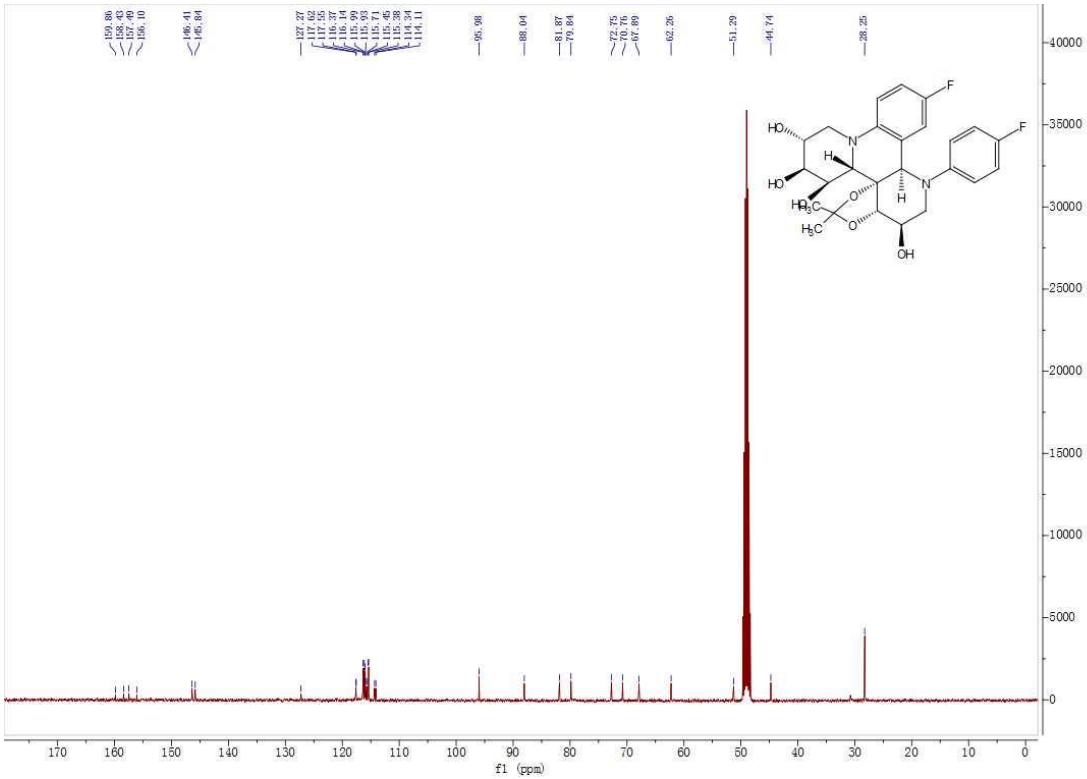


Fig.87 ^{13}C NMR of compound **7l-1'**

Fig S2:2D NMR analysis spectra

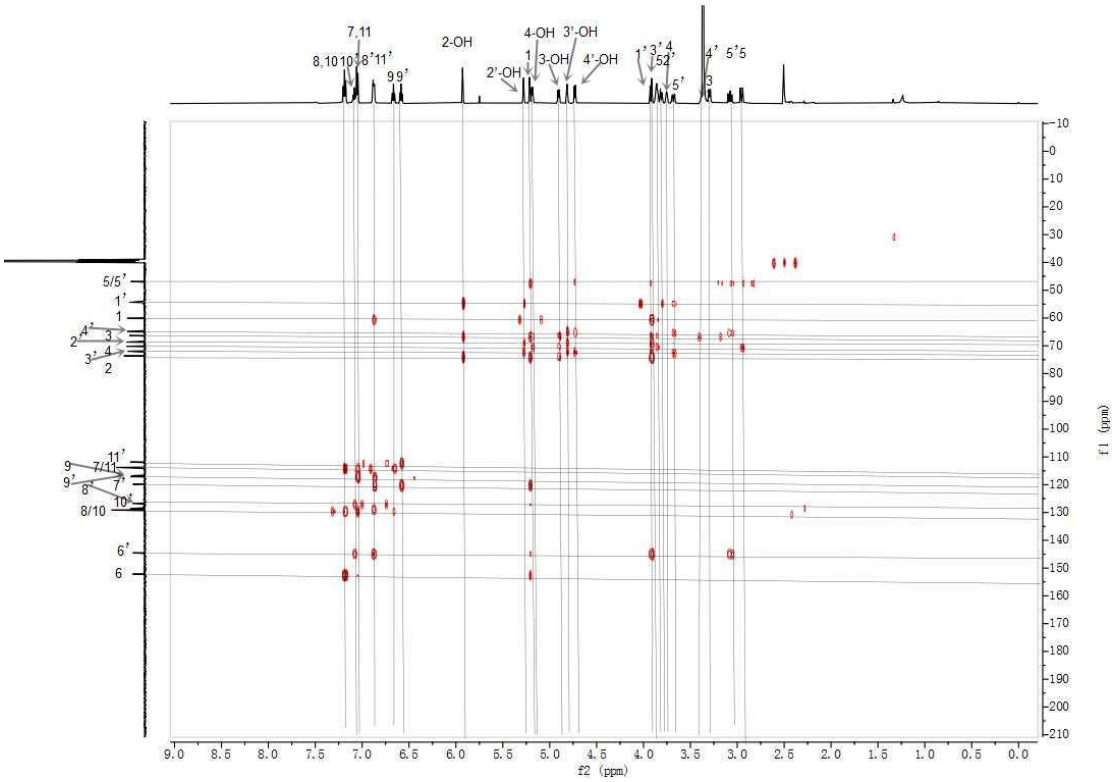


Fig.88 ^{1}H-^{13}C HMBC NMR of compound **5a**

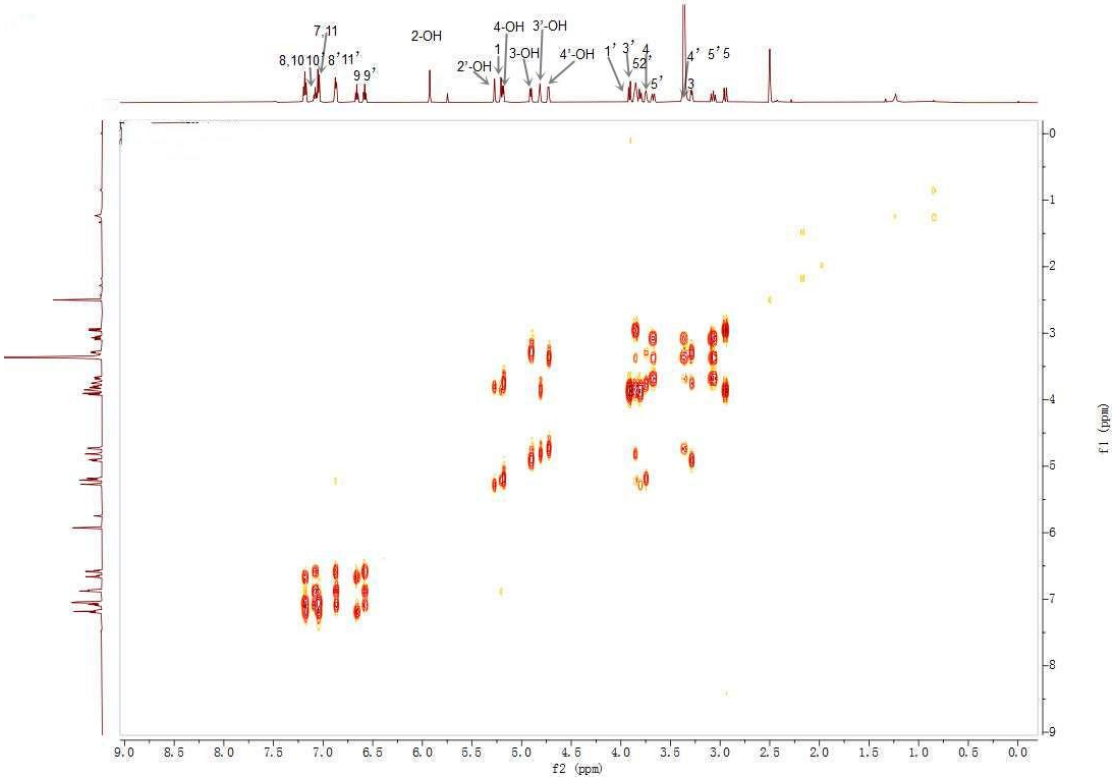


Fig.89 ^{1}H-^{1}H COSY NMR of compound **5a**

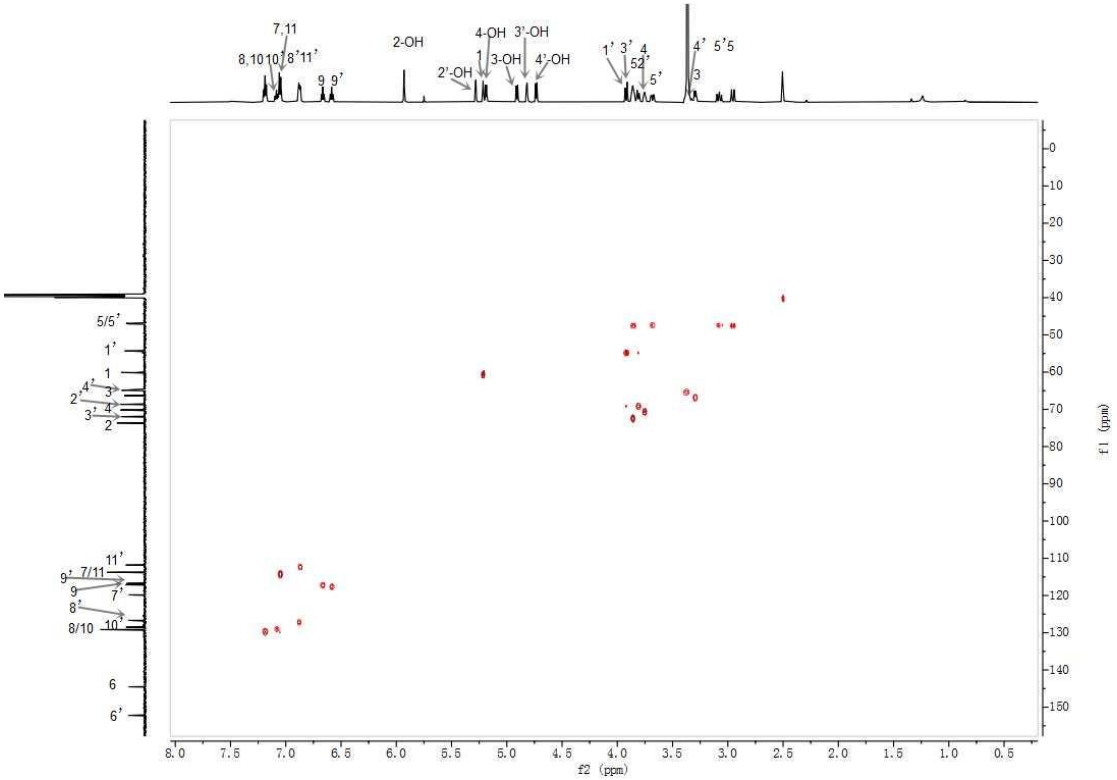


Fig.90 ^{1}H-^{13}C HSQC NMR of compound **5a**

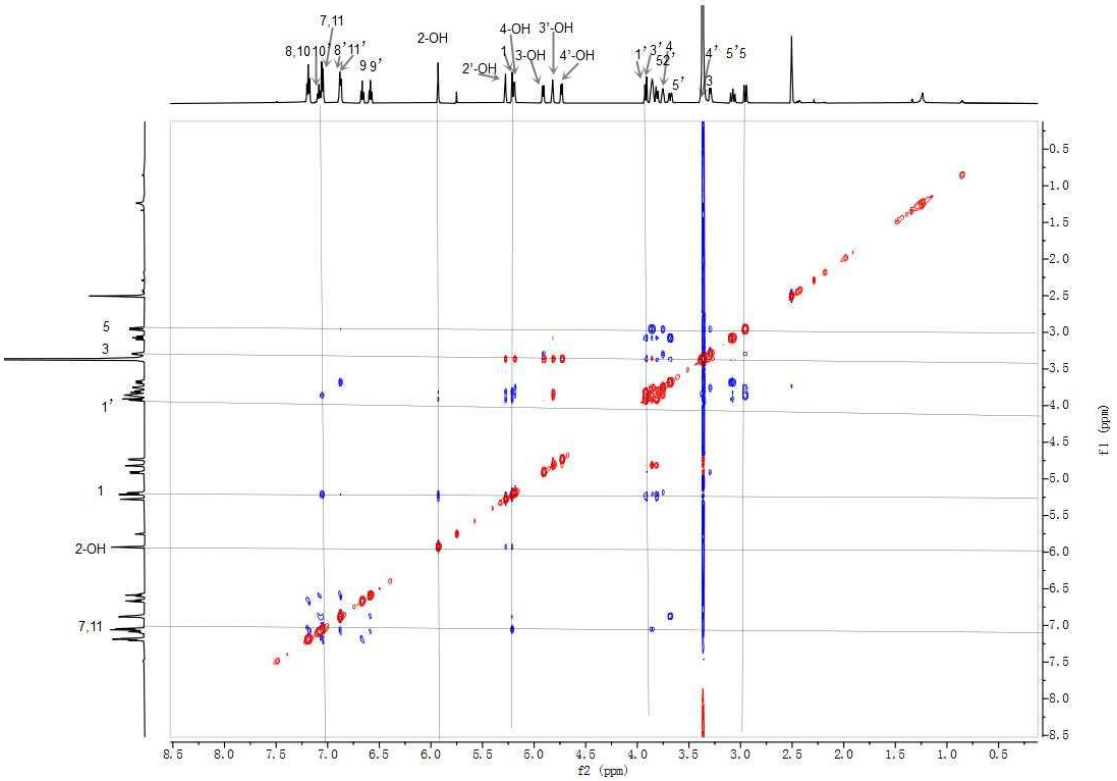


