Radical cyclization of enynes/dienes with alcohols in-water using green oxidant

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Supporting Information

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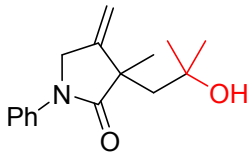
(A) Synthesis of enynes/dienes and typical experimental procedure for the radical cyclization

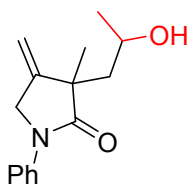
Enynes and dienes were prepared according to the known procedures.[1-2]

To a Schlenk tube were added enynes **1** (0.2 mmol) or dienes **4** (0.2 mmol), alcohols **2** (0.5 mL), $K_2S_2O_8$ (1.2 equiv), and H_2O (1.0 mL). Then the tube was stirred at 80 °C or 90 °C sealed in air for the indicated time until complete consumption of starting material as monitored by TLC and/or GC-MS analysis. After the reaction was finished, the mixture was extracted three times with EtOAc. The organic layer was dried over Na_2SO_4, filtration and evaporation of the solvent. The mixture was purified by flash column chromatography over silica gel (hexane/ethyl acetate = 5:1) to afford the desired products **3**, **5**, **6**, and **7**.

(B) Analytical data

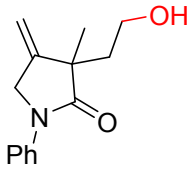


3-(2-Hydroxy-2-methylpropyl)-3-methyl-4-methylene-1-phenylpyrrolidin-2-one (3aa)[1], white solid (0.0471 g, 91% yield); ^{1}H NMR (400 MHz, DMSO-*d6*) δ: 7.73 (d, J = 8.0 Hz, 2H), 7.38 (t, J = 8.0 Hz, 2H), 7.13 (t, J = 7.6 Hz, 1H), 5.21-5.16 (m, 2H), 4.54-4.46 (m, 2H), 4.08 (s, 1H), 2.04 (d, J = 14.0 Hz, 1H), 1.80 (d, J = 14.0 Hz, 1H), 1.21 (s, 3H), 1.07 (s, 3H), 1.04 (s, 3H); ^{13}C NMR (100 MHz, DMSO-*d6*) δ: 177.5, 146.9, 139.9, 129.2, 124.4, 120.1, 108.5, 69.6, 52.6, 52.2, 48.0, 31.9, 31.6, 28.8.

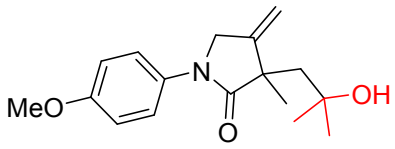


3-(2-Hydroxypropyl)-3-methyl-4-methylene-1-phenylpyrrolidin-2-one (3ab)[1], white solid (0.0407 g, 83% yield, d.r. = 1:1); ^{1}H NMR

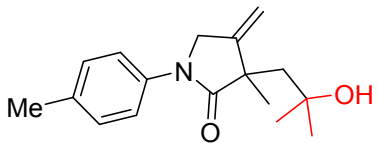
(500 MHz, $CDCl_3$) δ: 7.67-7.64 (m, 2H), 7.41-7.35 (m, 2H), 7.21-7.14 (m, 1H), 5.24 (d, J = 35.5 Hz, 1H), 5.11 (d, J = 24.5 Hz, 1H), 4.54-4.48 (m, 2H), 4.21-3.95 (m, 1H), 1.85-1.71 (m, 2H), 1.62 (s, 1H), 1.42 (s, 1.5H), 1.35 (s, 1.5H), 1.20-1.17 (m, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 178.3, 178.1, 147.3, 145.9, 139.1, 138.5, 129.0, 128.9, 125.2, 124.7, 120.4, 120.3, 107.9, 107.7, 65.6, 64.3, 52.2 (2), 48.7, 48.5, 48.1, 48.0, 26.8, 24.7, 24.3, 23.8.



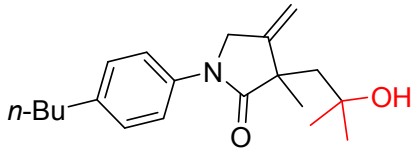
3-(2-Hydroxyethyl)-3-methyl-4-methylene-1-phenylpyrrolidin-2-one (3ac)[1], yellow solid (0.0328 g, 71% yield); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.66 (d, J = 8.0 Hz, 2H), 7.39 (t, J = 8.0 Hz, 2H), 7.18 (t, J = 7.5 Hz, 1H), 5.24 (t, J = 2.0 Hz, 1H), 5.13 (t, J = 2.5 Hz, 1H), 4.52-4.47 (m, 2H), 3.84-3.81 (m, 1H), 3.70-3.66 (m, 1H), 2.56 (s, 1H), 2.07-2.02 (m, 1H), 1.94-1.90 (m, 1H), 1.39 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 177.9, 146.1, 138.7, 128.9, 125.0, 120.2, 108.0, 59.3, 52.1, 48.4, 41.3, 24.6.



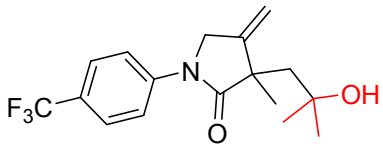
3-(2-Hydroxy-2-methylpropyl)-1-(4-methoxyphenyl)-3-methyl-4-methylenepyrrolidin-2-one (3ba)[1]**,** white solid (0.0544 g, 94% yield); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.54 (d, J = 9.5 Hz, 2H), 6.91 (d, J = 9.0 Hz, 2H), 5.21 (s, 1H), 5.16 (s, 1H), 4.54-4.45 (m, 2H), 3.80 (s, 3H), 2.75 (s, 1H), 2.22 (d, J = 15.0 Hz, 1H), 1.94 (d, J = 15.0 Hz, 1H), 1.36 (s, 3H), 1.23 (s, 3H), 1.18 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 177.8, 156.9, 147.2, 131.9, 122.2, 114.1, 107.9, 70.8, 55.4, 52.6, 51.3, 48.1, 31.6, 30.8, 28.6.



3-(2-Hydroxy-2-methylpropyl)-3-methyl-4-methylene-1-(*p*-tolyl)pyrrolidin-2-one (3ca)[1]**,** white solid (0.0503 g, 92% yield); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.52 (d, J = 8.5 Hz, 2H), 7.18 (d, J = 8.5 Hz, 2H), 5.23 (t, J = 2.0 Hz, 1H), 5.16 (t, J = 2.0 Hz, 1H), 4.57-4.53 (m, 1H), 4.50-4.46 (m, 1H), 2.33 (s, 3H), 2.31 (s, 1H), 2.22 (d, J = 15.0 Hz, 1H), 1.94 (d, J = 14.5 Hz, 1H), 1.37 (s, 3H), 1.23 (s, 3H), 1.18 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 178.0, 147.2, 136.2, 134.8, 129.5, 120.5, 107.9, 70.8, 52.3, 51.3, 48.3, 31.6, 30.9, 28.7, 20.9.

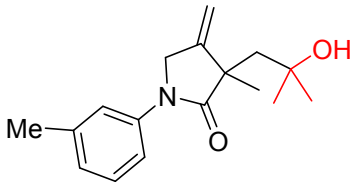


1-(4-Butylphenyl)-3-(2-hydroxy-2-methylpropyl)-3-methyl-4-methylenepyrrolidin-2-one (3da), yellow oil (0.0574 g, 91% yield); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.55 (d, J = 8.5 Hz, 2H), 7.19 (d, J = 8.0 Hz, 2H), 5.22 (s, 1H), 5.16 (s, 1H), 4.55 (d, J = 14.0 Hz, 1H), 4.48 (d, J = 14.0 Hz, 1H), 2.59 (t, J = 8.0 Hz, 2H), 2.23 (d, J = 15.0 Hz, 1H), 1.95 (d, J = 15.0 Hz, 1H), 1.61-1.56 (m, 2H), 1.37 (s, 3H), 1.35-1.31 (m, 2H), 1.23 (s, 3H), 1.18 (s, 3H), 0.92 (t, J = 7.5 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 178.0, 147.3, 139.8, 136.5, 128.9, 120.4, 107.9, 70.9, 52.3, 51.3, 48.4, 35.1, 33.6, 31.6, 30.9, 28.7, 22.3, 13.9; HRMS *m/z* (ESI) calcd for $C_{20}H_{30}NO_2$ ($[M+H]^+$) 316.2271, found 316.2273.

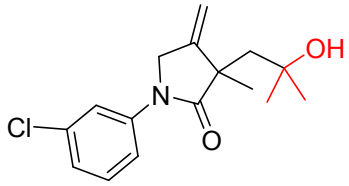


3-(2-Hydroxy-2-methylpropyl)-3-methyl-4-methylene-1-(4-(trifluoromethyl)phenyl)pyrrolidin-2-one (3ea)[1], white solid (0.0523 g, 80% yield); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.84 (d, J = 8.5 Hz, 2H), 7.63 (d, J = 8.5 Hz,

2H), 5.29 (t, J = 2.0 Hz, 1H), 5.21 (t, J = 2.0 Hz, 1H), 4.64-4.60 (m, 1H), 4.52-4.49 (m, 1H), 2.26 (d, J = 15.0 Hz, 1H), 2.12 (s, 1H), 1.94 (d, J = 14.5 Hz, 1H), 1.37 (s, 3H), 1.21 (s, 3H), 1.19 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 178.8, 146.2, 141.8, 126.3 (q, $J_{C\text{-}F}$ = 32.6 Hz), 126.1 (q, $J_{C\text{-}F}$ = 3.6 Hz), 122.9, 119.5, 108.6, 70.9, 51.9, 51.6, 48.4, 31.8, 31.0, 28.7; ^{19}F NMR (471 MHz, $CDCl_3$) δ: -62.2.

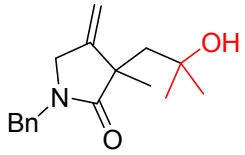


3-(2-Hydroxy-2-methylpropyl)-3-methyl-4-methylene-1-(*m*-tolyl)pyrrolidin-2-one (3fa), yellow oil (0.0486 g, 89% yield); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.52 (s, 1H), 7.42 (d, J = 8.0 Hz, 1H), 7.26 (t, J = 8.0 Hz, 1H), 6.99 (d, J = 7.5 Hz, 1H), 5.23 (s, 1H), 5.16 (s, 1H), 4.57 (d, J = 14.0 Hz, 1H), 4.48 (d, J = 14.0 Hz, 1H), 2.70 (s, 1H), 2.37 (s, 3H), 2.23 (d, J = 15.0 Hz, 1H), 1.94 (d, J = 15.0 Hz, 1H), 1.37 (s, 3H), 1.23 (s, 3H), 1.19 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 178.2, 147.1, 138.9, 138.8, 128.8, 125.9, 121.2, 117.5, 108.0, 70.9, 52.3, 51.3, 48.4, 31.7, 30.9, 28.7, 21.6; HRMS m/z (ESI) calcd for $C_{17}H_{24}NO_2$ ($[M+H]^+$) 274.1802, found 274.1800.

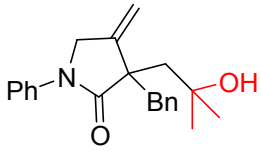


1-(3-Chlorophenyl)-3-(2-hydroxy-2-methylpropyl)-3-methyl-4-methylenepyrrolidin-2-one (3ga), yellow oil (0.0498 g, 85% yield); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.77 (s, 1H), 7.57 (d, J = 8.0 Hz, 1H), 7.29 (t, J = 8.0 Hz, 1H), 7.13 (d, J = 8.0 Hz, 1H), 5.26 (s, 1H), 5.18 (s, 1H), 4.56 (d, J = 13.5 Hz, 1H), 4.45 (d, J = 14.0 Hz, 1H), 2.37 (s, 1H), 2.24 (d, J = 15.0 Hz, 1H), 1.92 (d, J = 15.0 Hz, 1H), 1.35 (s, 3H), 1.35 (s, 3H), 1.18 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 178.5, 146.4, 140.1, 134.7,

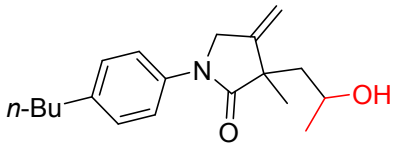
129.9, 124.8, 120.2, 118.0, 108.5, 70.9, 52.1, 51.6, 48.4, 31.8, 30.9, 28.7; HRMS *m/z* (ESI) calcd for $C_{16}H_{21}ClNO_2$ ($[M+H]^+$) 294.1255, found 294.1257.



1-Benzyl-3-(2-hydroxy-2-methylpropyl)-3-methyl-4-methylenepyrrolidin-2-one (3ha)[1], white solid (0.0393 g, 72% yield); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.32 (t, J = 7.5 Hz, 2H), 7.29-7.24 (m, 3H), 5.05-5.02 (m, 2H), 4.56 (d, J = 14.5 Hz, 1H), 4.47 (d, J = 15.0 Hz, 1H), 3.94-3.86 (m, 2H), 3.24 (s, 1H), 2.14 (d, J = 15.0 Hz, 1H), 1.89 (d, J = 15.0 Hz, 1H), 1.29 (s, 3H), 1.22 (s, 3H), 1.09 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 178.7, 147.9, 135.7, 128.7, 128.3, 127.7, 107.6, 70.6, 50.7, 50.1, 47.2, 46.5, 31.7, 30.6, 28.7.

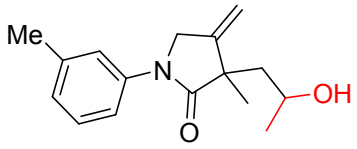


3-Benzyl-3-(2-hydroxy-2-methylpropyl)-4-methylene-1-phenylpyrrolidin-2-one (3ia)[1], white solid (0.0489 g, 73% yield); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.34-7.30 (m, 4H), 7.17-7.14 (m, 6H), 5.35-5.28 (m, 2H), 4.16-4.12 (m, 1H), 3.45-3.41 (m, 1H), 3.29 (d, J = 12.5 Hz, 1H), 3.02 (s, 1H), 2.67 (d, J = 12.5 Hz, 1H), 2.46 (d, J = 15.0 Hz, 1H), 2.14 (d, J = 15.0 Hz, 1H), 1.27 (s, 3H), 1.21 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 176.6, 144.6, 138.2, 135.6, 130.4, 128.8, 127.8, 126.8, 125.4, 121.1, 109.3, 70.9, 54.8, 52.8, 50.0, 48.7, 32.2, 30.9.

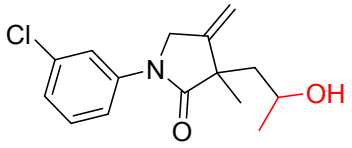


1-(4-Butylphenyl)-3-(2-hydroxypropyl)-3-methyl-4-methylenepyrrolidin-2-one (3db), yellow oil (0.0524 g, 87% yield, d.r. = 1:1); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.48-7.45 (m, 2H), 7.13-7.09 (m, 2H), 5.19-5.11 (m, 1H), 5.05-5.00 (m, 1H), 4.44-4.38 (m, 1H), 4.15-4.06 (m, 1H), 4.03-3.99 (m, 1H), 2.54-2.49 (m, 2H), 1.74-1.66 (m, 2H), 1.52-1.47 (m, 2H), 1.27 (s, 3H), 1.23-1.84 (m, 2H), 1.12 (d, J = 6.0 Hz, 1.5H), 1.09 (d, J = 6.5 Hz,

1.5H), 0.85 (t, J = 8.5 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 178.1, 178.0, 147.6, 146.2, 140.1, 139.6, 136.7, 136.1, 128.9, 128.8, 120.5, 120.4, 107.8, 107.6, 73.2, 52.4 (2), 48.6, 48.5, 48.1, 48.0, 35.1, 33.6 (2), 30.6, 30.5, 30.4, 22.3, 13.9; HRMS *m/z* (ESI) calcd for $C_{19}H_{28}NO_2$ ($[M+H]^+$) 302.2115, found 302.2117.

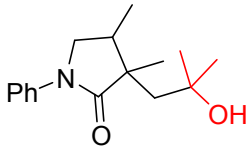


3-(2-Hydroxypropyl)-3-methyl-4-methylene-1-(*m*-tolyl)pyrrolidin-2-one (3fb), yellow oil (0.0301 g, 88% yield, d.r. = 1:1); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.56-7.51 (m, 1H), 7.42-7.37 (m, 1H), 7.28-7.23 (m, 1H), 7.02-6.97 (m, 1H), 5.26-5.19 (m, 1H), 5.13-5.07 (m, 1H), 4.55-4.46 (m, 2H), 4.16-4.12 (m, 0.5H), 3.91-3.85 (m, 0.5H), 2.37 (s, 1.5H), 2.36 (s, 1.5H), 1.82-1.74 (m, 2H), 1.41 (s, 1.5H), 1.34 (s, 1.5H), 1.19 (d, J = 6.5 Hz, 1.5H), 1.17 (d, J = 6.5 Hz, 1.5H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 178.3, 178.2, 147.5, 146.1, 139.0, 138.9, 138.8, 138.5, 128.8, 128.7, 126.1, 125.7, 121.3, 121.2, 117.6, 117.5, 107.8, 107.7, 65.6, 64.4, 52.4 (2), 48.7, 48.6, 48.2, 48.0, 26.8, 24.7, 24.3, 23.8, 21.6; HRMS *m/z* (ESI) calcd for $C_{16}H_{22}NO_2$ ($[M+H]^+$) 260.1645, found 260.1643.

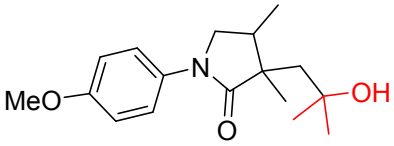


1-(3-Chlorophenyl)-3-(2-hydroxypropyl)-3-methyl-4-methylenepyrrolidin-2-one (3gb), yellow oil (0.0452 g, 81% yield, d.r. = 1:1); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.75 (s, 1H), 7.60-7.54 (m, 1H), 7.32-7.27 (m, 1H), 7.16-7.11 (m, 1H), 5.29-5.21 (m, 1H), 5.14-5.09 (m, 1H), 4.55-4.45 (m, 2H), 4.13-4.07 (m, 0.5H), 3.90-3.84 (m, 0.5H), 1.82-1.70 (m, 2H), 1.41 (s, 1.5H), 1.34 (s, 1.5H), 1.19-1.16 (m, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 178.5 (2), 146.8, 145.3, 140.3, 139.7, 134.7, 134.6, 130.0, 129.8, 125.1, 124.6, 120.3, 120.2,

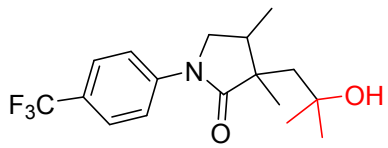
118.1, 118.0, 108.2, 108.0, 65.6, 64.6, 52.1 (2), 48.8, 48.5, 48.3, 48.2, 26.8, 24.7, 24.4, 24.0; HRMS *m/z* (ESI) calcd for $C_{15}H_{19}ClNO_2$ ($[M+H]^+$) 280.1099, found 280.1097.



3-(2-Hydroxy-2-methylpropyl)-3,4-dimethyl-1-phenylpyrrolidin-2-one (5aa)[2], yellow oil (0.0428 g, 82% yield, d.r. > 20:1); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.59 (d, J = 8.0 Hz, 2H), 7.36 (t, J = 8.0 Hz, 2H), 7.14 (t, J = 7.5 Hz, 1H), 3.78 (t, J = 8.5 Hz, 1H), 3.44 (t, J = 10.0 Hz, 1H), 2.75-2.69 (m, 1H), 2.00 (d, J = 15.0 Hz, 1H), 1.73 (d, J = 15.0 Hz, 1H), 1.33 (s, 3H), 1.28 (s, 3H), 1.25 (s, 1H), 1.12 (s, 3H), 1.07 (d, J = 6.5 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 180.2, 139.3, 128.8, 124.7, 120.1, 70.5, 52.5, 48.2, 47.9, 35.1, 32.4, 31.0, 18.6, 11.4.

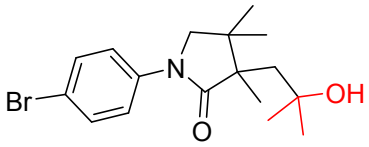


3-(2-Hydroxy-2-methylpropyl)-1-(4-methoxyphenyl)-3,4-dimethylpyrrolidin-2-one (5ba)[2], yellow oil (0.0582 g, 88% yield, d.r. > 20:1); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.47 (d, J = 9.0 Hz, 2H), 6.89 (d, J = 9.0 Hz, 2H), 3.80 (s, 3H), 3.74 (t, J = 8.5 Hz, 1H), 3.42 (t, J = 10.0 Hz, 1H), 2.68-2.63 (m, 1H), 1.97 (d, J = 15.0 Hz, 1H), 1.74 (d, J = 15.0 Hz, 1H), 1.62 (s, 1H), 1.33 (s, 3H), 1.28 (s, 3H), 1.13 (s, 3H), 1.06 (d, J = 7.0 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 179.9, 156.8, 132.6, 122.0, 114.1, 70.4, 55.5, 53.1, 48.2, 48.0, 35.7, 32.4, 31.2, 18.6, 11.5.

