Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.


# Supporting Information for

## Nickel-catalysed SET-reduction-based access to functionalized allenes *via* 1,4-carbohydrogenation of 1,3-enynes with alkyl bromides

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# 1 General Information

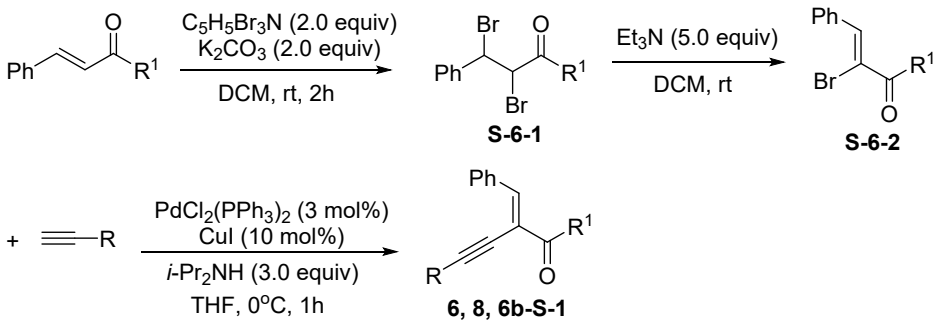
## 1.1 Solvents, Reagents, and Starting Materials

All reactions were carried out under an atmosphere of nitrogen in oven-dried glassware. 2-(1-Alkynyl)-2-alken-1-ones **1, 4,** and **12** were reported in our previous works.[1, 2] Tertiary alkyl bromides **2** and **9** were prepared according to the published procedures.[3] Dried solvents were obtained from commercial sources and used without further purification unless otherwise noted.

## 1.2 Instruments

NMR spectra were recorded on a Bruker Avance 500 spectrometer (500 MHz) (500 MHz for $^{1}$H NMR and 126 MHz for $^{13}$C NMR). Chemical shifts were reported in ppm downfield from tetramethylsilane and calibrated using residue undeuterated solvent ($CDCl_3$ at 7.26 ppm $^{1}$H NMR; 77.0 ppm $^{13}$C NMR). Spectra were reported as follows: chemical shift (δ ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad). Coupling constants are reported in Hertz where available. High resolution mass spectra (HRMS) were recorded on Waters Premier GC-TOF MS. Analytical thin layer chromatography was performed on Polygram SIL G/$UV_{254}$ plates. Visualization was accomplished with short wave UV light, or $KMnO_4$ staining solutions. Flash column chromatography was performed using silica gel (300-400 mesh) with solvents to use.

# 2 Synthesis of 1,3-enynes 6, 8, and 14

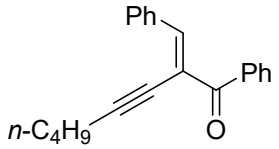



To a solution of (*E*)-chalcone (15.0 mmol, 1.0 equiv) in DCM (50 mL), pyridinium tribromide (9.6 g, 30.0 mmol, 1.0 equiv) and potassium carbonate (4.2 g, 30.0 mmol, 2.0 equiv) was added, and the mixture was stirred for 2 h at room temperature. Then, the saturated $Na_2S_2O_3$ solution was added, the mixture was filtered and extracted with ethyl acetate (3x25 mL), dried over $MgSO_4$, the solvent was evaporated in vacuum.

The product was recrystallized from DCM/hexane to afford the desired product **S-6-1** with good yield.

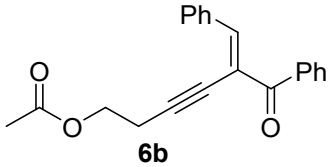
To a solution of 2,3-dibromopropan-1-one **S-6-1** (10.0 mmol, 1.0 equiv) in DCM (30 mL), triethylamine (7 mL, 50.0 mmol, 5.0 equiv) was added and the reaction mixture was stirred at room temperature for 12-36 h. Then, the saturated $NH_4Cl$ solution (20 mL) was added, phases were separated, water phase was extracted by ethyl acetate (3x15 mL). Combined organic phase was washed with 1M HCl (4x15 mL), dried over $MgSO_4$ and evaporated in vacuo. The mixture was purified by flash column chromatography to afford **S-6-2**.

A solution of (*Z*)-2-bromoprop-2-en-1-one **S-6-2** (5.0 mmol, 1.0 equiv) in THF (25 mL) was treated with $PdCl_2(PPh_3)_2$ (105.3 mg, 0.15 mmol, 3 mol%) and CuI (95.2 mg, 0.5 mmol, 10 mol%) and cooled down to 0°C in the dark. After 10 min of stirring, 3,3-dimethylbut-1-yne (1.2 mL, 10.0 mmol, 2.0 equiv) and diisopropylamine (2.1 mL, 15.0 mmol, 3.0 equiv) were added, and the resulting dark brown solution was stirred at 0 ° C for 1 h. The reaction mixture was partitioned between ethyl acetate and 0.5 N aqueous HCl solution. The aqueous layer was extracted with ethyl acetate (3x10 mL) and the combined organic phases were washed with brine, dried over $MgSO_4$, filtered and concentrated under vacuum. The crude product was purified by flash column chromatography to yield the corresponding 2-(1-alkynyl)-2-alken-1-one **6, 8 (6b-S-1)**. Additional reaction of **6b-S-1** with acetyl chloride (1.1 equiv) and trimethylamine (2.7 equiv) in DCM is required to obtain **6b**.



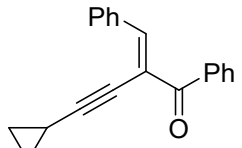

**6a**

**(*E*)-2-Benzylidene-1-phenyloct-3-yn-1-one (6a).** Yellow oil. $^1$H NMR (500 MHz, $CDCl_3$) δ 8.06-8.03 (m, 2H), 7.93-7.91 (m, 2H), 7.57-7.54 (m, 1H), 7.47-7.40 (m, 6H), 2.46 (t, *J* = 7.0 Hz, 2H), 1.58-1.52 (m, 2H), 1.42-1.37 (m, 2H), 0.90 (t, *J* = 7.3 Hz, 3H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 194.3, 144.0, 137.3, 134.9, 132.3, 130.2, 130.0, 129.7, 128.4, 128.0, 121.8, 103.2, 78.0, 30.2, 21.9, 19.7, 13.6. These data are consistent with the published literature.[4]



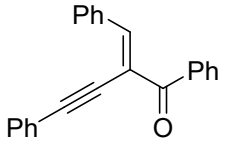

**6b**

**(*E*)-5-Benzoyl-6-phenylhex-5-en-3-yn-1-yl acetate (6b).** Yellow oil. $^1$H NMR (500 MHz, $CDCl_3$) δ 8.03-8.01 (m, 2H), 7.92-7.90 (m, 2H), 7.58-7.55 (m, 1H), 7.49-7.40 (m, 6H), 4.21 (t, *J* = 6.6 Hz, 2H), 2.81 (t, *J* = 6.7 Hz, 2H), 2.04 (s, 3H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 193.9, 170.8, 145.2, 137.1, 134.6, 132.4, 130.5, 130.1, 129.7, 128.5, 128.0, 121.1, 97.9, 79.2, 61.9, 20.8, 20.5. HRMS (ESI) $[M+Na]^+$: calculated for $C_{21}H_{18}O_3Na$: 341.1154, found 341.1152.



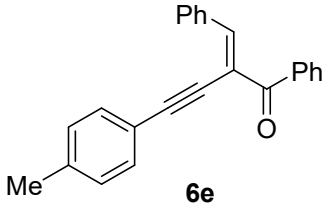

**6c**

**(*E*)-2-Benzylidene-4-cyclopropyl-1-phenylbut-3-yn-1-one (6c).** Yellow oil. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 8.02-8.00 (m, 2H), 7.91-7.89 (m, 2H), 7.57-7.54 (m, 1H), 7.47-7.39 (m, 6H), 1.52-1.47 (m, 1H), 0.89-0.85 (m, 2H), 0.77-0.74 (m, 2H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 194.1, 144.0, 137.3, 134.9, 132.3, 130.2, 129.9, 129.7, 128.4, 127.9, 121.6, 106.1, 73.3, 8.7, 0.9. These data are consistent with the published literature.[5]



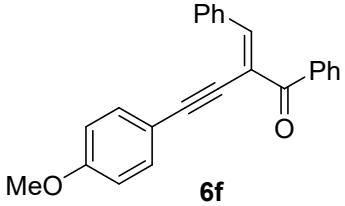

**6d**

**(*E*)-2-Benzylidene-1,4-diphenylbut-3-yn-1-one (6d).** Yellow solid. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 8.14-8.12 (m, 2H), 8.02-8.00 (m, 2H), 7.64 (s, 1H), 7.61-7.57 (m, 1H), 7.51-7.44 (m, 5H), 7.41-7.39 (m, 2H), 7.36-7.32 (m, 3H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 193.4, 145.1, 137.1, 134.8, 132.5, 131.3, 130.6, 130.4, 129.7, 128.8, 128.6, 128.4, 128.1, 122.8, 120.9, 100.8, 87.1. These data are consistent with the published literature.[6]




**6e**

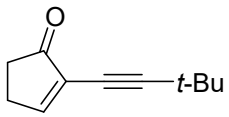
**(*E*)-2-Benzylidene-1-phenyl-4-(p-tolyl)but-3-yn-1-one (6e).** Yellow oil. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 8.14-8.12 (m, 2H), 8.02-8.00 (m, 2H), 7.61 (s, 1H), 7.60-7.57 (m, 1H), 7.50-7.43 (m, 4H), 7.31-7.29 (m, 2H), 7.15-7.11 (m, 2H), 2.37 (s, 3H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 193.5, 144.6, 139.1, 137.2, 134.9, 132.5, 131.2, 130.5, 130.3, 129.7, 129.2, 128.5, 128.0, 121.0, 119.8, 101.2, 86.6, 21.6. These data are consistent with the published literature.[5]




**6f**

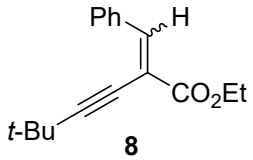
**(*E*)-2-Benzylidene-4-(4-methoxyphenyl)-1-phenylbut-3-yn-1-one (6f).** Yellow solid. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 8.13-8.11 (m, 2H), 8.01-7.99 (m, 2H), 7.60-7.56 (m, 2H), 7.50-7.42 (m, 5H), 7.35-7.32 (m, 2H), 6.91-6.84 (m, 2H), 3.82 (s, 3H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 193.6, 160.1, 144.1, 137.2, 135.0, 132.9, 132.4, 130.4,

130.3, 129.7, 128.5, 128.0, 121.1, 115.0, 114.1, 101.1, 86.1, 55.3. These data are consistent with the published literature.[6]



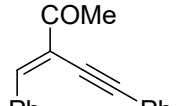

**12a**

**2-(3,3-Dimethylbut-1-yn-1-yl)cyclopent-2-en-1-one (12a).** Pale yellow solid. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 7.67 (d, *J* = 3.1 Hz, 1H), 2.67-2.65 (m, 2H), 2.44-2.42 (m, 2H), 1.28 (s, 9H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 206.0, 163.8, 130.5, 105.4, 69.7, 33.9, 30.8, 28.1, 27.0. HRMS (ESI) $[M+H]^+$: calculated for $C_{11}H_{15}O$: 163.1123, found 163.1121.




**8**

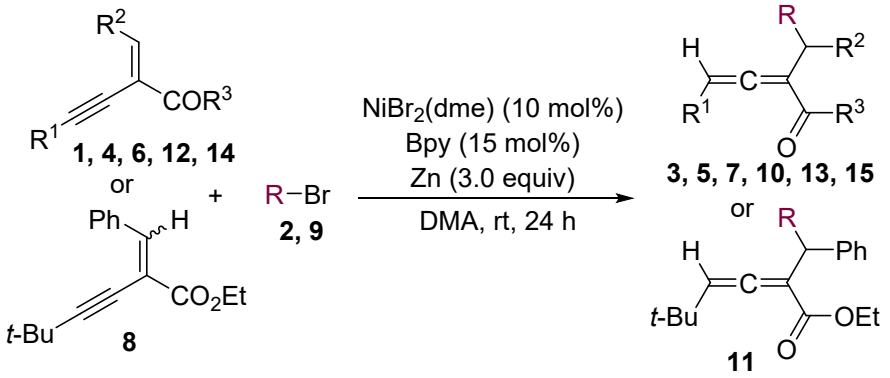
**Ethyl 2-benzylidene-5,5-dimethylhex-3-ynoate (8):** *E*/*Z* isomer (1:1 based on $^{1}$H NMR)**.** Colorless oil. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 8.05-8.04 (m, 1H), 7.80 (s, 0.5H), 7.41-7.27 (m, 4H), 7.07 (s, 0.5H), [4.29 (q, *J* = 7.1 Hz, 1H), 4.20 (q, *J* = 7.1 Hz, 1H)], [1.36 (s, 4.5H), 1.29 (s, 4.5H)], [1.38-1.35 (t, *J* = 7.2 Hz, 1.5H), 1.20 (t, *J* = 7.1 Hz, 1.5H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 166.2, 166.1, 143.7, 141.5, 135.0, 134.7, 130.2, 130.1, 128.6, 128.4, 128.2(2), 128.1(8), 117.4, 113.8, 107.8, 101.1, 76.7, 75.1, 61.5, 61.4, 30.8, 30.6, 28.6, 28.1, 14.1, 13.7. HRMS (ESI) $[M+H]^+$: calculated for $C_{17}H_{21}O_2$: 257.1542, found 257.1546.



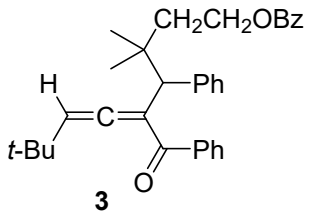

**14**

**(*E*)-2-benzylidene-1,4-diphenylbut-3-yn-1-one (14).** Pale yellow solid. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 8.11-8.09 (m, 2H), 7.83 (s, 1H), 7.57-7.55 (m, 2H), 7.45-7.40 (m, 6H), 2.62 (s, 3H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 196.2, 142.9, 134.5, 131.4, 130.7, 128.9, 128.6, 122.8, 120.0, 99.1, 87.0, 28.2. These data are consistent with the published literature.[7]

# 3 General procedure for the preparation of 1,3-allenes 3, 5, 7, 10, 11, 13, and 15

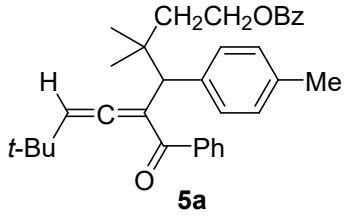



To an oven-dried Schlenk tube was charged with 2-(1-alkynyl)-2-alken-1-one (0.2 mmol, 1.0 equiv), $NiBr_2$(dme) (10 mol%), 2,2'-bipyridine (15 mol%), Zn (0.6 mmol, 3.0 equiv). The tube was capped with a rubber septum, evacuated and back-filled with nitrogen three times, at which point DMA (2 mL) was added via a syringe prior to the addition of alkyl halide (0.4 mmol, 2.0 equiv) . The reaction mixture was allowed to stir at room temperature for 24 h, 3 mL of $H_2O$ was added to quench the reaction and the mixture was extracted by ethyl acetate. The combined organic layer was dried over $MgSO_4$. After filtration and concentration, the residue was purified by column chromatography on silica gel. The ratio of diastereoisomers was determined by $^1H$ NMR analysis.



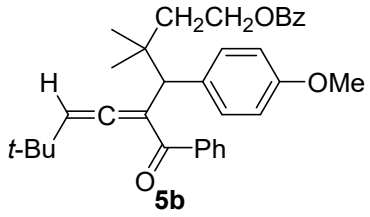

**5-Benzoyl-3,3,8,8-tetramethyl-4-phenylnona-5,6-dien-1-yl benzoate (3).** Flash column chromatography to afford product **3** as a white solid (85.5 mg, 89% yield, dr = 49:51). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1H$ NMR (500 MHz, $CDCl_3$) δ 8.03-8.00 (m, 2H), 7.65-7.63 (m, 1H), 7.56-7.51 (m, 2H), 7.47-7.39 (m, 5H), 7.36-7.25 (m, 4H), 7.24-7.20 (m, 1H), [5.47 (d, *J* = 0.9 Hz, 0.45H), 5.46 (d, *J* = 1.0 Hz, 0.55H)], 4.49-4.39 (m, 2H), [4.26 (s, 0.45H), 4.23 (s, 0.55H)], 2.05-1.80 (m, 2H), 1.16-1.13 (m, 6H), [0.95 (s, 4.95H), 0.69 (s, 4.05H)]. $^{13}C$ NMR (126 MHz, $CDCl_3$) δ 213.4, 212.5, 196.2, 195.5, 166.6(0), 166.5(8), 141.0, 140.9, 138.5(2), 138.4(7), 132.8, 131.2, 131.0, 130.5, 130.4(5), 130.4(1), 129.5, 128.7, 128.5, 128.3(1), 128.2(6), 127.6(3), 127.5(5), 127.4(6), 126.5(2), 126.5(0), 111.5, 111.3, 108.7, 108.5, 62.3, 52.4, 51.7, 38.7, 38.3, 38.0, 36.8, 33.6, 33.3, 29.5, 29.1, 25.8, 25.4, 25.1, 24.9. HRMS (ESI) $[M+H]^+$: calculated for

$C_{33}H_{37}O_3$: 481.2743, found 481.2733.