Fig.91 ^{1}H-^{1}H ROESY NMR of compound **5a**

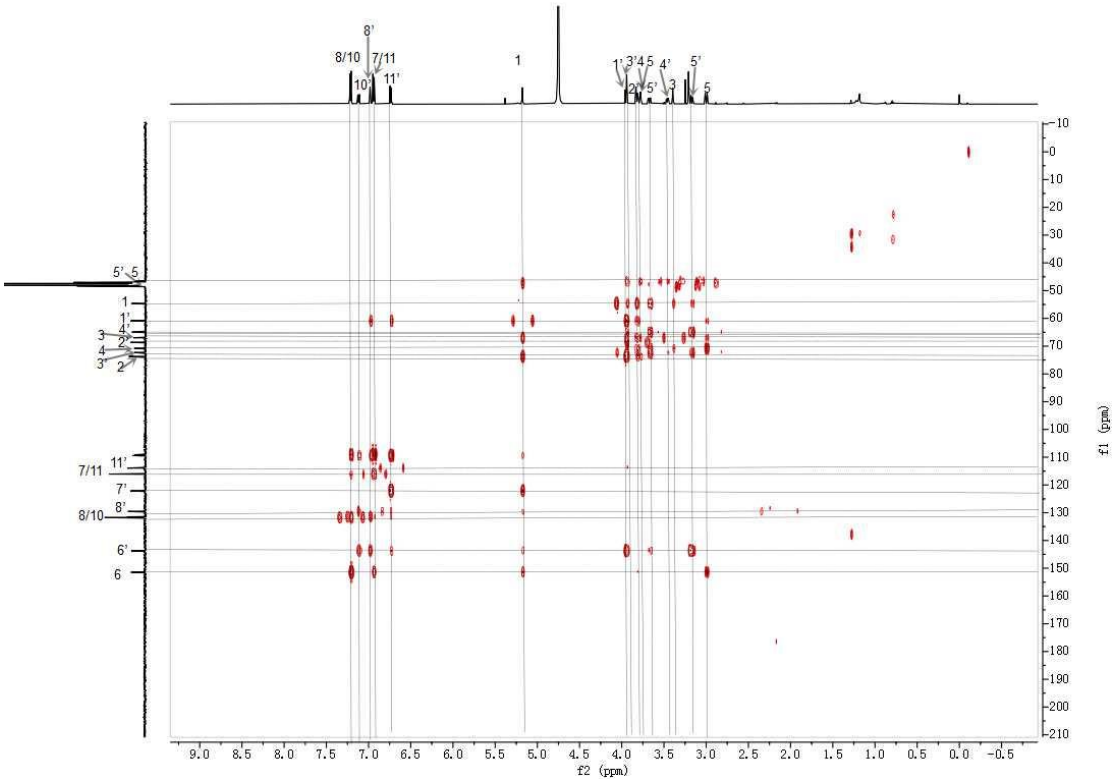


Fig.92 ^{1}H-^{13}C HMBC NMR of compound **5q**

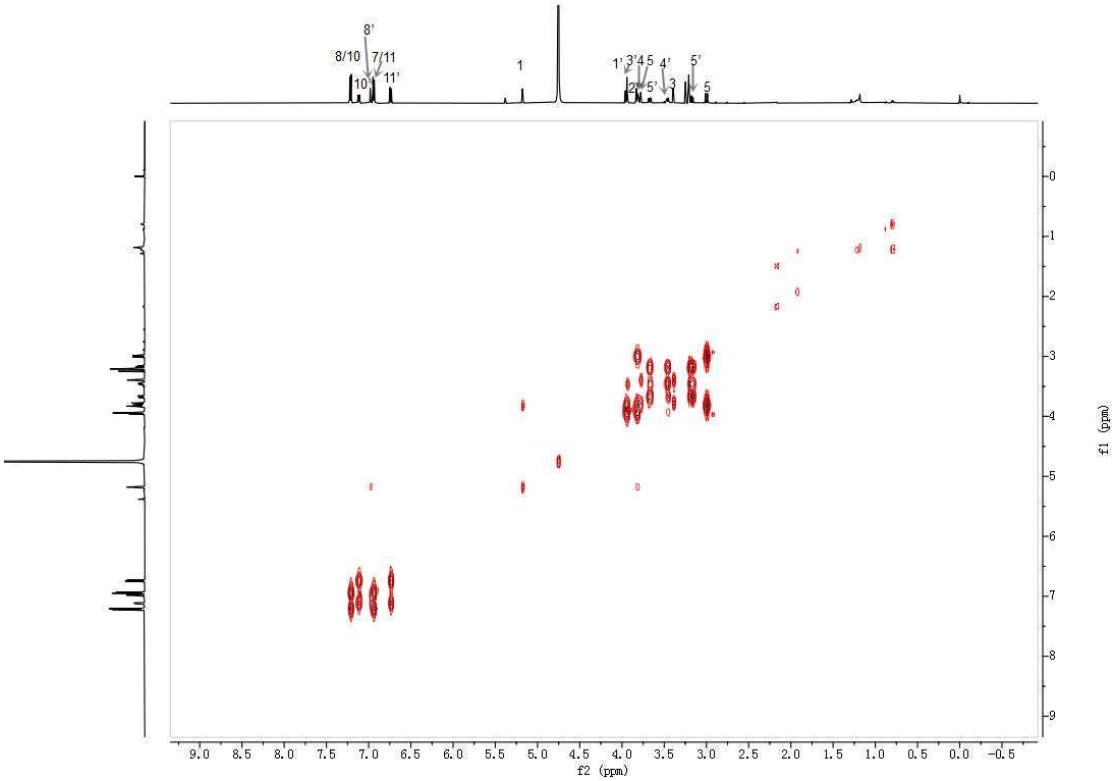


Fig.93 ^{1}H-^{1}H COSY NMR of compound **5q**

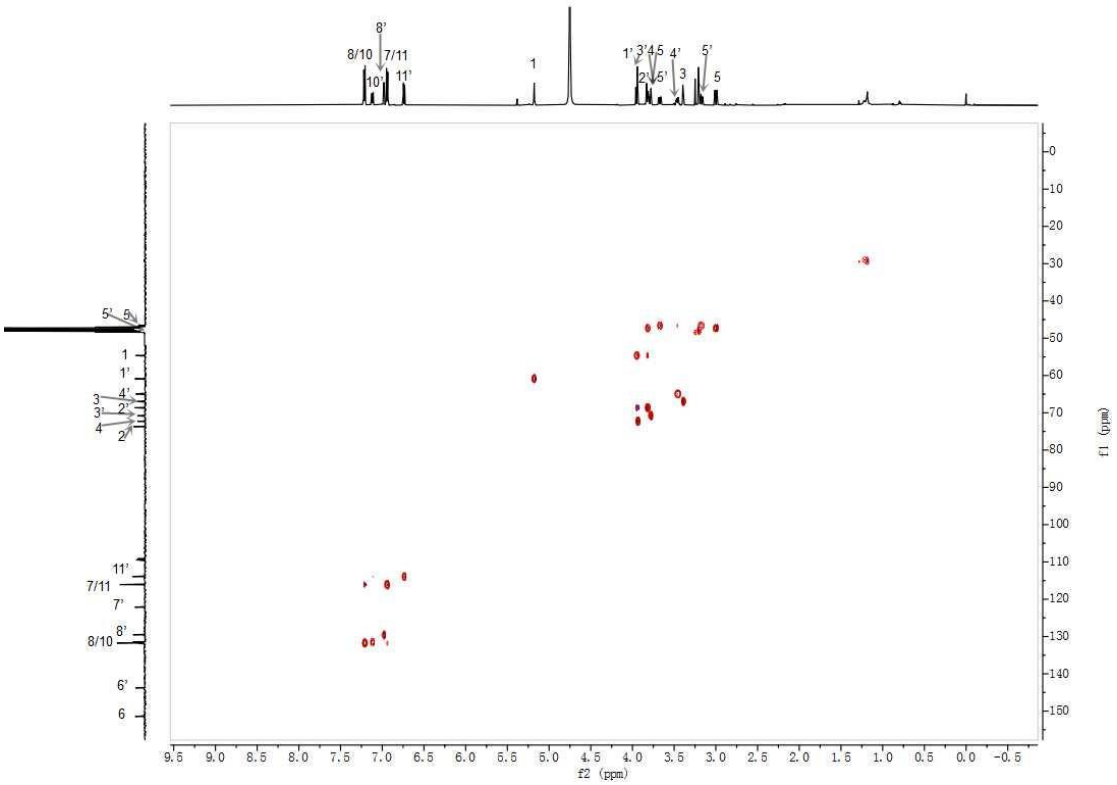


Fig.94 ^{1}H-^{13}C HSQC NMR of compound **5q**

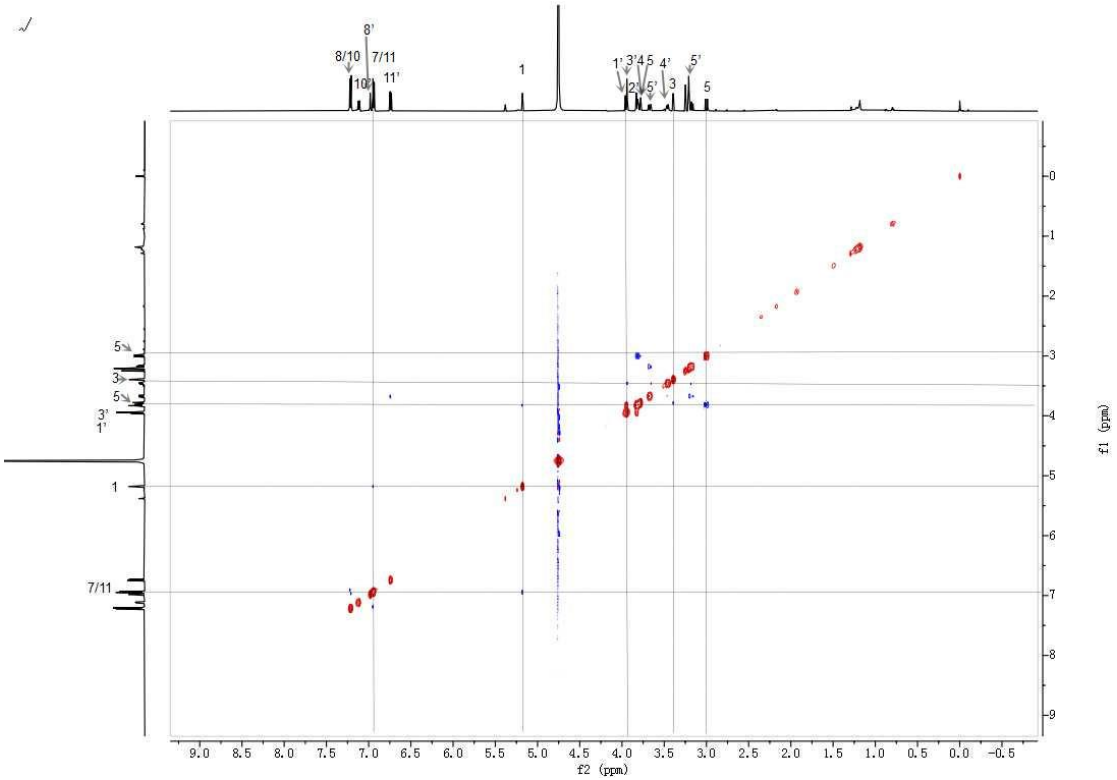


Fig.95 ^{1}H-^{1}H ROESY NMR of compound **5q**

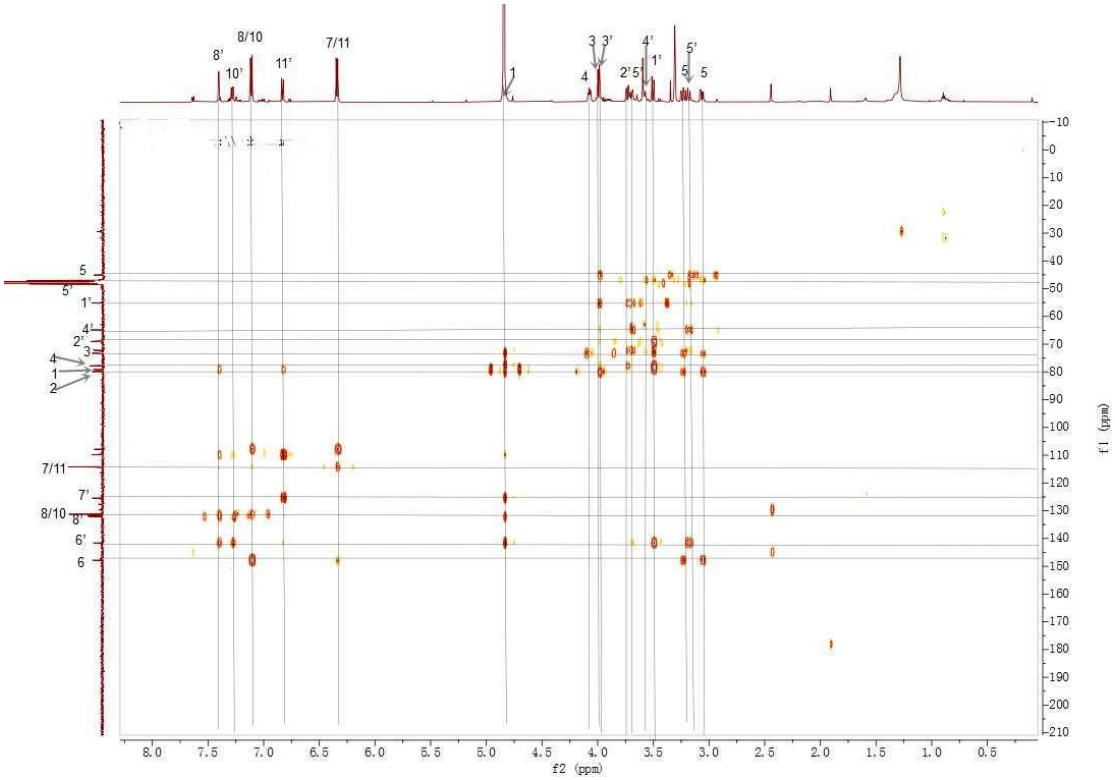