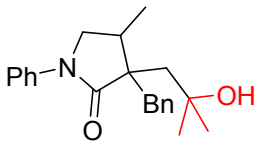


3-(2-Hydroxy-2-methylpropyl)-3,4-dimethyl-1-(4-(trifluoromethyl)phenyl)pyrrolidin-2-one (5ca) yellow oil (0.0513 g, 78% yield, d.r. > 20:1); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.39 (d, J = 8.5 Hz, 2H), 6.61 (d, J = 8.5 Hz, 2H), 3.17-3.13 (m, 1H), 3.01-2.97 (m, 1H), 2.16-

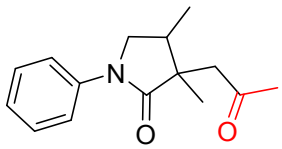
2.12 (m, 1H), 2.07 (d, J = 13.5 Hz, 1H), 1.83 (d, J = 13.5 Hz, 1H), 1.49 (s, 3H), 1.35 (s, 3H), 1.33 (s, 3H), 1.02 (d, J = 7.0 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 181.7, 150.4, 126.6 (q, $J_{C\text{-}F}$ = 3.8 Hz), 126.1, 119.4, 111.9, 70.4, 52.0, 48.0, 46.6, 38.8, 30.2, 30.1, 22.7, 13.6; ^{19}F NMR (471 MHz, $CDCl_3$) δ: -61.0; HRMS m/z (ESI) calcd for $C_{17}H_{23}F_3NO_2$ ($[M+H]^+$) 330.1675, found 330.1671.



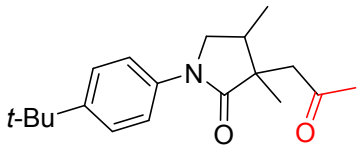
1-(4-Bromophenyl)-3-(2-hydroxy-2-methylpropyl)-3,4,4-trimethylpyrrolidin-2-one (5da), yellow oil (0.0600 g, 85% yield); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.51 (d, J = 9.0 Hz, 2H), 7.47 (d, J = 9.0 Hz, 2H), 5.23 (s, 1H), 3.56-3.50 (m, 2H), 1.92 (d, J = 14.5 Hz, 1H), 1.45 (d, J = 14.5 Hz, 1H), 1.35 (s, 3H), 1.34 (s, 3H), 1.19 (s, 3H), 1.08 (s, 3H), 1.06 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 180.5, 138.4, 131.9, 121.5, 117.7, 70.1, 59.1, 51.1, 44.2, 40.3, 33.3, 31.5, 22.5, 21.9, 17.6; HRMS m/z (ESI) calcd for $C_{17}H_{25}BrNO_2$ ($[M+H]^+$) 354.1063, found 354.1067.



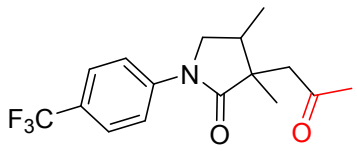
3-Benzyl-3-(2-hydroxy-2-methylpropyl)-4-methyl-1-phenylpyrrolidin-2-one (5ea)[2], colorless oil (0.0499 g, 74% yield, d.r. > 20:1); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.54 (d, J = 8.0 Hz, 2H), 7.35 (t, J = 8.0 Hz, 2H), 7.29-7.27 (m, 4H), 7.22-7.19 (m, 1H), 7.15 (t, J = 7.5 Hz, 1H), 4.03 (s, 1H), 3.83 (d, J = 14.0 Hz, 1H), 3.50-3.45 (m, 2H), 2.80 (d, J = 14.0 Hz, 1H), 2.38-2.32 (m, 1H), 1.82 (d, J = 14.5 Hz, 1H), 1.64 (d, J = 14.5 Hz, 1H), 1.42 (s, 3H), 1.17 (s, 3H), 0.95 (d, J = 7.0 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 178.8, 139.0, 137.9, 130.8, 128.8, 128.2, 126.5, 125.0, 120.3, 70.4, 52.3, 51.9, 43.2, 42.1, 34.4, 32.3, 31.8, 10.8.



3,4-Dimethyl-3-(2-oxopropyl)-1-phenylpyrrolidin-2-one (6ab)[2], yellow oil (0.0368 g, 75% yield, d.r. > 20:1); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.62 (d, J = 8.0 Hz, 2H), 7.37 (t, J = 8.0 Hz, 2H), 7.14 (t, J = 7.0 Hz, 1H), 3.96-3.92 (m, 1H), 3.47-3.44 (m, 1H), 2.85 (d, J = 18.0 Hz, 1H), 2.73 (d, J = 18.0 Hz, 1H), 2.50-2.47 (m, 1H), 2.15 (s, 3H), 1.30 (s, 3H), 1.02 (d, J = 7.0 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 207.1, 177.3, 139.7, 128.8, 124.5, 120.1, 53.3, 47.0, 46.7, 35.9, 30.8, 23.4, 15.3.

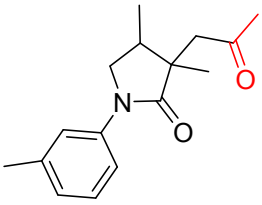


1-(4-(*tert*-Butyl)phenyl)-3,4-dimethyl-3-(2-oxopropyl)pyrrolidin-2-one (6fb), yellow oil (0.0458 g, 76% yield, d.r. > 20:1); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.55 (d, J = 8.5 Hz, 2H), 7.39 (d, J = 8.5 Hz, 2H), 3.95-3.92 (m, 1H), 3.45-3.42 (m, 1H), 2.86 (d, J = 18.0 Hz, 1H), 2.72 (d, J = 18.0 Hz, 1H), 2.50-2.46 (m, 1H), 2.15 (s, 3H), 1.33 (s, 3H), 1.31 (s, 9H), 1.01 (d, J = 7.5 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 207.2, 177.2, 147.5, 137.1, 125.7, 119.8, 53.4, 47.0, 46.6, 36.0, 34.4, 31.4, 31.3, 23.3, 15.5; HRMS *m/z* (ESI) calcd for $C_{19}H_{28}NO_2$ ($[M+H]^+$) 302.2115, found 302.2111.

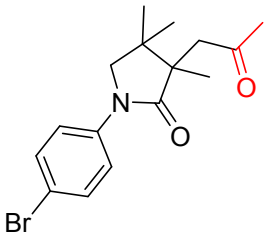


3,4-Dimethyl-3-(2-oxopropyl)-1-(4-(trifluoromethyl)phenyl)pyrrolidin-2-one (6cb), yellow oil (0.0445 g, 71% yield, d.r. > 20:1); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.78 (d, J = 8.5 Hz, 2H), 7.62 (d, J = 9.0 Hz, 2H), 3.96-3.93 (m, 1H), 3.52-3.49 (m, 1H), 2.85 (d, J = 18.0 Hz, 1H), 2.76 (d, J = 18.0 Hz, 1H), 2.52-2.48 (m, 1H), 2.15 (s, 3H), 1.30 (s, 3H), 1.03 (d, J = 7.0 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 206.9, 178.0, 142.6, 126.1 (q, $J_{C\text{-}F}$ = 32.5 Hz), 126.0 (q, $J_{C\text{-}F}$ = 3.8 Hz), 125.2, 119.4, 53.1, 47.1, 47.0, 35.8,

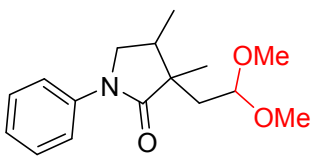
30.6, 24.1, 15.1; ^{19}F NMR (471 MHz, $CDCl_3$) δ: -62.2; HRMS *m/z* (ESI) calcd for $C_{16}H_{19}F_3NO_2$ ($[M+H]^+$) 314.1362, found 314.1364.



3,4-Dimethyl-3-(2-oxopropyl)-1-(*m*-tolyl)pyrrolidin-2-one (6gb), yellow oil (0.0399 g, 77% yield, d.r. > 20:1); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.49 (s, 1H), 7.39 (d, J = 8.0 Hz, 1H), 7.25 (t, J = 7.0 Hz, 1H), 6.97 (d, J = 7.5 Hz, 1H), 3.95-3.91 (m, 1H), 3.46-3.43 (m, 1H), 2.85 (d, J = 18.0 Hz, 1H), 2.73 (d, J = 18.0 Hz, 1H), 2.50-2.46 (m, 1H), 2.36 (s, 3H), 2.16 (s, 3H), 1.29 (s, 3H), 1.02 (d, J = 7.0 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 207.2, 177.3, 139.6, 138.7, 128.7, 125.4, 120.9, 117.2, 53.5, 47.1, 46.7, 35.9, 30.9, 23.4, 21.6, 15.4; HRMS *m/z* (ESI) calcd for $C_{16}H_{22}NO_2$ ($[M+H]^+$) 260.1645, found 260.1647.

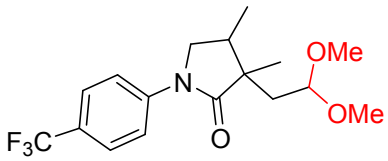


1-(4-Bromophenyl)-3,4,4-trimethyl-3-(2-oxopropyl)pyrrolidin-2-one (6db), yellow oil (0.0485 g, 72% yield); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.46-7.44 (m, 2H), 7.41-7.39 (m, 2H), 3.47 (d, J = 9.5 Hz, 1H), 3.30 (d, J = 9.5 Hz, 1H), 2.87 (d, J = 17.0 Hz, 1H), 2.53 (d, J = 17.0 Hz, 1H), 2.13 (s, 3H), 1.17 (s, 3H), 1.16 (s, 3H), 1.01 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 206.2, 176.6, 137.6, 130.8, 120.2, 116.3, 58.2, 49.5, 45.5, 37.3, 30.7, 23.8, 21.8, 17.1; HRMS *m/z* (ESI) calcd for $C_{16}H_{21}BrNO_2$ ($[M+H]^+$) 338.0750, found 338.0752.

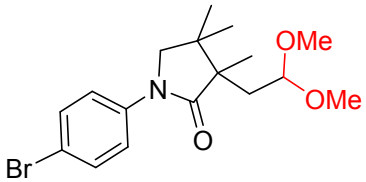


3-(2,2-Dimethoxyethyl)-3,4-dimethyl-1-phenylpyrrolidin-2-one (7ac)[2], yellow solid (0.0421 g, 76% yield, d.r. > 20:1); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.64 (d, J = 8.0 Hz, 2H), 7.35

(t, J = 8.0 Hz, 2H), 7.12 (t, J = 7.5 Hz, 1H), 4.63 (t, J = 5.0 Hz, 1H), 3.79-3.76 (m, 1H), 3.43 (t, J = 9.0 Hz, 1H), 3.33 (s, 3H), 3.26 (s, 3H), 2.26-2.22 (m, 1H) , 1.85-1.81 (m, 1H) , 1.70-1.66 (m, 1H) , 1.33 (s, 3H), 1.11 (d, J = 7.0 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 177.6, 139.8, 128.8, 124.2, 119.7, 102.4, 53.4, 53.3, 52.2, 45.8, 38.8, 35.7, 22.1, 12.3.



3-(2,2-Dimethoxyethyl)-3,4-dimethyl-1-(4-(trifluoromethyl)phenyl)pyrrolidin-2-one (7cc), yellow oil (0.0476 g, 69% yield, d.r. > 20:1); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.80 (d, J = 8.5 Hz, 2H), 7.61 (d, J = 9.0 Hz, 2H), 4.59 (t, J = 5.0 Hz, 1H), 4.31 (t, J = 7.0 Hz, 1H), 3.80 (t, J = 8.5 Hz, 1H), 3.44 (t, J = 9.5 Hz, 1H), 3.31 (s, 3H), 3.24 (s, 3H), 1.86-1.82 (m, 1H), 1.75-1.68 (m, 1H), 1.33 (s, 3H), 1.13 (d, J = 7.0 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 178.2, 142.6, 130.9, 128.8, 126.0 (q, $J_{C\text{-}F}$ = 3.8 Hz), 118.9, 102.1, 53.6, 53.1, 51.9, 45.9, 38.6, 35.8, 22.1, 13.7; ^{19}F NMR (471 MHz, $CDCl_3$) δ: -62.1; HRMS m/z (ESI) calcd for $C_{17}H_{23}F_3NO_3$ ([M+H]$^+$) 346.1625, found 346.1629.



1-(4-Bromophenyl)-3-(2,2-dimethoxyethyl)-3,4,4-trimethylpyrrolidin-2-one (7dc), yellow oil (0.0539 g, 73% yield); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.54-7.51 (m, 2H), 7.46-7.43 (m, 2H), 4.67 (t, J = 5.0 Hz, 1H), 3.50 (d, J = 9.5 Hz, 1H), 3.40 (d, J = 9.5 Hz, 1H), 3.33 (s, 3H), 3.25 (s, 3H), 1.97-1.93 (m, 1H), 1.65-1.61 (m, 1H), 1.12 (s, 3H), 1.09 (s, 3H), 1.08 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 177.9, 139.0, 131.7, 121.0, 116.8, 102.3, 58.5, 53.5, 53.1, 48.9, 38.9, 37.2, 23.6, 21.8, 16.4; HRMS m/z (ESI) calcd for $C_{17}H_{25}BrNO_3$ ([M+H]$^+$) 370.1012, found 370.1010.

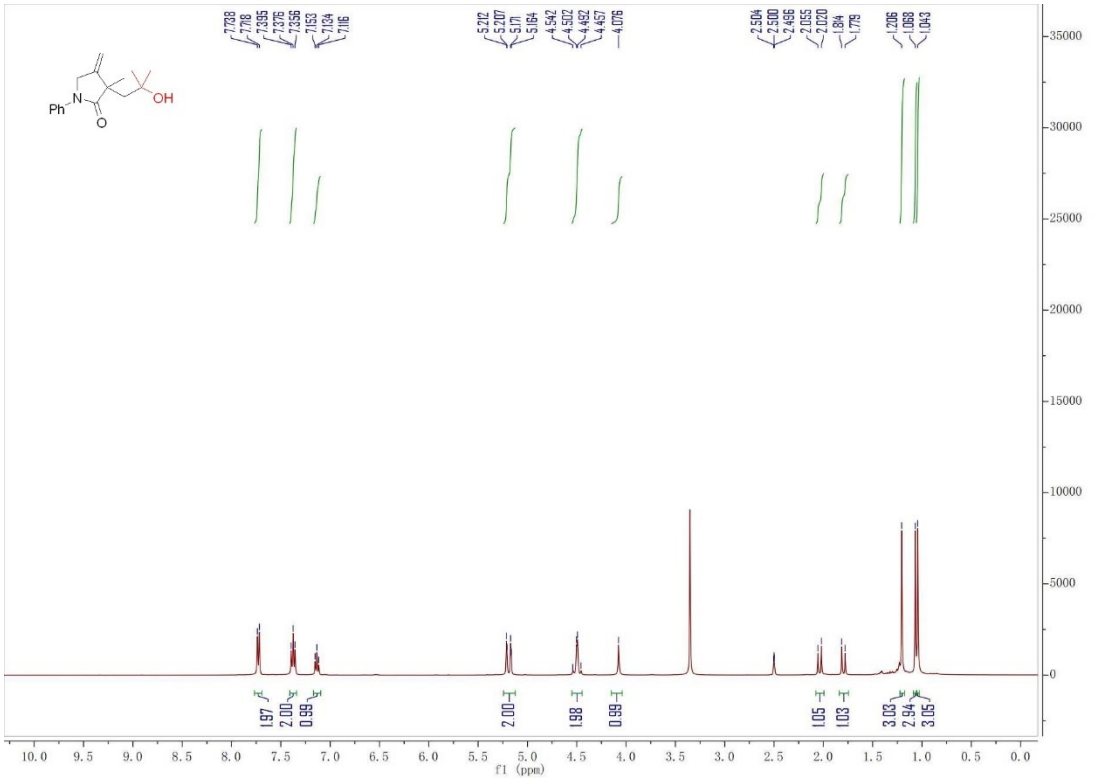
(C) References

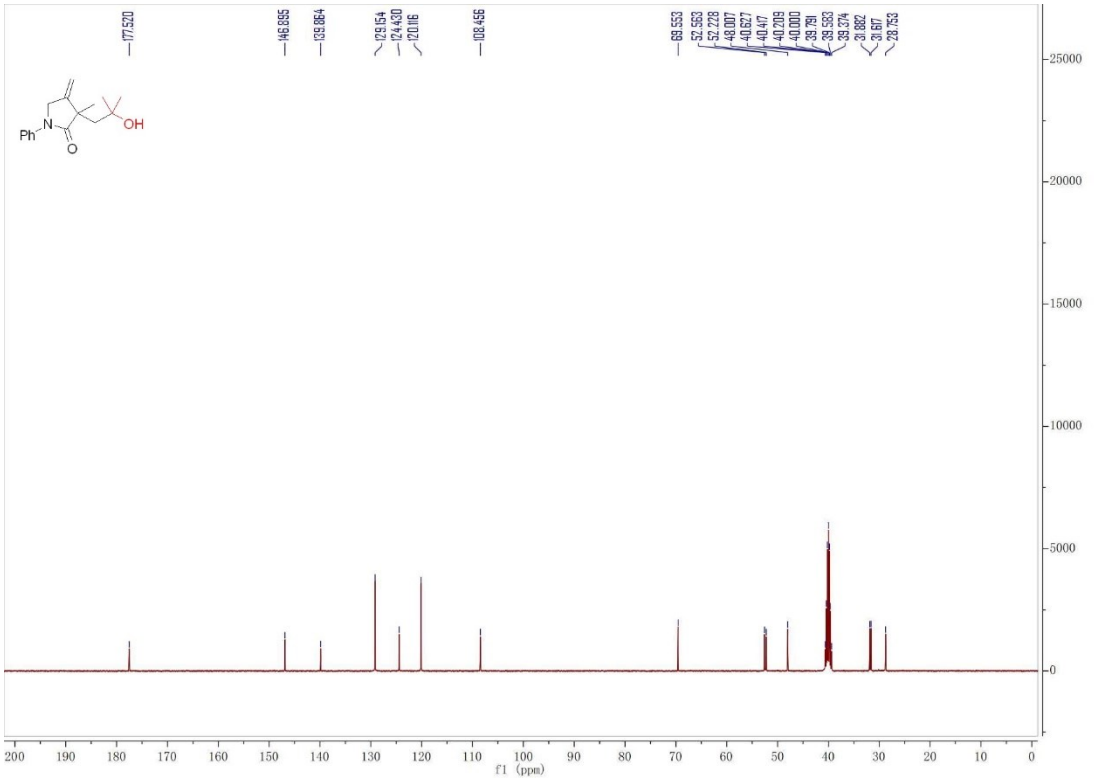
[1] X.-X. Meng, T.-T. Cao, S.-Z. Song, G. Zhou, Q. Li and W.-T. Wei, *Asian J. Org. Chem*., 2019, **8**, 1827.

[2] F.-H. Qin, X.-J. Huang, Y. Liu, H. Liang, Q. Li, Z. Cao, W.-T. Wei and W.-M. He, *Chin. Chem. Lett.*, 2020, Doi: 10.1016/j.cclet.2020.04.042.