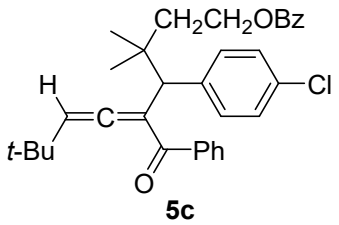
**5a**

**5-Benzoyl-3,3,8,8-tetramethyl-4-(*p*-tolyl)nona-5,6-dien-1-yl benzoate (5a).** Flash column chromatography to afford product **5a** as a white solid (79.1 mg, 80% yield, dr = 30:70). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 8.04-8.01 (m, 2H), 7.65-7.52 (m, 3H), 7.44-7.39 (m, 3H), 7.37-7.30 (m, 4H), 7.12-7.08 (m, 2H), [5.48 (d, *J* = 0.9 Hz, 0.24H), 5.46 (d, *J* = 1.0 Hz, 0.76H)], 4.50-4.41 (m, 2H), [4.22 (s, 0.24H), 4.18 (s,0.76H)], [2.33 (s, 2.28H), 2.32 (s, 0.72H)], 2.06-1.82 (m, 2H), 1.17-1.13 (m, 6H), [0.95 (s, 6.84H), 0.73 (s, 2.16H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 213.3, 212.5, 196.2, 195.6, 166.6, 166.5, 138.5, 137.7, 136.0, 135.9, 132.7, 131.1, 131.0, 130.4(2), 130.4(0), 130.3(4), 130.2(8), 129.5, 128.6, 128.5, 128.3(4), 128.2(7), 128.2(3), 127.5, 127.4, 111.7, 111.4, 108.5, 108.3, 62.3, 52.0, 51.2, 38.6, 38.3, 37.9, 36.8, 33.6, 33.3, 29.5, 29.1, 25.7, 25.3, 25.0, 24.9, 20.9(6), 20.9(5). HRMS (ESI) $[M+H]^+$: calculated for $C_{34}H_{39}O_3$: 495.2899, found 495.2899.



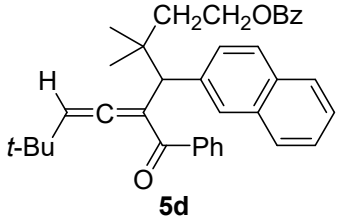
**5b**

**5-Benzoyl-4-(4-methoxyphenyl)-3,3,8,8-tetramethylnona-5,6-dien-1-yl benzoate (5b).** Flash column chromatography to afford product **5b** as a white solid (86.7 mg, 85% yield, dr = 24:76). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 8.03-8.00 (m, 2H), 7.64-7.51 (m, 3H), 7.44-7.29 (m, 7H), 6.85-6.81 (m, 2H), [5.47 (d, *J* = 0.9 Hz, 0.22H), 5.45 (d, *J* = 1.0 Hz, 0.78H)], 4.49-4.39 (m, 2H), [4.20 (s, 0.22H), 4.10 (s, 0.78H)], [3.79 (s, 2.34H), 3.79 (s, 0.66)], 2.25-1.80 (m, 2H), 1.15-1.12 (m, 6H), [0.94 (s, 7.02H), 0.71 (s, 1.98H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 213.3, 212.3, 196.2, 195.6, 166.5(9), 166.5(7), 158.1(8), 158.1(5), 138.5(5), 138.5(1), 133.0, 132.9, 132.7, 131.4, 131.3, 131.2, 131.0, 130.4(3), 130.4(2), 129.5, 128.7, 128.5, 128.3, 127.5, 127.4, 113.0, 112.9, 111.8, 111.5, 108.6, 108.4, 62.3, 55.2, 55.1, 51.6, 50.8, 38.6, 38.3, 38.0, 36.8, 33.6, 33.3, 29.5, 29.1, 25.7, 25.3, 25.0, 24.9. HRMS (ESI) $[M+H]^+$: calculated for $C_{34}H_{39}O_4$: 511.2848, found 511.2844.



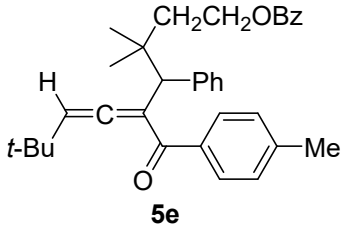

**5c**

**5-Benzoyl-4-(4-chlorophenyl)-3,3,8,8-tetramethylnona-5,6-dien-1-yl benzoate (5c).** Flash column chromatography to afford product **5c** as a pale yellow solid (69.9 mg, 68% yield, dr = 40:60). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 8.05-7.97 (m, 2H), 7.64-7.50 (m, 3H), 7.44-7.30 (m, 7H), 7.28-7.25 (m, 2H), [5.50 (d, *J* = 1.0 Hz, 0.26H), 5.47 (d, *J* = 1.0 Hz, 0.74H)], 4.49-4.41 (m, 2H), [ 4.25 (s, 0.26H), 4.19 (s, 0.74H)], 2.03-1.77 (m, 2H), 1.15-1.12 (m, 6H), [0.95 (s, 6.66H), 0.71 (s, 2.34H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 213.1, 212.3, 195.9, 195.3, 166.5(3), 166.5(1), 139.5, 139.4, 138.2(8), 138.2(5), 132.8, 132.4, 132.3, 131.7, 131.6, 131.3, 131.1, 130.3(2), 130.3(0), 129.5, 128.6, 128.5, 128.3, 128.3, 127.8, 127.7, 127.6, 127.5, 111.1, 111.0, 109.0, 108.7, 62.1, 51.7, 50.9, 38.6, 38.3, 37.9, 36.7, 33.7, 33.3, 29.5, 29.1, 25.6, 25.3, 24.9, 24.8. HRMS (ESI) $[M+H]^+$: calculated for $C_{33}H_{36}O_3Cl$: 515.2353, found 515.2346.




**5d**

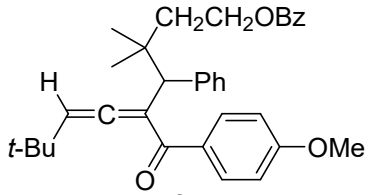
**5-Benzoyl-3,3,8,8-tetramethyl-4-(naphthalen-2-yl)nona-5,6-dien-1-yl benzoate (5d).** Flash column chromatography to afford product **5d** as a white solid (89.1 mg, 84% yield, dr = 44:56). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 8.04-8.01 (m, 2H), 7.95-7.86 (m, 1H), 7.85-7.77 (m, 3H), 7.68-7.62 (m, 2H), 7.56-7.52 (m, 2H), 7.49-7.39 (m, 5H), 7.37-7.29 (m, 2H), [5.56 (s, 0.32H), 5.52 (s, 0.68H)], 4.54-4.41 (m, 3H), 2.12-1.88 (m, 2H), 1.24-1.21 (m, 6H), [1.00 (s, 6.12H), 0.71 (s, 2.88H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 213.4, 212.5, 196.1, 195.6, 166.6, 138.5(4), 138.4(9), 138.5, 138.4, 133.0, 132.7, 132.3, 131.2, 131.1, 130.3(9), 130.3(6), 129.5, 129.3, 129.0, 128.7, 128.6, 128.5, 128.2, 127.9, 127.8, 127.5(5), 127.4(5), 127.4(1), 127.4(0), 127.0(1), 126.9(6), 125.8, 125.7, 125.5, 125.4, 111.5, 111.3, 108.8, 108.6, 62.2, 52.5, 51.7, 38.8, 38.5, 38.3, 37.1, 33.7, 33.3, 29.5, 29.1, 25.8, 25.5, 25.2, 25.1. HRMS (ESI) $[M+H]^+$: calculated for $C_{37}H_{39}O_3$: 531.2899, found 531.2892.




**5e**

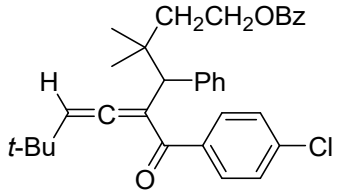
**3,3,8,8-Tetramethyl-5-(4-methylbenzoyl)-4-phenylnona-5,6-dien-1-yl benzoate**

**(5e).** Flash column chromatography to afford product **5e** as a white solid (67.2 mg, 68% yield, dr = 26:74). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 8.05-8.00 (m, 2H), 7.62-7.40 (m, 7H), 7.30-7.26 (m, 2H), 7.24-7.20 (m, 1H), 7.16-7.11 (m, 2H), [5.48 (d, *J* = 1.0 Hz, 0.25H), 5.46 (d, *J* = 1.1 Hz, 0.75H)], 4.49-4.39 (m, 2H), [4.26 (s, 0.25H), 4.19 (s, 0.75H)], [2.37 (s, 0.75H), 2.35 (s, 2.25H)], 2.05-1.80 (m, 2H), 1.17-1.10 (m, 6H), [0.99 (s, 6.75H), 0.72 (s, 2.25H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 212.6, 211.6, 195.6, 194.9, 166.6, 142.0, 141.7, 141.0, 140.9, 135.5, 135.4, 132.8, 132.7, 130.5, 130.4(4), 130.4(1), 130.3(9), 129.5, 129.1, 128.9, 128.3, 128.2(3), 128.2(2), 128.1, 127.6, 126.5, 126.4, 111.3, 111.0, 108.4, 108.2, 62.3, 62.2, 52.7, 52.0, 38.7, 38.3, 38.0, 36.8, 33.6, 33.3, 29.6, 29.1, 25.9, 25.4, 25.1, 24.9, 21.4(9), 21.4(6). HRMS (ESI) $[M+H]^+$: calculated for $C_{34}H_{39}O_3$: 495.2899, found 495.2896.




**5f**

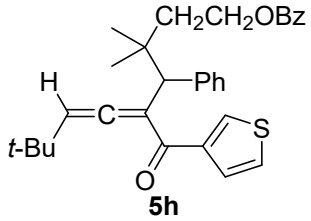
**5-(4-Methoxybenzoyl)-3,3,8,8-tetramethyl-4-phenylnona-5,6-dien-1-yl benzoate (5f).** Flash column chromatography to afford product **5f** as a white solid (66.3 mg, 65% yield, dr = 43:57). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 8.02-7.99 (m, 2H), 7.76-7.60 (m, 2H), 7.55-7.51 (m, 1H), 7.47-7.39 (m, 4H), 7.29-7.19 (m, 3H), 6.87-6.80 (m, 2H), [5.48 (d, *J* = 0.9 Hz, 0.43H), 5.47 (d, *J* = 1.0 Hz, 0.57H)], 4.49-4.38 (m, 2H), [4.23 (s, 0.43H), 4.14 (s, 0.57H)], [3.83 (s, 1.29H), 3.81 (s, 1.71H)], 2.06-1.79 (m, 2H), 1.16-1.11 (m, 6H), [1.01 (s, 5.13H), 0.72 (s, 3.87H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 211.7, 210.7, 194.4, 193.7, 166.6, 162.5, 162.3, 141.1, 140.9, 132.7, 131.4, 131.3, 130.6, 130.5(3), 130.4(9), 130.4(5), 130.4(1), 129.5, 128.2, 127.6(1), 127.5(9), 126.5, 126.4, 112.8, 112.7, 111.0, 110.7, 108.3, 108.1, 62.2(8), 62.2(5), 55.4, 55.3, 53.2, 52.4, 38.7, 38.4, 38.0, 36.8, 33.6, 33.3, 29.7, 29.2, 26.0, 25.5, 25.1, 25.0. HRMS (ESI) $[M+H]^+$: calculated for $C_{34}H_{39}O_4$: 511.2848, found 511.2850.




**5g**

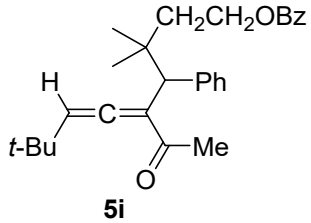
**5-(4-chlorobenzoyl)-3,3,8,8-tetramethyl-4-phenylnona-5,6-dien-1-yl benzoate (5g).** Flash column chromatography to afford product **5g** as a white solid (60.7 mg, 59% yield, dr = 53:47). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 8.02-7.99 (m, 2H), 7.62-7.59 (m, 1H), 7.56-7.52 (m, 1H), 7.49-7.38 (m, 5H), 7.34-7.20 (m, 5H), [5.51 (d, *J* = 1.0 Hz, 0.53H), 5.50 (d, *J* = 1.0 Hz, 0.47H)], 4.48-4.38 (m, 2H), [4.23 (s, 0.53H), 4.16(s, 0.47H)], 2.04-1.79 (m, 2H), 1.15-1.11 (m, 6H), [0.98 (s, 4.23H), 0.72 (s,

4.77H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 213.1, 212.2, 194.8, 194.1, 166.5(8), 166.5(6), 140.8, 140.7, 137.6, 137.3, 136.6(3), 136.5(9), 132.7(9), 132.7(8), 130.4(3), 130.4(0), 130.3(8), 130.2, 130.1, 129.5, 128.3, 127.9, 127.8, 127.7(0), 127.6(9), 126.6(2), 126.5(9), 111.4, 111.2, 108.9, 108.7, 62.2, 52.5, 51.8, 38.7, 38.3, 38.0, 36.8, 33.8, 33.4, 29.6, 29.1, 25.9, 25.4, 25.0(3), 24.9(8). HRMS (ESI) $[M+H]^+$: calculated for $C_{33}H_{36}O_3Cl$: 515.2353, found 515.2350.



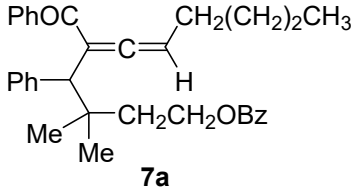

**5h**

**3,3,8,8-Tetramethyl-4-phenyl-5-(thiophene-3-carbonyl)nona-5,6-dien-1-yl benzoate (5h).** Flash column chromatography to afford product **5h** as a white solid (65.2 mg, 67% yield, dr = 59:41). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 8.02-7.99 (m, 2H), 7.96-7.81 (m, 1H), 7.56-7.52 (m, 1H), 7.46-7.33 (m, 5H), 7.29-7.17 (m, 4H), [5.61 (d, $J$ = 1.0 Hz, 0.58H), 5.60 (d, $J$ = 0.9 Hz, 0.42H)], 4.48-4.38 (m, 2H), [4.23 (s, 0.42H), 4.16 (s, 0.58H)], 2.05-1.78 (m, 2H), 1.15-1.07 (m, 6H), [1.07 (s, 5.22H), 0.78 (s, 3.78H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 212.1, 211.2, 188.8, 188.0, 166.6, 141.0, 140.9, 140.8(2), 140.7(7), 132.7, 131.5, 131.3, 130.5, 130.4(3), 130.4(1), 129.5, 128.3(2), 128.2(8), 128.2(6), 127.6(5), 127.6(3), 126.5(2), 126.4(9), 124.8, 124.7, 112.0, 111.8, 108.9, 108.6, 62.3, 62.2, 52.7, 52.0, 38.7, 38.3, 38.0, 36.8, 33.8, 33.4, 29.6, 29.2, 26.0, 25.4, 25.0, 24.9. HRMS (ESI) $[M+H]^+$: calculated for $C_{31}H_{35}O_3$: 487.2307, found 487.2306.



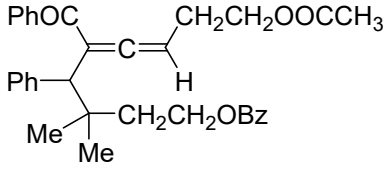

**5i**

**5-Acetyl-3,3,8,8-tetramethyl-4-phenylnona-5,6-dien-1-yl benzoate (5i).** Flash column chromatography to afford product **5i** as a white solid (77.8 mg, 93% yield, dr = 62:38). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 8.02-8.00 (m, 2H), 7.56-7.52 (m, 1H), 7.44-7.41 (m, 2H), 7.39-7.33 (m, 2H), 7.27-7.23 (m, 2H), 7.22-7.19 (m, 1H), [5.75 (s, 0.79H), 5.74 (d, $J$ = 1.0 Hz, 0.21H)], 4.43-4.05 (m, 2H), [4.09 (s, 0.79H), 4.06 (s, 0.21H)], [2.26 (s, 2.37H), 2.25 (s, 0.63H)], 1.94-1.73 (m, 2H), [1.27 (s, 7.11H), 1.09 (s, 1.89H)], 1.07-1.02 (m, 6H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 211.6, 211.5, 198.3(4), 198.3(2), 166.6, 166.5, 141.3, 140.9, 132.7, 130.4(3), 130.4(1), 130.3, 129.5, 128.2, 127.6, 127.5, 126.4, 112.5, 112.4, 108.1, 107.7, 62.3, 62.2, 50.3, 50.1, 38.6, 38.2, 37.4, 36.6, 34.0, 33.7, 29.9, 29.5, 26.5, 26.4, 25.2, 25.1, 24.8. HRMS (ESI) $[M+H]^+$: calculated for $C_{28}H_{35}O_3$: 419.2586, found 419.2586.



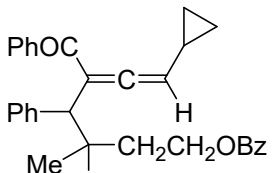

**7a**

**5-Benzoyl-3,3-dimethyl-4-phenylundeca-5,6-dien-1-yl benzoate (7a).** Flash column chromatography to afford product **7a** as a pale yellow solid (78.8 mg, 82% yield, dr = 36:64). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 8.03-7.99 (m, 2H), 7.64-7.60 (m, 2H), 7.56-7.53 (m, 1H), 7.46-7.41 (m, 5H), 7.35-7.28 (m, 4H), 7.24-7.21 (m, 1H), [5.50 (t, *J* = 7.4 Hz, 0.41H), 5.46 (t, *J* = 7.6 Hz, 0.59H)], 4.48-4.39 (m, 2H), [4.16 (s, 0.41H), 4.15 (s, 0.59H)], 2.28-2.03 (m, 2H), 2.02-1.82 (m, 2H), 1.37-1.16 (m, 4H), 1.14-1.12 (m, 6H), 0.83-0.77 (m, 3H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 214.6, 214.5, 195.6(5), 195.5(8), 166.6, 166.5, 140.9, 140.7, 138.5(2), 138.4(6), 132.8, 131.5, 130.4(2), 130.4(1), 130.3(3), 130.2(9), 129.5, 128.9, 128.3, 127.6(7), 127.6(5), 127.6(0), 126.5(0), 126.4(8), 108.8, 108.3, 97.2, 96.8, 62.3, 62.2, 52.1(0), 52.0(7), 38.5(1), 38.4(8), 37.4, 37.0, 30.9, 30.7, 28.6, 28.4, 25.4, 25.3, 25.2, 22.1, 13.7. HRMS (ESI) $[M+Na]^+$: calculated for $C_{33}H_{36}O_3Na$: 503.2562, found 503.2561.