Fig.96 ^{1}H-^{13}C HMBC NMR of compound **5q-1**

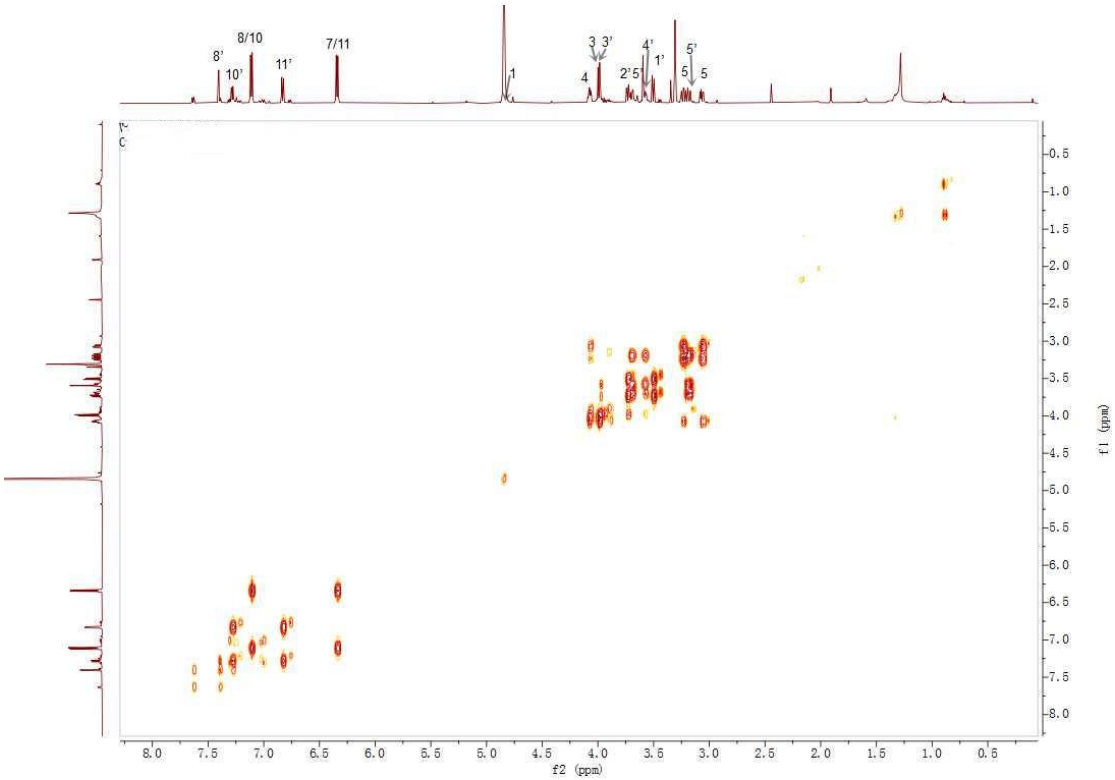


Fig.97 ^{1}H-^{1}H COSY NMR of compound **5q-1**

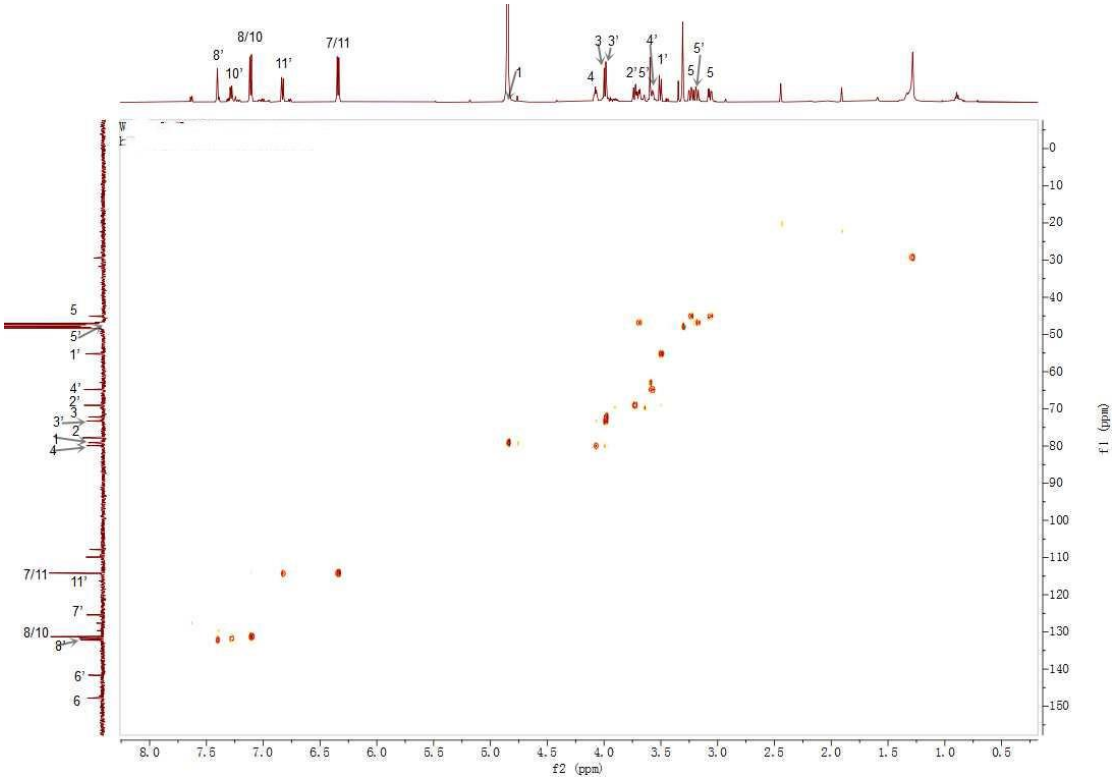


Fig.98 ^{1}H-^{13}C HSQC NMR of compound **5q-1**

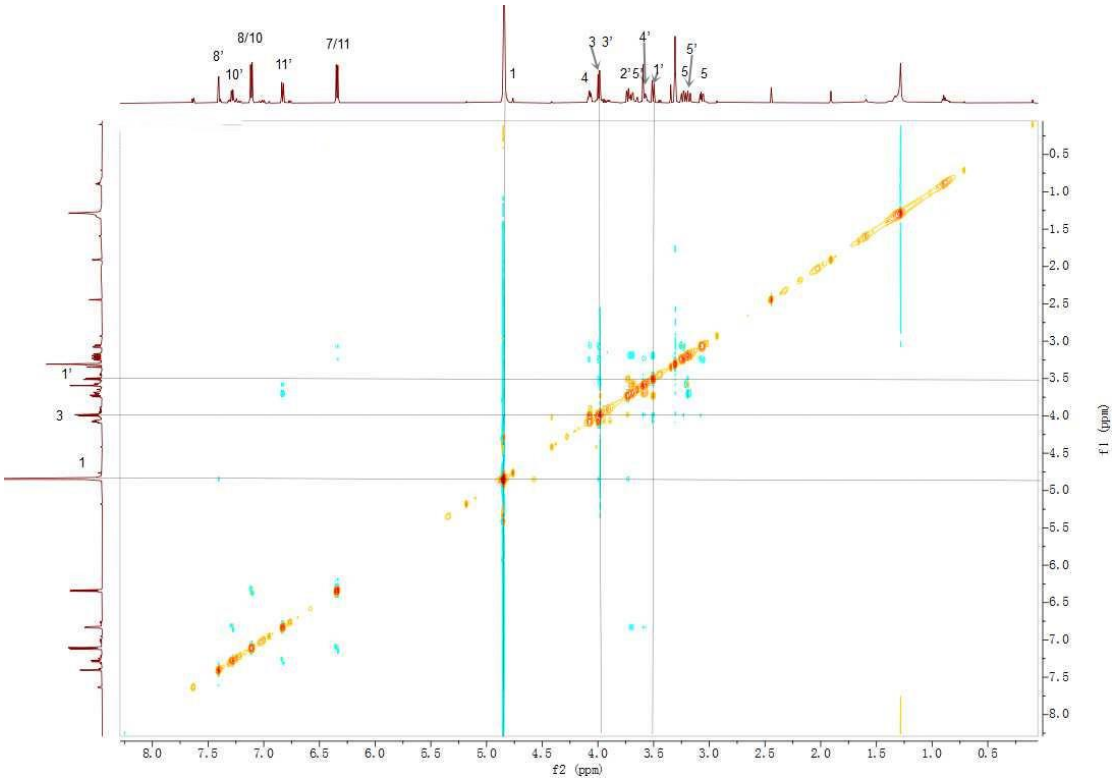


Fig.99 ^{1}H-^{1}H ROESY NMR of compound **5q-1**

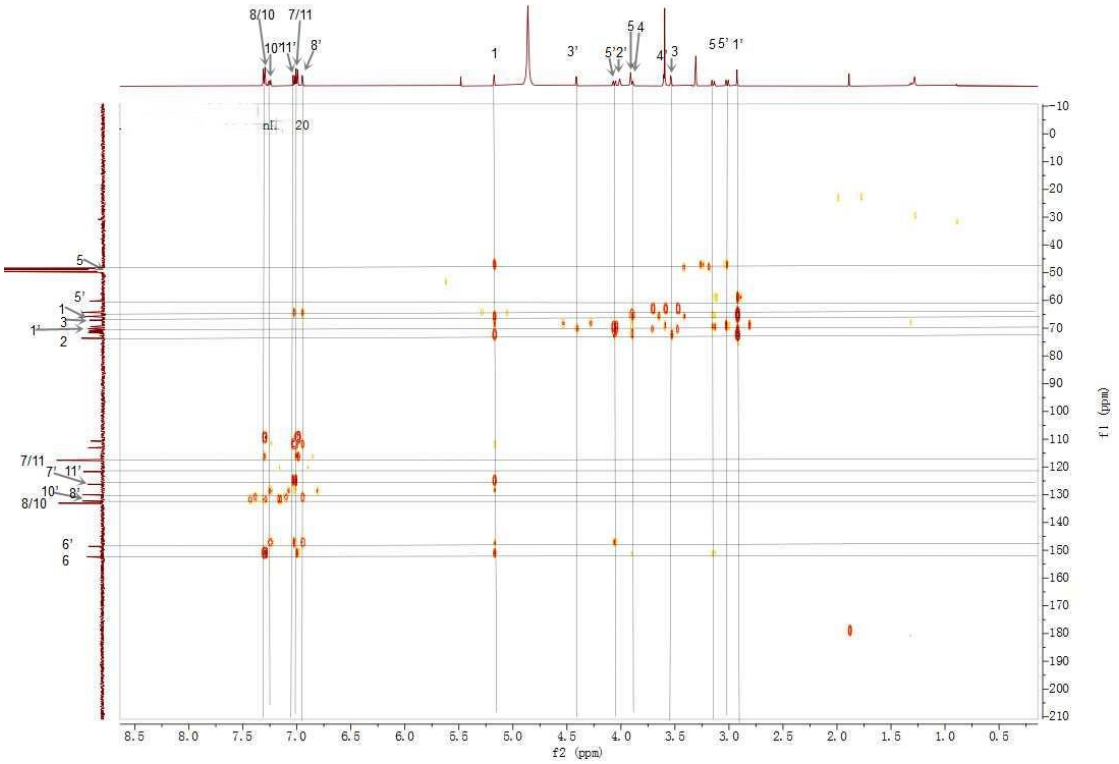


Fig.100 ^{1}H-^{13}C HMBC NMR of compound **5q-2**