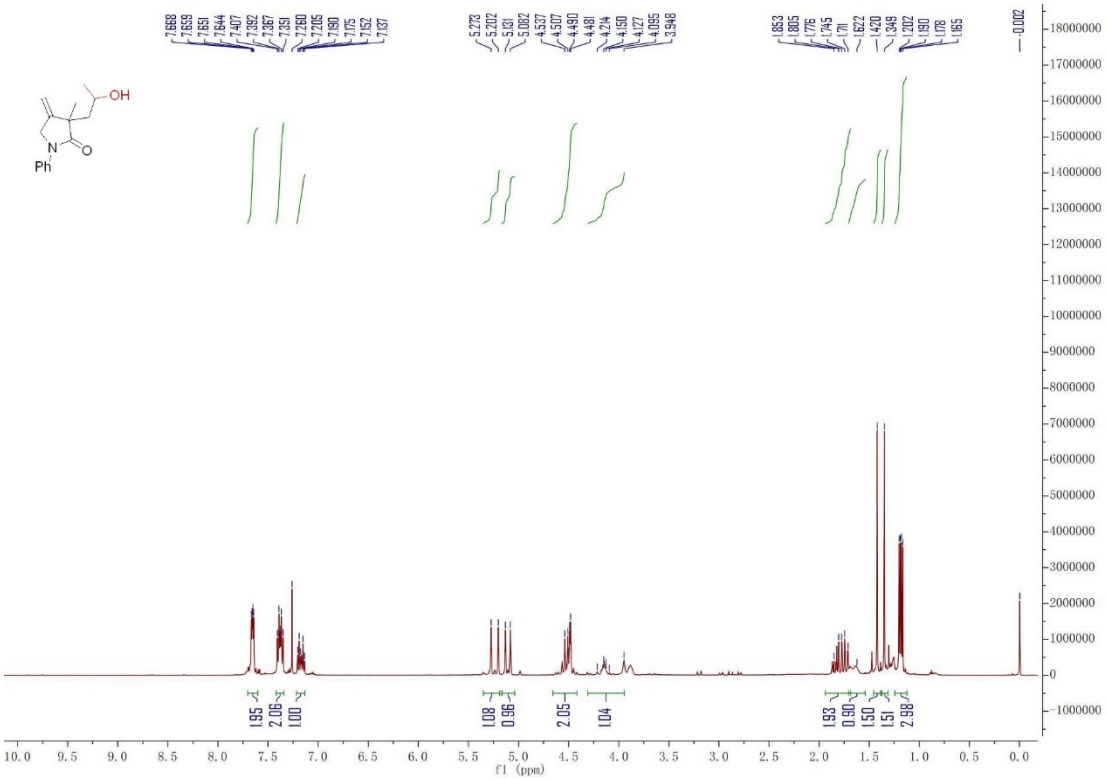
(D) Spectra

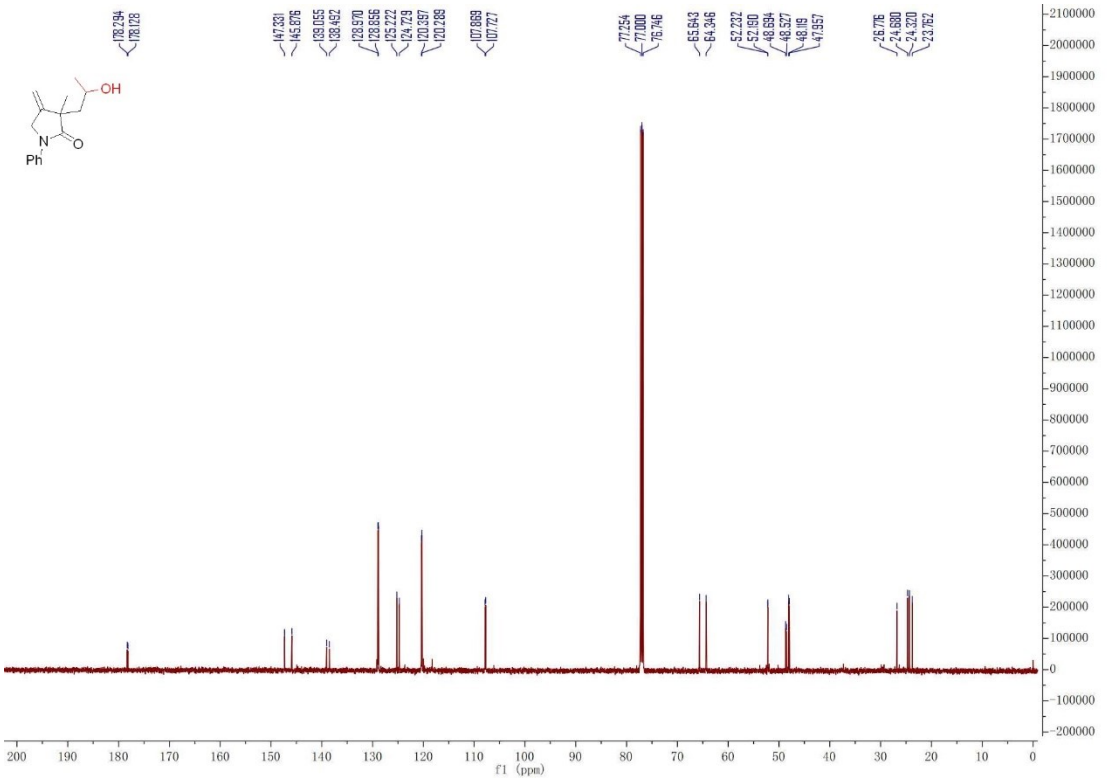
3-(2-Hydroxy-2-methylpropyl)-3-methyl-4-methylene-1-phenylpyrrolidin-2-one (3aa)





3-(2-Hydroxypropyl)-3-methyl-4-methylene-1-phenylpyrrolidin-2-one (3ab)





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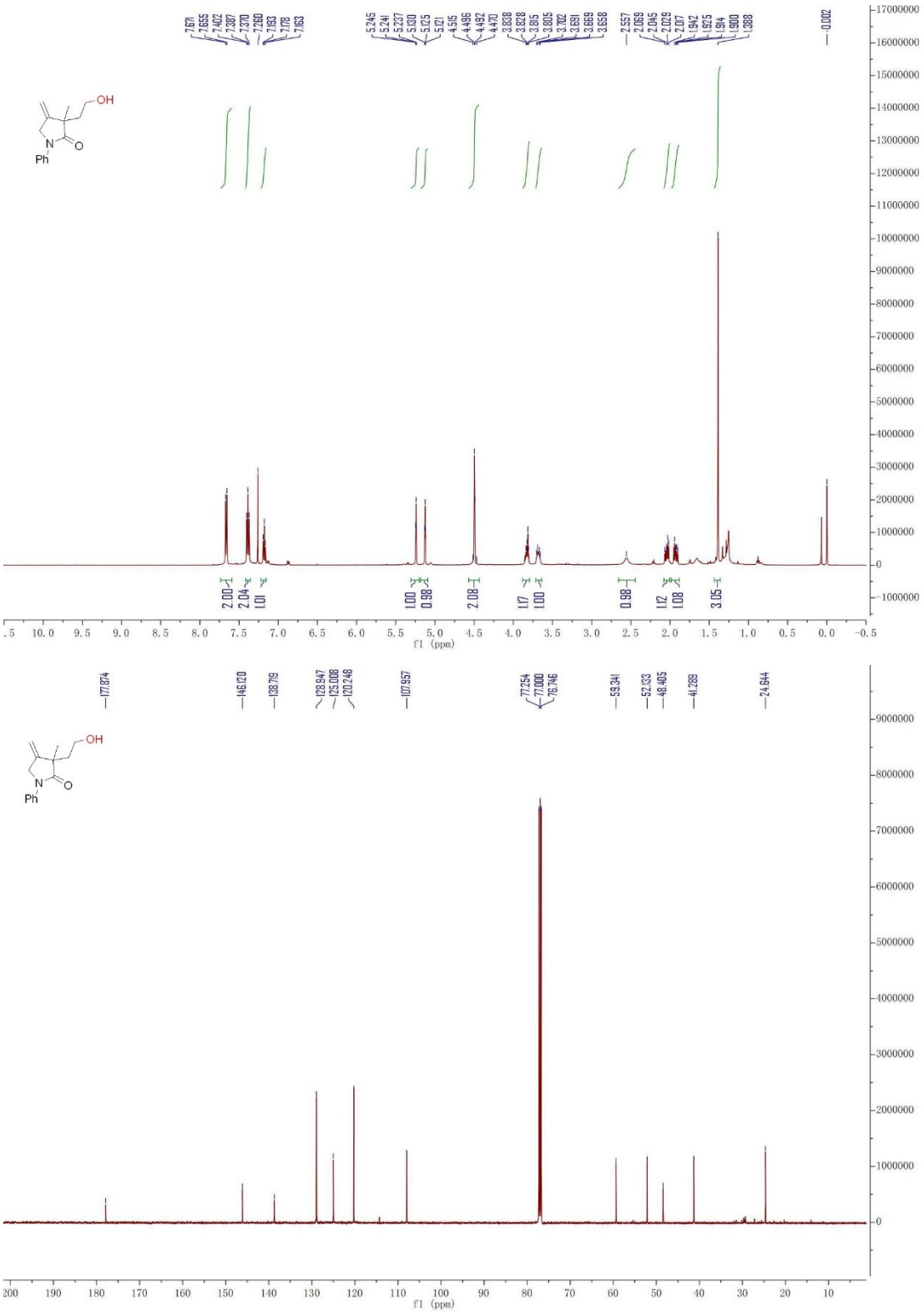

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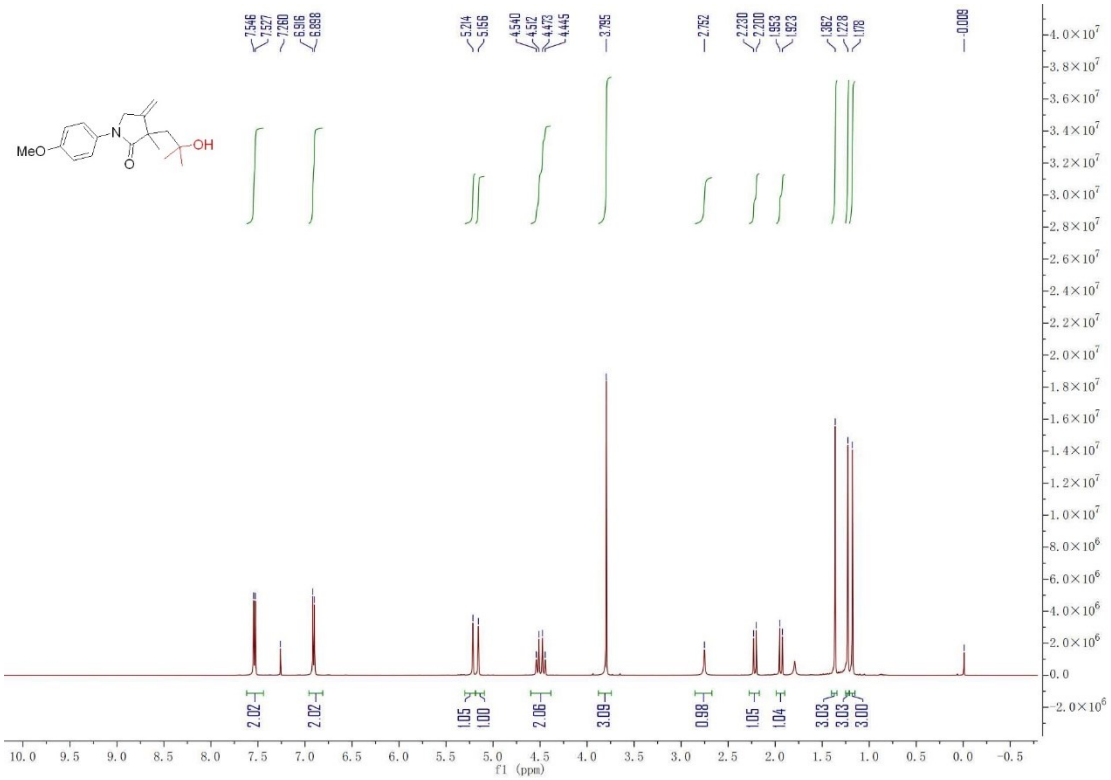

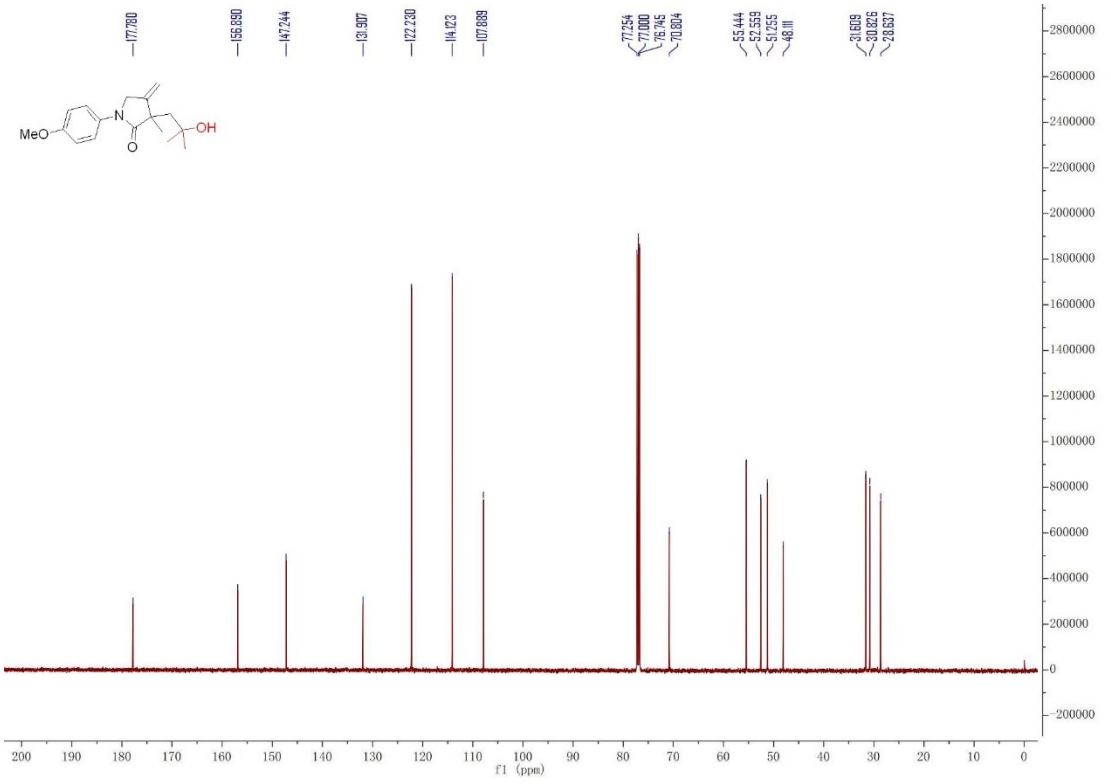

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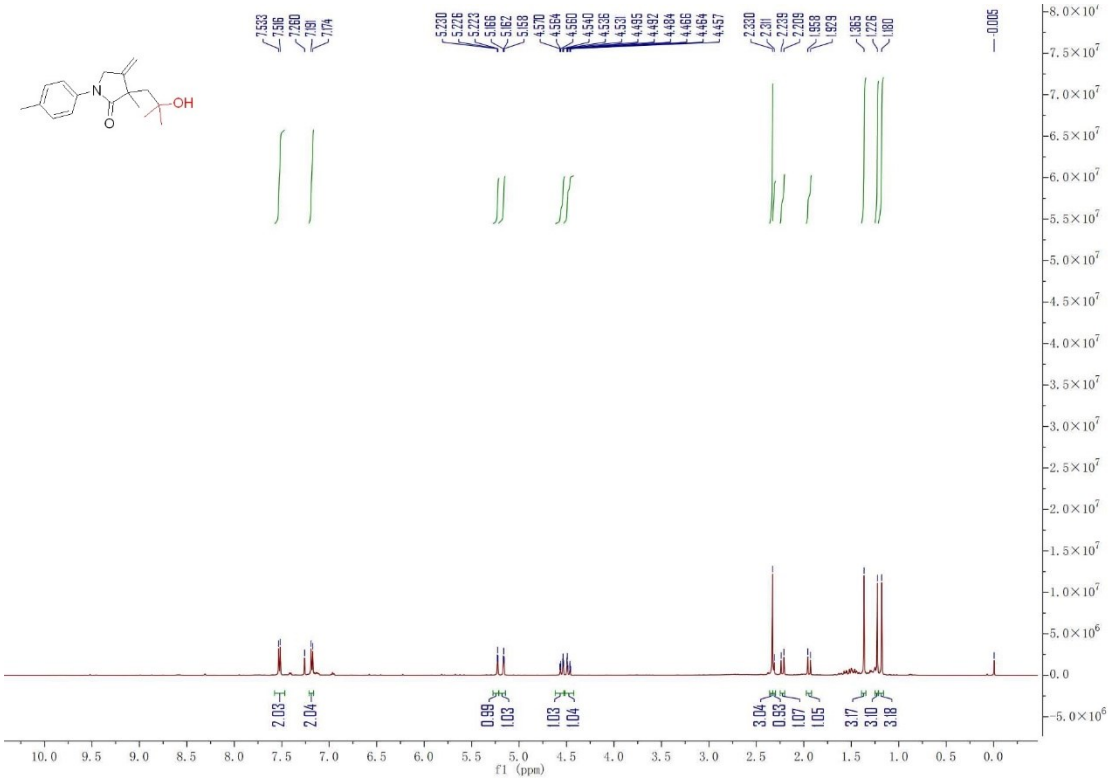
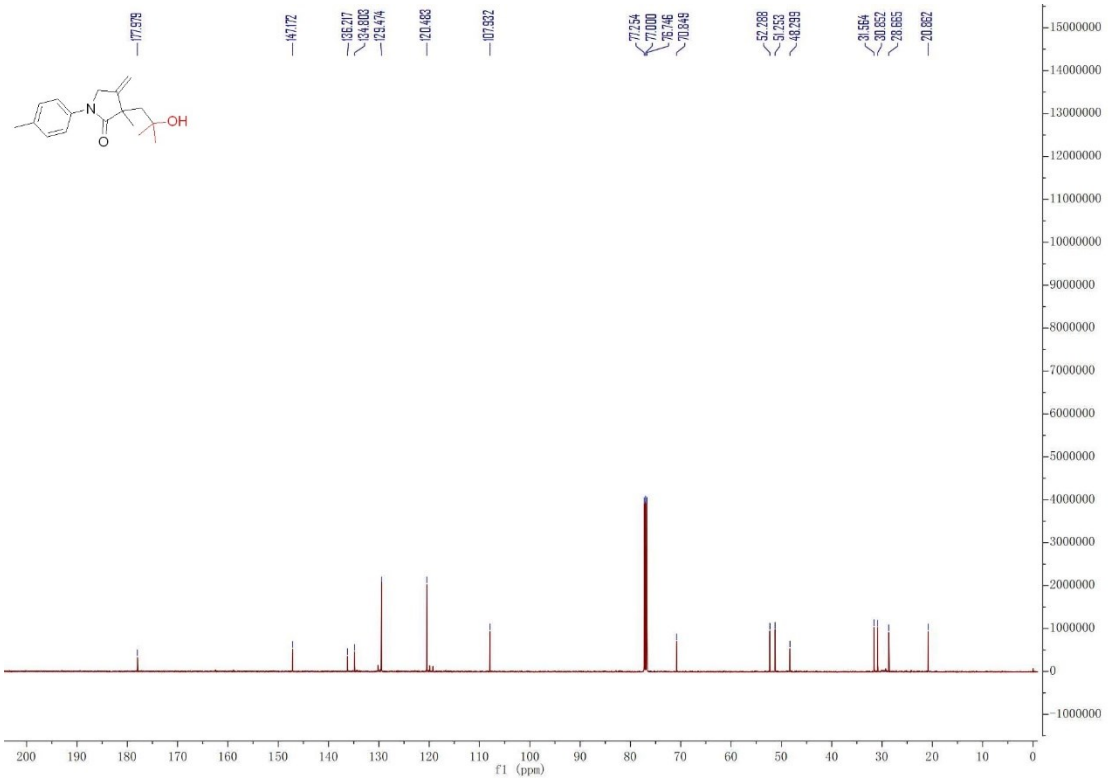
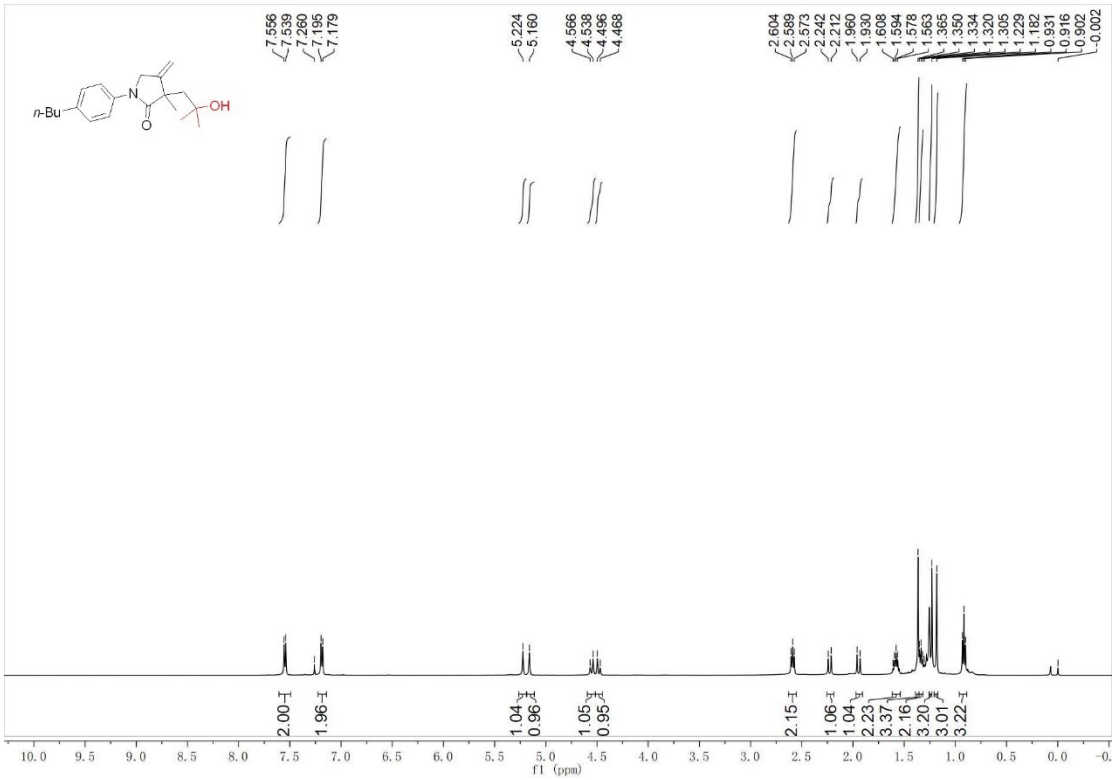
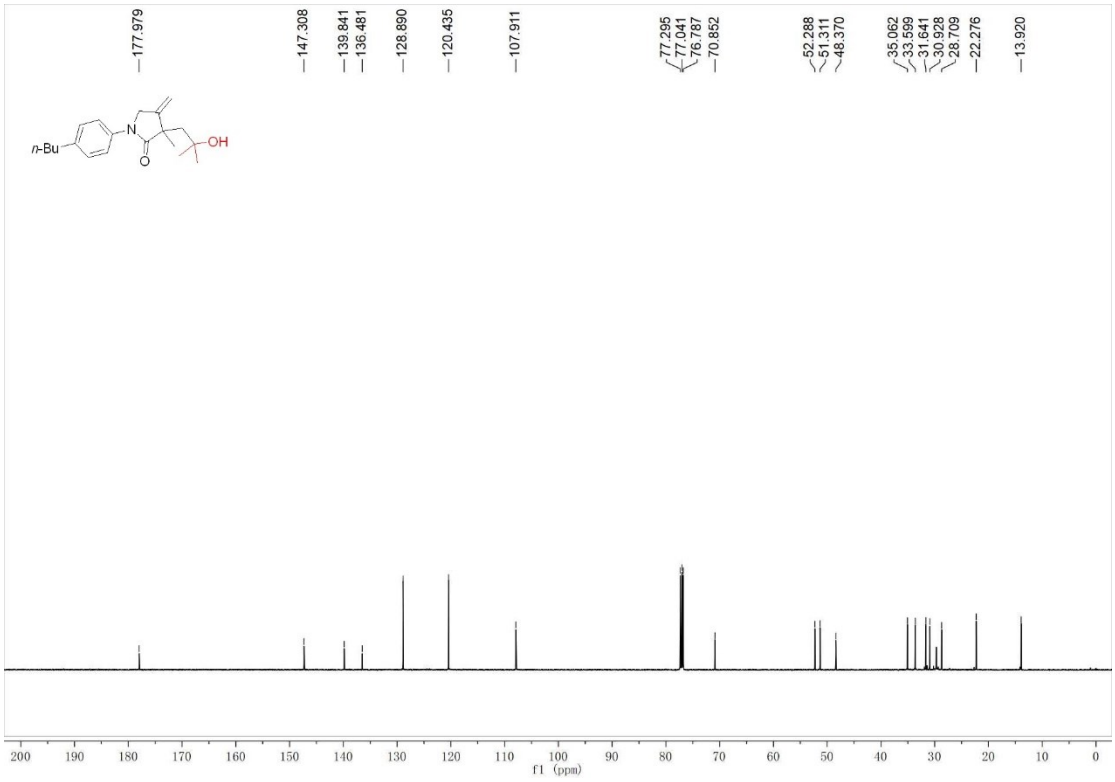