**7b**

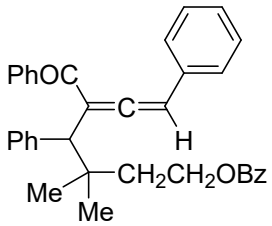
**9-Acetoxy-5-benzoyl-3,3-dimethyl-4-phenylnona-5,6-dien-1-yl benzoate (7b).** Flash column chromatography to afford product **7b** a pale yellow oil (74.5 mg, 73% yield, dr = 34:66). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 8.03-8.01 (m, 2H), 7.66-7.64 (m, 2H), 7.56-7.52 (m, 1H), 7.47-7.40 (m, 5H), 7.37-7.34 (m, 2H), 7.32-7.28 (m, 2H), 7.26-7.21 (m, 1H), [5.54 (t, *J* = 7.3 Hz, 0.41H), 5.49 (t, *J* = 7.5 Hz, 0.59H)], 4.49-4.40 (m, 2H), [4.16 (s, 0.41H), 4.15 (s, 0.59H)], 4.12-3.88 (m, 2H), 2.61-2.35 (m, 2H), 2.10-1.83 (m, 5H), 1.15-1.12 (m, 6H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 214.7, 214.6, 195.0, 194.9, 170.7, 166.4(7), 166.4(5), 140.5, 140.4, 138.1, 138.0, 132.7(3), 132.7(1), 131.8(2), 131.8(1), 130.3(2), 130.3(0), 130.2, 129.4, 128.8(8), 128.8(6), 128.2, 127.6(9), 127.6(7), 127.7, 126.6(0), 126.5(8), 109.1, 108.7, 93.2, 92.9, 62.7, 62.6, 62.1(2), 62.0(9), 52.3, 52.2, 38.6, 38.5, 37.4, 37.0, 28.4, 28.2, 25.3, 25.2(2), 25.2(0), 25.1, 20.6(9), 20.6(6). HRMS (ESI) $[M+Na]^+$: calculated for $C_{33}H_{34}O_5Na$: 533.2304, found 533.2299.




**7c**

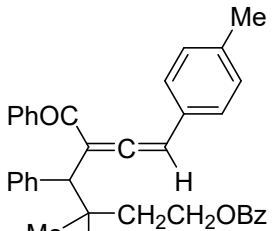
**5-Benzoyl-7-cyclopropyl-3,3-dimethyl-4-phenylhepta-5,6-dien-1-yl benzoate (7c).**

Flash column chromatography to afford product **7c** as a pale yellow oil (60.4 mg, 65% yield, dr = 33:67). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 8.04-8.02 (m, 2H), 7.69-7.66 (m, 2H), 7.56-7.53 (m, 1H), 7.48-7.41 (m, 5H), 7.37-7.28 (m, 4H), 7.24-7.21 (m, 1H), [5.27 (d, *J* = 8.2 Hz, 0.35H), 5.19 (d, *J* = 8.3 Hz, 0.65H)], 4.50-4.40 (m, 2H), [4.19 (s, 0.35H), 4.18 (s, 0.65H)], 2.04-1.83 (m, 2H), 1.53-1.37 (m, 1H), 1.17-1.12 (m, 6H), 0.81-0.67 (m, 2H), 0.35-0.22 (m, 2H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 215.1, 214.9, 195.1(4), 195.0(9), 166.5(4), 166.5(2), 140.9, 140.6, 138.2(3), 138.1(8), 132.7(3), 132.7(1), 131.5(9), 131.5(8), 130.4, 130.3, 129.4(7), 129.4(6), 129.0(1), 129.0(0), 128.2, 127.6(5), 127.6(3), 127.5(7), 126.5, 110.1, 109.7, 101.3, 101.0, 62.3, 52.2(9), 52.2(5), 38.5(3), 38.4(9), 37.4, 37.1, 25.4, 25.3, 25.2, 25.1, 9.8, 9.6, 6.4, 6.3, 5.9, 5.8. HRMS (ESI) $[M+Na]^+$: calculated for $C_{32}H_{32}O_3Na$: 487.2249, found 487.2245.




**7d**

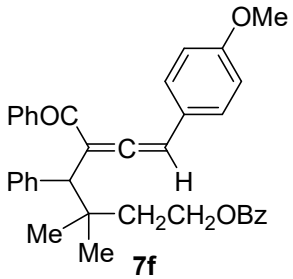
**5-Benzoyl-3,3-dimethyl-4,7-diphenylhepta-5,6-dien-1-yl benzoate (7d).** Flash column chromatography to afford product **7d** as a pale yellow solid (63.0 mg, 63% yield, dr = 43:57). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 8.02-7.96 (m, 2H), 7.72-7.68 (m, 2H), 7.56-7.46 (m, 3H), 7.44-7.36 (m, 3H), 7.33-7.22 (m, 9H), 7.15-7.13 (m, 1H), [6.63 (s, 0.54H), 6.59 (s, 0.46H)], 4.49-4.39 (m, 2H), 4.30 (s, 1H), 2.03-1.87 (m, 2H), 1.18-1.12 (m, 6H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 216.4, 215.1, 194.3, 194.2, 166.6, 166.5, 140.4, 140.3, 137.9, 137.8, 132.8, 132.7, 132.2, 132.1(2), 132.0(6), 132.0(4), 130.3(8), 130.3(7), 130.3(5), 129.5, 128.9(4), 128.8(8), 128.8(2), 128.7(6), 128.3, 128.2, 127.9(0), 127.8(7), 127.8(1), 127.8(0), 127.7(7), 127.5, 127.4, 126.7(4), 126.7(0), 112.4, 111.8, 100.6, 100.2, 62.2, 62.1, 53.9, 53.6, 38.7, 38.6, 37.7, 37.1, 25.5, 25.3, 25.2(5), 25.2(0). HRMS (ESI) $[M+ Na]^+$: calculated for $C_{35}H_{32}O_3Na$: 523.2249, found 523.2247.




**7e**

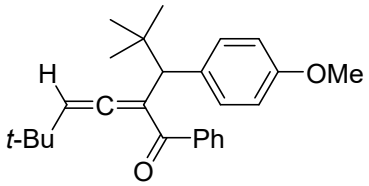
**5-Benzoyl-3,3-dimethyl-4-phenyl-7-(*p*-tolyl)hepta-5,6-dien-1-yl benzoate (7e).** Flash column chromatography to afford product **7e** as a pale yellow solid (60.1 mg, 59% yield, dr = 52:48). Two diastereoisomers are hard to be separated by column

chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 8.03-7.97 (m, 2H), 7.72-7.68 (m, 2H), 7.56-7.53 (m, 1H), 7.49-7.46 (m, 2H), 7.44-7.36 (m, 3H), 7.33-7.30 (m, 1H), 7.28-7.20 (m, 5H), 7.14-7.10 (m, 2H), 7.06-7.04 (m, 1H), [6.61(s, 0.49H), 6.57 (s, 0.51H)], 4.48-4.41 (m, 2H), 4.30 (s, 1H), [2.34 (s, 1.47H), 2.31(s, 1.53H)], 2.03-1.87 (m, 2H), 1.18-1.12 (m, 6H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 216.4, 215.1, 194.4, 194.3, 166.6, 166.5, 140.5, 140.4, 137.8(5), 137.8(3), 137.7(5), 132.7(5), 132.7(1), 132.0(2), 131.9(7), 130.4(2), 130.3(9), 130.3(7), 129.7, 129.5, 129.2, 129.0, 128.9, 128.8, 128.3, 128.2, 127.9, 127.7(7), 127.7(6), 127.7(3), 127.4, 127.3, 126.6(9), 126.6(5), 112.4, 111.8, 100.4, 100.1, 62.2, 62.1, 53.8, 53.5, 38.6, 37.7, 37.0, 25.6, 25.4, 25.2(0), 25.1(6), 21.2(3), 21.1(9). HRMS (ESI) $[M+H]^+$: calculated for $C_{36}H_{35}O_3$: 515.2586, found 515.2582.




**7f**

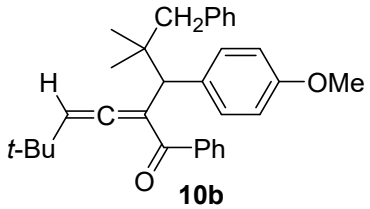
**5-Benzoyl-7-(4-methoxyphenyl)-3,3-dimethyl-4-phenylhepta-5,6-dien-1-yl benzoate (7f).** Flash column chromatography to afford product **7f** as a white solid (75.3 mg, 71% yield, dr = 45:55). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 8.03-7.98 (m, 2H), 7.72-7.68 (m, 2H), 7.56-7.53 (m, 1H), 7.49-7.47 (m, 2H), 7.44-7.37 (m, 3H), 7.34-7.30 (m, 1H), 7.28-7.23 (m, 5H), 7.09-7.08 (m, 1H), 6.88-6.83 (m, 2H), [6.60 (d, $J$ = 1.0 Hz, 0.42H), 6.56 (d, $J$ = 1.0 Hz, 0.58H)], 4.50-4.41 (m, 2H), 4.30 (s, 1H), [3.81 (s, 1.26H), 3.76 (s, 1.74H)], 2.03-1.88 (m, 2H), 1.18-1.13 (m, 6H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 216.3, 214.9, 194.5, 194.4, 166.6, 166.5, 159.4, 159.3, 140.6, 140.4, 138.0, 137.9, 132.7(4), 132.7(2), 132.0, 131.9, 130.3(9), 130.3(7), 130.3(6), 129.5, 128.8(5), 128.7(9), 128.7(4), 128.6, 128.3, 128.2, 127.9, 127.8, 127.7(5), 127.7(4), 126.7, 126.6, 124.4, 124.2, 114.5, 114.3, 112.4, 111.8, 100.0, 99.7, 62.2(3), 62.1(5), 55.3, 55.2, 53.7, 53.4, 38.6(3), 38.6(1), 37.7, 37.0, 25.6, 25.3, 25.2(2), 25.1(6). HRMS (ESI) $[M+H]^+$: calculated for $C_{36}H_{35}O_4$: 531.2535, found 531.2544




**10a**

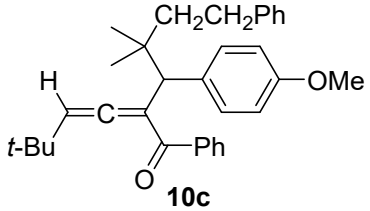
**2-(1-(4-Methoxyphenyl)-2,2-dimethylpropyl)-5,5-dimethyl-1-phenylhexa-2,3-dien-1-one (10e).** Flash column chromatography to afford product **10a** as a white solid (60.2 mg, 80% yield, dr = 14:86). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 7.64-7.51 (m, 2H), 7.43-7.38 (m, 1H), 7.37-7.29 (m, 4H), 6.83-6.78 (m, 2H), [5.43 (d, $J$ = 0.9 Hz, 0.38H), 5.40 (d, $J$ = 1.1 Hz, 0.62H)], [4.08 (s, 0.38H), 4.03 (s, 0.62H)], [3.79 (s,

1.86H), 3.78 (s, 1.14H)], [1.03 (s, 5.58H), 1.00 (s, 3.42H), 0.95 (s, 5.58H), 0.70 (s, 3.42H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 213.2, 212.4, 196.5, 195.8, 157.98, 157.96, 138.8, 138.7, 134.0, 133.9, 131.2, 131.1(1), 131.0(9), 130.9, 128.7, 128.5, 127.5, 127.4, 112.8, 112.7, 112.3, 112.2, 108.4, 108.1, 55.1(3), 55.1(2), 51.8, 51.2, 36.1, 34.9, 33.6, 33.2, 29.5, 29.1, 28.4, 28.3. HRMS (ESI) $[M+H]^+$: calculated for $C_{26}H_{33}O_2$: 377.2481, found 377.2486.



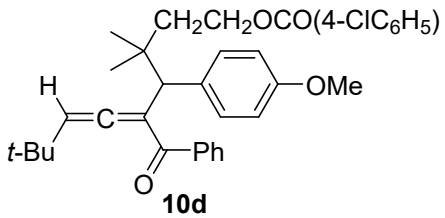

**10b**

**2-(1-(4-methoxyphenyl)-2,2-dimethyl-3-phenylpropyl)-5,5-dimethyl-1-phenylhexa-2,3-dien-1-one (10b).** Flash column chromatography to afford product **10b** as a pale yellow solid (73.3 mg, 81% yield, dr = 38:62). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 7.67-7.54 (m, 2H), 7.46-7.31 (m, 5H), 7.27-7.17 (m, 3H), 7.12-7.09 (m, 2H), 6.86-6.83 (m, 2H), [5.50 (s, 0.62H), 5.48 (d, *J* = 1.0 Hz, 0.38H)], [4.23 (s, 0.62H), 4.19 (s, 0.38H)], 3.81 (s, 3H), 2.81-2.65 (m, 2H), [1.01-0.91 (m, 9.42H), 0.76 (s, 5.58H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 213.3, 212.5, 196.4, 195.7, 158.1(0), 158.0(9), 139.1, 139.0, 138.7, 138.6, 133.4, 133.3, 131.6, 131.5, 131.2, 130.9(5), 130.9(0), 130.8(8), 128.7, 128.5, 127.6, 127.5, 127.4, 125.7, 112.9(5), 112.8(7), 112.1, 111.9, 108.5, 108.3, 55.1(5), 55.1(3), 52.3, 51.7, 46.4, 46.1, 39.7, 38.6, 33.6, 33.3, 29.6, 29.1, 24.7, 24.6, 24.3, 23.9. HRMS (ESI) $[M+H]^+$: calculated for $C_{32}H_{37}O_2$: 453.2794, found 453.2788.



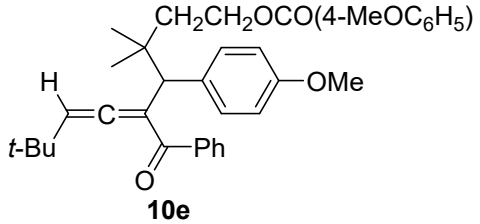

**10c**

**2-(1-(4-Methoxyphenyl)-2,2-dimethyl-4-phenylbutyl)-5,5-dimethyl-1-phenylhexa-2,3-dien-1-one (10c).** Flash column chromatography to afford product **10c** as a pale yellow solid (69.0 mg, 74% yield, dr = 25:75). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 7.66-7.51 (m, 2H), 7.46-7.39 (m, 2H), 7.37-7.30 (m, 3H), 7.27-7.22 (m, 2H), 7.17-7.09 (m, 3H), 6.84-6.81 (m, 2H), [5.43 (d, *J* = 0.9 Hz, 0.45H), 5.42 (d, *J* = 1.0 Hz, 0.55H)], [4.28 (s, 0.45H), 4.22 (s, 0.55H)], 3.80 (s, 3H), 2.73-2.58 (m, 2H), 1.83-1.55 (m, 2H), 1.14-1.09 (m, 6H), [0.93 (s, 4.95H), 0.72 (s, 4.05H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 213.3, 212.5, 196.4, 195.7, 158.0(4), 158.0(2), 143.3, 143.3, 138.7, 138.6, 133.5, 133.4, 131.3(4), 131.2(7), 131.2, 130.9, 128.7, 128.5, 128.4, 128.3, 128.2, 127.5, 127.4, 125.4, 112.9, 112.8, 112.1, 111.9, 108.4, 108.2, 55.1(4), 55.1(1), 50.6, 49.5, 43.4, 42.8, 38.7, 37.6, 33.6, 33.2, 30.6(3), 30.5(6), 29.5, 29.1, 25.6, 25.4, 25.1, 24.9. HRMS (ESI) $[M+H]^+$: calculated for $C_{33}H_{39}O_2$: 467.2950, found 467.2947.



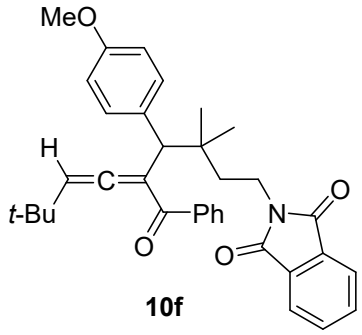

**10d**

**5-Benzoyl-4-(4-methoxyphenyl)-3,3,8,8-tetramethylnona-5,6-dien-1-yl 4-chlorobenzoate (10d).** Flash column chromatography to afford product **10d** as a white solid (66.4 mg, 61% yield, dr = 33:67). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 7.95-7.92 (m, 2H), 7.63-7.50 (m, 2H), 7.44-7.29 (m, 7H), 6.85-6.80 (m, 2H), [5.46 (s, 0.37H), 5.45 (d, *J* = 0.9 Hz, 0.63H)], 4.47-4.38 (m, 2H), [4.20 (s, 0.37), 4.14 (s, 0.63H)], [3.79 (s, 1.89H), 3.78 (s, 1.11H)], 2.01-1.78 (m, 2H), 1.16-1.09 (m, 6H), [0.94 (s, 5.67H), 0.71 (s, 3.33H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 213.3, 212.3, 196.2, 195.6, 165.7(2), 165.7(0), 158.2(0), 158.1(7), 139.2, 138.4(9), 138.4(8), 133.0, 132.8, 131.4, 131.3, 131.2, 131.0, 130.9, 128.8(7), 128.8(5), 128.7, 128.6, 128.5, 127.5(4), 127.4(5), 113.0(4), 112.9(6), 111.7, 111.5, 108.6, 108.4, 62.6, 55.2, 55.1, 51.5, 50.6, 38.7, 38.3, 38.0, 36.8, 33.6, 33.3, 29.5, 29.1, 25.7, 25.3, 25.0, 24.9. HRMS (ESI) $[M+Na]^+$: calculated for $C_{34}H_{37}ClO_4Na$: 567.2278, found 567.2279.