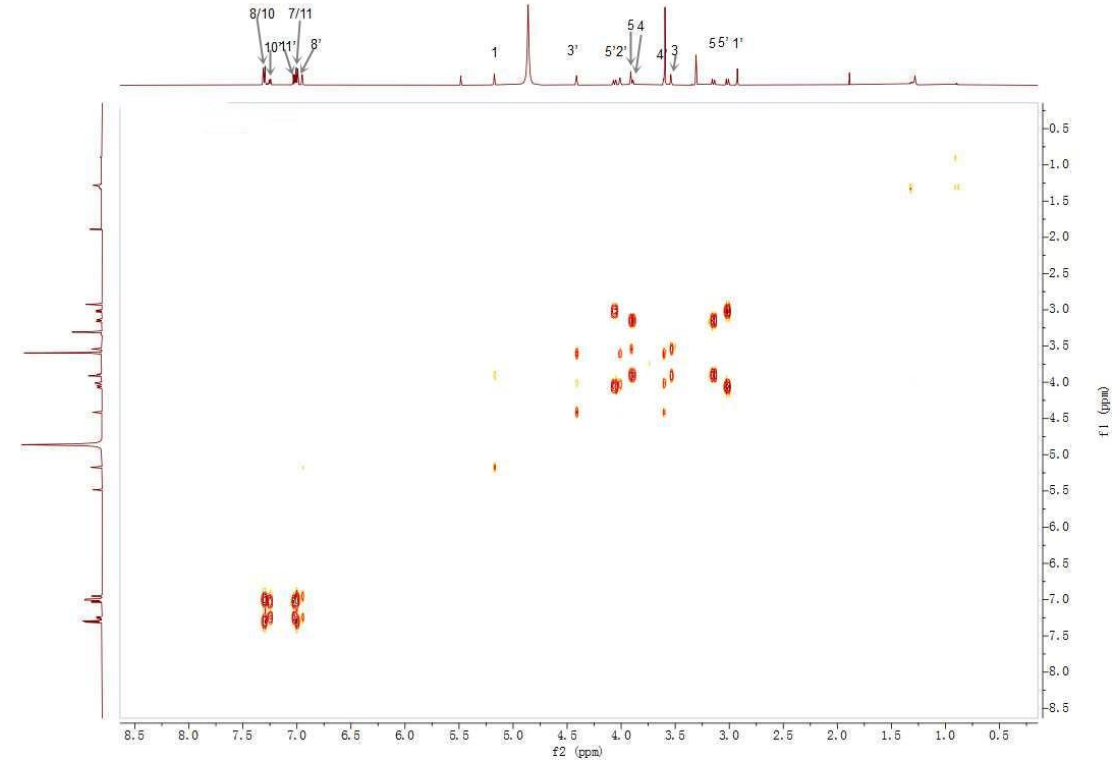


Fig.101 ^{1}H-^{1}H COSY NMR of compound **5q-2**

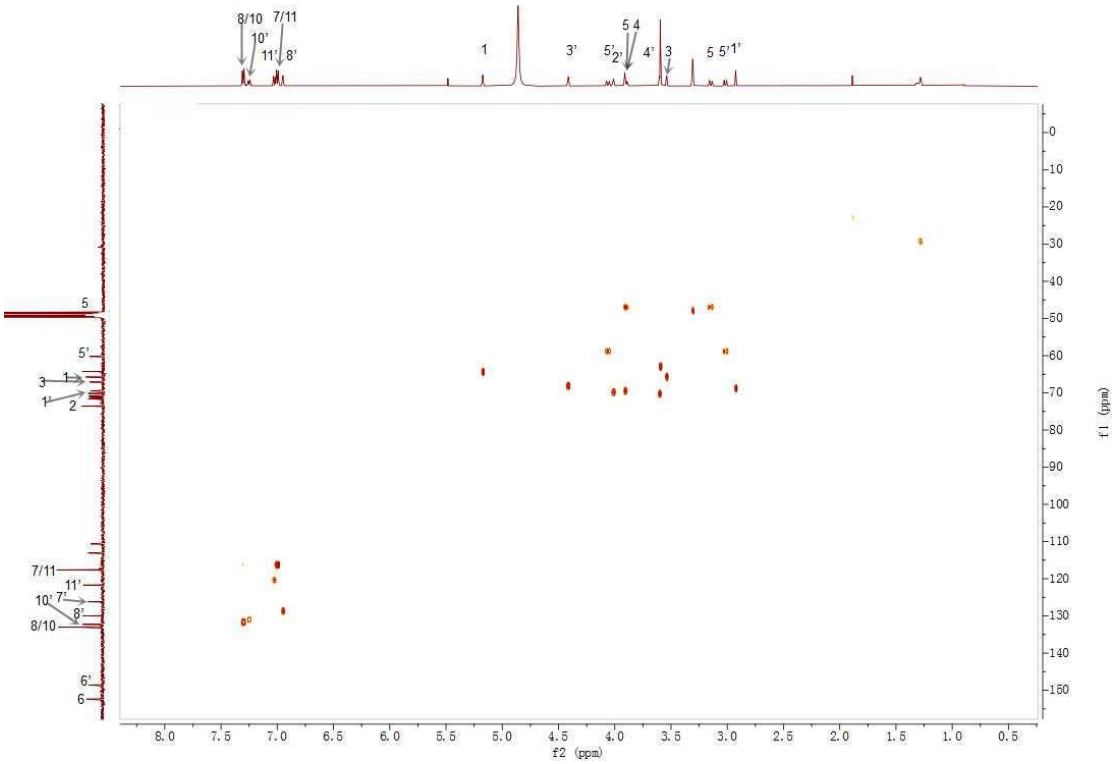


Fig.102 ^{1}H-^{13}C HSQC NMR of compound **5q-2**

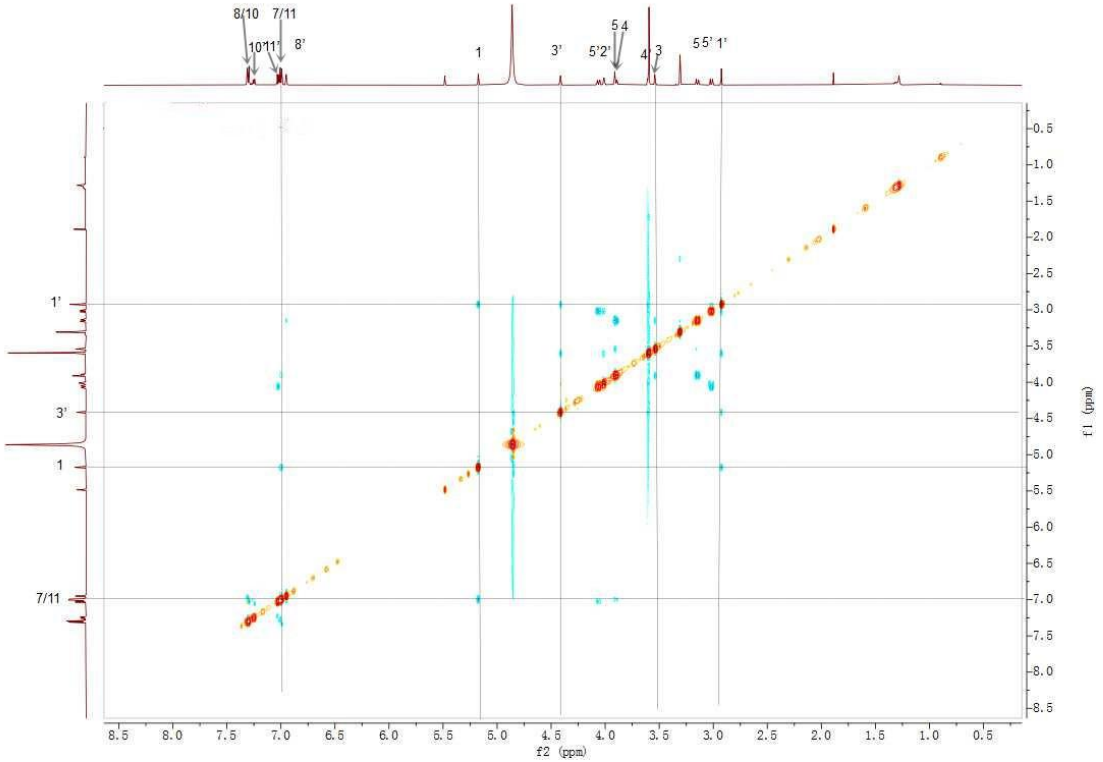


Fig.103 ^{1}H-^{1}H ROESY NMR of compound **5q-2**

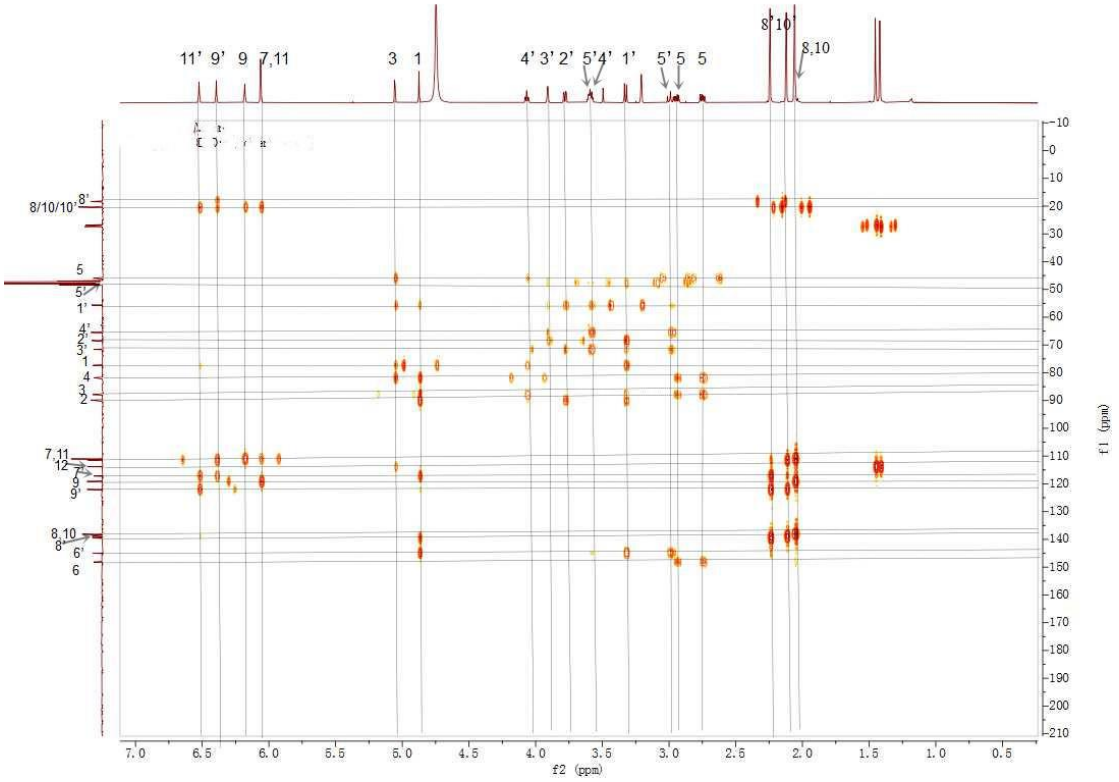


Fig.104 ^{1}H-^{13}C HMBC NMR of compound **5t'**

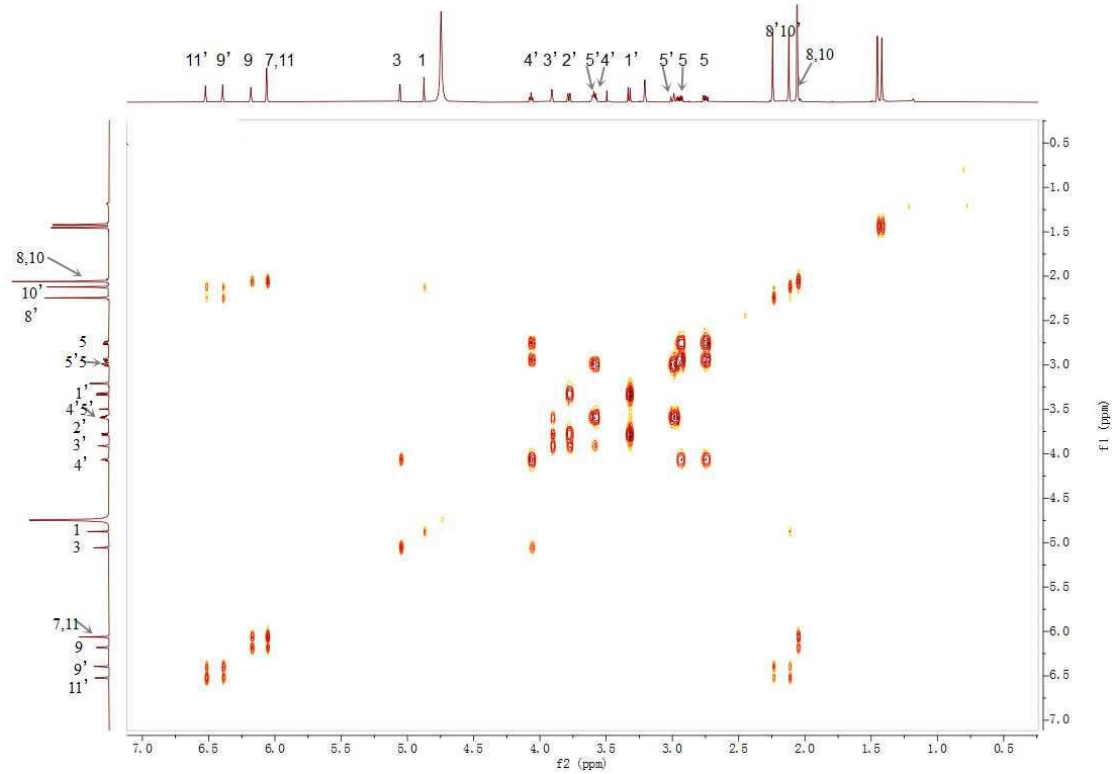