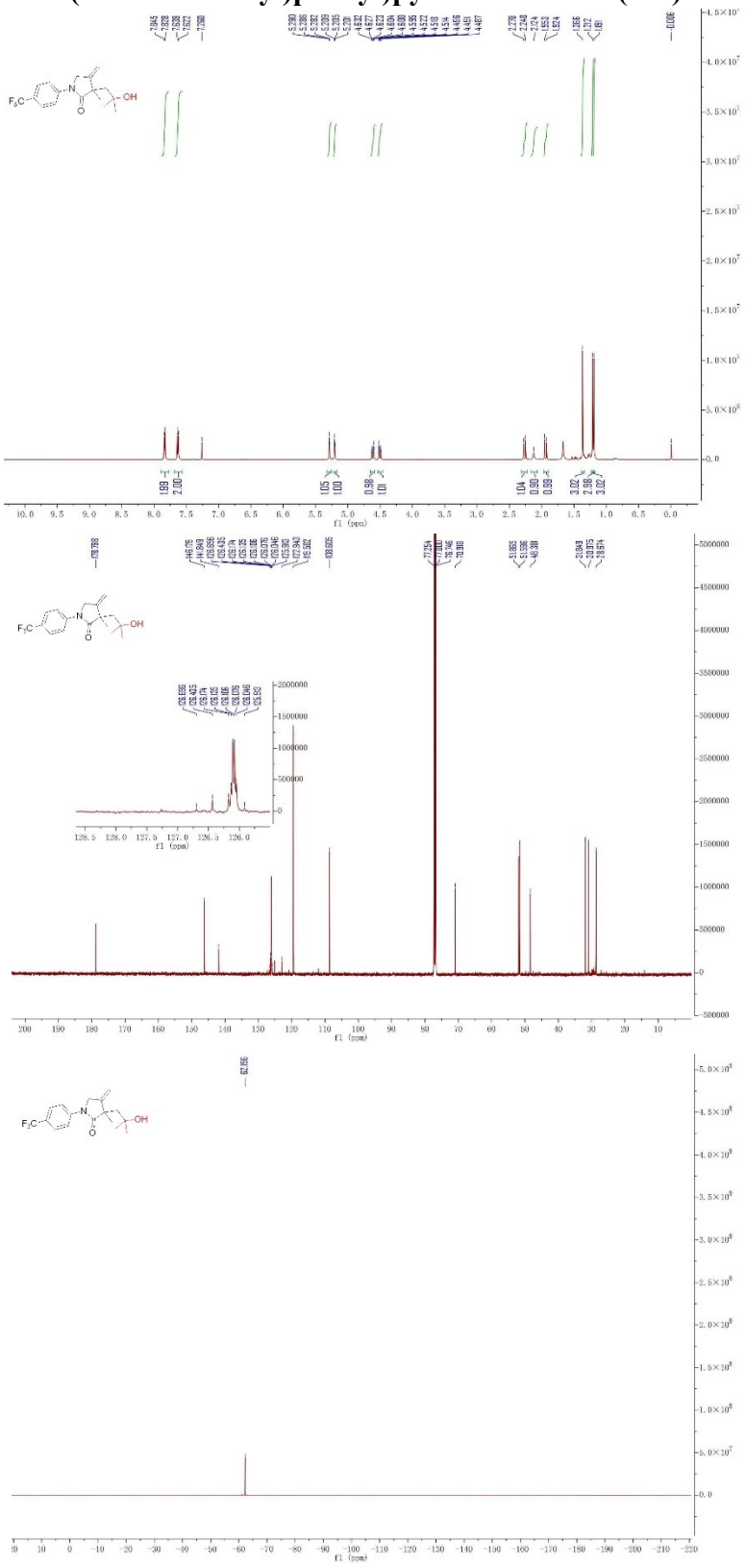


1-(4-Butylphenyl)-3-(2-hydroxy-2-methylpropyl)-3-methyl-4-methylenepyrrolidin-2-one (3da)

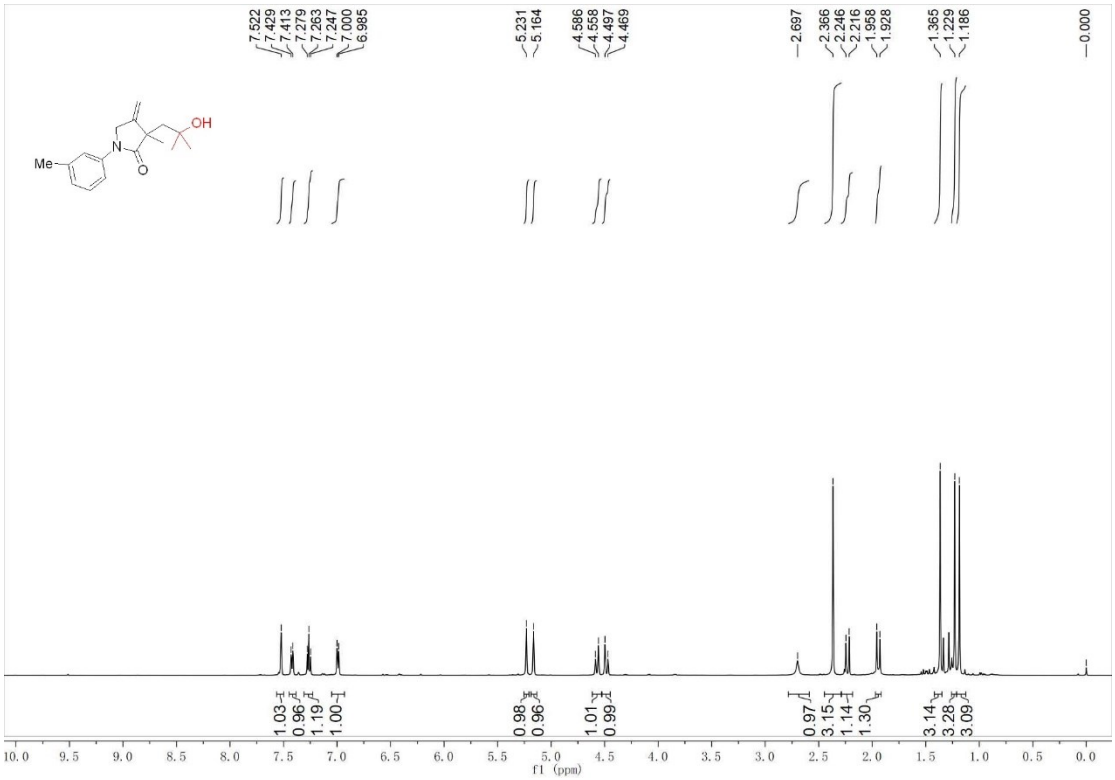


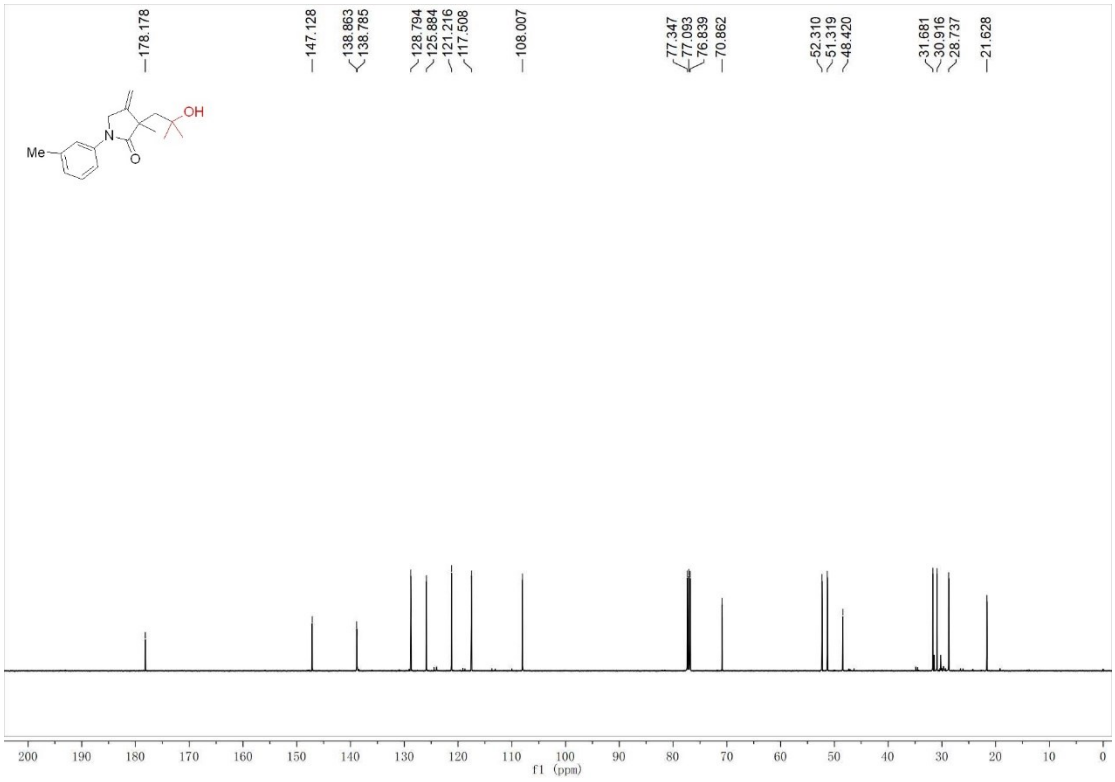


3-(2-Hydroxy-2-methylpropyl)-3-methyl-4-methylene-1-(4-(trifluoromethyl)phenyl)pyrrolidin-2-one (3ea)



3-(2-Hydroxy-2-methylpropyl)-3-methyl-4-methylene-1-(*m*-tolyl)pyrrolidin-2-one (3fa)





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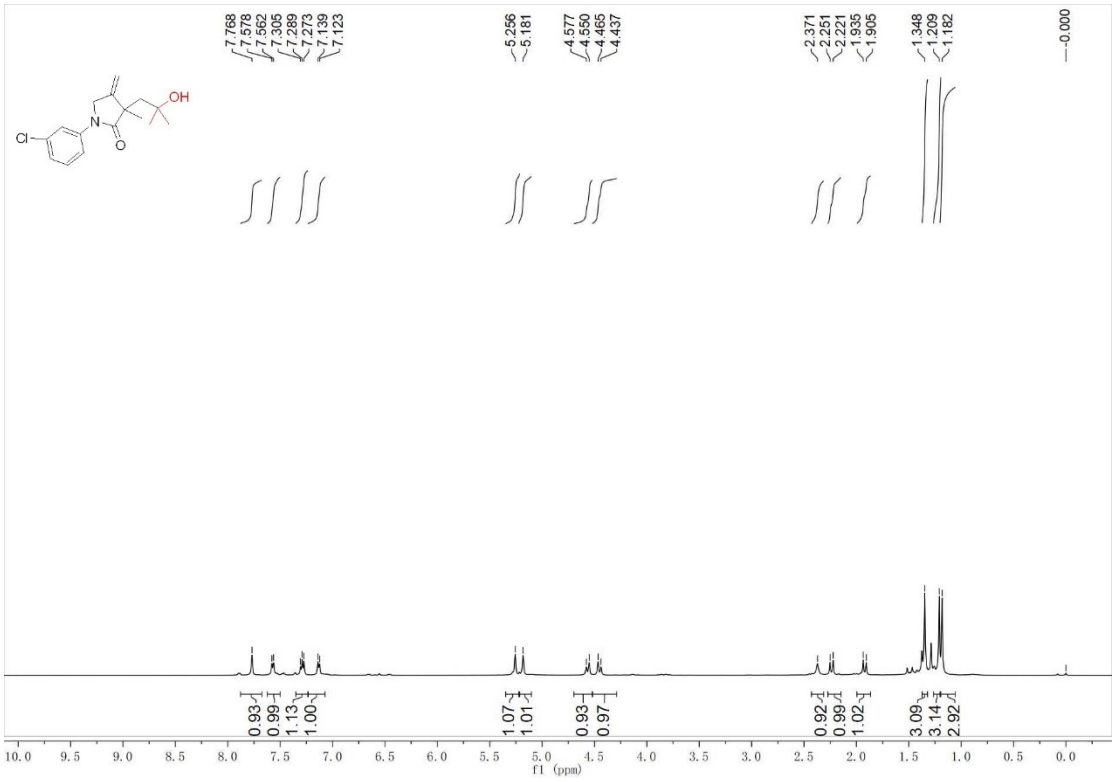
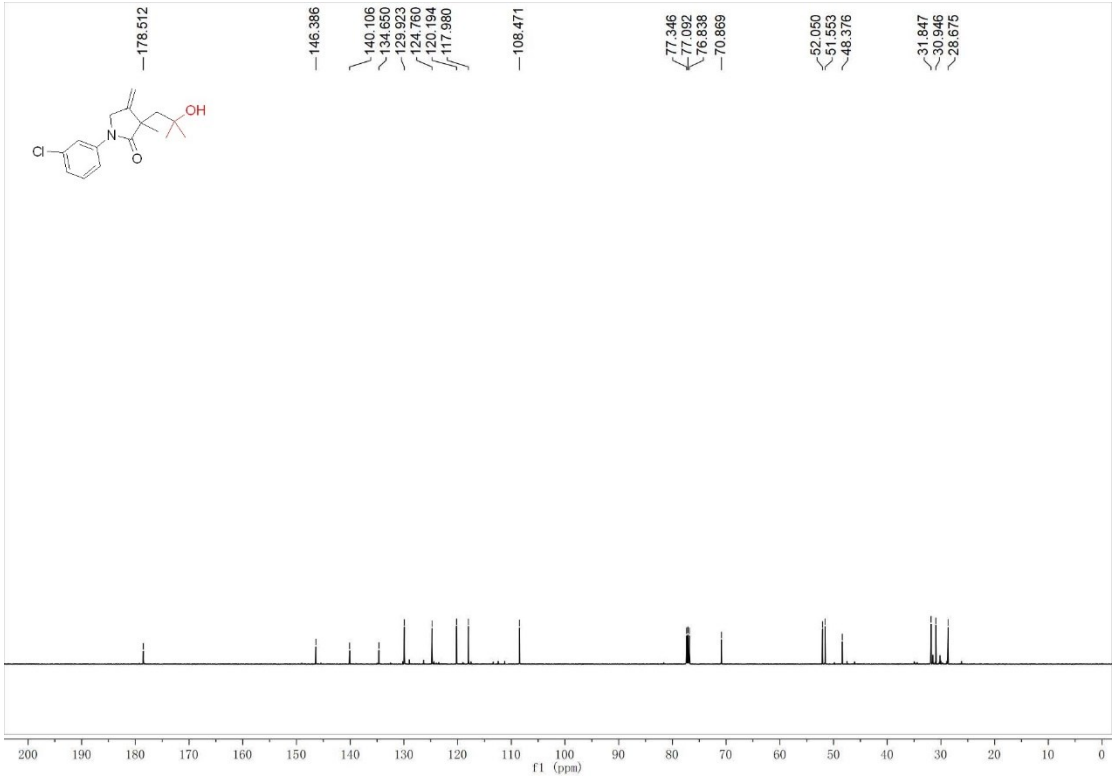
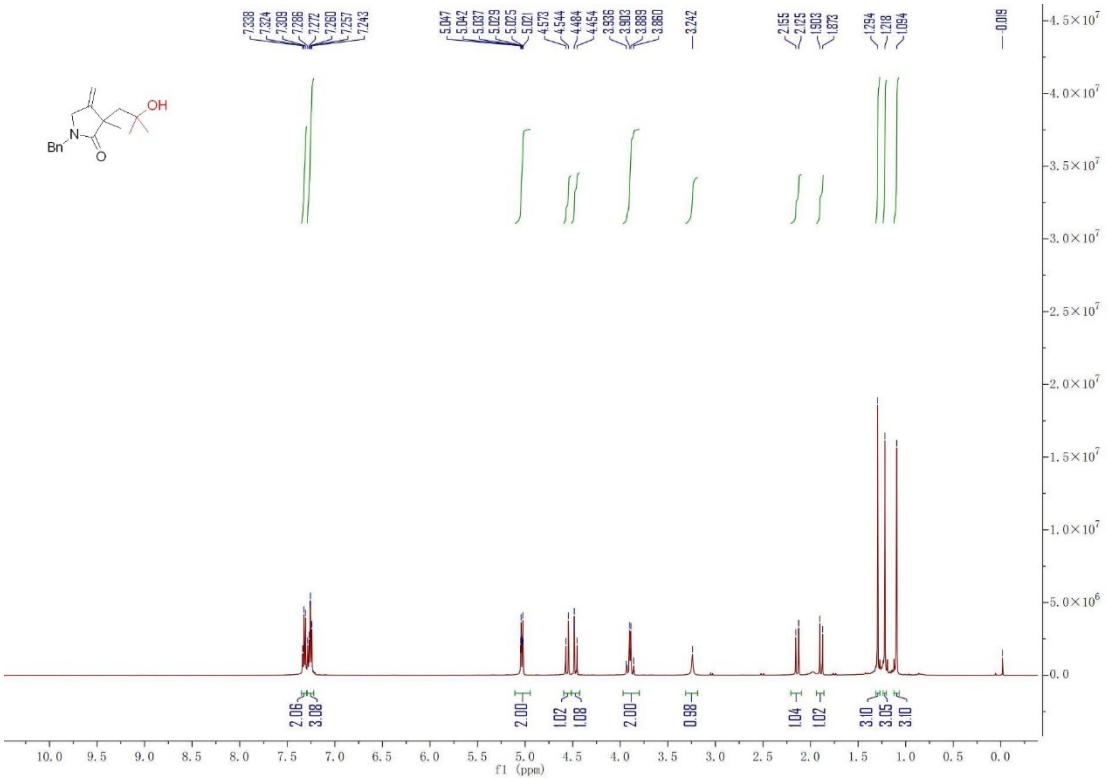
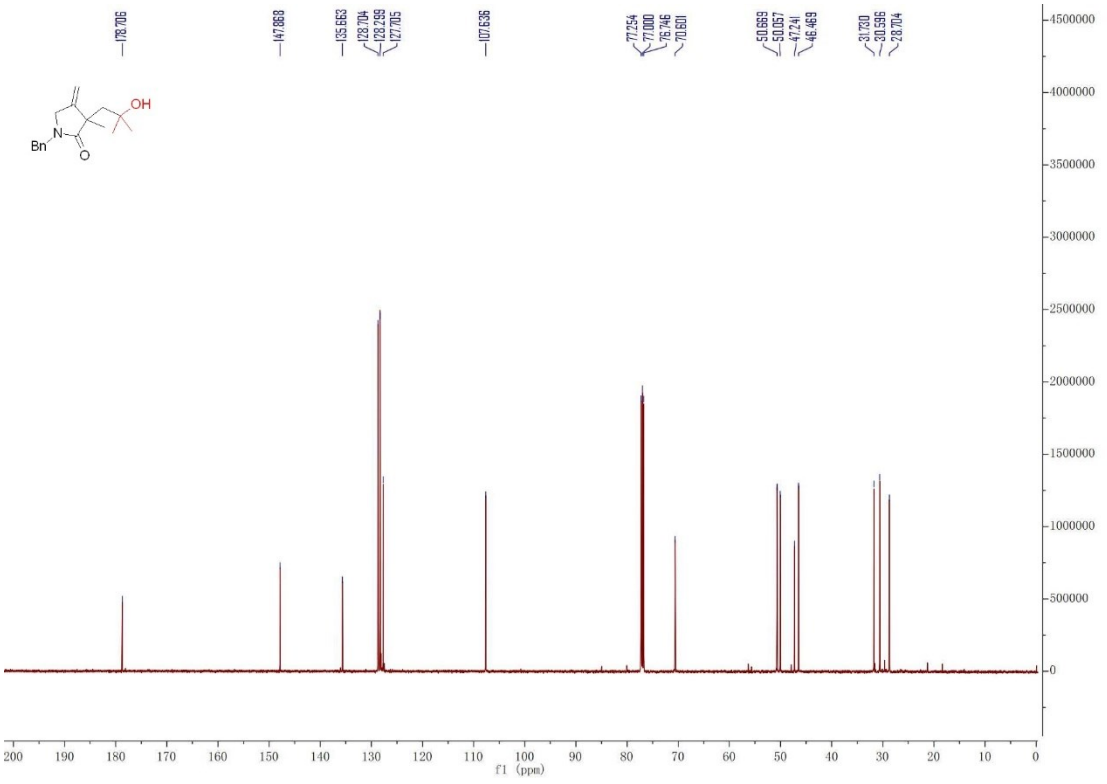