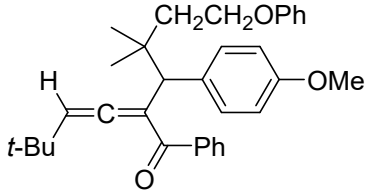

**10e**

**5-Benzoyl-4-(4-methoxyphenyl)-3,3,8,8-tetramethylnona-5,6-dien-1-yl 4-methoxybenzoate (10e).** Flash column chromatography to afford product **10e** as a pale yellow solid (97.3 mg, 90% yield, dr = 38:62). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 7.98-7.95 (m, 2H), 7.64-7.51 (m, 2H), 7.43-7.29 (m, 5H), 6.91-6.80 (m, 2H), 6.85-6.79 (m, 2H), [5.46 (s, 0.40H), 5.44 (s, 0.60H)], 4.45-4.36 (m, 2H), [4.20 (s, 0.40H), 4.14 (s, 0.60H)], 3.84-3.76 (m, 6H), 1.99-1.80 (m, 2H), 1.14-1.11 (m, 6H), [0.94 (s, 5.40H), 0.71 (s, 3.60H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 213.2, 212.3, 196.2, 195.6, 166.3(1), 166.2(9), 163.2, 158.2, 158.1, 138.5(5), 138.5(1), 133.1, 132.9, 131.5, 131.4, 131.3, 131.2, 131.0, 128.7, 128.5, 127.5, 127.4, 122.8(8), 122.8(6), 113.5(3), 113.4(8), 113.0, 112.9, 111.8, 111.5, 108.6, 108.4, 61.9, 55.3, 55.1(2), 55.1(0), 51.6, 50.8, 38.7, 38.3, 38.0, 36.8, 33.6, 33.2, 29.5, 29.1, 25.7, 25.3, 25.0, 24.9. HRMS (ESI) $[M+Na]^+$: calculated for $C_{35}H_{40}O_5Na$: 563.2773, found 563.2772.



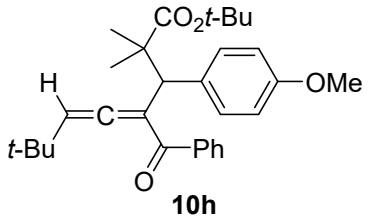

**10f**

**2-(5-Benzoyl-4-(4-methoxyphenyl)-3,3,8,8-tetramethylnona-5,6-dien-1-yl) isoindoline-1,3-dione (10f).** Flash column chromatography to afford product **10f** as a white solid (92.1 mg, 86% yield, dr = 62:38). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 7.81-7.77 (m, 2H), 7.67-7.64 (m, 2H), 7.62-7.50 (m, 2H), 7.43-7.28 (m, 5H), 6.82-6.79 (m, 2H), [5.48 (d, *J* = 1.1 Hz, 0.62H), 5.43 (s, 0.38H)], [4.18 (s, 0.62H), 4.15 (s, 0.38H)], 3.82-3.66 (m, 5H), 1.83-1.60 (m, 2H), 1.15-1.11 (m, 6H), [0.93 (s, 3.42H), 0.73 (s, 5.58H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 213.2, 212.6, 196.2, 195.7, 168.1, 168.0, 158.1(0), 158.0(7), 138.6(4), 138.6(0), 133.7, 132.8(3), 132.7(5), 132.2(0), 132.1(8), 131.4, 131.2, 131.0, 130.8, 128.6, 128.5, 127.4, 127.3, 122.9(7), 122.9(6), 113.0, 112.9, 111.7, 111.5, 108.5, 108.4, 55.0(6), 55.0(5), 50.8, 50.1, 38.6, 38.5, 37.9, 36.9, 34.3, 34.2, 33.6, 33.2, 29.5, 29.1, 25.0, 24.9, 24.5. HRMS (ESI) $[M+H]^+$: calculated for $C_{35}H_{38}NO_4$: 536.2801, found 536.2796.



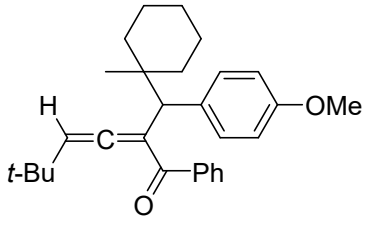

**10g**

**2-(1-(4-Methoxyphenyl)-2,2-dimethyl-4-phenoxybutyl)-5,5-dimethyl-1-phenylhexa-2,3-dien-1-one (10g).** Flash column chromatography to afford product **10g** as a colorless oil (76.2 mg, 79% yield, dr = 39:61). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 7.66-7.53 (m, 2H), 7.45-7.26 (m, 7H), 6.95-6.83 (m, 5H), 5.47 (s, 1H), [4.24 (s, 0.67H), 4.18 (s, 0.33H)], 4.12-4.03 (m, 2H), 3.80 (s, 3H), 2.10-1.85 (m, 2H), 1.16-1.09 (m, 6H), [0.97 (s, 2.97H), 0.74 (s, 6.03H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 213.2, 212.3, 196.2, 195.6, 159.0, 158.9, 158.1(5), 158.1(3), 138.6, 138.5, 133.1, 133.0, 131.4, 131.3, 131.2, 131.0, 129.3, 128.7, 128.5, 127.5, 127.4, 120.4(0), 120.3(7), 114.5, 113.0, 112.9, 111.8, 111.6, 108.5, 108.3, 64.8, 64.7, 55.1(2), 55.1(0), 51.3, 50.6, 39.1, 38.9, 37.9, 36.8, 33.6, 33.2, 29.5, 29.1, 25.8, 25.6, 25.2(4), 25.1(8). HRMS (ESI) $[M+H]^+$: calculated for $C_{33}H_{39}O_3$: 483.2899, found 483.2896.




**10h**

***tert*-Butyl 4-benzoyl-3-(4-methoxyphenyl)-2,2,7,7-tetramethylocta-4,5-dienoate (10h).** Flash column chromatography to afford product **10h** as a pale yellow oil (84.1 mg, 91% yield, dr = 25:75). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 7.62-7.52 (m, 2H), 7.43-7.29 (m, 5H), 6.82-6.79 (m, 2H), [5.44 (s, 0.32H), 5.40 (d, *J* = 1.6 Hz, 0.68H)], [4.65 (s, 0.32H), 4.58 (s, 0.68H)], [3.77 (s, 0.96H), 3.76 (s, 2.04H)], [1.40 (s, 2.88H), 1.36 (s, 6.12H)], 1.21-1.18 (m, 6H), [0.96 (s, 2.88H), 0.80 (s, 6.12H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 212.5, 212.3, 195.3, 194.9, 176.1, 176.0, 158.2(8), 158.2(7), 138.7, 138.6, 132.3, 132.0, 131.3(7), 131.3(5), 131.1, 130.9, 128.6, 128.5, 127.4(4), 127.3(7), 112.9(4), 112.9(1), 111.7, 111.6, 108.8, 108.5, 80.1, 80.0, 55.1(3), 55.1(0), 47.9, 47.4, 47.3, 47.1, 33.4, 33.2, 29.4, 29.2, 28.0, 27.9, 25.5, 25.2, 22.2, 21.9. HRMS (ESI) $[M+Na]^+$: calculated for $C_{30}H_{38}O_4Na$: 485.2668, found 485.2663.

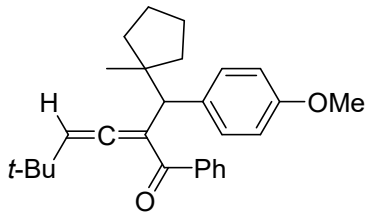



**10i**

**2-((4-Methoxyphenyl)(1-methylcyclohexyl)methyl)-5,5-dimethyl-1-phenylhexa-2,3-dien-1-one (10i).** Flash column chromatography to afford product **10i** (76.6 mg, 92% yield, dr = 42:58).

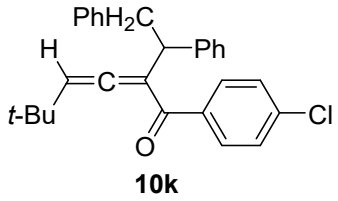
The first fraction：colorless oil. $^1$H NMR (500 MHz, $CDCl_3$) δ 7.65-7.63 (m, 2H), 7.45-7.41 (m, 1H), 7.38-7.33 (m, 4H), 6.80-6.77 (m, 2H), 5.41 (d, *J* = 0.8 Hz, 1H), 4.15 (s, 1H), 3.78 (s, 3H), 1.55-1.40 (m, 6H), 1.36-1.26 (m, 2H), 1.22-1.17 (m, 2H), 1.06 (s, 3H), 0.68 (s, 9H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 213.6, 195.7, 157.9, 138.6, 133.5, 131.5, 131.1, 128.8, 127.5, 112.7, 111.9, 108.3, 55.1, 51.2, 38.7, 37.0, 36.2, 33.2, 29.1, 26.2, 22.0, 20.4. HRMS (ESI) $[M+H]^+$: calculated for $C_{29}H_{37}O_2$: 417.2794, found 417.2789.

The second fraction：white solid. $^1$H NMR (500 MHz, $CDCl_3$) δ 7.53-7.51 (m, 2H), 7.42-7.38 (m, 1H), 7.32-7.29 (m, 4H), 6.83-6.80 (m, 2H), 5.37 (s, 1H), 4.11 (s, 1H), 3.79 (s, 3H), 1.60-1.49 (m, 6H), 1.43-1.34 (m, 2H), 1.29-1.20 (m, 2H), 1.05 (s, 3H), 0.95 (s, 9H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 212.6, 196.5, 158.0, 138.9, 133.4, 131.4, 130.9, 128.6, 127.4, 112.8, 111.7, 107.7, 55.1, 51.9, 37.4, 36.7, 35.7, 33.5, 29.6, 26.2, 21.9(2), 21.8(7), 20.4. HRMS (ESI) $[M+H]^+$: calculated for $C_{29}H_{37}O_2$: 417.2794, found 417.2790.



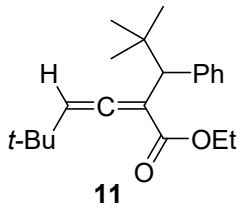

**10j**

**2-((4-Methoxyphenyl)(1-methylcyclopentyl)methyl)-5,5-dimethyl-1-phenylhexa-2,3-dien-1-one (10j).** Flash column chromatography to afford product **10j** as a pale yellow oil (59.5 mg, 74% yield, dr = 60:40). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 7.64-7.62 (m, 2H), 7.45-7.39 (m, 1H), 7.37-7.29 (m, 4H), 6.82-6.78 (m, 2H), 5.40 (s, 1H), [4.20 (s, 0.62H), 4.15 (s, 0.38)], 3.78 (s, 3H), 1.79-1.21 (m, 8H), [1.07 (s, 1.14H), 1.04 (s, 1.86H)], [0.92 (s, 3.42H), 0.71 (s, 5.58H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 213.1, 212.1, 196.4, 195.8, 157.9, 157.9, 138.8, 138.7, 134.7, 134.4, 131.2, 131.0, 130.9(2), 130.8(7), 128.7, 128.6, 127.5, 127.4, 112.9(3), 112.8(8), 112.7, 112.5, 108.2(5), 108.1(7), 55.2, 55.1, 51.2, 50.6, 47.6, 46.7, 39.0, 38.9, 38.0, 37.3, 33.5, 33.2, 29.5, 29.2, 24.3, 24.2, 24.0, 23.9, 23.8. HRMS (ESI) $[M+H]^+$: calculated for $C_{28}H_{35}O_2$: 403.2637, found 403.2637.




**10k**

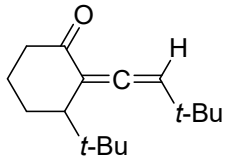
**1-(4-Chlorophenyl)-2-(1,2-diphenylethyl)-5,5-dimethylhexa-2,3-dien-1-one (10k).** Flash column chromatography to afford product **10k** as a white solid (44.7 mg, 54% yield, dr = 41:59). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 7.60-7.50 (m, 2H), 7.35-7.25 (m, 5H), 7.23-7.12 (m, 6H), 7.07-7.05 (m, 1H), [5.59 (d, $J$ = 1.9 Hz, 0.40H), 5.48 (d, $J$ = 1.8 Hz, 0.60H)], 4.51-4.42 (m, 1H), 3.24-3.01 (m, 2H), [0.95 (s, 3.6H), 0.83 (s, 5.4H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 211.1, 210.6, 193.2, 193.0, 142.8, 142.4, 139.9, 139.7, 137.7, 137.6, 137.0, 136.8, 130.2, 130.1, 129.0(3), 128.9(9), 128.2, 128.1(2), 128.0(9), 128.0(6), 128.0, 127.8(3), 127.7(7), 126.4(4), 126.4(1), 126.0, 125.9, 114.0, 113.9, 109.3, 109.2, 44.4(5), 44.4(0), 41.5, 40.8, 33.3, 33.2, 29.7, 29.5. These data are consistent with the published literature.[1]




**11**

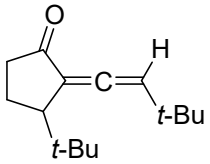
**Ethyl 2-(2,2-dimethyl-1-phenylpropyl)-5,5-dimethylhexa-2,3-dienoate (11).** Flash column chromatography to afford product **11** as a colorless oil (44.0 mg, 70% yield, dr = 51:49). Two diastereoisomers are hard to be separated by column

chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 7.38-7.31 (m, 2H), 7.26-7.22 (m, 2H), 7.21-7.17 (m, 1H), 5.63 (s, 1H), 4.20-3.98 (m, 2H), [3.80 (s, 0.52H), 3.78 (s, 0.48H)], 1.22 (s, 4.68H), 1.20 (m, 3H), 1.07 (s, 4.32H), [1.00 (s, 4.68H), 0.96 (s, 4.32H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 209.2, 209.1, 168.4, 168.3, 142.1, 141.6, 130.3, 130.1, 127.3(1), 127.2(8), 126.2, 126.1, 107.5, 107.2, 103.9, 60.8, 53.5, 53.4, 35.6, 34.9, 33.7, 33.4, 29.9, 29.6, 28.2(2), 28.1(9), 14.1. HRMS (ESI) $[M+H]^+$: calculated for $C_{21}H_{31}O_2$: 315.2324, found 315.2323.



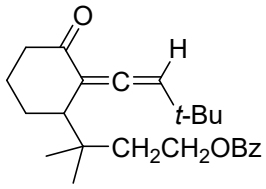

**13a**

**3-(*tert*-Butyl)-2-(3,3-dimethylbut-1-en-1-ylidene)cyclohexan-1-one (13a).** Flash column chromatography to afford product **13a** as a pale yellow oil (29.0 mg, 62% yield, dr = 48:52). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ [5.45 (d, $J$ = 3.1 Hz, 0.60H), 5.41 (d, $J$ = 2.6 Hz, 0.40H)], 2.51-2.37 (m, 2H), 2.29-2.17 (m, 1H), 2.01-1.94 (m, 1H), 1.93-1.87 (m, 1H), 1.73-1.61 (m, 1H), 1.54-1.41 (m, 1H), [1.11 (s, 5.4H), 1.05 (s, 3.6H), 0.95 (s, 5.4H), 0.88 (s, 3.6H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 206.7, 205.1, 203.6, 203.4, 109.2, 108.9, 105.4, 105.0, 48.9, 48.5, 40.0, 35.8, 34.2, 33.0, 32.9, 30.1, 30.0, 27.7, 27.4, 25.6, 25.0, 21.4, 21.1. HRMS (ESI) $[M+H]^+$: calculated for $C_{16}H_{27}O$: 235.2062, found 235.2056.




**13b**

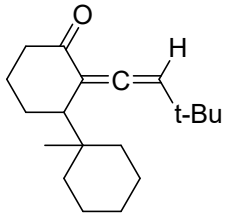
**3-(*tert*-Butyl)-2-(3,3-dimethylbut-1-en-1-ylidene)cyclopentan-1-one (13b).** Flash column chromatography to afford product **13b** as a pale yellow oil (23.8 mg, 54% yield, dr = 71:29). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ [5.64 (d, $J$ = 5.2 Hz, 0.72H), 5.61 (d, $J$ = 5.0 Hz, 0.28H)], 2.80-2.75 (m, 1H), 2.42-2.23 (m, 2H), 2.04-1.97 (m, 1H), 1.78-1.68 (m, 1H), [1.13 (s, 6.48H), 1.09 (s, 2.52H)], [0.99 (s, 6.48H), 0.95 (s, 2.52H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 207.6(5), 207.6(3), 204.2, 203.7, 107.9, 107.8, 107.7, 107.5, 51.5, 51.2, 38.2(3), 38.2(0), 34.2, 33.6(0), 33.5(7), 33.3, 30.2, 30.1(5), 27.5, 27.3, 23.0, 22.7. HRMS (ESI) $[M+H]^+$: calculated for $C_{15}H_{24}O$: 221.1905, found 221.1906.