Fig.105 ^{1}H-^{1}H COSY NMR of compound **5t'**

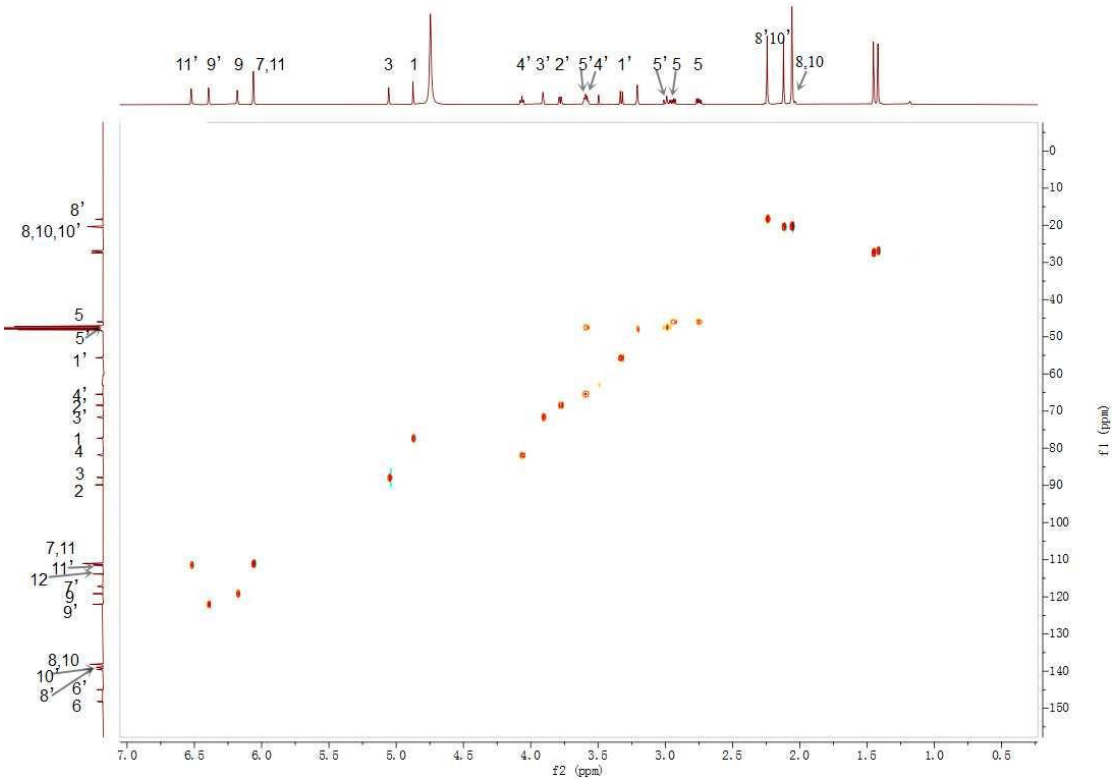


Fig.106 ^{1}H-^{13}C HSQC NMR of compound **5t'**

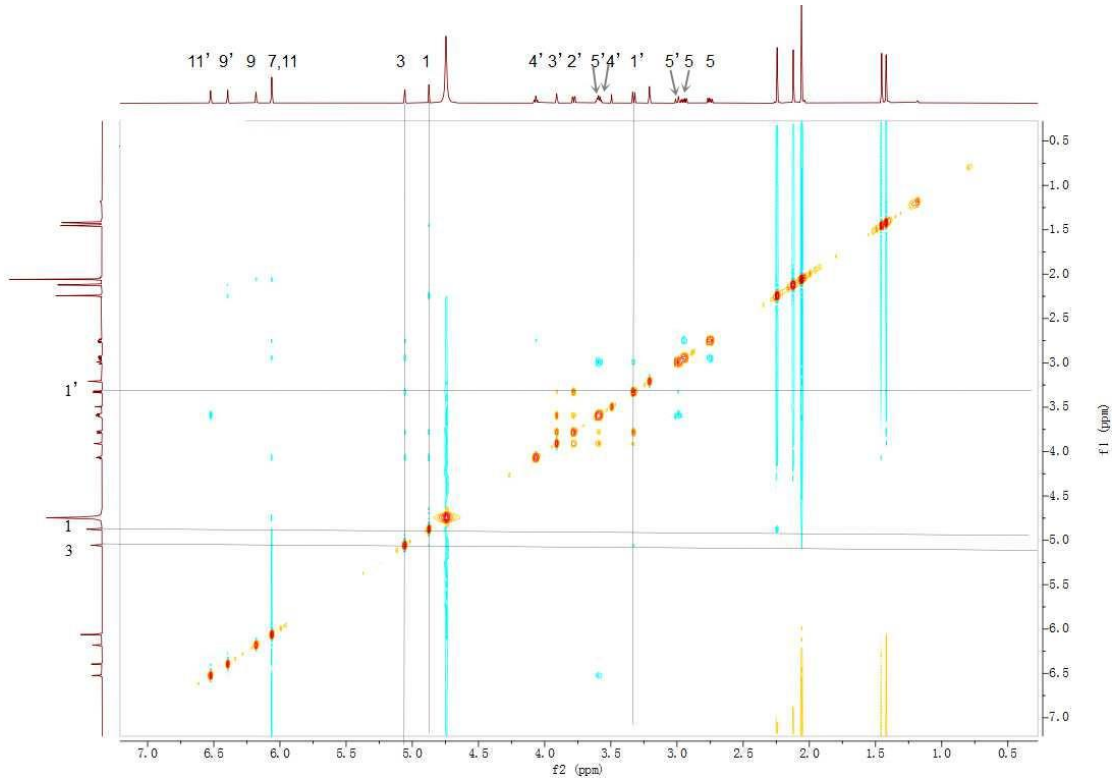


Fig.107 ^{1}H-^{1}H ROESY NMR of compound **5t'**

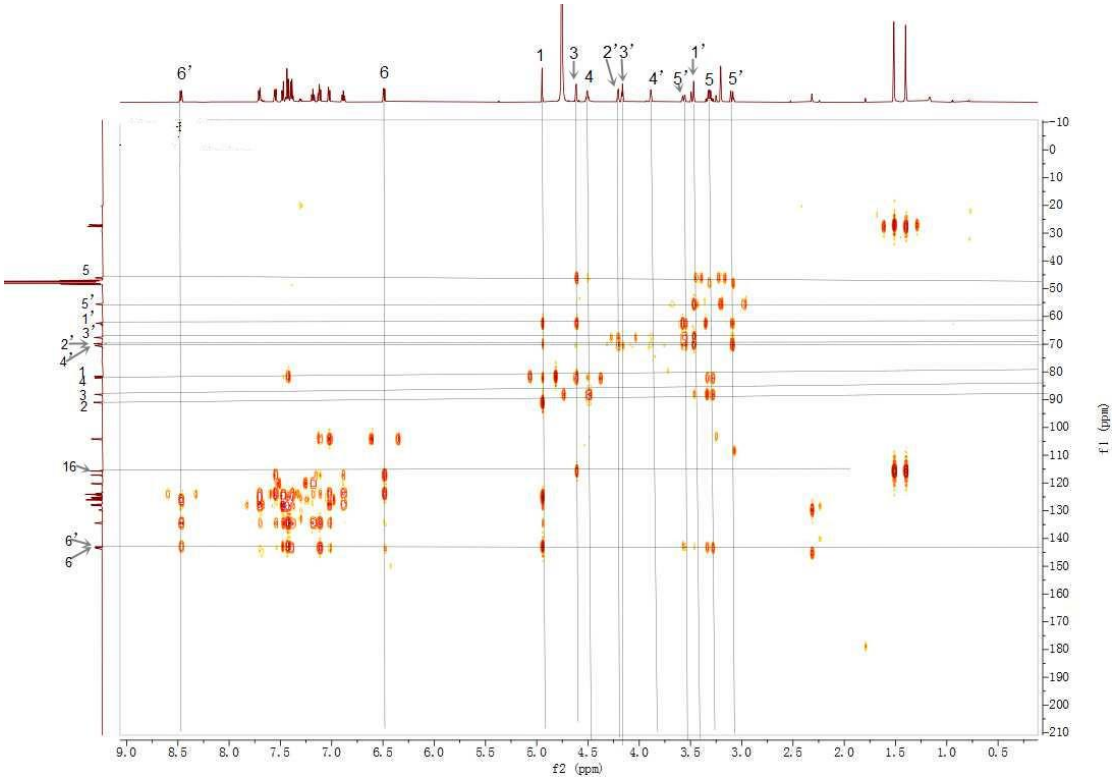


Fig.108 ^{1}H-^{13}C HMBC NMR of compound **6w'**

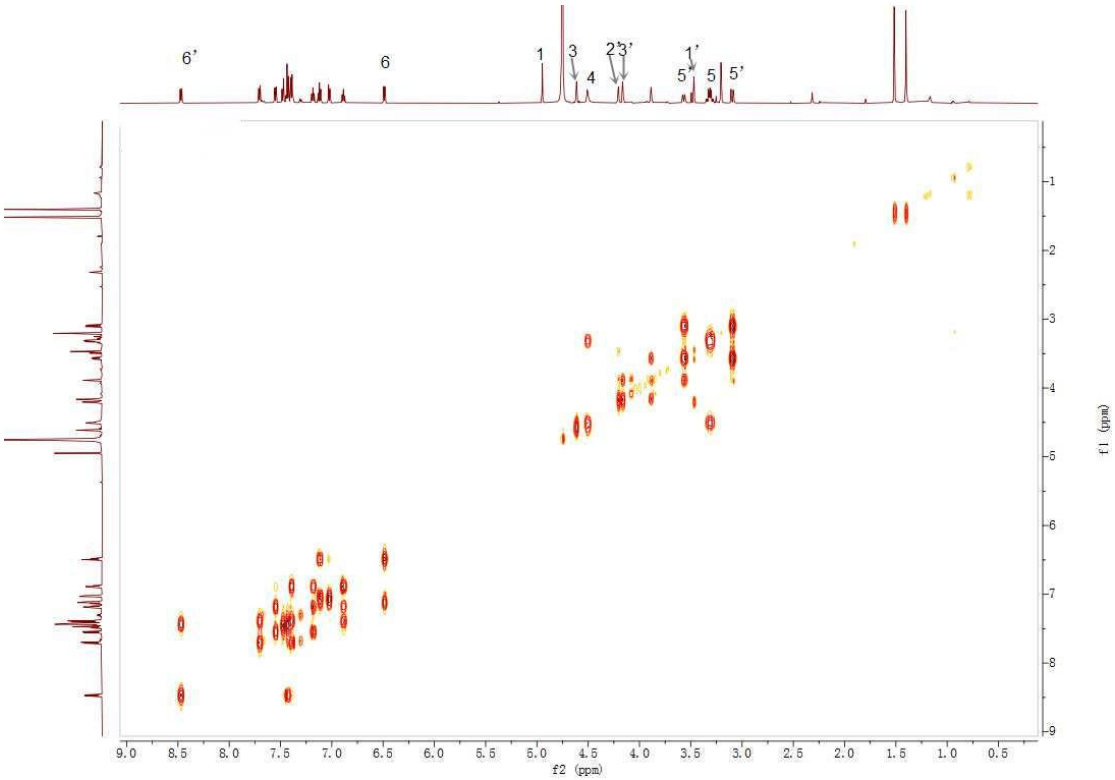


Fig.109 ^{1}H-^{1}H COSY NMR of compound **6w'**

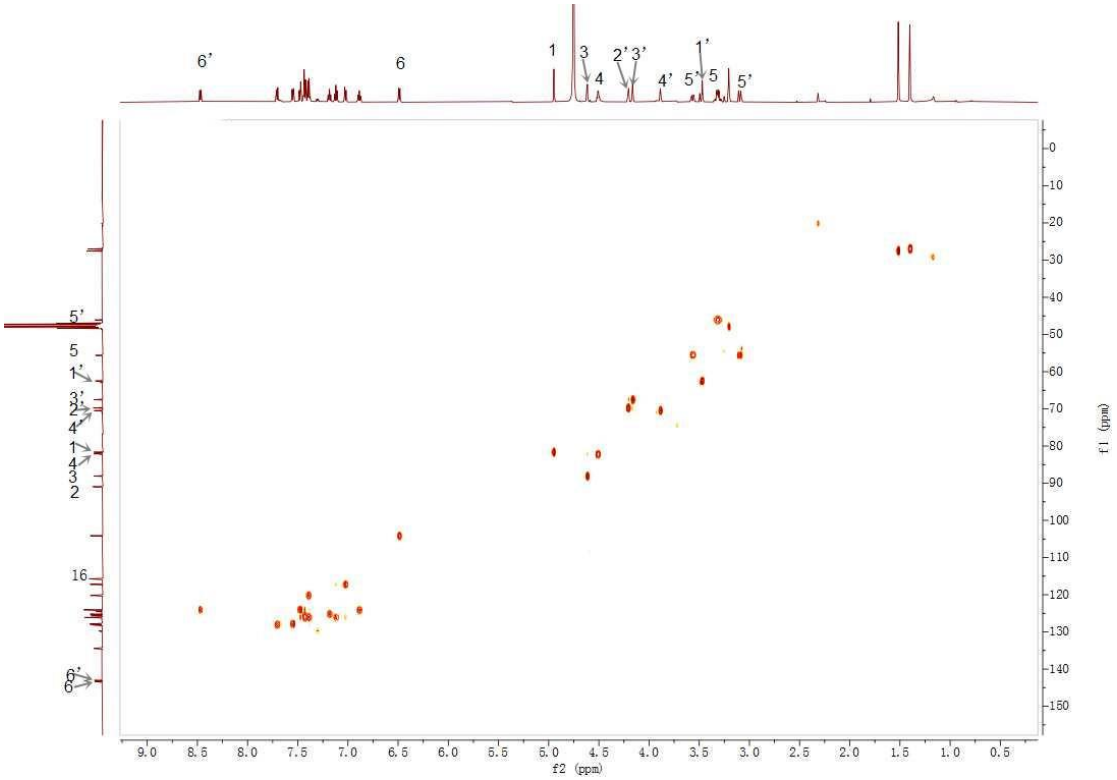