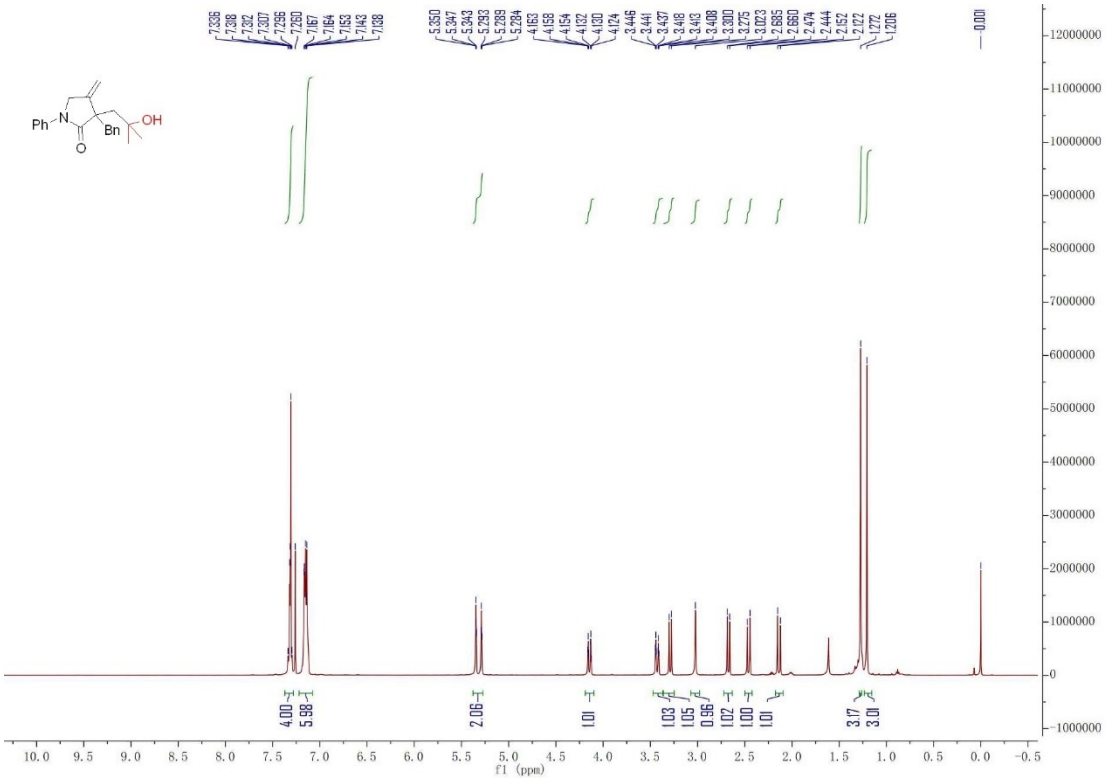


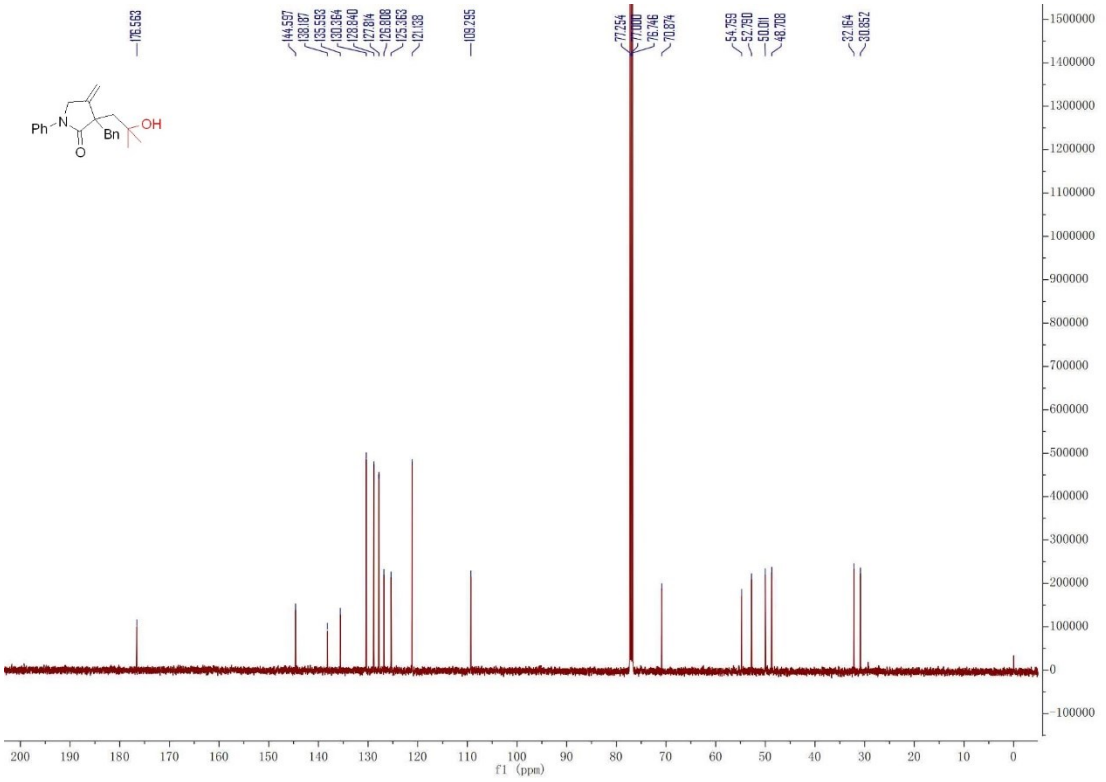
1-Benzyl-3-(2-hydroxy-2-methylpropyl)-3-methyl-4-methylenepyrrolidin-2-one (3ha)



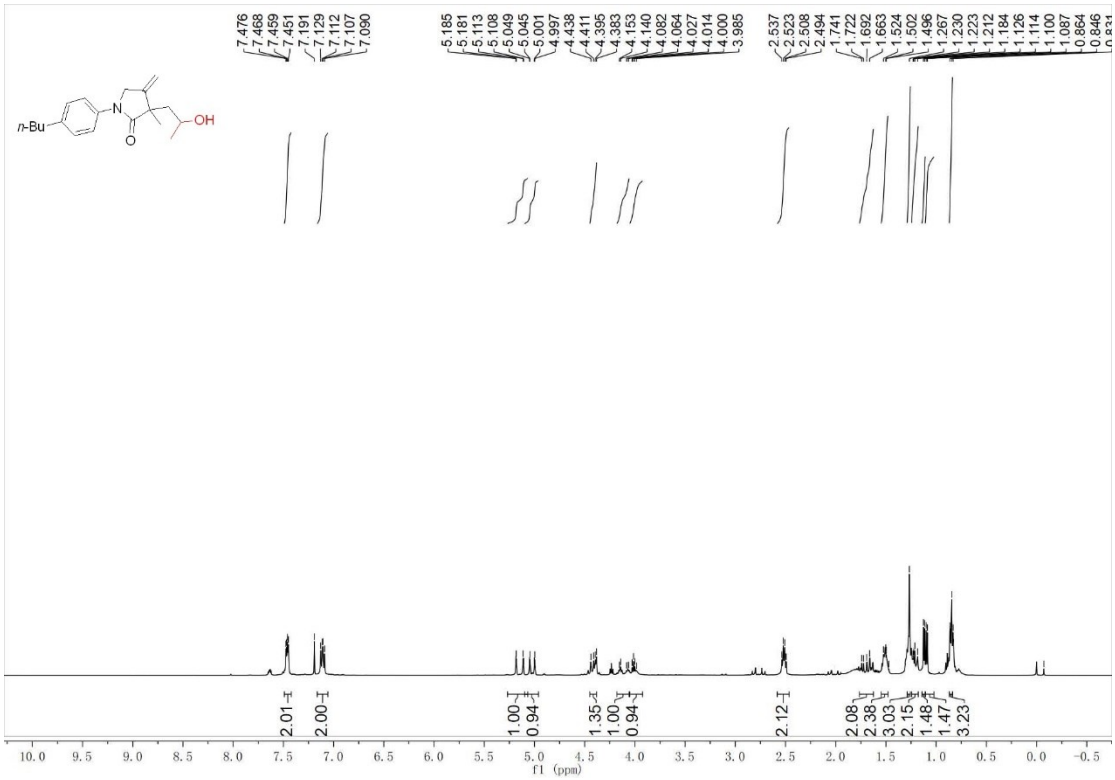


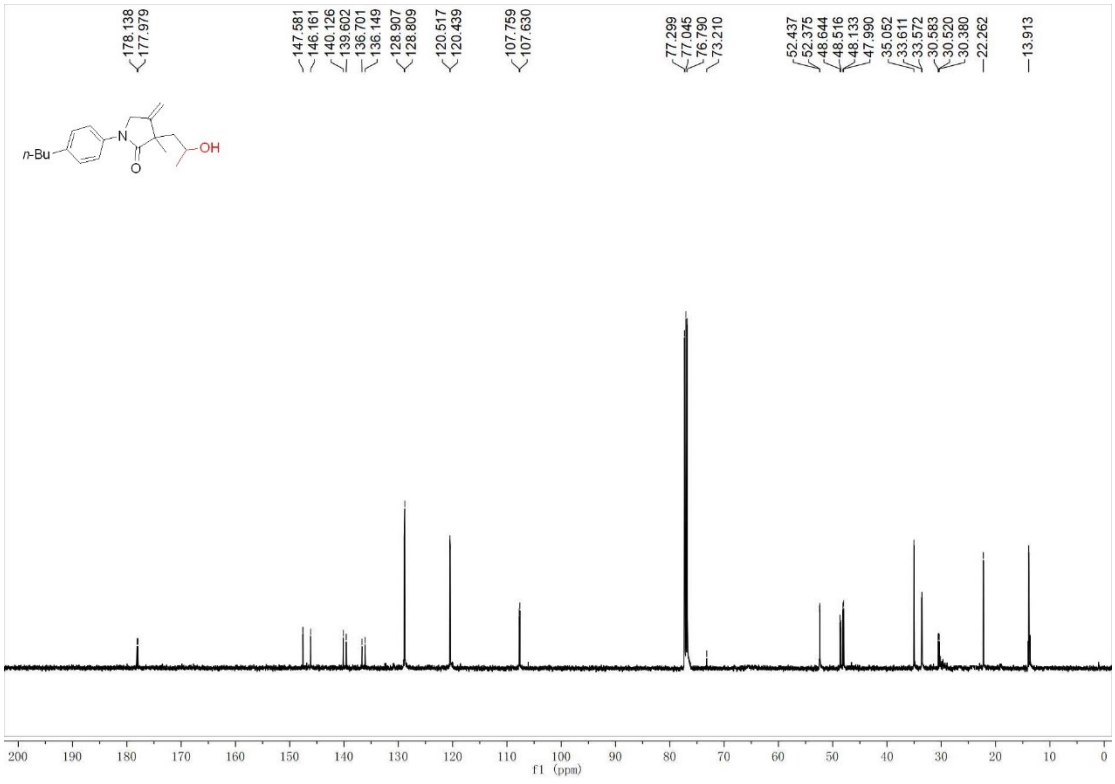
3-Benzyl-3-(2-hydroxy-2-methylpropyl)-4-methylene-1-phenylpyrrolidin-2-one (3ia)



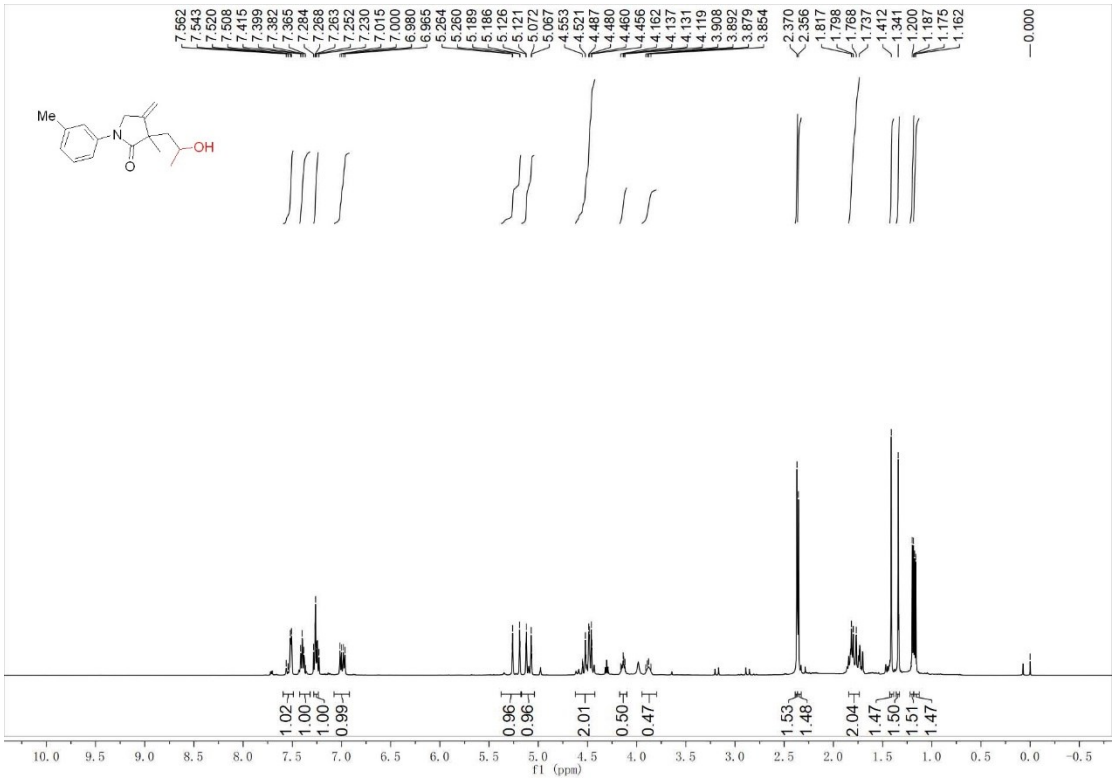


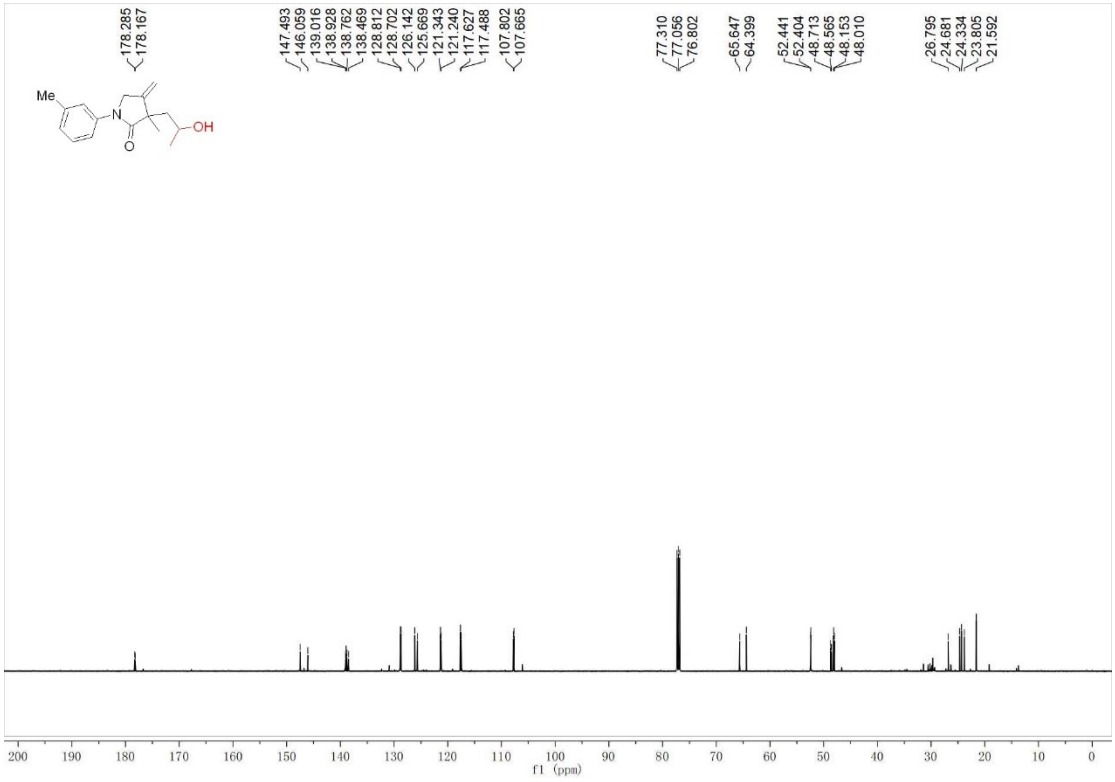
1-(4-Butylphenyl)-3-(2-hydroxypropyl)-3-methyl-4-methylenepyrrolidin-2-one (3db)