**13c**

**3-(2-(3,3-Dimethylbut-1-en-1-ylidene)-3-oxocyclohexyl)-3-methylbutyl benzoate**

**(13c).** Flash column chromatography to afford product **13c** as a pale yellow oil (35.4 mg, 48% yield, dr = 48:52). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 8.01 (m, 2H), 7.57-7.51 (m, 1H), 7.45-7.43 (m, 2H), [5.49 (d, *J* = 3.1 Hz, 0.55H), 5.46 (d, *J* = 2.7 Hz, 0.45H)], 4.45-4.31 (m, 2H), 2.71-2.54 (m, 1H), 2.55-2.45 (m, 1H), 2.31-2.17 (m, 1H), 2.07-1.82 (m, 4H), 1.76-1.65 (m, 1H), 1.58-1.45 (m, 1H), [1.12 (s, 4.95H), 1.05 (s, 4.05H)], 1.05-0.96 (m, 6H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 206.6, 205.2, 203.2, 203.0, 166.6, 132.8, 130.3, 129.5, 128.3(2), 128.3(0), 108.6, 108.3, 105.8, 105.4, 62.1(2), 62.0(7), 47.4, 46.6, 39.9, 38.0, 37.9, 37.6, 36.2, 33.1, 33.0, 30.1, 30.0, 25.1, 24.9, 24.8, 24.7, 24.6, 21.3, 21.0. HRMS (ESI) $[M+Na]^+$: calculated for $C_{24}H_{32}O_3Na$: 391.2252, found 391.2249.

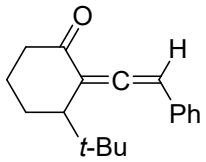



**13d**

**2-(3,3-Dimethylbut-1-en-1-ylidene)-1'-methyl-[1,1'-bi(cyclohexan)]-3-one (13d).** Flash column chromatography to afford product **13d** as a pale yellow oil (33.5 mg, 61% yield, dr = 52:48).

The first fraction: pale yellow oil.$^1$H NMR (500 MHz, $CDCl_3$) δ 5.43 (d, *J* = 2.8 Hz, 1H), 2.65-2.61 (m, 1H), 2.50-2.44 (m, 1H), 2.26-2.20 (m, 1H), 1.97-1.86 (m, 2H), 1.71-1.65 (m, 1H), 1.52-1.24 (m, 11H), 1.11 (s, 9H), 0.85 (s, 3H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 205.5, 203.7, 108.6, 104.9, 46.2, 40.0, 36.7, 35.8, 32.9, 30.1, 26.2, 24.3, 21.9, 21.6, 21.3, 21.0. HRMS (ESI) $[M+H]^+$: calculated for $C_{19}H_{31}O$: 275.2375, found 275.2377.

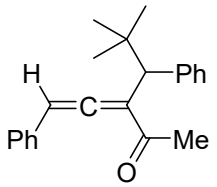
The second fraction: pale yellow oil. $^1$H NMR (500 MHz, $CDCl_3$) δ 5.40 (d, *J* = 2.6 Hz, 1H), 2.76-2.72 (m, 1H), 2.50-2.45 (m, 1H), 2.23-2.16 (m, 1H), 1.96-1.87 (m, 2H), 1.67-1.62 (m, 1H), 1.48-1.17 (m, 11H), 1.05 (s, 9H), 0.76 (s, 3H). $^{13}$C NMR (126 MHz, $CDCl_3$) δ 206.5, 203.9, 108.4, 104.8, 45.3, 40.0, 38.0, 35.9, 35.6, 33.0, 30.2, 26.2, 23.8, 21.8, 21.6, 21.1, 20.9. HRMS (ESI) $[M+H]^+$: calculated for $C_{19}H_{31}O$: 274.2375, found 274.2375.




**13e**

**3-(*tert*-Butyl)-2-(2-phenylvinylidene)cyclohexan-1-one (13e).** Flash column chromatography to afford product **13e** as a pale yellow oil (23.4 mg, 46% yield, dr = 50:50). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 7.32-7.29 (m, 3H), 7.23-7.21 (m, 2H), [6.53 (d, *J* = 3.0 Hz, 0.47H), 6.45 (d, *J* = 3.0 Hz, 0.53H)], 2.67-2.53 (m, 2H), 2.37-2.29 (m,

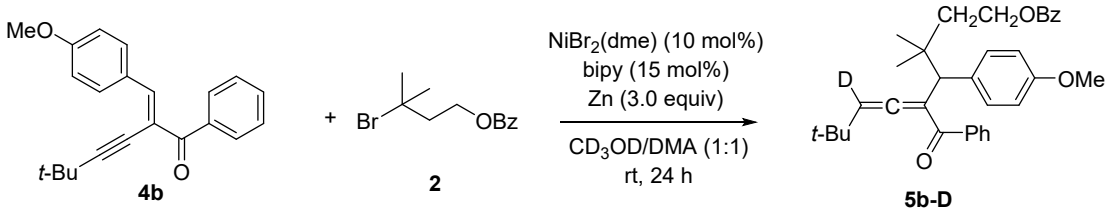
1H), 2.11-1.97 (m, 2H), 1.87-1.73 (m, 1H), 1.58-1.52 (m, 1H), [0.95 (s, 4.77H), 0.94 (s, 4.23H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 210.2, 209.4, 202.6, 202.3, 132.8, 132.6, 128.7(3), 128.6(7), 127.5, 127.4, 127.3, 127.0, 110.9, 110.8, 97.6, 97.2, 49.7, 48.5, 40.3, 40.3, 35.5, 34.4, 27.5, 27.4, 25.5, 25.1, 21.5, 21.4. HRMS (ESI) $[M+H]^+$: calculated for $C_{18}H_{22}O$: 255.1749, found 255.1751.



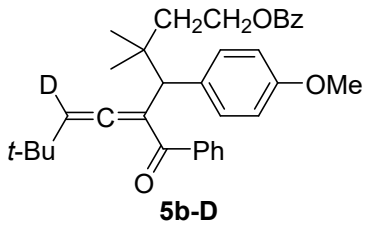

**15**

**5,5-Dimethyl-4-phenyl-3-(2-phenylvinylidene)hexan-2-one (15).** Flash column chromatography to afford product **15** as a white solid (44.9 mg, 74% yield, dr = 49:51). Two diastereoisomers are hard to be separated by column chromatography on silica gel. $^1$H NMR (500 MHz, $CDCl_3$) δ 7.40-7.28 (m, 3H), 7.29-7.18 (m, 4H), 7.20-7.08 (m, 3H), 6.73 (s, 1H), [3.98 (s, 0.49H), 3.97 (s, 0.51H)], [2.22 (s, 1.47H), 2.20 (s, 1.53H)], [0.90 (s, 4.59H), 0.87 (s, 4.41H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 217.0, 216.5, 197.4, 197.3, 141.6, 141.3, 132.1, 131.9, 130.1, 130.0, 129.1, 128.9, 127.9(8), 127.9(7), 127.6, 127.5, 127.4, 127.2, 126.3(4), 126.2(8), 114.8, 114.3, 100.3, 99.9, 51.7, 35.5, 35.0, 28.2(0), 28.1(6), 26.8, 26.7. These data are consistent with the published literature.[7]

# 4 Deuteration study

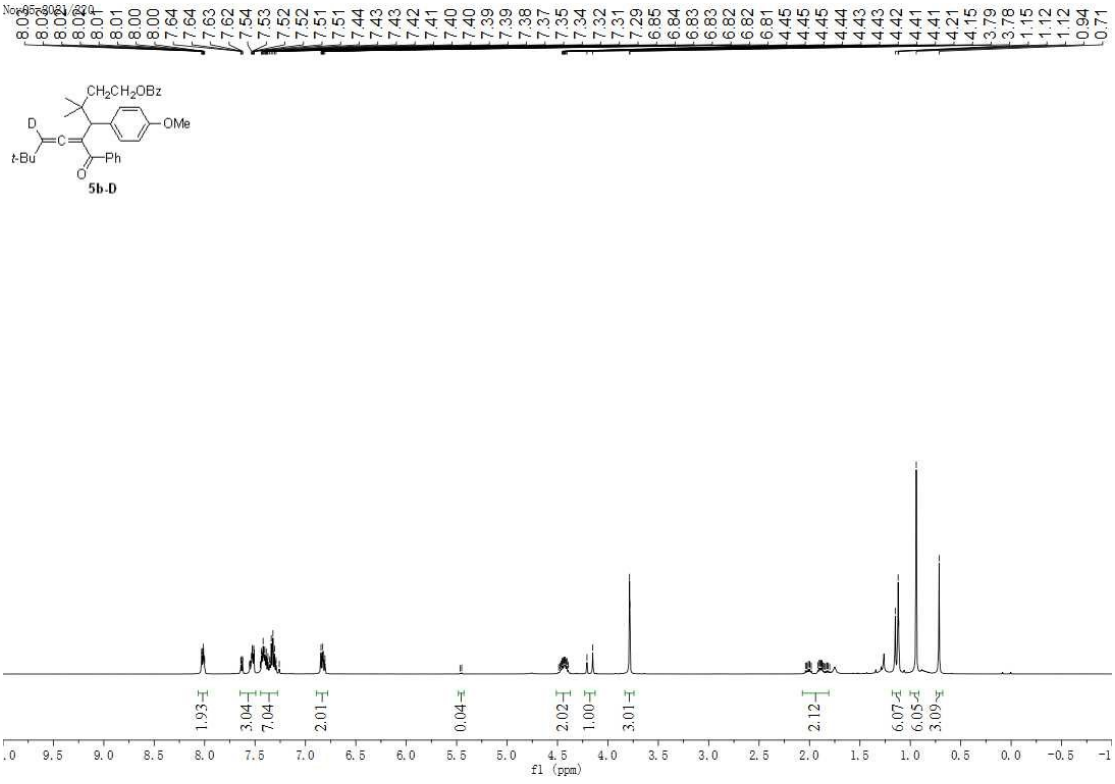


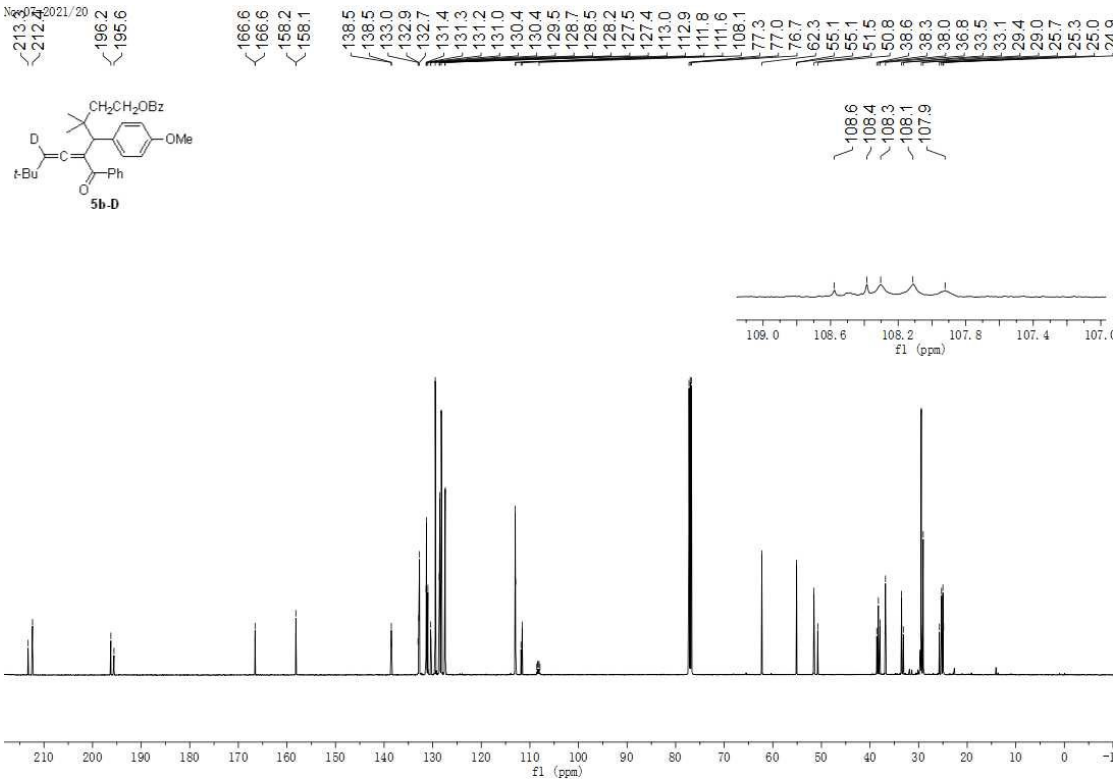

To an oven-dried Schlenk tube was charged with **4b** (63.8 mg, 0.2 mmol, 1.0 equiv), $NiBr_2$(dme) (6.2 mg, 10 mol%), 2,2'-bipyridine (4.7 mg, 15 mol%), Zn (39 mg, 0.6 mmol, 3.0 equiv). The tube was capped with a rubber septum, evacuated and back-filled with nitrogen three times, at which point DMA (1 mL) and $CD_3OD$ (1mL) was added via a syringe prior to the addition of tertiary alkyl bromide **2** (108.2 mg, 0.4 mmol, 2.0 equiv). The reaction mixture was allowed to stir at room temperature for 24 h, 3 mL of $H_2O$ was added to quench the reaction and the mixture was extracted by ethyl acetate. The combined organic layer was dried over $MgSO_4$. After filtration and concentration, the residue was purified by column chromatography on silica gel. The product **5b-D** with 95% D-incorporation was determined by $^1$H NMR.



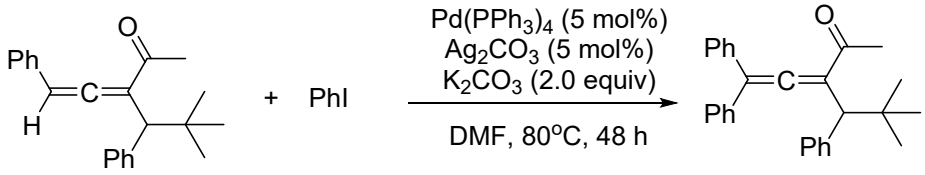

**5b-D**

**5-Benzoyl-4-(4-methoxyphenyl)-3,3,8,8-tetramethylnona-5,6-dien-1-yl-7-*d* benzoate (5b-D).** The product 5b-D was obtained in 74% yield (75.7 mg, D-incorporation > 95 %, dr = 36:64) as a white solid after column chromatography. The mixtures are hard to be separated by column chromatography on silica gel. $^{1}$H NMR (500 MHz, $CDCl_3$) δ 8.03-8.00 (m, 2H), 7.64-7.51 (m, 3H), 7.45-7.29 (m, 7H), 6.85-6.81 (m, 2H), 4.49-4.39 (m, 2H), [4.21 (s, 0.37H), 4.15 (s, 0.63H)], 3.78 (s, 3H), 2.04-1.80 (m, 2H), 1.15-1.12 (m, 6H), [0.94 (s, 5.67H), 0.71 (s, 3.33H)]. $^{13}$C NMR (126 MHz, $CDCl_3$) δ 213.3, 212.4, 196.2, 195.6, 166.5(7), 166.5(6), 158.2, 158.1, 138.5(2), 138.4(9), 133.0, 132.9, 132.7, 131.4, 131.3, 131.2, 131.0, 130.4(1), 130.3(9), 129.5, 128.7, 128.5, 128.2, 127.5, 127.4, 113.0, 112.9, 111.8, 111.6, 108.6, 108.4, 108.1(t, *J* = 23.9 Hz), 62.3, 55.1(2), 55.1(1), 51.5, 50.8, 38.6, 38.3, 38.0, 36.8, 33.5, 33.1, 29.4, 29.0, 25.7, 25.3, 25.0, 24.9. HRMS (ESI) $[M+Na]^+$: calculated for $C_{34}H_{37}DO_4Na$: 534.2731, found 534.2731.



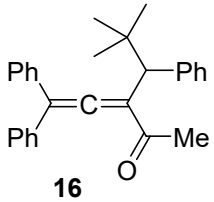



# 5 Transformation of 1,2-allenyl ketones




**15** (1.0 equiv) 2.0 equiv **16**, 53%

The reaction of **15** (55.2 mg, 0.2 mmol), iodobenzene (81.3 mg, 0.4 mmol), $Pd(PPh_3)_4$ (11.3 mg, 0.01 mmol), $Ag_2CO_3$ (2.8 mg, 0.01 mmol), and $K_2CO_3$ (55.3 mg, 0.4 mmol) in 2 mL dried DMF at 80 °C under $N_2$ for 48 h. Then, 3 mL of $H_2O$ was added to quench the reaction and the mixture was extracted by ethyl ester (3x10 mL). The combined organic layer was dried over $MgSO_4$. After filtration and concentration, the residue was purified by column chromatography on silica gel to give **16** (40.3 mg) in 53% yield.



**16**

**3-(2,2-Diphenylvinylidene)-5,5-dimethyl-4-phenylhexan-2-one (16).** White solid**.** $^1H$ NMR (500 MHz, $CDCl_3$) δ 7.47-7.45 (m, 4H), 7.41-7.38 (m, 1H), 7.34-7.30 (m,

5H), 7.24-7.22 (m, 2H), 7.20-7.18 (m, 3H), 4.07 (s, 1H), 2.36 (s, 3H), 0.89 (s, 9H). $^{13}C$ NMR (126 MHz, $CDCl_3$) δ 215.4, 197.6, 141.3, 134.9, 134.7, 130.3, 128.9, 128.7(2), 128.6(8), 128.4, 128.1, 128.0(1), 127.9(6), 127.5, 126.3, 113.7, 52.5, 35.1, 28.3, 27.1. HRMS (ESI) $[M+ Na]^+$: calculated for $C_{28}H_{28}ONa$: 403.2038, found 403.2039.

# 6 Reference


[1] W. Lei, Y. Liu, Y. Fang, Y. Li, C. Du and J. Fang, Modular access to 1,2-allenyl ketones based on a photoredox-catalysed radical-polar crossover process, *Org. Biomol. Chem.*, 2021, **19**, 8502-8506.