Fig.110 ^{1}H-^{13}C HSQC NMR of compound **6w'**

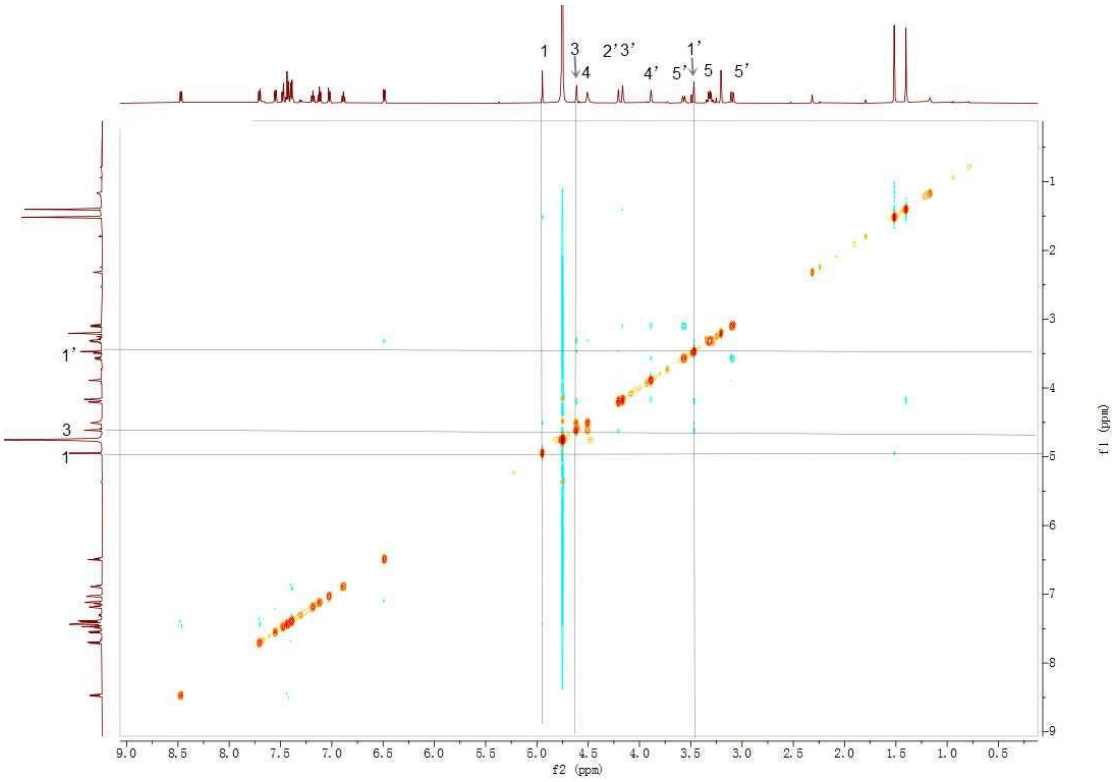


Fig.111 ^{1}H-^{1}H ROESY NMR of compound **6w'**

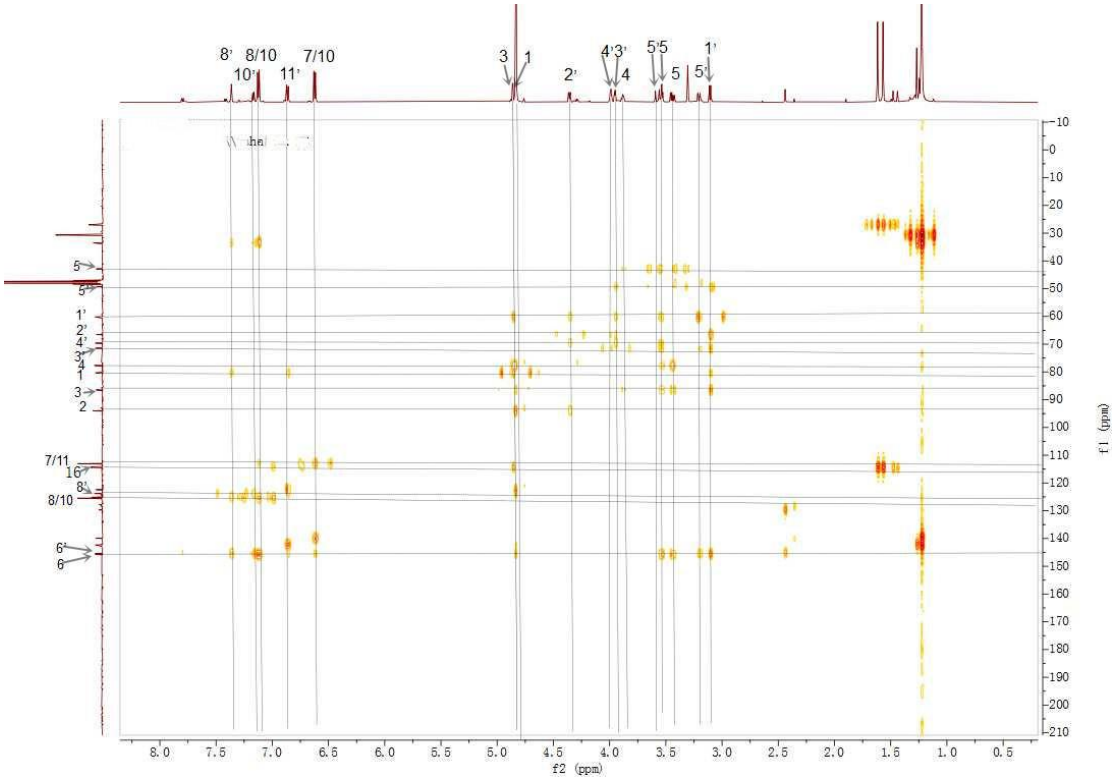


Fig.112 ^{1}H-^{13}C HMBC NMR of compound **7f-1'**

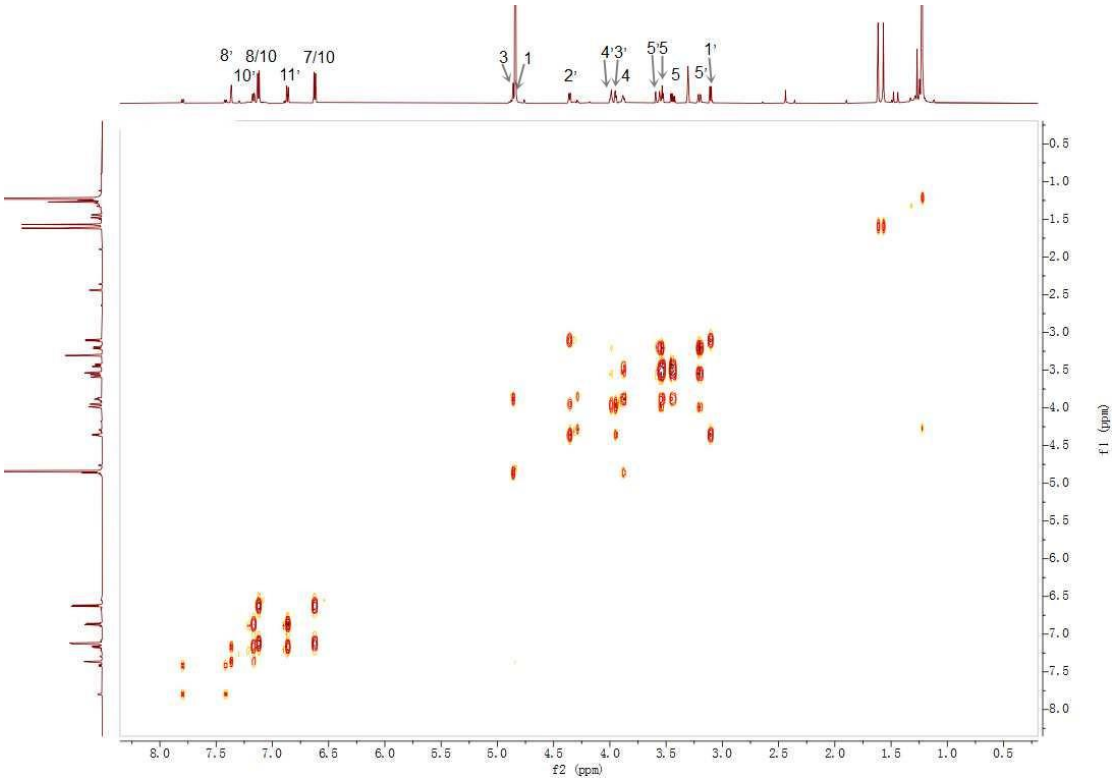


Fig.113 ^{1}H-^{1}H COSY NMR of compound **7f-1'**

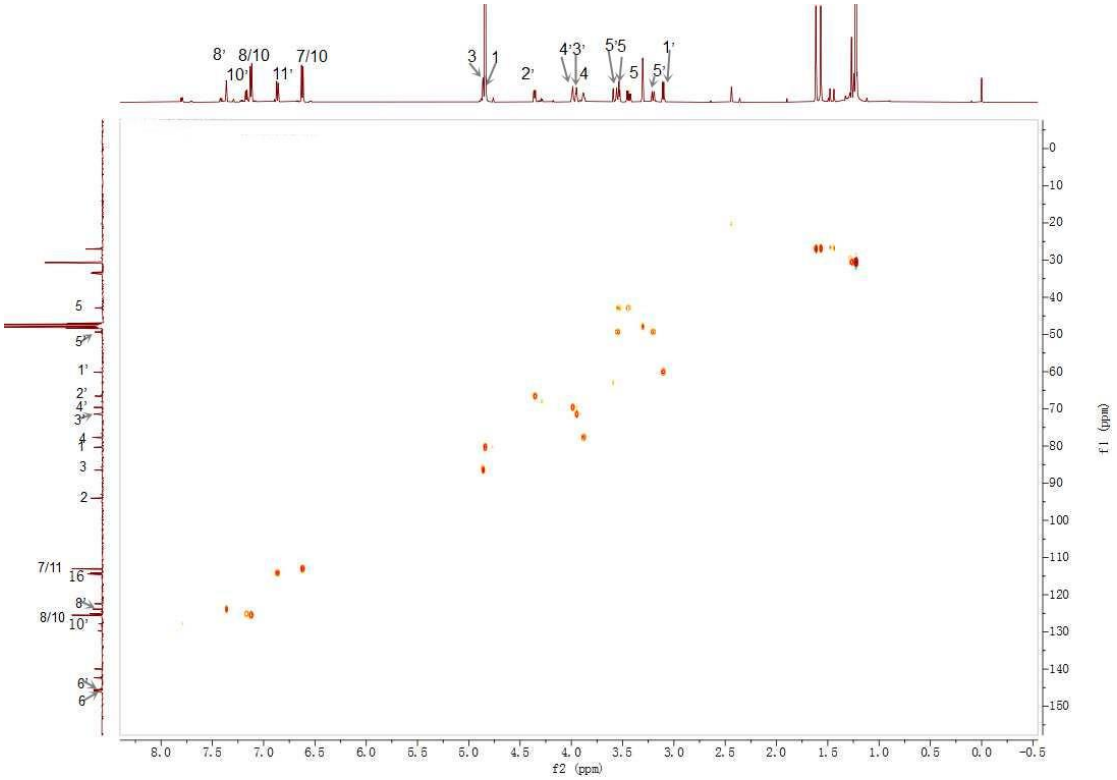


Fig.114 ^{1}H-^{13}C HSQC NMR of compound **7f-1'**