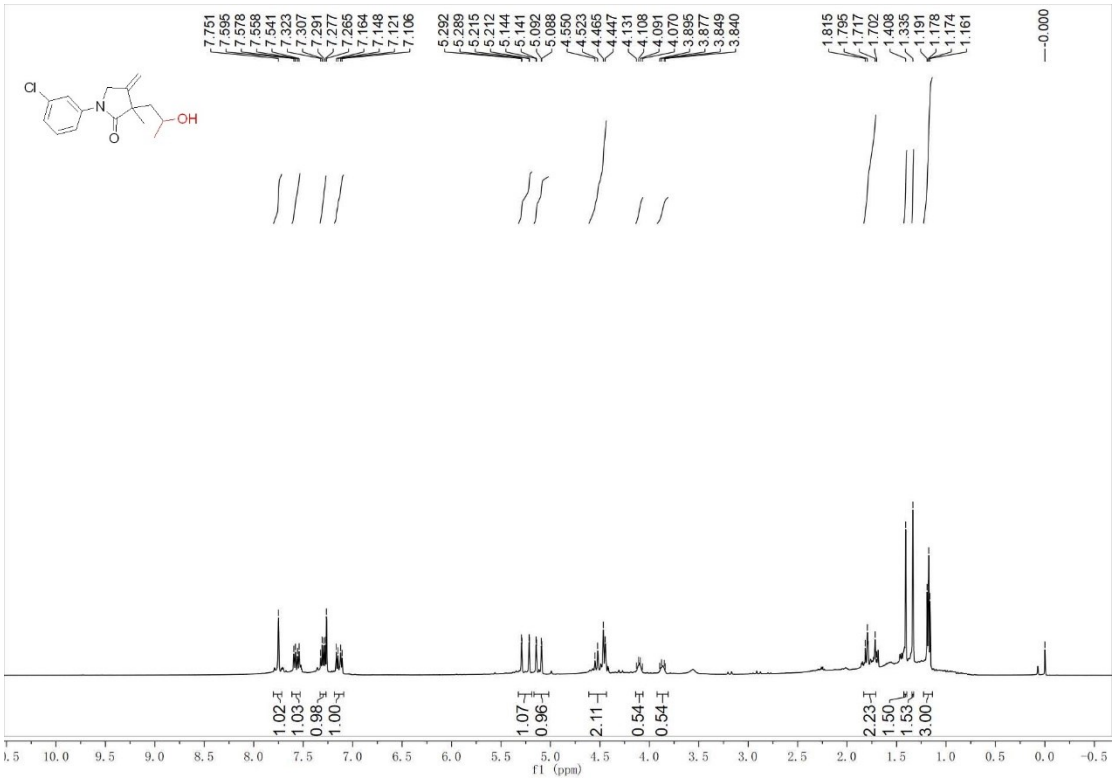


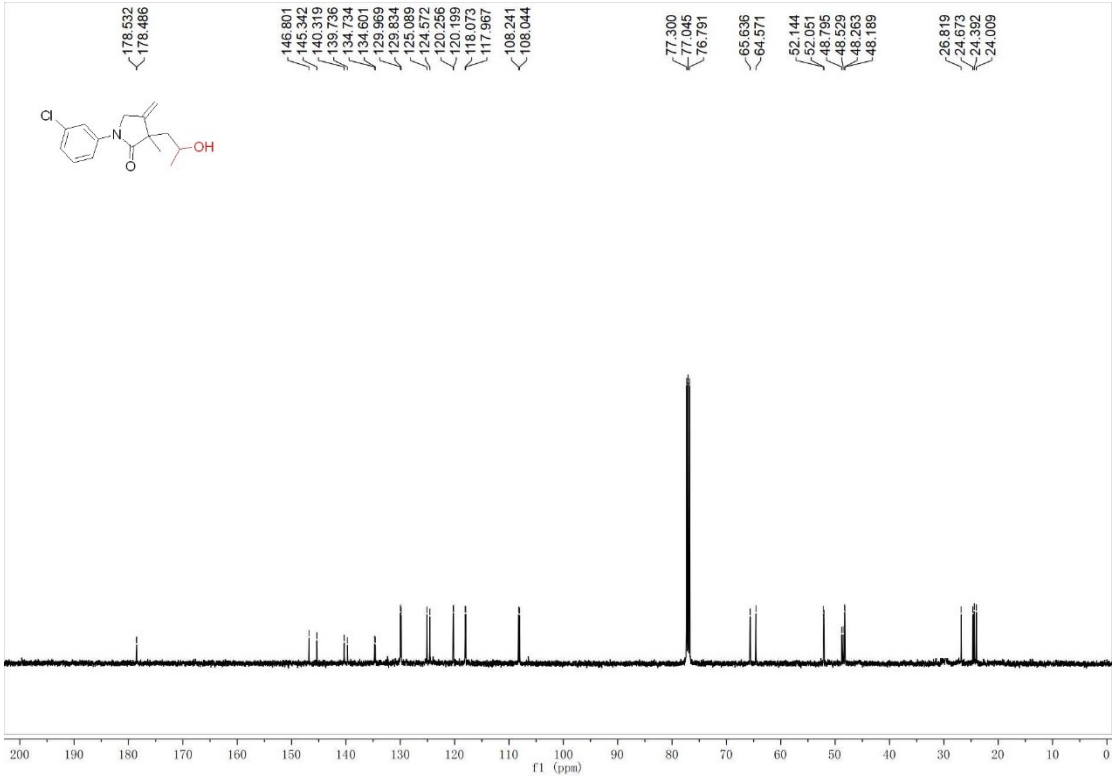
3-(2-Hydroxypropyl)-3-methyl-4-methylene-1-(*m*-tolyl)pyrrolidin-2-one (3fb)



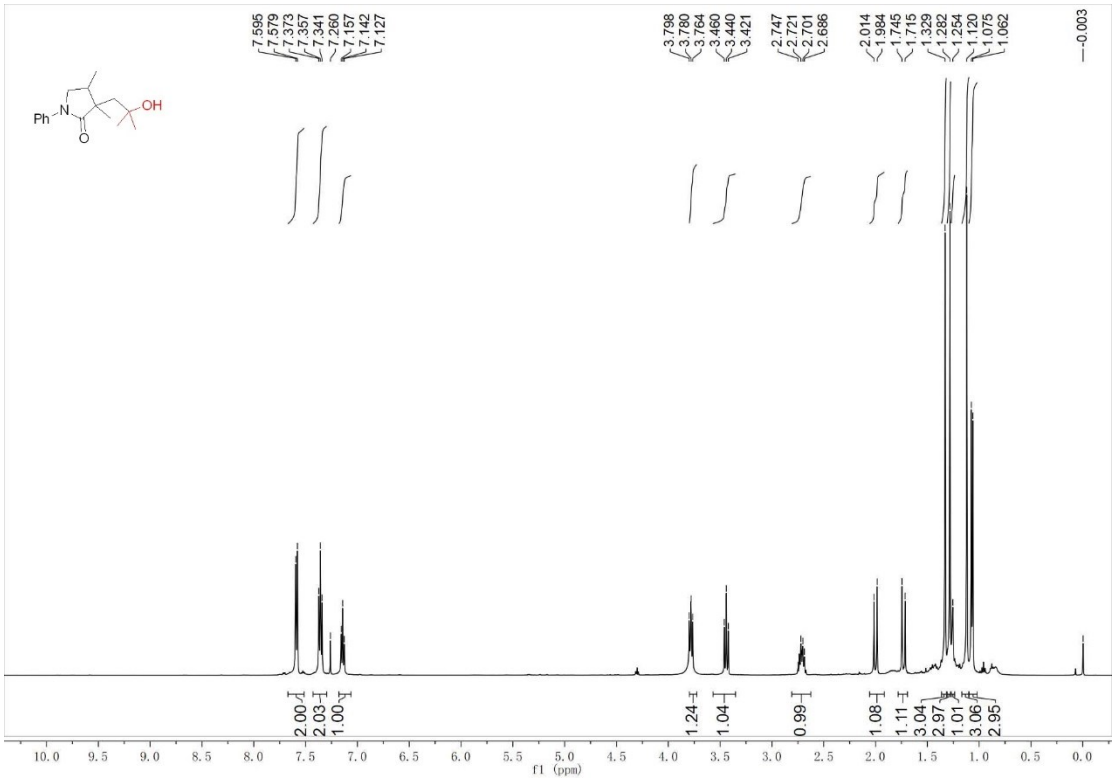


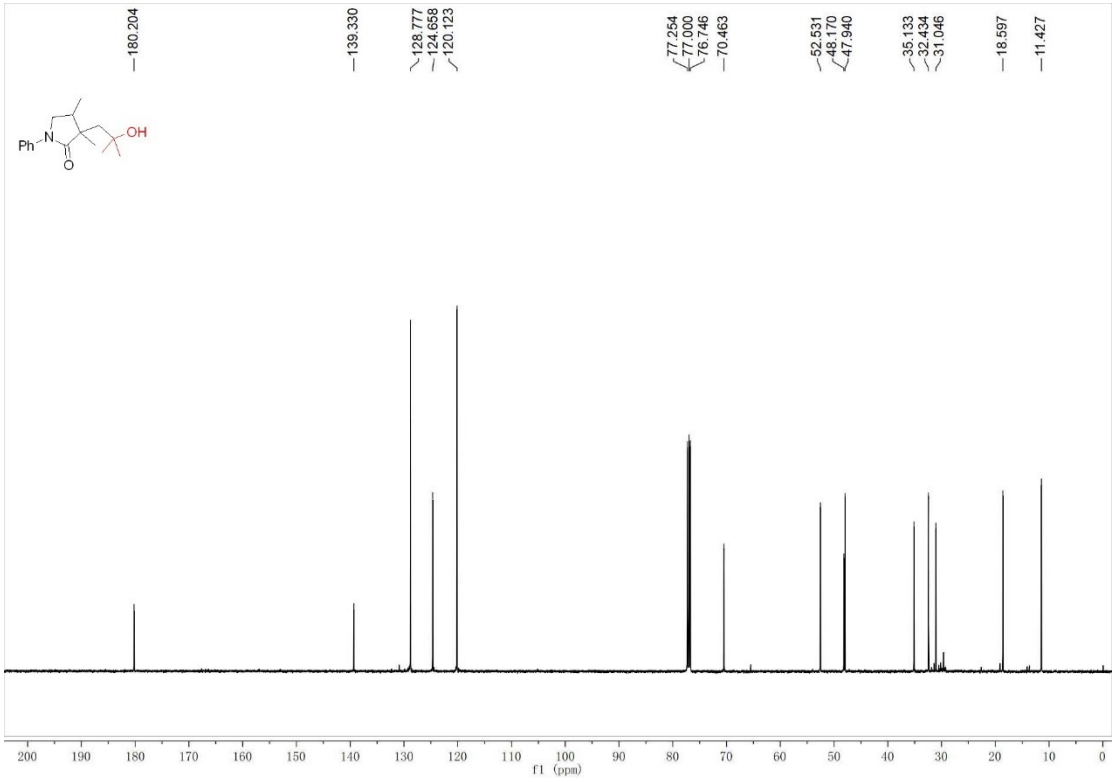
1-(3-Chlorophenyl)-3-(2-hydroxypropyl)-3-methyl-4-methylenepyrrolidin-2-one (3gb)



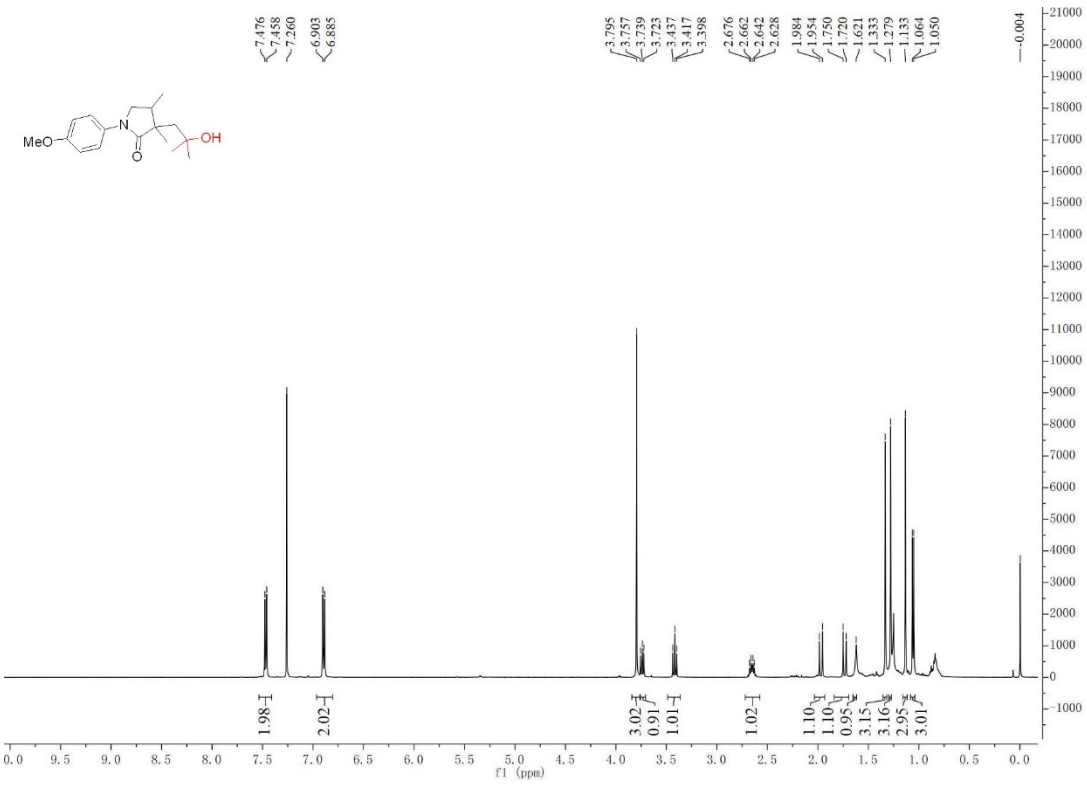


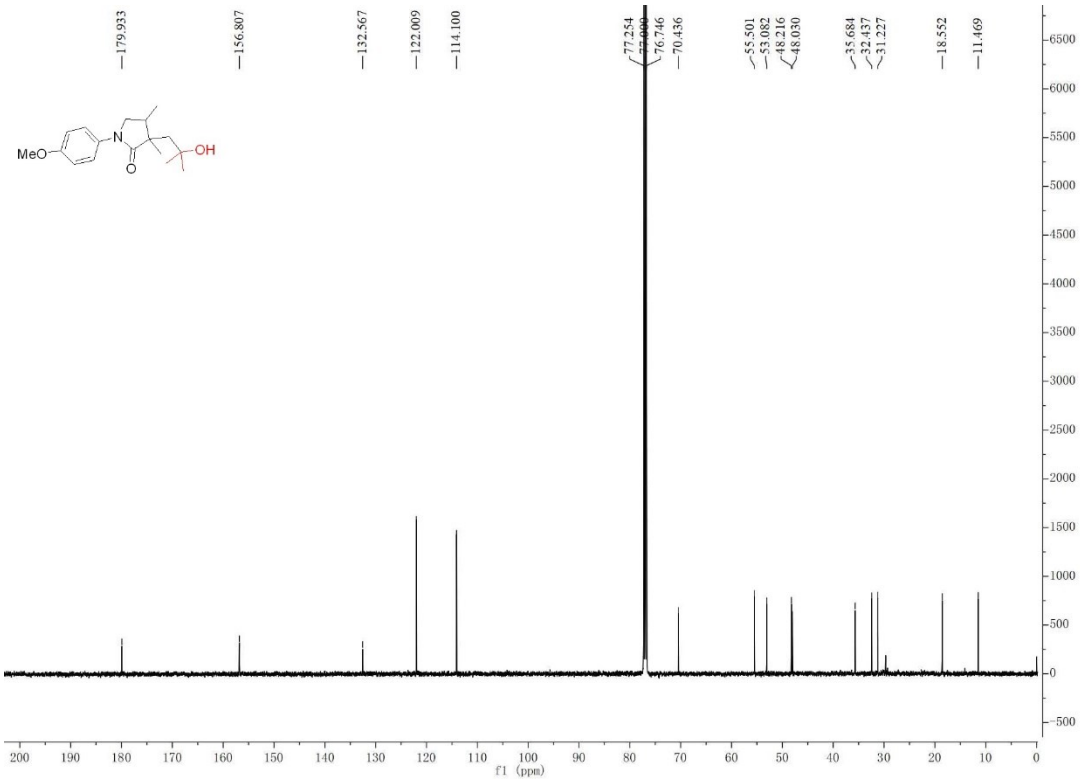
3-(2-Hydroxy-2-methylpropyl)-3,4-dimethyl-1-phenylpyrrolidin-2-one (5aa)



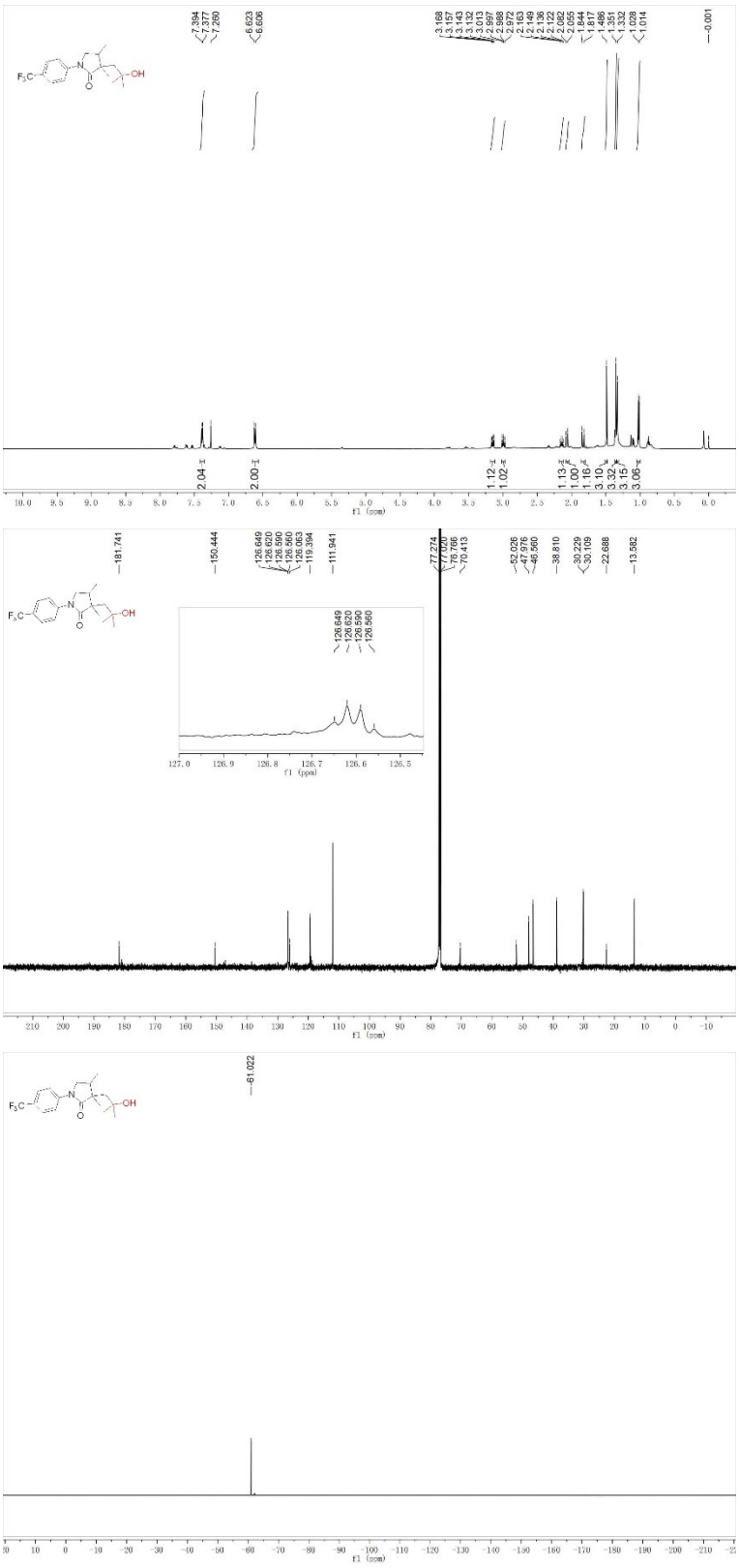


3-(2-Hydroxy-2-methylpropyl)-1-(4-methoxyphenyl)-3,4-dimethylpyrrolidin-2-one (5ba)





3-(2-Hydroxy-2-methylpropyl)-3,4-dimethyl-1-(4-(trifluoromethyl)phenyl)pyrrolidin-2-one (5ca)