[2] Y. Liu, W. Luo, T. Xia, Y. Fang, C. Du, X. Jin, Y. Li, L. Zhang, W. Lei and H. Wu. Merging radical-polar crossover/cycloisomerization processes: access to polyfunctional furans enabled by metallaphotoredox catalysis, *Org. Chem. Front*., 2021, **8**, 1732-1738.

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[6] X. Wang; J. Dong; X. Xu, B. Tang, Dinucleophilic Reactivity of Isocyanoacetate: Base-Catalyzed One-Pot Access to 4-Azafluorenes and 4-Azafluorenones, *Org. Lett.,* 2021*,* **23**, 9063-9067.

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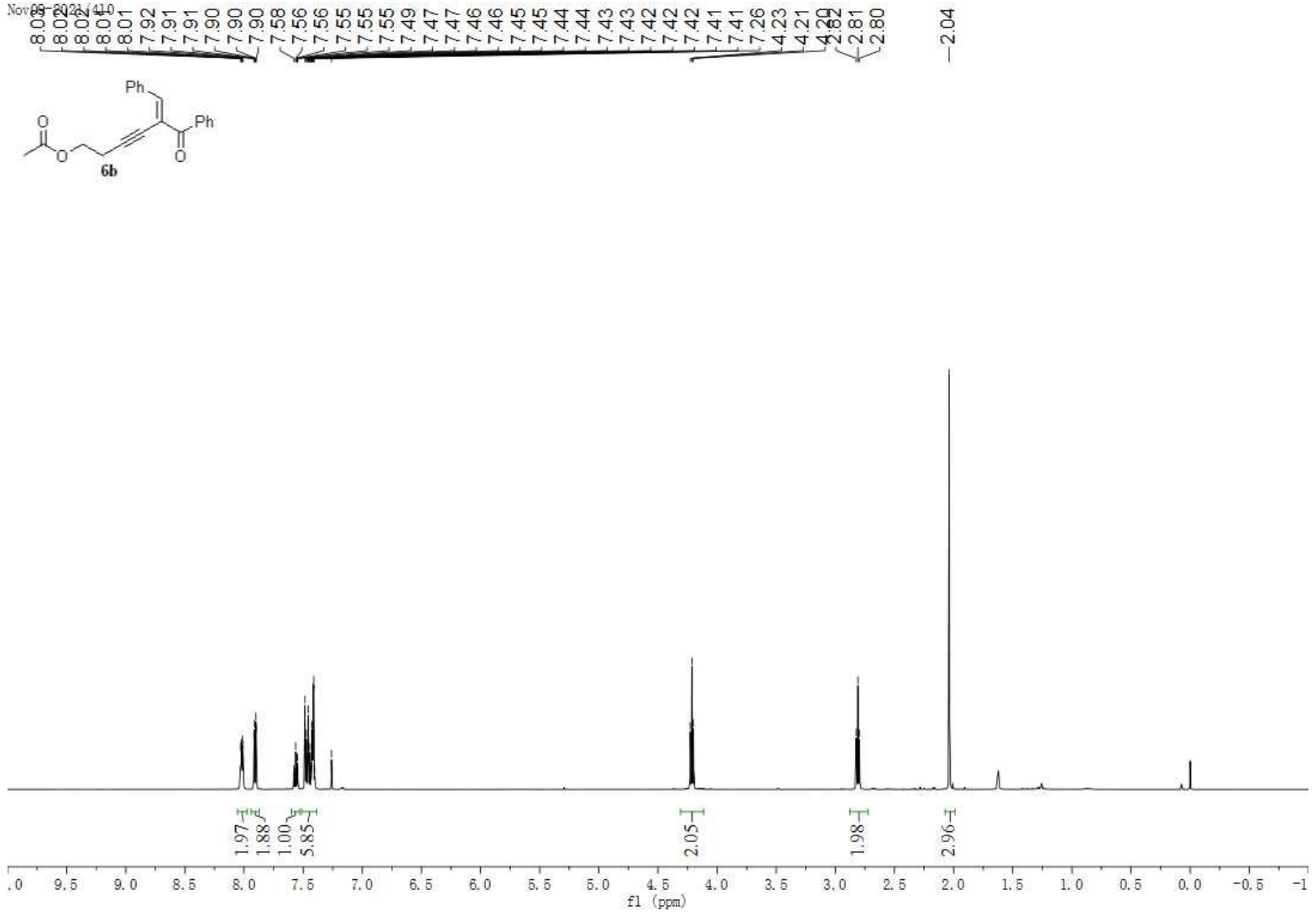
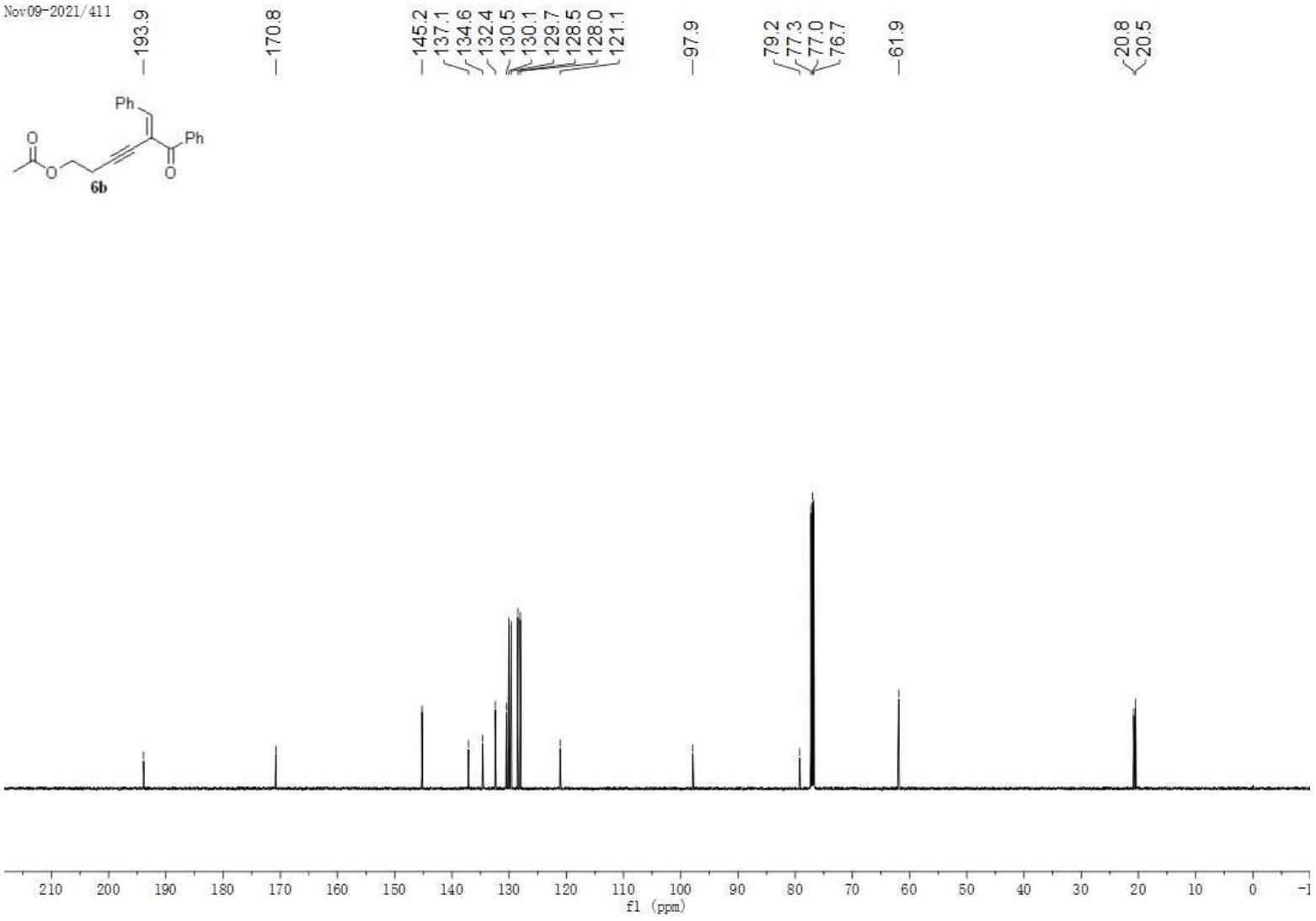
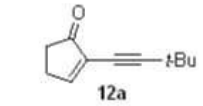
# 7 NMR spectra of new compound

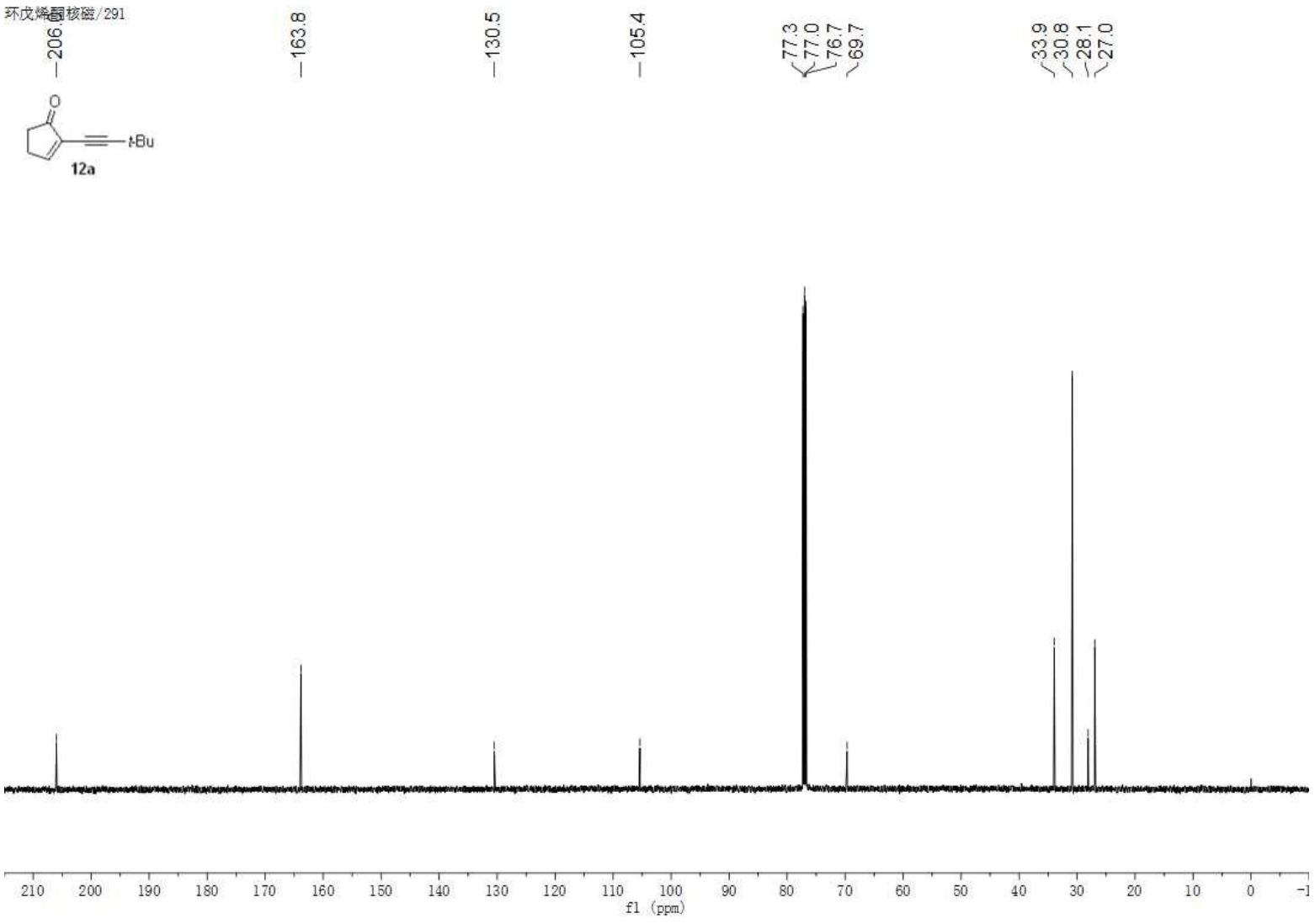

8.03
8.02
8.02
8.01
8.01
7.92
7.91
7.91
7.90
7.90
7.90
7.58
7.56
7.56
7.55
7.55
7.55
7.49
7.47
7.47
7.46
7.46
7.45
7.45
7.44
7.44
7.43
7.43
7.42
7.42
7.42
7.41
7.41
7.26
4.23
4.21
2.82
2.81
2.80
2.04
Ph
Ph
O
O
O
6b
1.97
1.88
1.00
5.85
2.05
1.98
2.96
f1 (ppm)

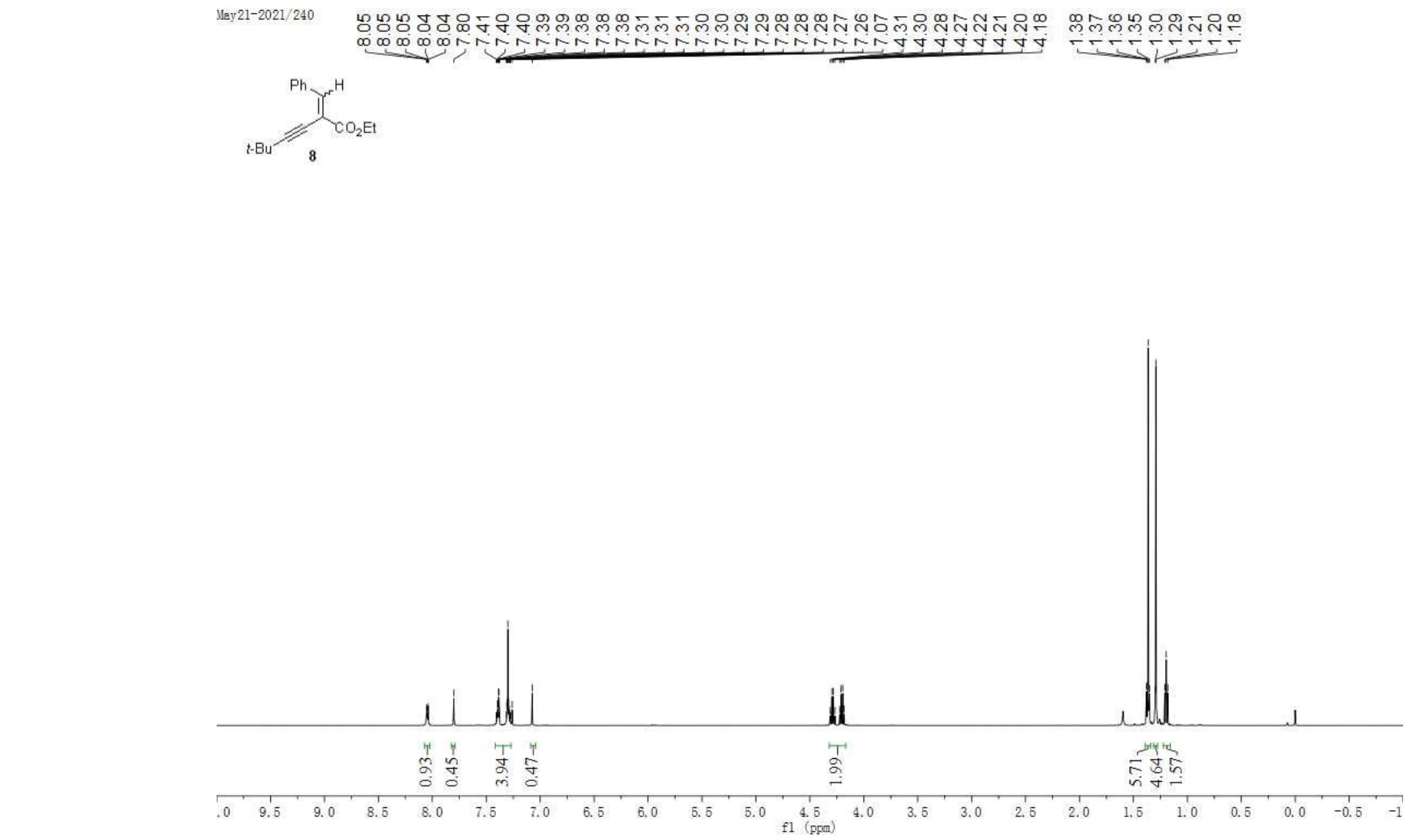

Nov09-2021/411
193.9
170.8
145.2
137.1
134.6
132.4
130.5
130.1
129.7
128.5
128.0
121.1
97.9
79.2
77.3
77.0
76.7
61.9
20.8
20.5
Ph
Ph
O
O
O
6b
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