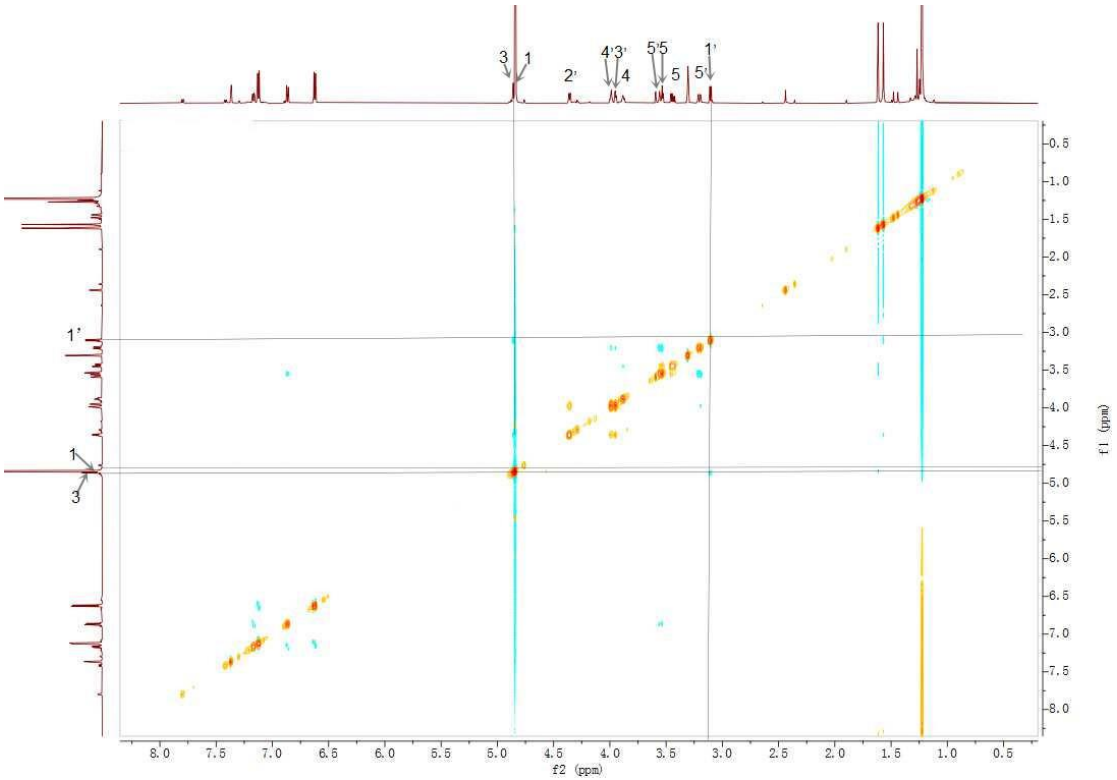


Fig.115 ^{1}H-^{1}H ROESY NMR of compound **7f-1'**

Fig S3 and S4: Key HMBC (C→H) and ROESY (H↔H) correlations

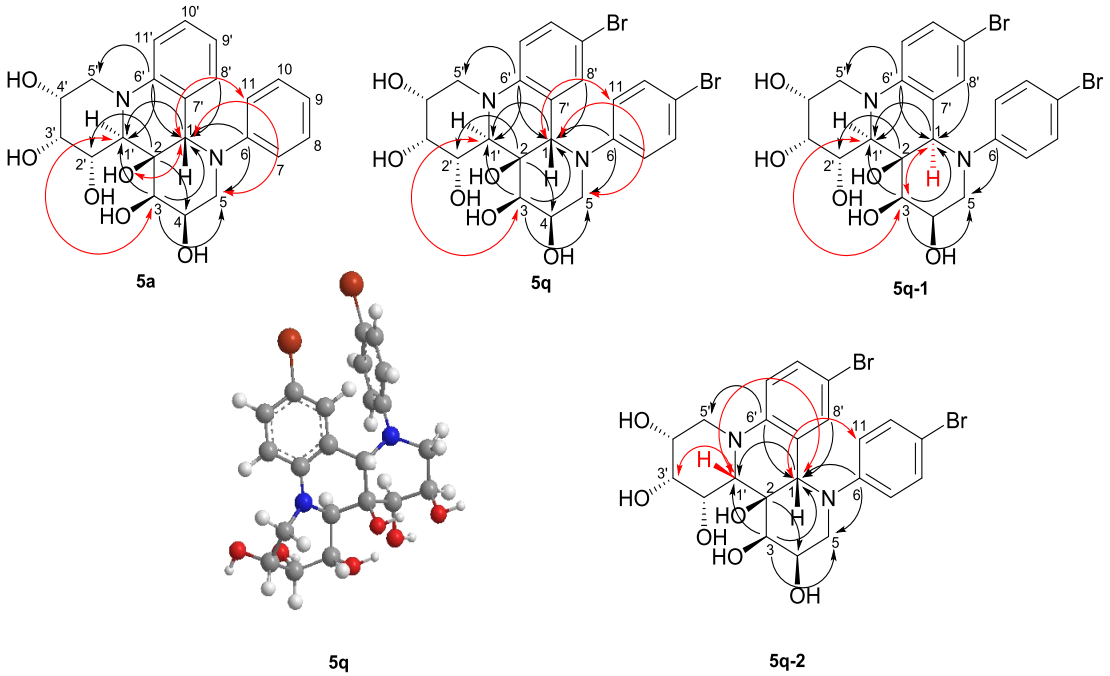


Fig. S3 Key HMBC (C→H) and ROESY (H↔H) correlations of the complex fused iminosugars.

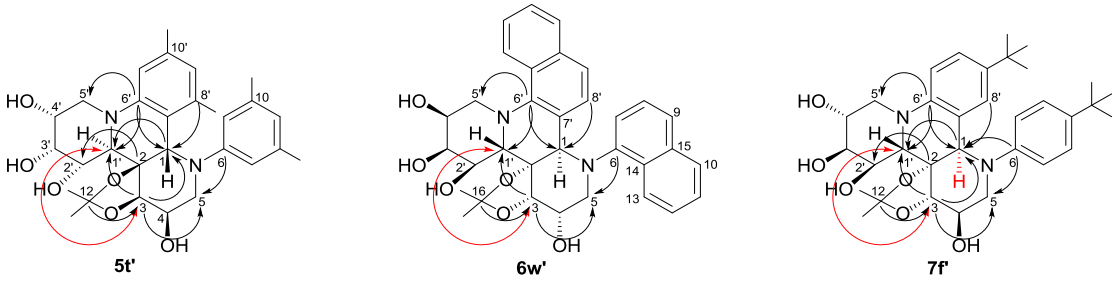


Fig. S4 Key HMBC (C→H) and ROESY (H↔H) correlations of the isopropylidene protected iminosugars.