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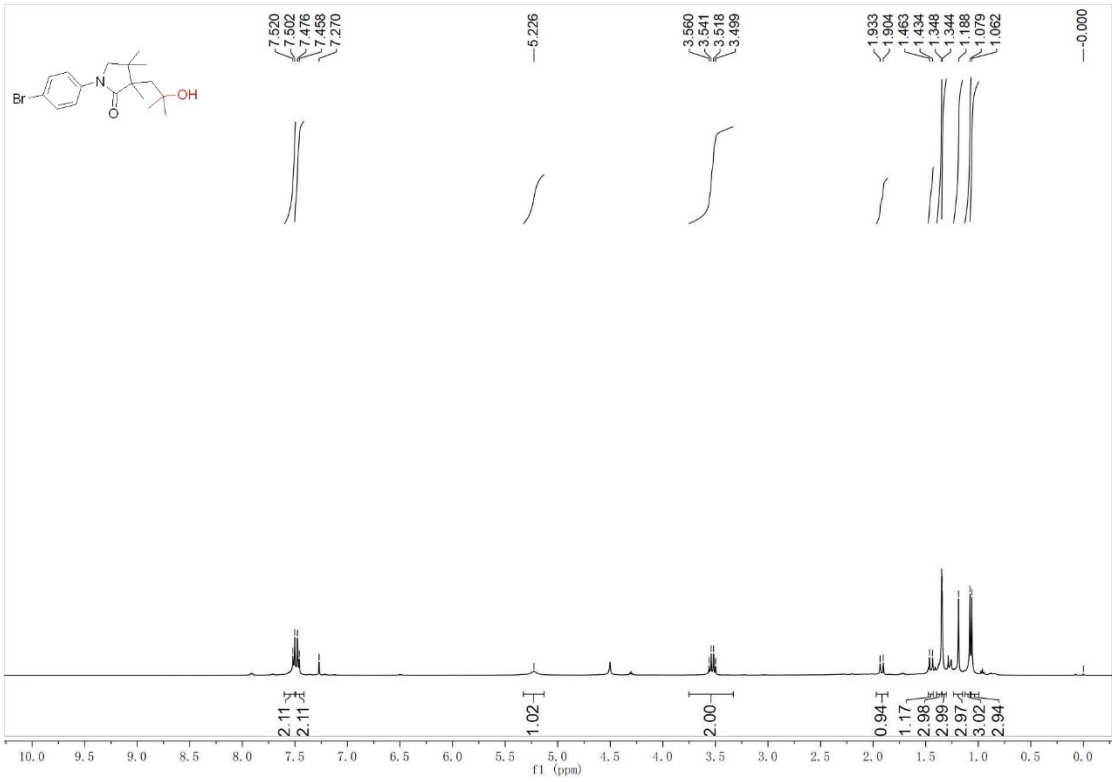
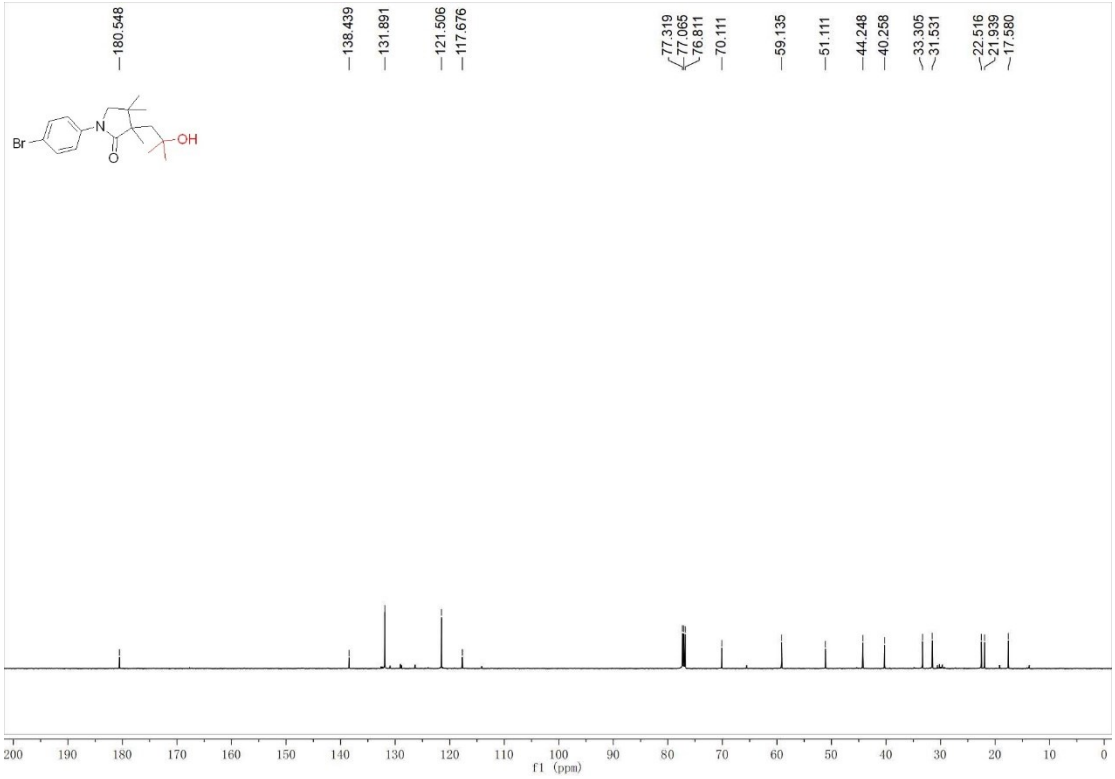
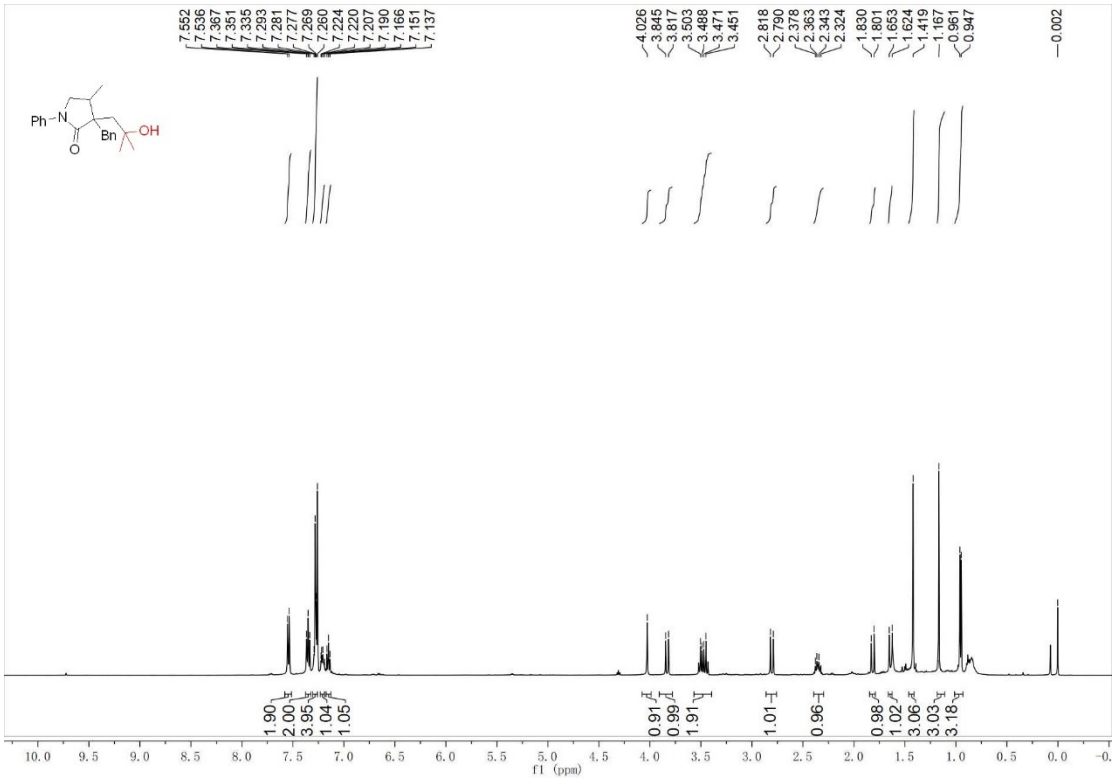
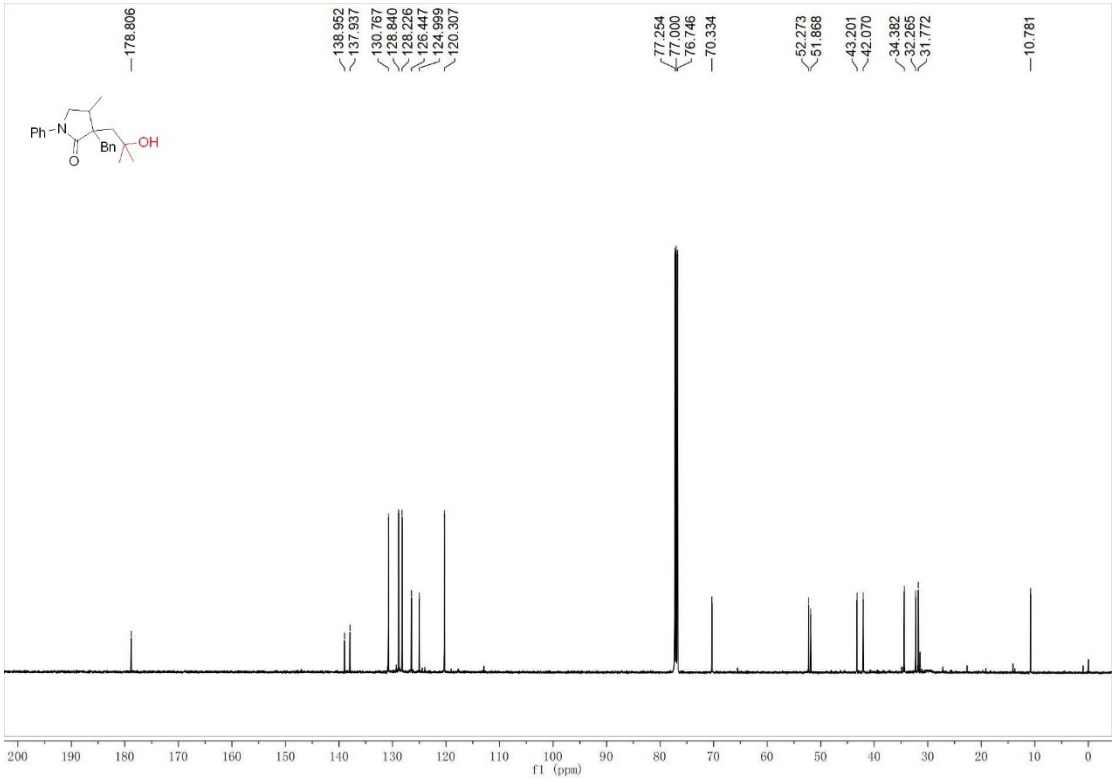


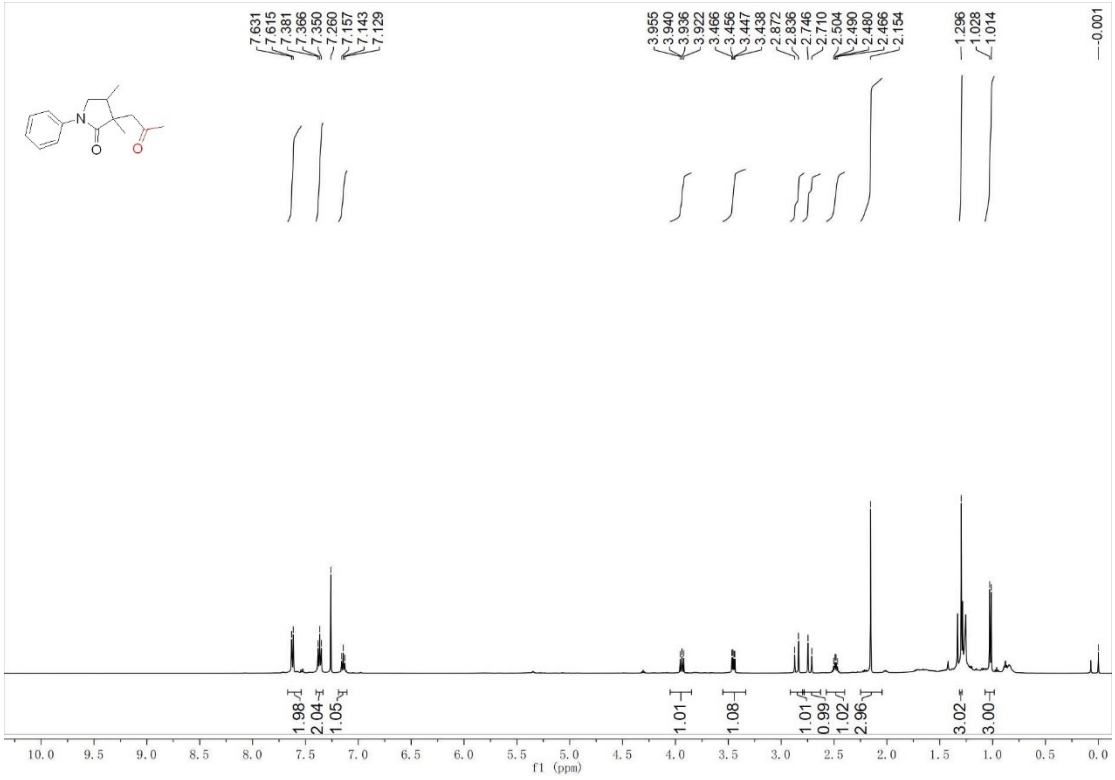


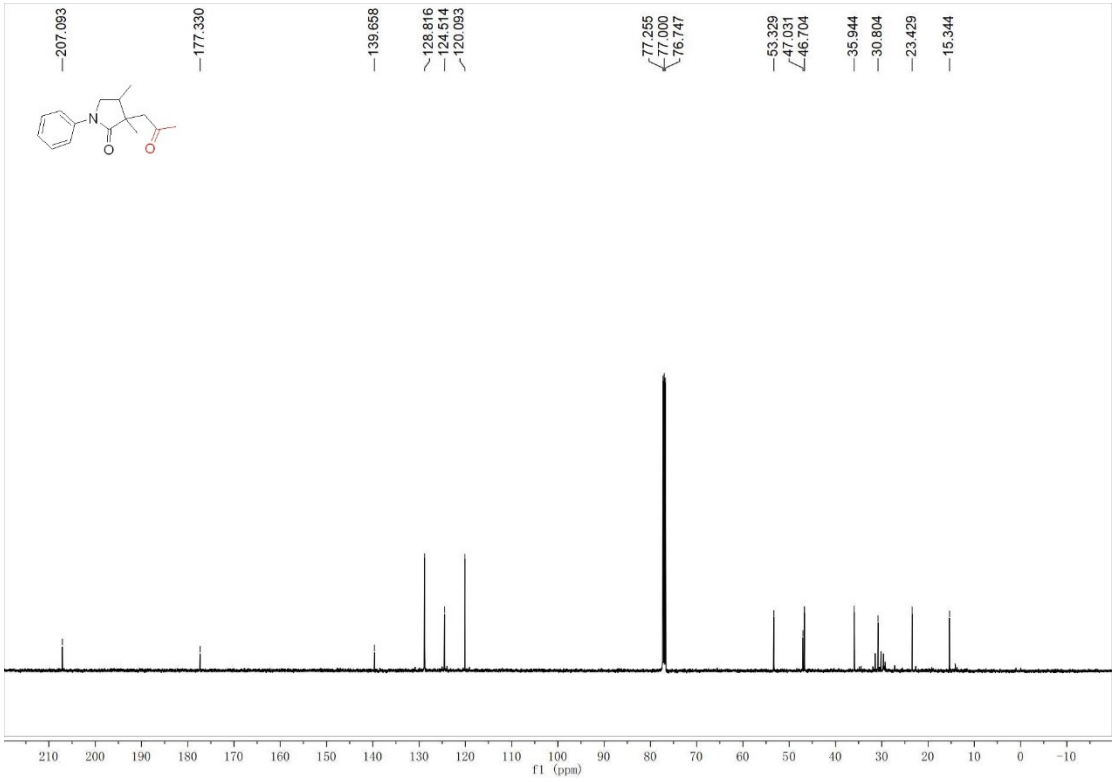
3-Benzyl-3-(2-hydroxy-2-methylpropyl)-4-methyl-1-phenylpyrrolidin-2-one (5ea)



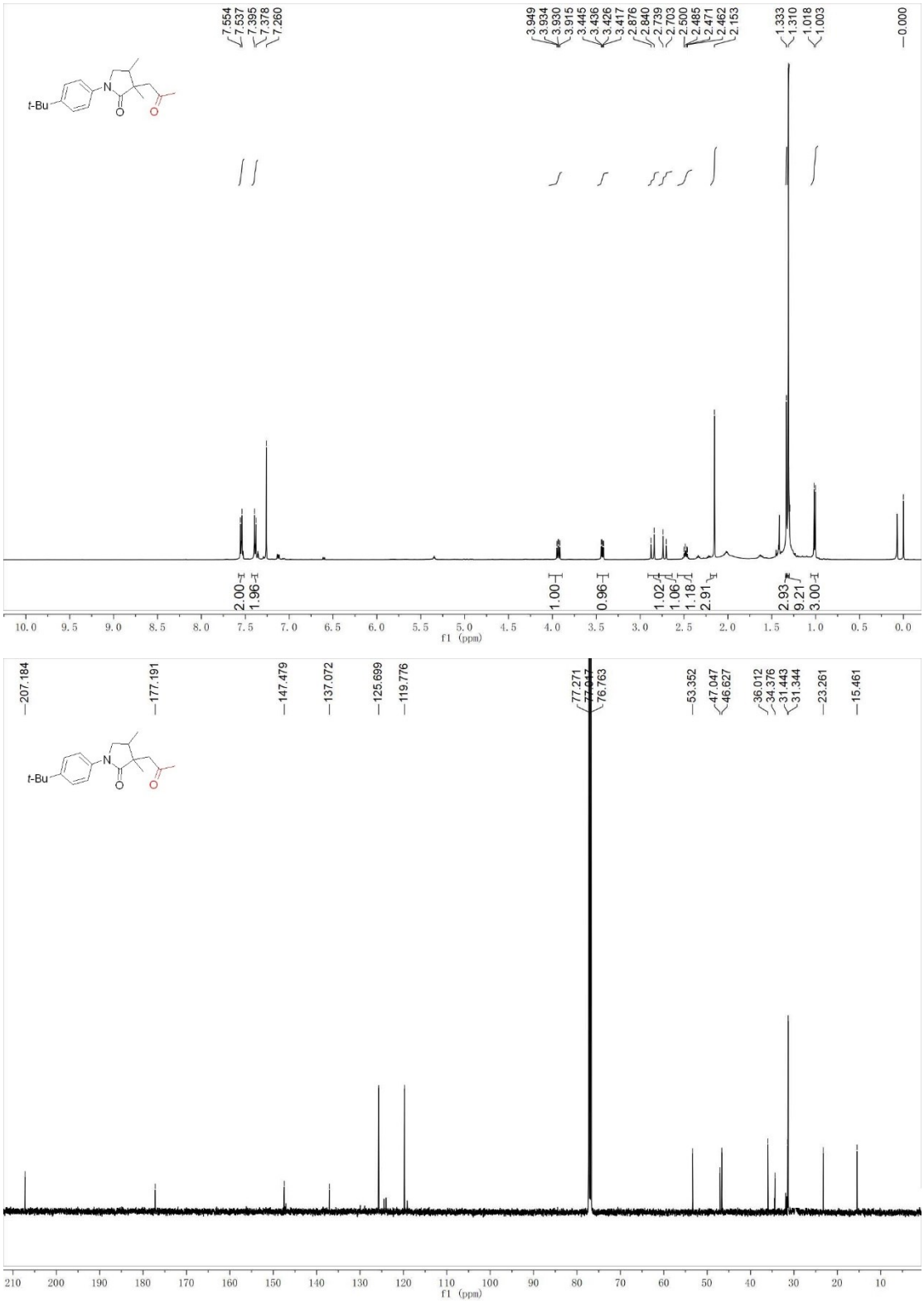


3,4-Dimethyl-3-(2-oxopropyl)-1-phenylpyrrolidin-2-one (6ab)

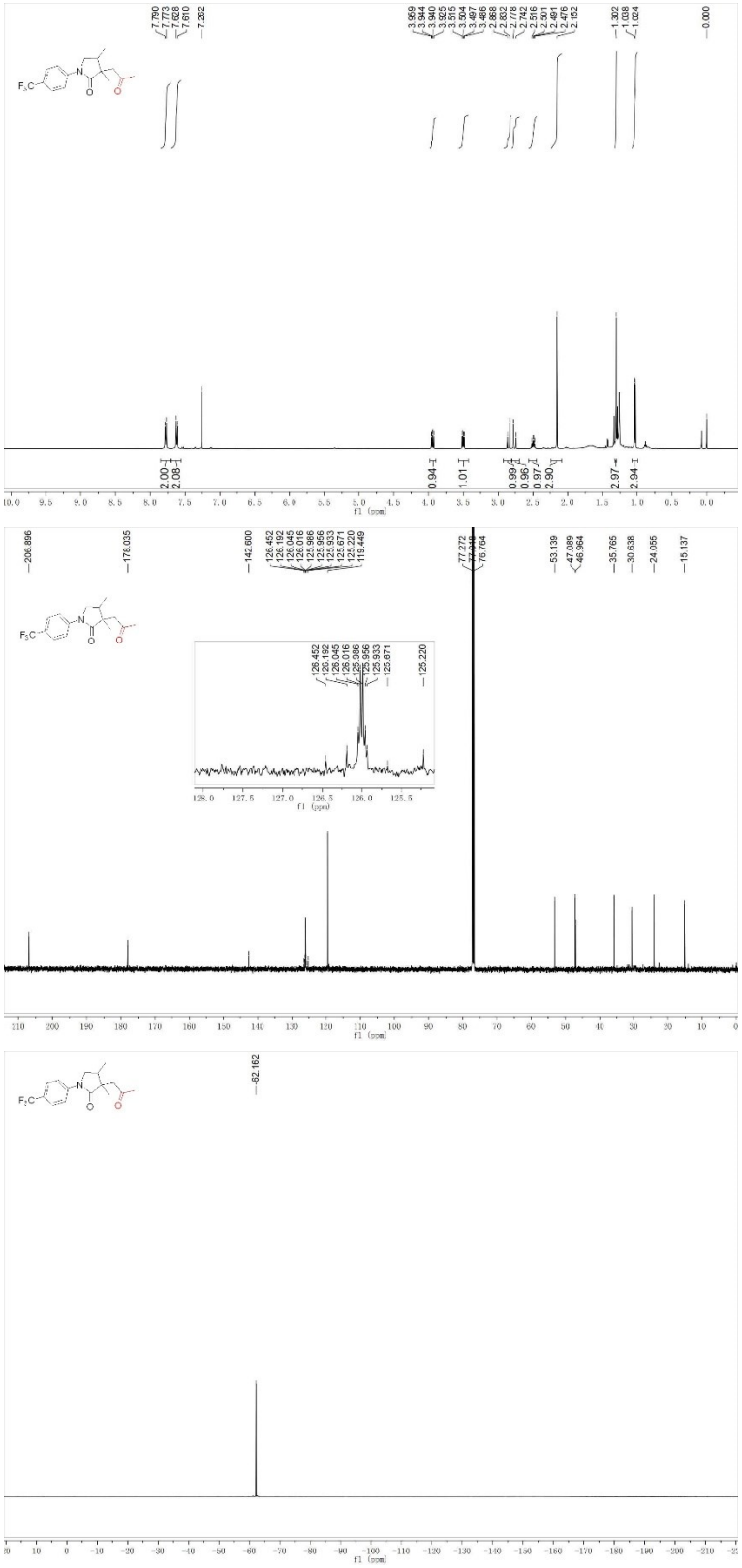




1-(4-(*tert*-Butyl)phenyl)-3,4-dimethyl-3-(2-oxopropyl)pyrrolidin-2-one (6fb)