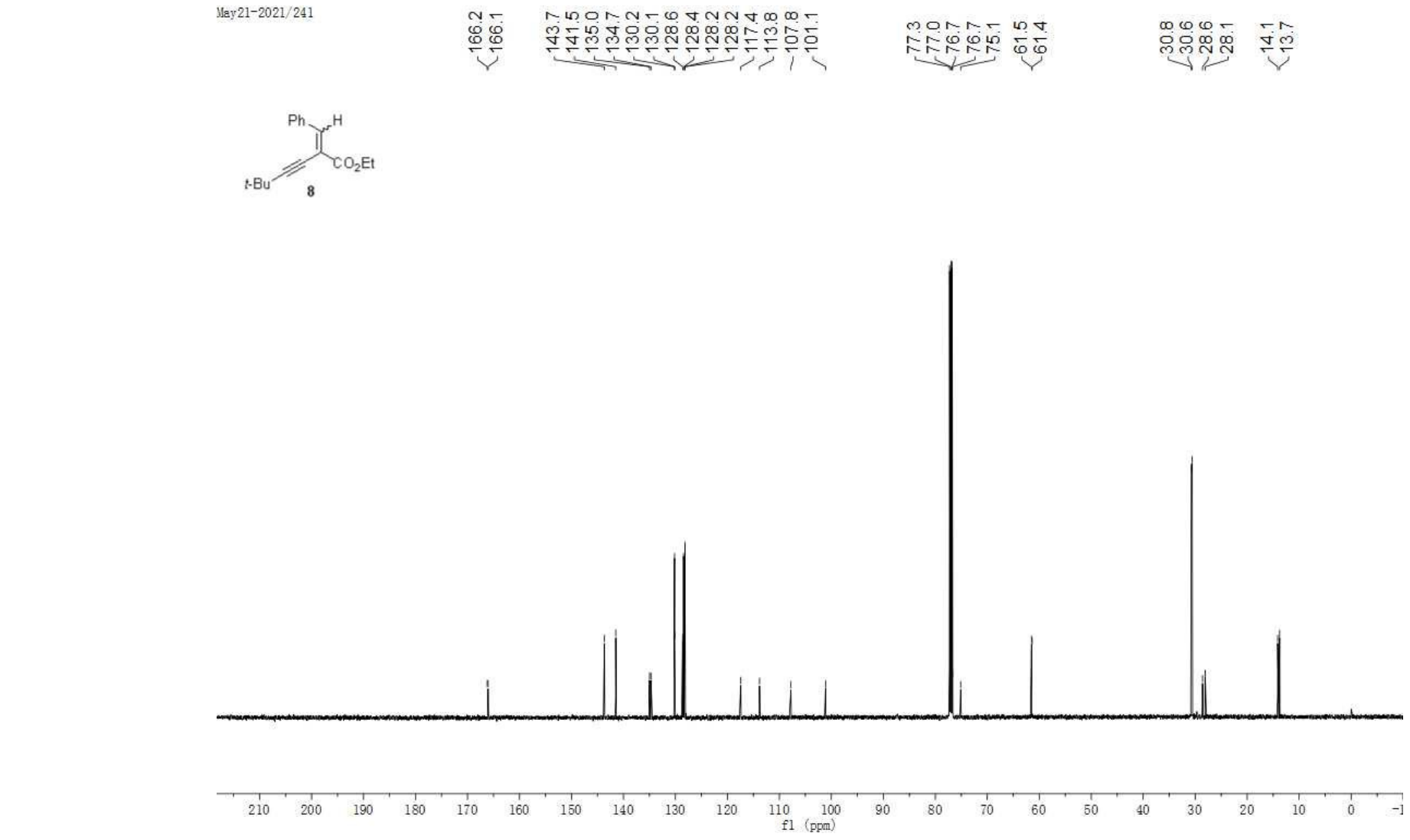
环戊烯酮核磁/290

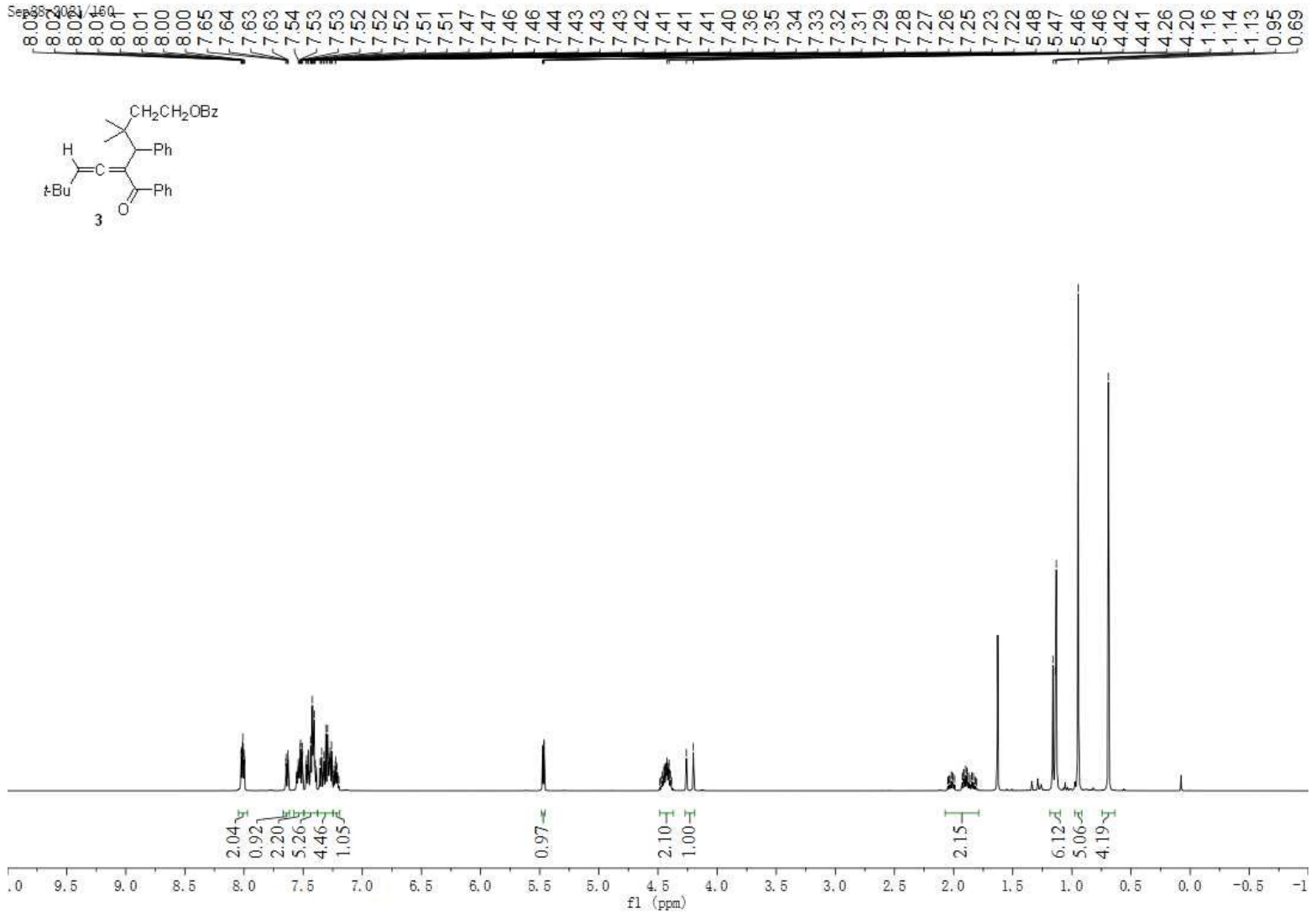


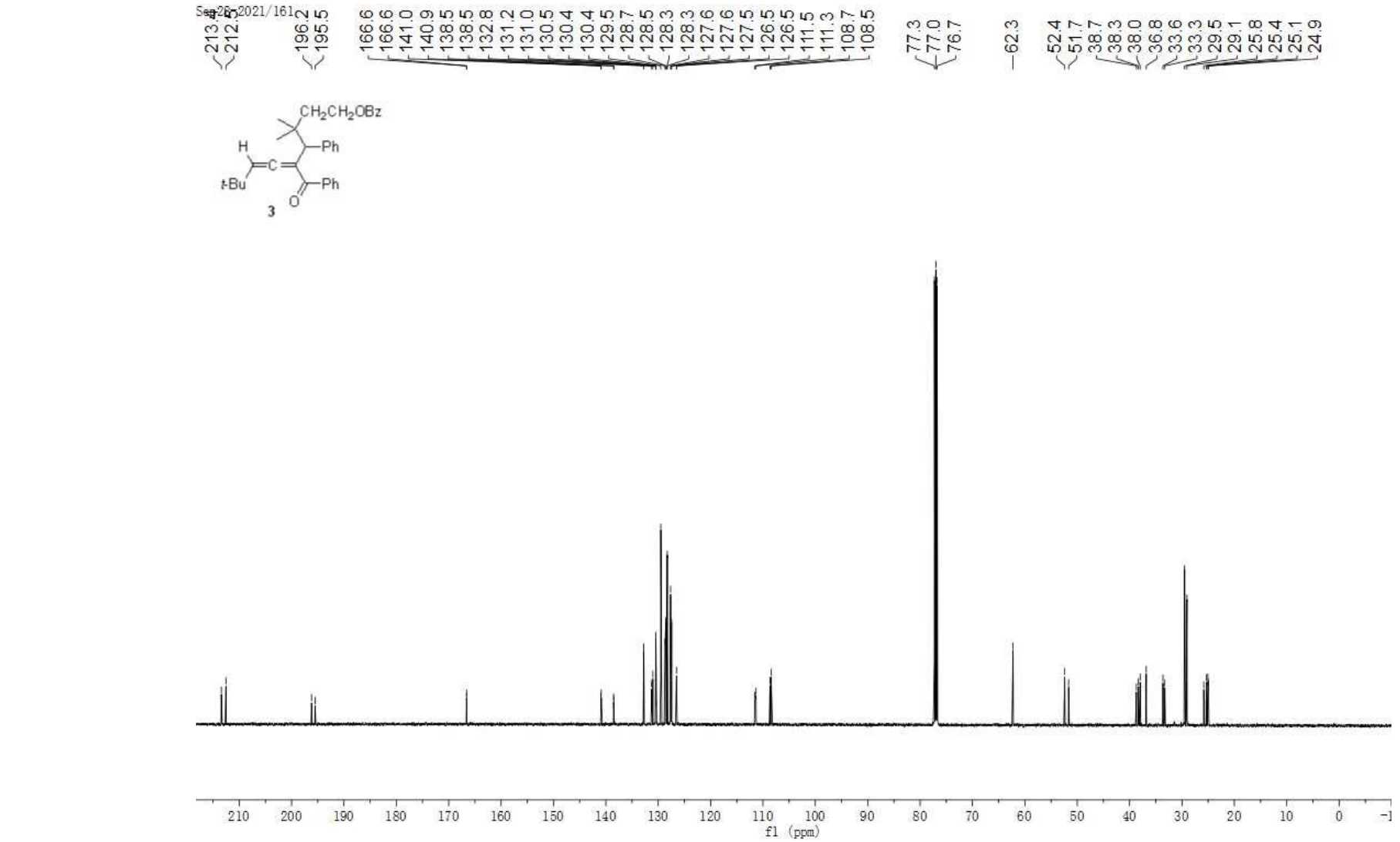

12a

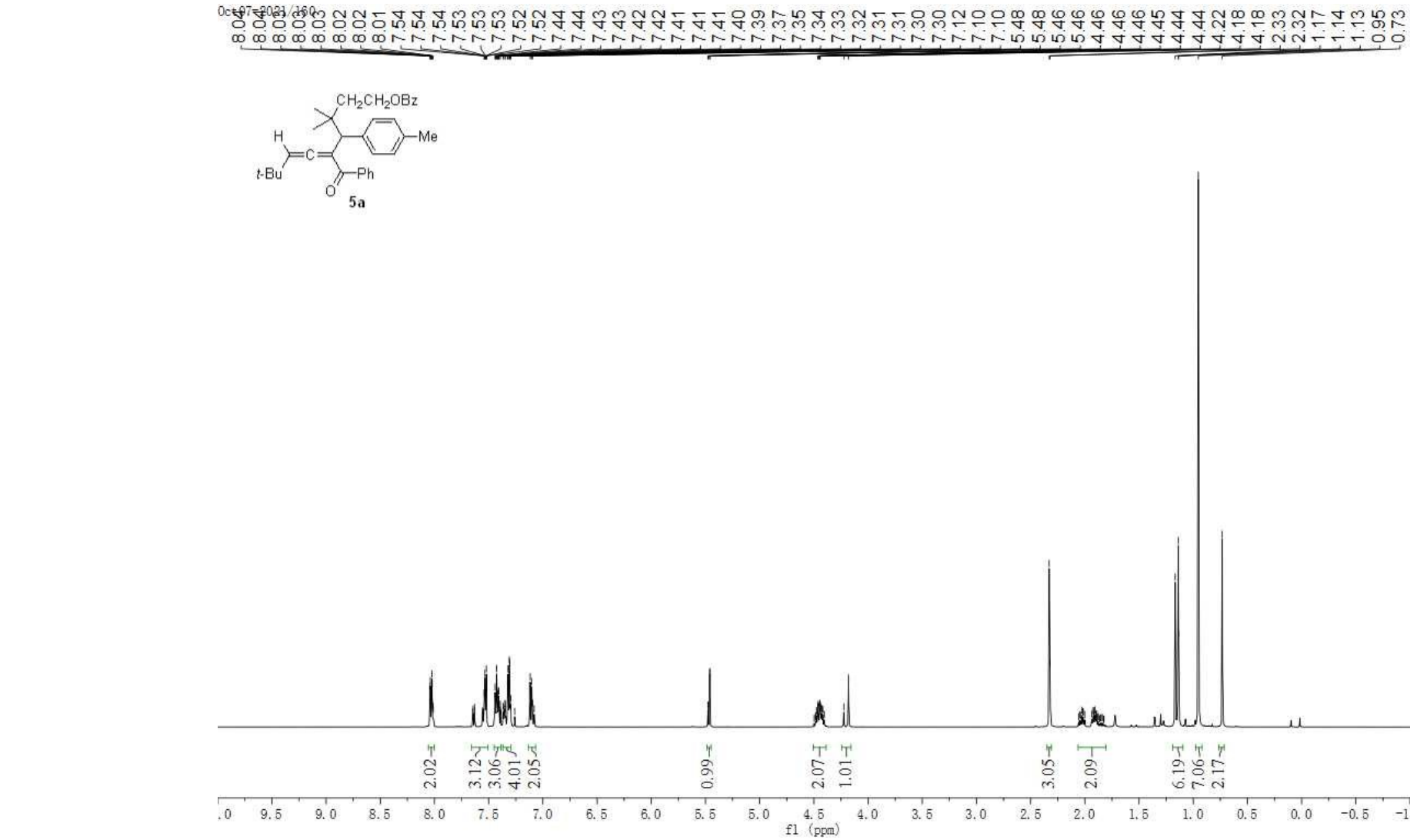

环戊烯酮核磁/291
206.1
163.8
130.5
105.4
77.3
77.0
76.7
69.7
33.9
30.8
28.1
27.0
O
t-Bu
12a
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -1
f1 (ppm)

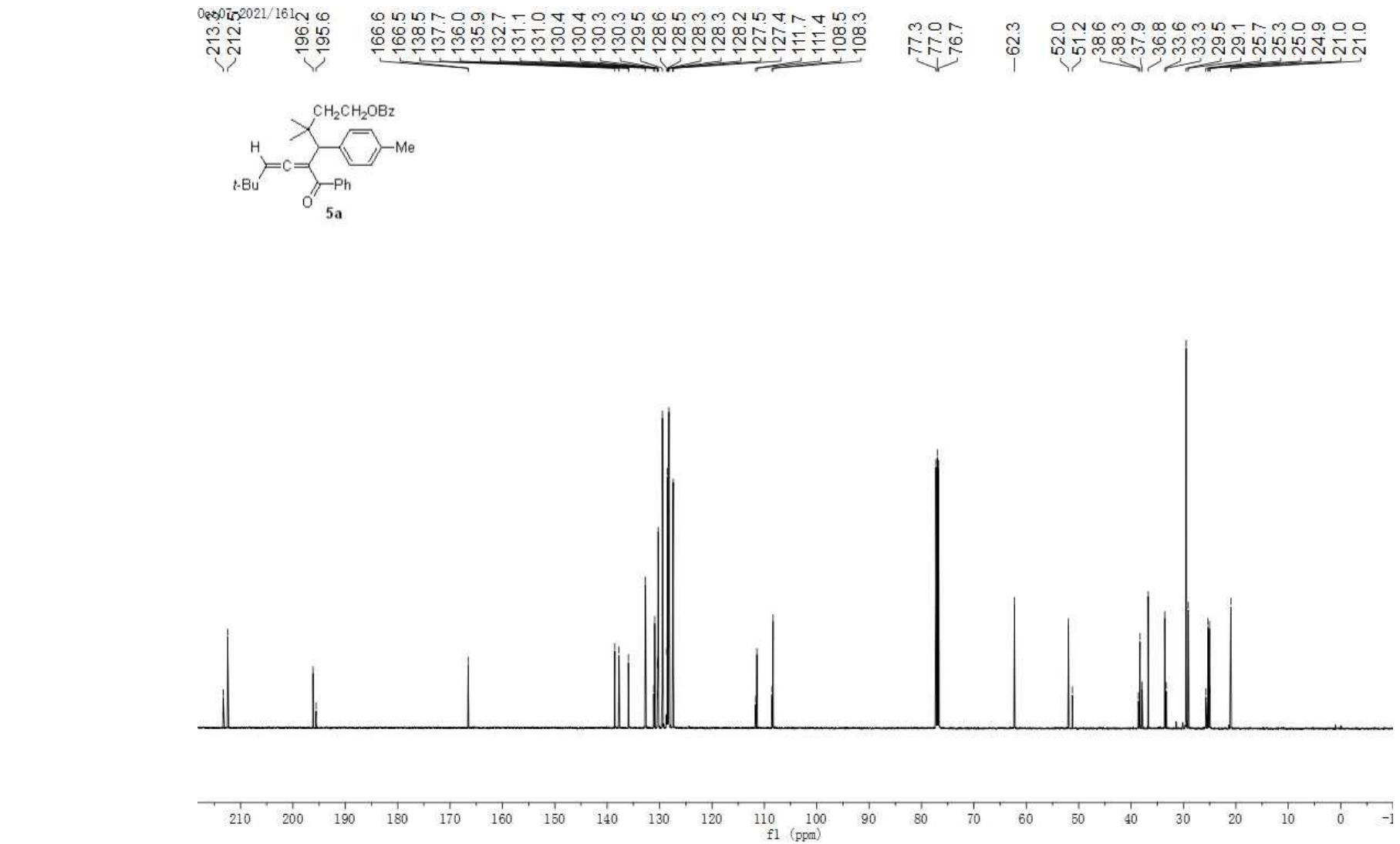

May21-2021/240
8.05 8.05 8.05 8.04 8.04 7.80 7.41 7.40 7.40 7.39 7.39 7.38 7.38 7.38 7.31 7.31 7.31 7.30 7.30 7.29 7.29 7.28 7.28 7.28 7.27 7.26 7.07 4.31 4.30 4.28 4.27 4.22 4.21 4.20 4.18
1.38 1.37 1.36 1.35 1.30 1.29 1.21 1.20 1.18
Ph
H
CO2Et
t-Bu
8
0.93
0.45
3.94
0.47
1.99
5.71
4.64
1.57
f1 (ppm)