Table S1 The related chemical shifts of C-1, C-1' and C-2 in **5q**, **5q-1**, **5q-2**, and **5q-3**

Compounds	**5q**	**5q-1**	**5q-2**	**5q-3**
1-H (ppm)	5.28 s	4.88 s	5.18 s	4.84 s[a]
C-1 (ppm)	60.9	79.1	64.3	-[b]
1'-H (ppm)	4.07 d *J* = 7.6 Hz	3.54 d *J* = 10.4 Hz	2.93 s	2.93 s[a]
C-1' (ppm)	54.6	55.2	71.2	-[b]
C-2 (ppm)	73.7	77.8	73.6	-[b]

[a]Determined by the ^{1}H NMR of the mixture of **5q-1** and **5q-3**; [b]Not tested

Fig S5:High resolution mass spectra

A： MS (ESI): Calculated for $C_{14}H_{17}NO_3$ ($[M-H]^+$): 247.1281, found: 247.1237

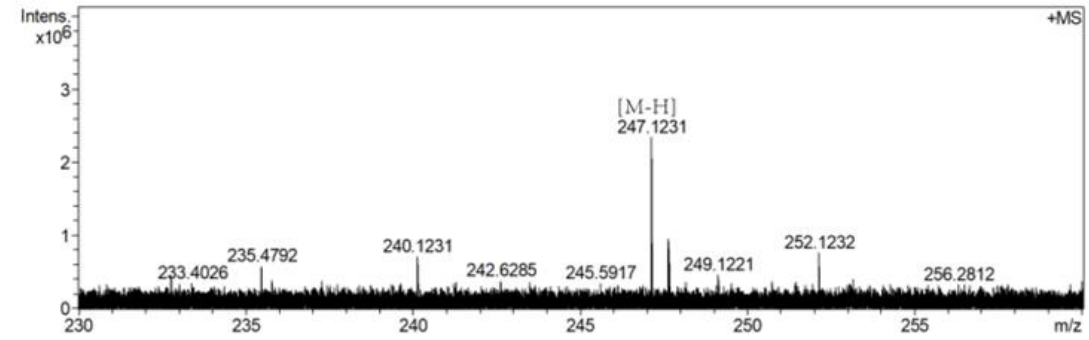
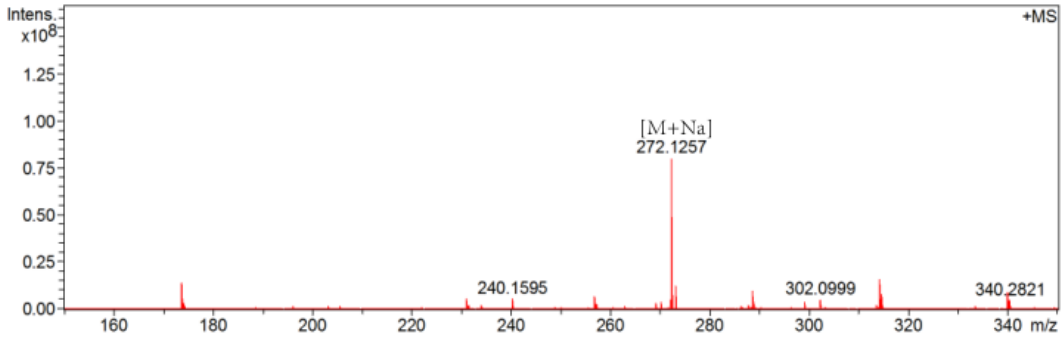


Fig.116 High resolution mass spectrum of intermediate **A**

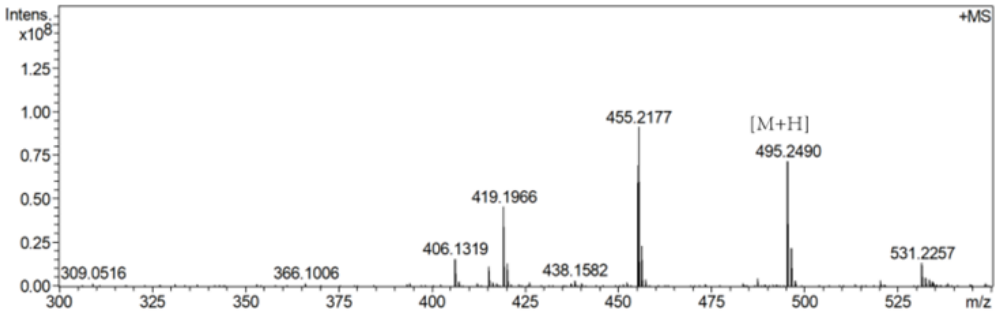
The reducing product of intermediate **A** or **B**： MS (ESI): Calculated for $C_{14}H_{19}NO_3Na$($[M+Na]^+$): 272.1257, found: 272.1257



Meas. m/z	#	Formula	m/z	err [ppm]	Mean err [ppm]	rdb	N-Rule	e¡¥ Conf	mSigma	Std I	Std Mean m/z	Std I VarNorm	Std m/z Diff	Std Comb Dev
272.1257	1	C 14 H 19 N Na O 3	272.1257	-0.1	-0.1	5.5	ok	even	5.47	0.0089	0.0000	0.0063	0.0000	0.8427

Fig.117 High resolution mass spectrum of the reducing product of intermediate **A** or **B**

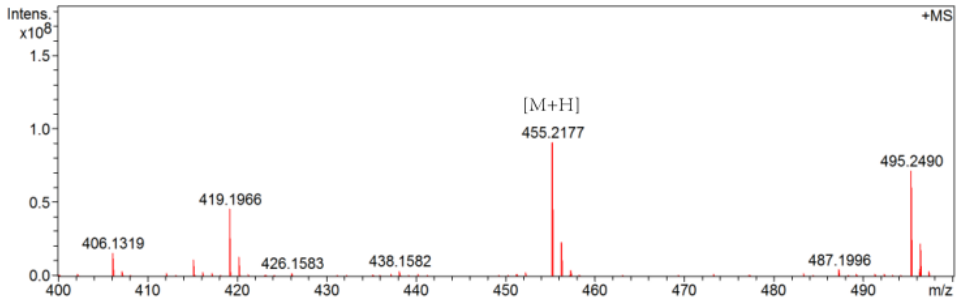
5a” or **D:** MS (ESI): Calculated for $C_{28}H_{35}N_2O_6$ ($[M+H]^+$): 495.2490, found: 495.2490.



Meas. m/z	#	Formula	m/z	err [ppm]	Mean err [ppm]	rdb	N-Rule	e¡¥ Conf	mSigma	Std I	Std Mean m/z	Std I VarNorm	Std m/z Diff	Std Comb Dev
495.2490	1	C 28 H 35 N 2 O 6	495.2490	-0.0	-0.1	12.5	ok	even	7.44	0.0131	0.0000	0.0063	0.0001	0.8427

Fig.118 High resolution mass spectrum of compound **5a”** or intermediate **D**

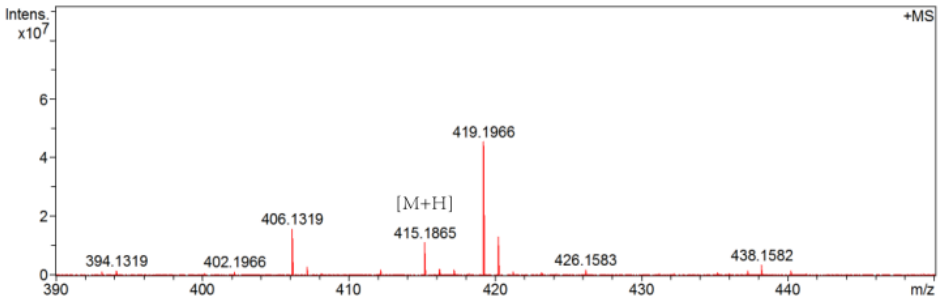
5a’： MS (ESI): Calculated for $C_{25}H_{31}N_2O_6$ ($[M+H]^+$): 455.2177, found: 455.2177.



Meas. m/z	#	Formula	m/z	err [ppm]	Mean err [ppm]	rdb	N-Rule	e¡¥ Conf	mSigma	Std I	Std Mean m/z	Std I VarNorm	Std m/z Diff	Std Comb Dev
455.2177	1	C 25 H 31 N 2 O 6	455.2177	-0.1	-0.1	11.5	ok	even	13.36	0.0213	0.0001	0.0095	0.0000	0.8427

Fig.119 High resolution mass spectrum of compound **5a’**

5a:MS (ESI): Calculated for $C_{22}H_{27}N_2O_6$ ($[M+H]^+$): 415.1864, found: 415.1865.



Meas. m/z	#	Formula	m/z	err [ppm]	Mean err [ppm]	rdb	N-Rule	e¡¥ Conf	mSigma	Std I	Std Mean m/z	Std I VarNorm	Std m/z Diff	Std Comb Dev
415.1865	1	C 22 H 27 N 2 O 6	415.1864	-0.2	-0.3	10.5	ok	even	14.02	0.0197	0.0002	0.0099	0.0001	0.8427

Fig.120 High resolution mass spectrum of compound **5a**

Fig S6: Crystal Information

To determine the absolute configuration of (3*R*,4*R*,4a*R*,4b*R*,5*S*,6*R*,7*R*,13b*S*)-12-bromo-1-(4-bromophenyl)-1,3,4,5,6,7,8,13b-octahydro-2*H*-benzo[*h*]pyrido[2,1-*f*][1,6]naphthyridine-3,4,4a,5,6,7(4b*H*)-hexaol (5q): Firstly, 5q was recrystallized from dichloromethane/ methabol. The solvents were slowly evaporated directly, and the single crystal was obtained after three days. The CCDC number is 2173338.

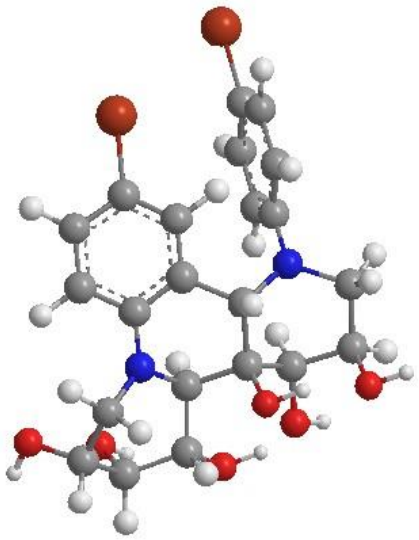


Fig.121 X-Ray Structure of of 5q

Bond precision: C-C = 0.0079 A Wavelength=0.71073

Cell: a=12.4566(3) b=13.9128(4) c=29.9476(8)
alpha=90 beta=90 gamma=90
Temperature: 170 K

	Calculated	Reported
Volume	5190.1(2)	5190.1(2)
Space group	P 21 21 21	P 21 21 21
Hall group	P 2ac 2ab	P 2ac 2ab
Moiety formula	2(C22 H24 Br2 N2 O6), C H Cl2, 3(C H4 O)	2(C22 H24 Br2 N2 O6), 3(C H4 O), C H Cl2
Sum formula	C48 H61 Br4 Cl2 N4 O15	C48 H61 Br4 Cl2 N4 O15
Mr	1324.51	1324.54
Dx,g cm-3	1.695	1.695
Z	4	4
Mu (mm-1)	3.276	3.276
F000	2684.0	2684.0
F000'	2681.84	
h,k,lmax	15,17,37	15,17,37
Nref	10648[5899]	10031
Tmin,Tmax	0.737,0.849	0.018,0.045
Tmin'	0.606	

Correction method= # Reported T Limits: Tmin=0.018 Tmax=0.045
AbsCorr = MULTI-SCAN

Data completeness= 1.70/0.94 Theta(max)= 26.383

R(reflections)= 0.0373(7589) wR2(reflections)= 0.0799(10031)

S = 0.924 Npar= 706