3,4-Dimethyl-3-(2-oxopropyl)-1-(4-(trifluoromethyl)phenyl)pyrrolidin-2-one (6cb)



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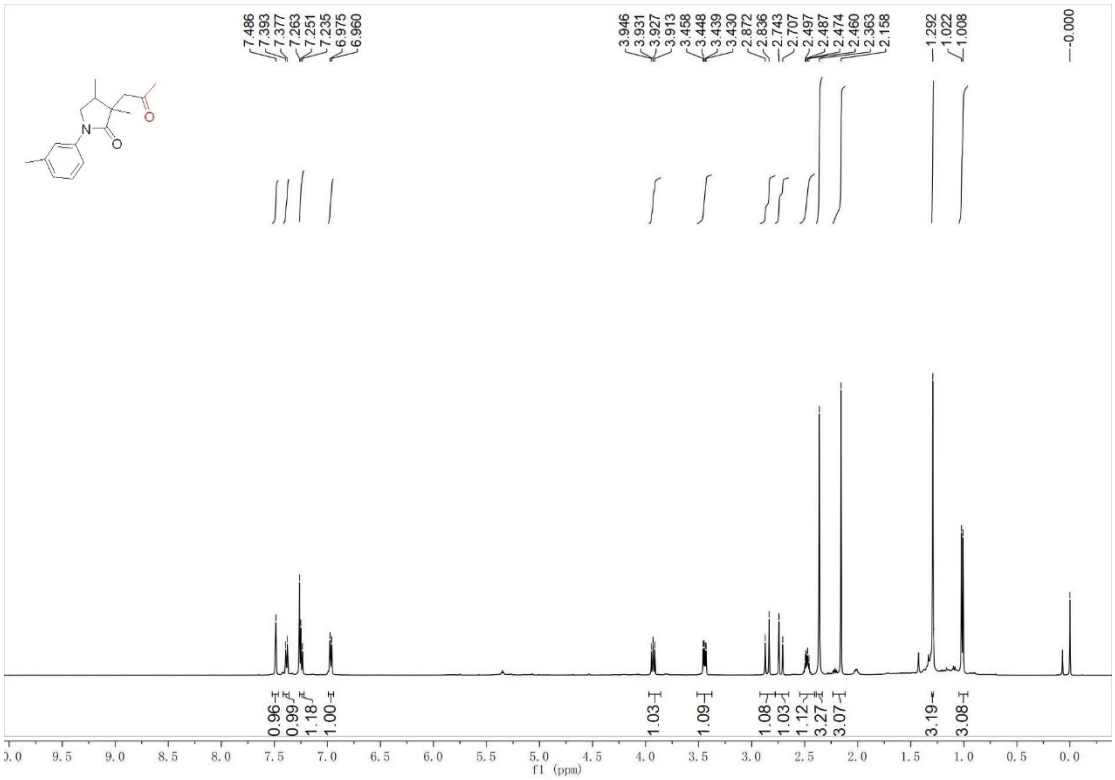
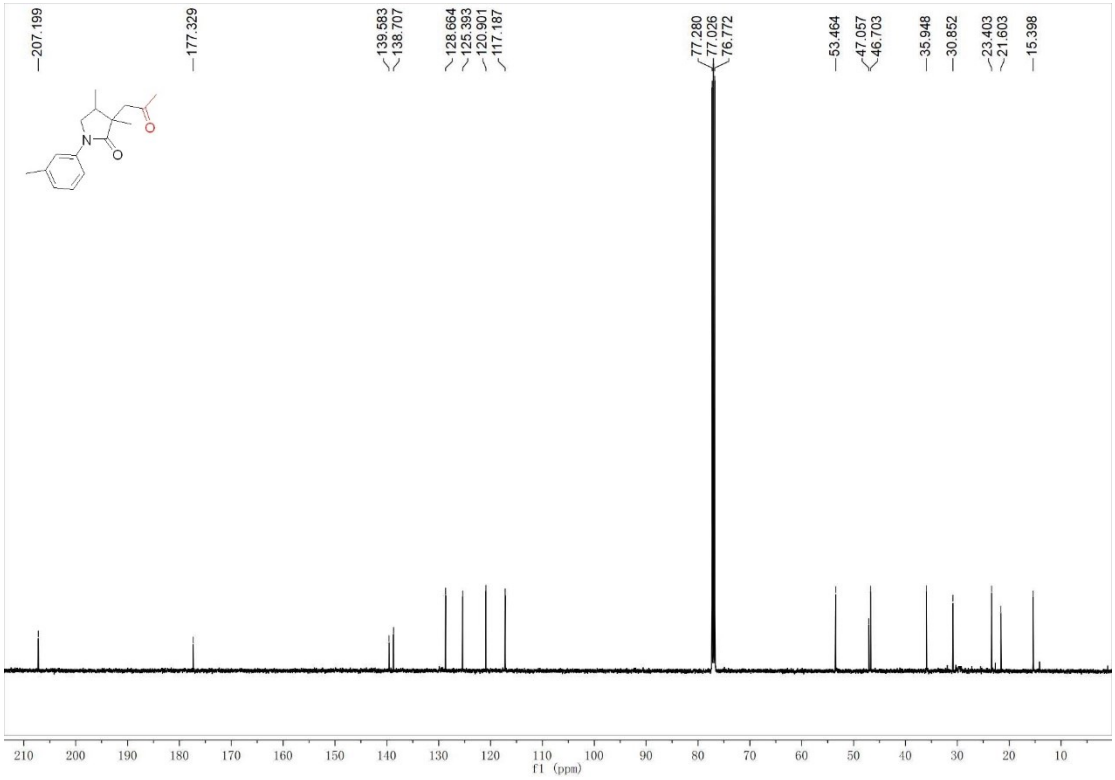
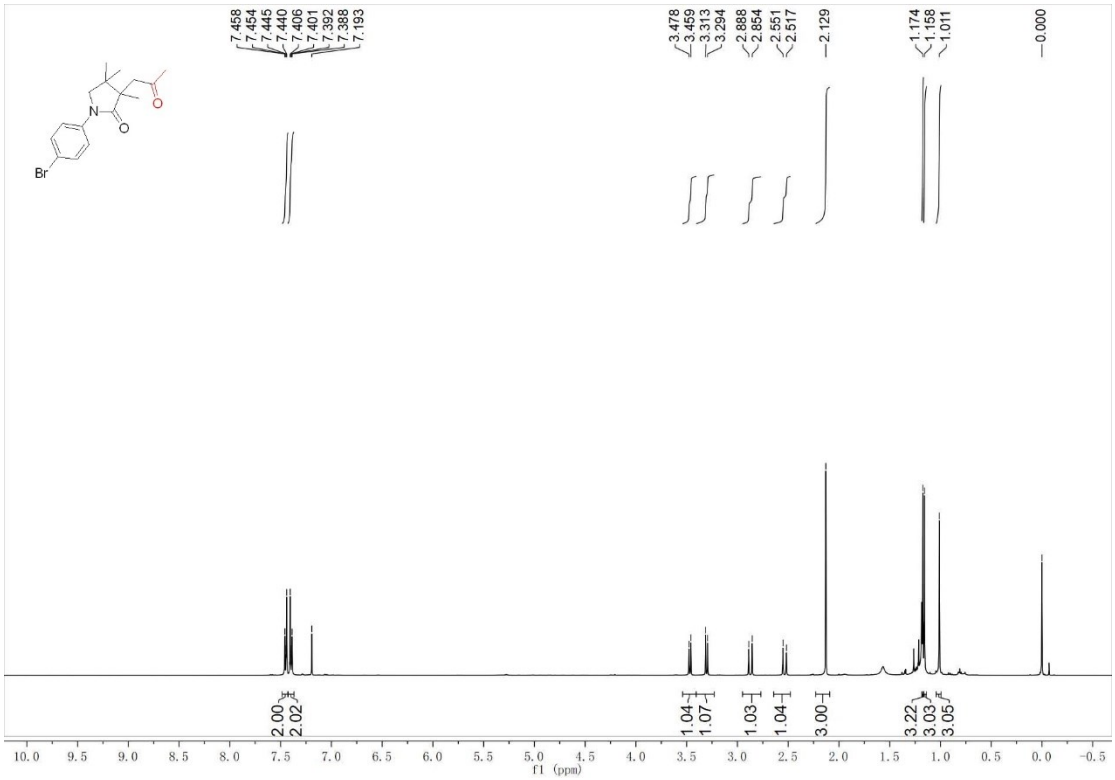
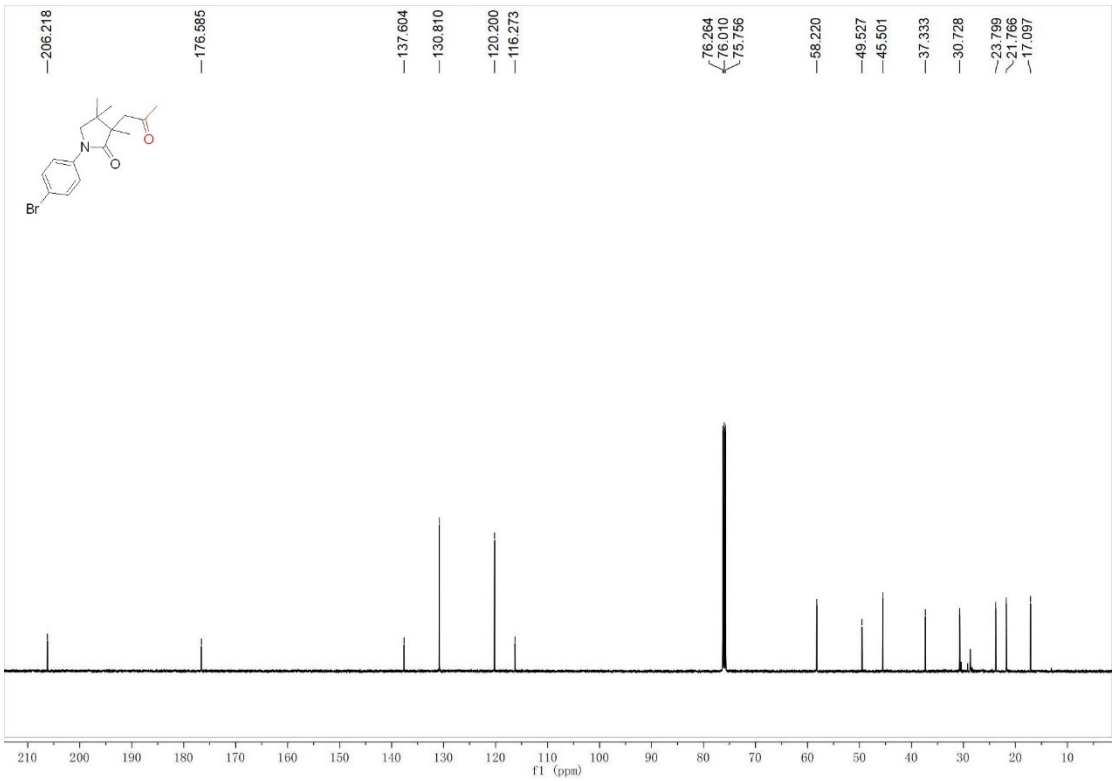


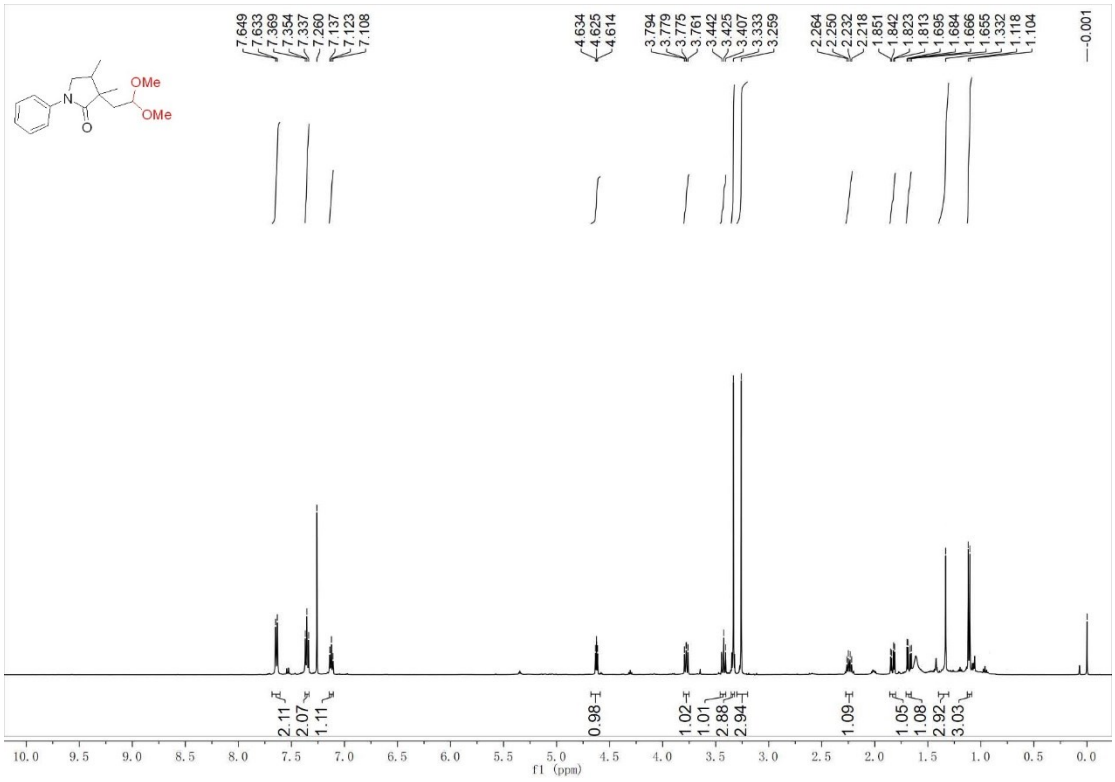


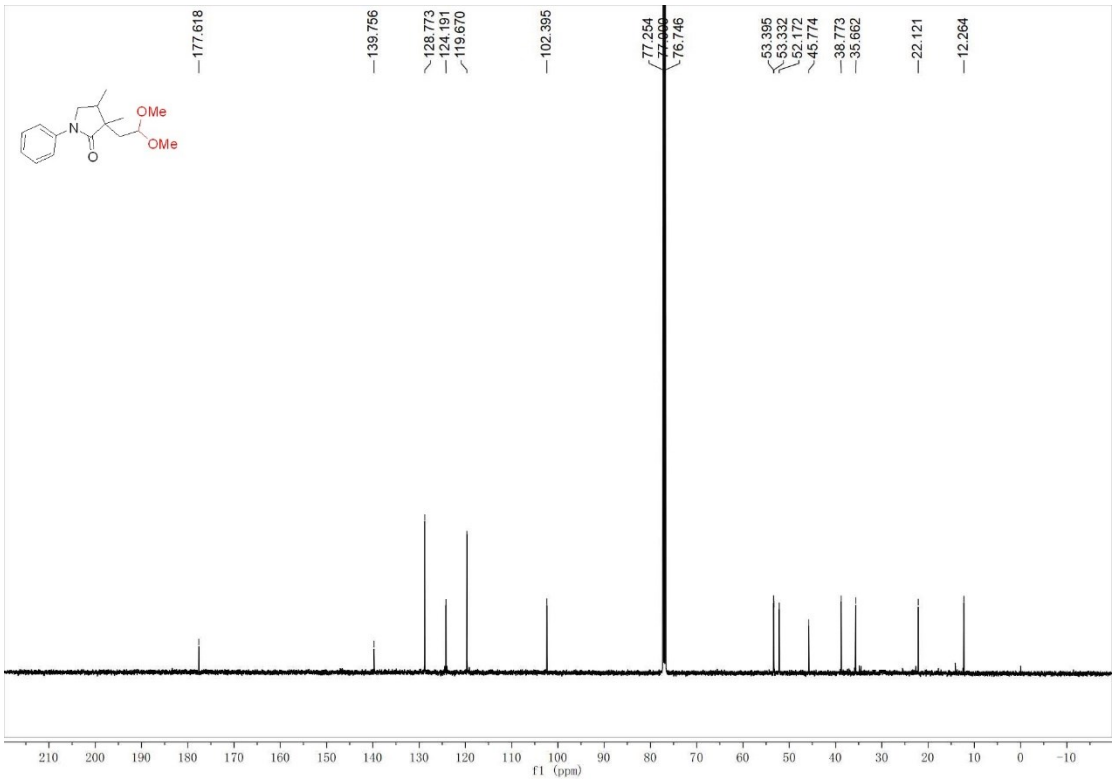
1-(4-Bromophenyl)-3,4,4-trimethyl-3-(2-oxopropyl)pyrrolidin-2-one (6db)



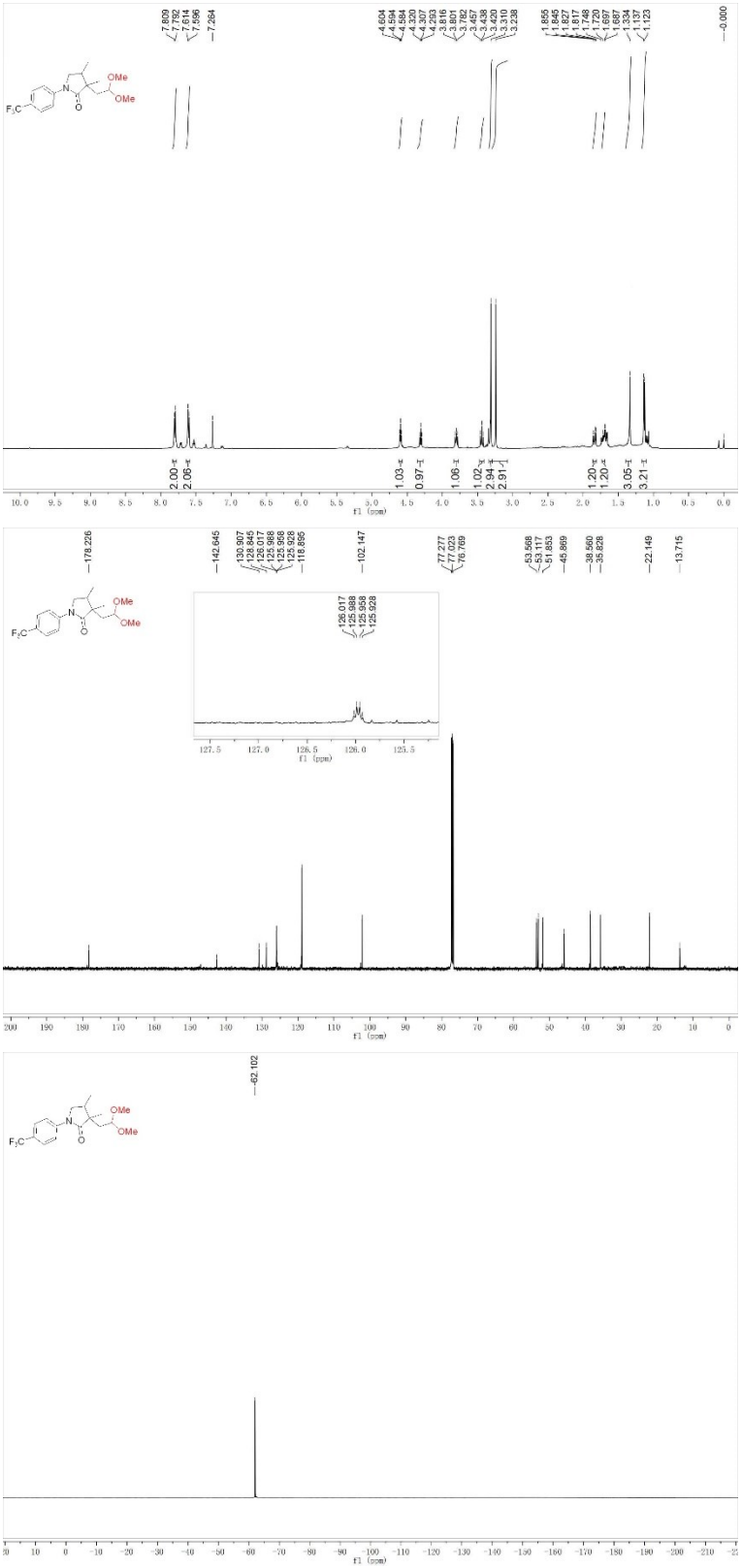


3-(2,2-Dimethoxyethyl)-3,4-dimethyl-1-phenylpyrrolidin-2-one (7ac)





3-(2,2-Dimethoxyethyl)-3,4-dimethyl-1-(4-(trifluoromethyl)phenyl)pyrrolidin-2-one (7cc)



1-(4-Bromophenyl)-3-(2,2-dimethoxyethyl)-3,4,4-trimethylpyrrolidin-2-one (7dc)