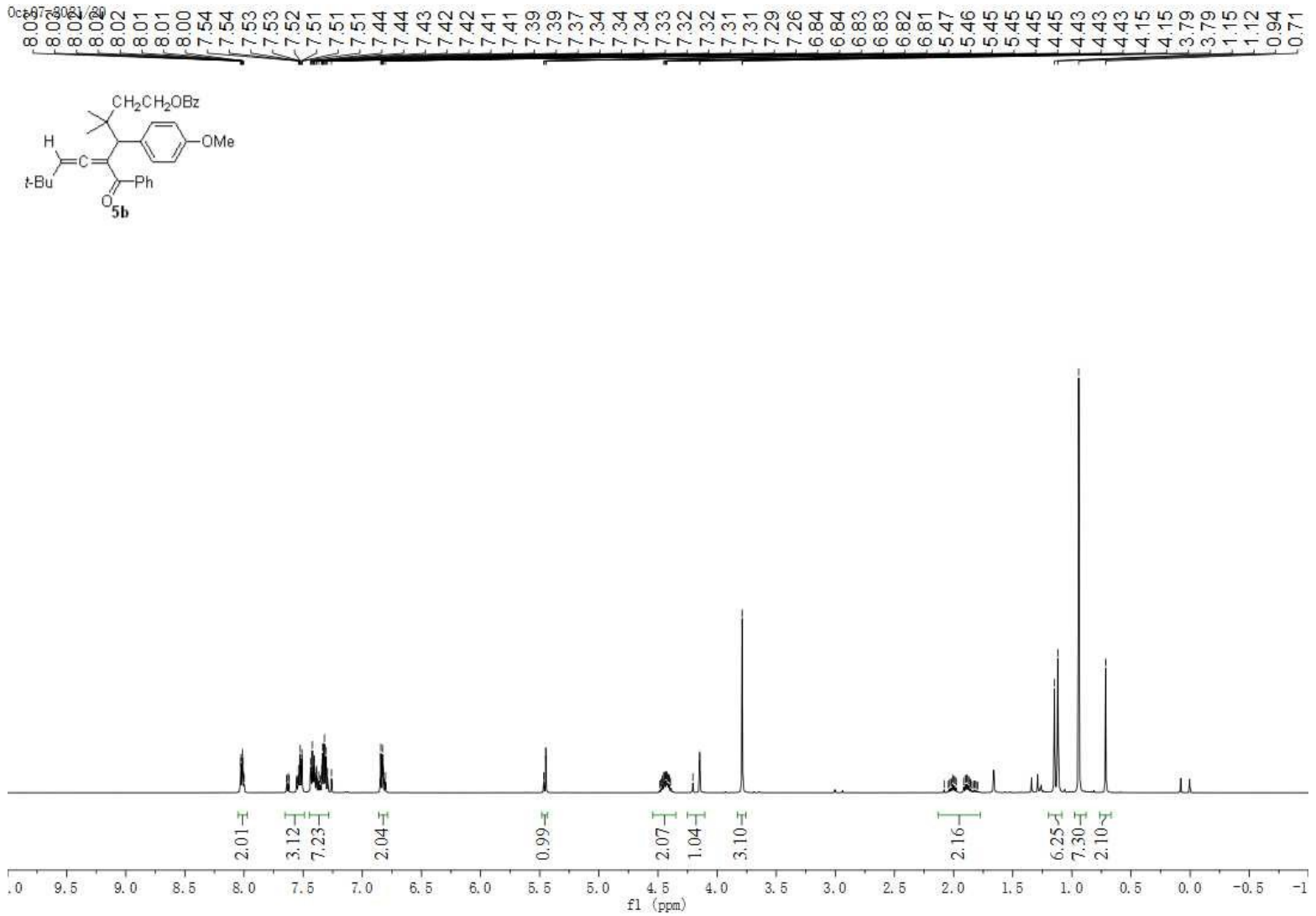

May21-2021/241
166.2
166.1
143.7
141.5
135.0
134.7
130.2
130.1
128.6
128.4
128.2
128.2
117.4
113.8
107.8
101.1
77.3
77.0
76.7
76.7
75.1
61.5
61.4
30.8
30.6
28.6
28.1
14.1
13.7
Ph
H
CO2Et
t-Bu
8
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

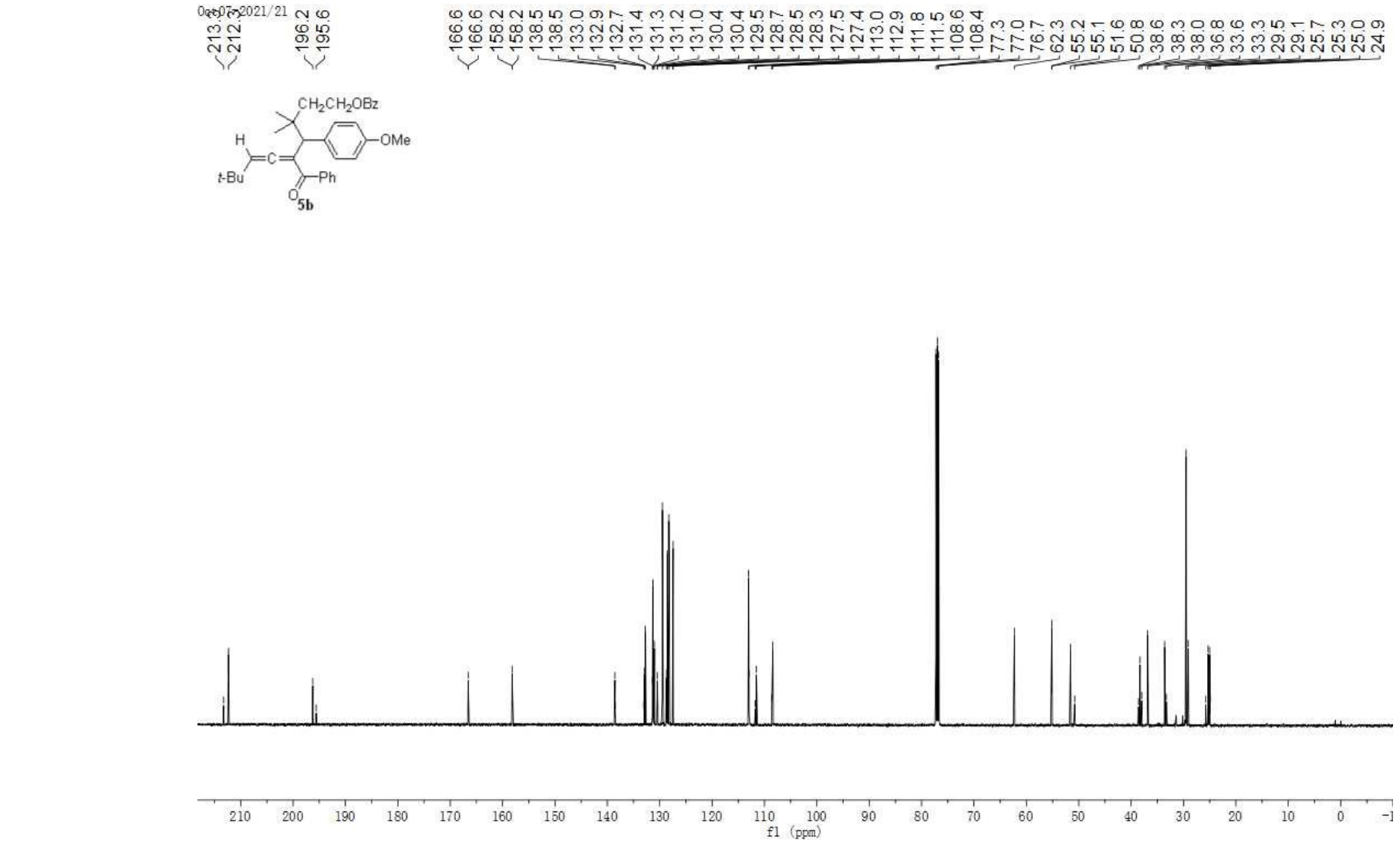

8.02 8.02 8.01 8.01 8.01 8.01 8.00 8.00 7.65 7.64 7.63 7.63 7.54 7.53 7.53 7.52 7.52 7.52 7.51 7.51 7.47 7.47 7.46 7.46 7.44 7.43 7.43 7.43 7.42 7.41 7.41 7.41 7.40 7.36 7.35 7.34 7.33 7.32 7.31 7.29 7.28 7.27 7.26 7.25 7.23 7.22 5.48 5.47 5.46 5.46 4.42 4.41 4.26 4.20 1.16 1.14 1.13 0.95 0.69
CH2CH2OBz
H
Ph
t-Bu
Ph
O
3
2.04 0.92 2.20 5.26 4.46 1.05 0.97 2.10 1.00 2.15 6.12 5.06 4.19
f1 (ppm)

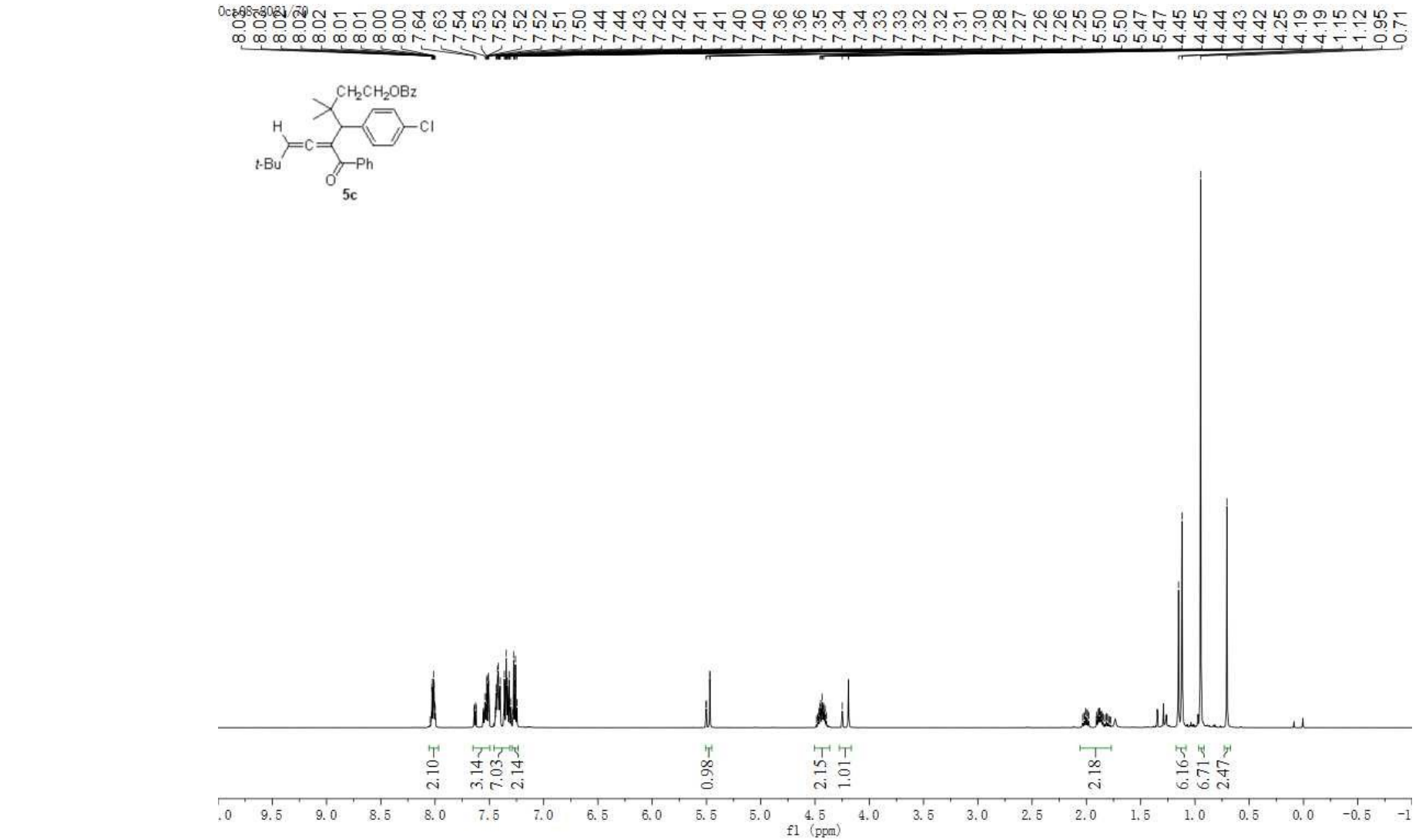

Sep 28 2021/161
213.4
212.2
196.2
195.5
166.6
166.6
141.0
140.9
138.5
138.5
132.8
131.2
131.0
130.5
130.4
130.4
129.5
128.7
128.5
128.3
128.3
127.6
127.6
127.5
126.5
126.5
111.5
111.3
108.7
108.5
77.3
77.0
76.7
62.3
52.4
51.7
38.7
38.3
38.0
36.8
33.6
33.3
29.5
29.1
25.8
25.4
25.1
24.9
CH2CH2OBz
H
Ph
t-Bu
Ph
O
3
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

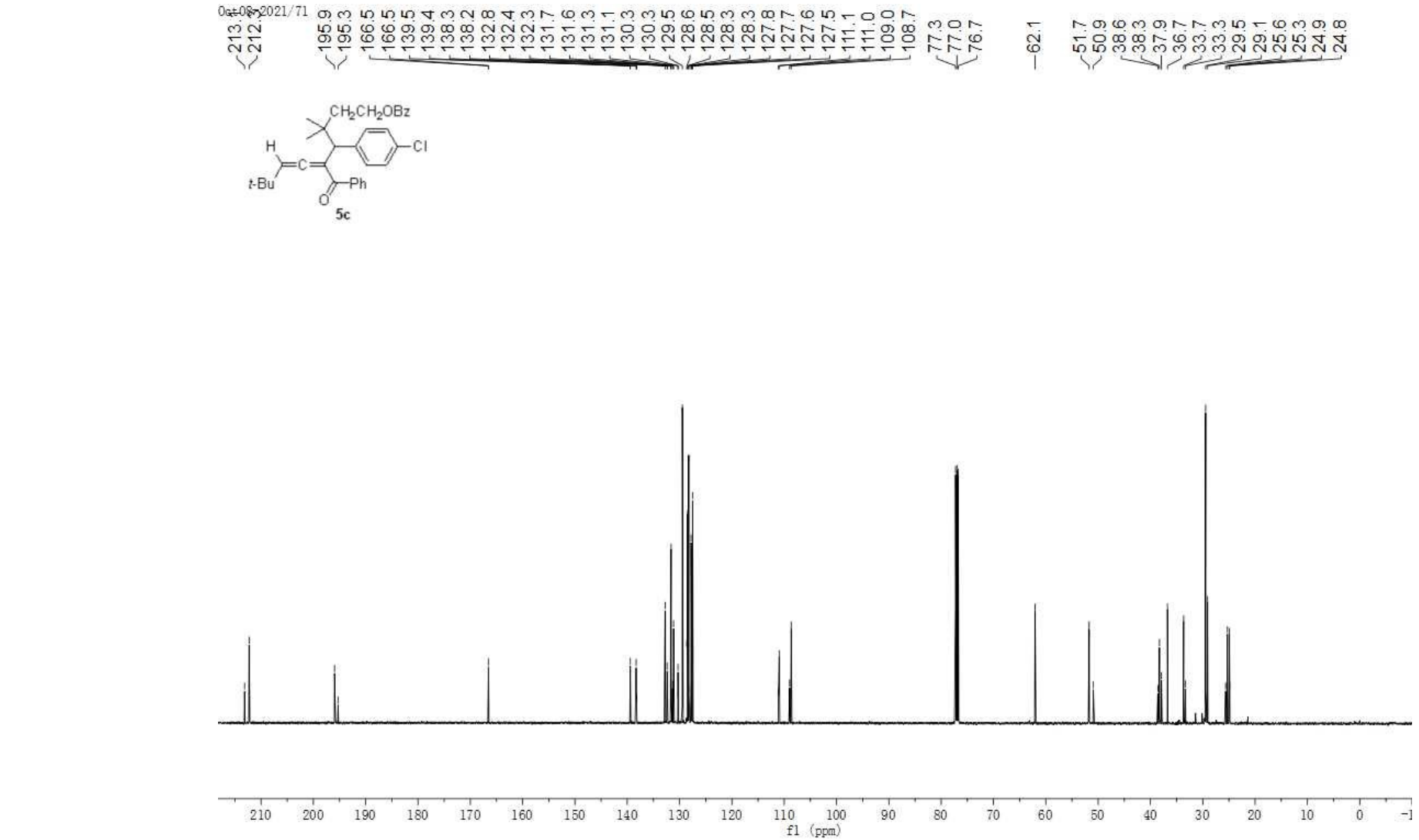

CH2CH2OBz
Me
H
t-Bu
Ph
O
5a
f1 (ppm)

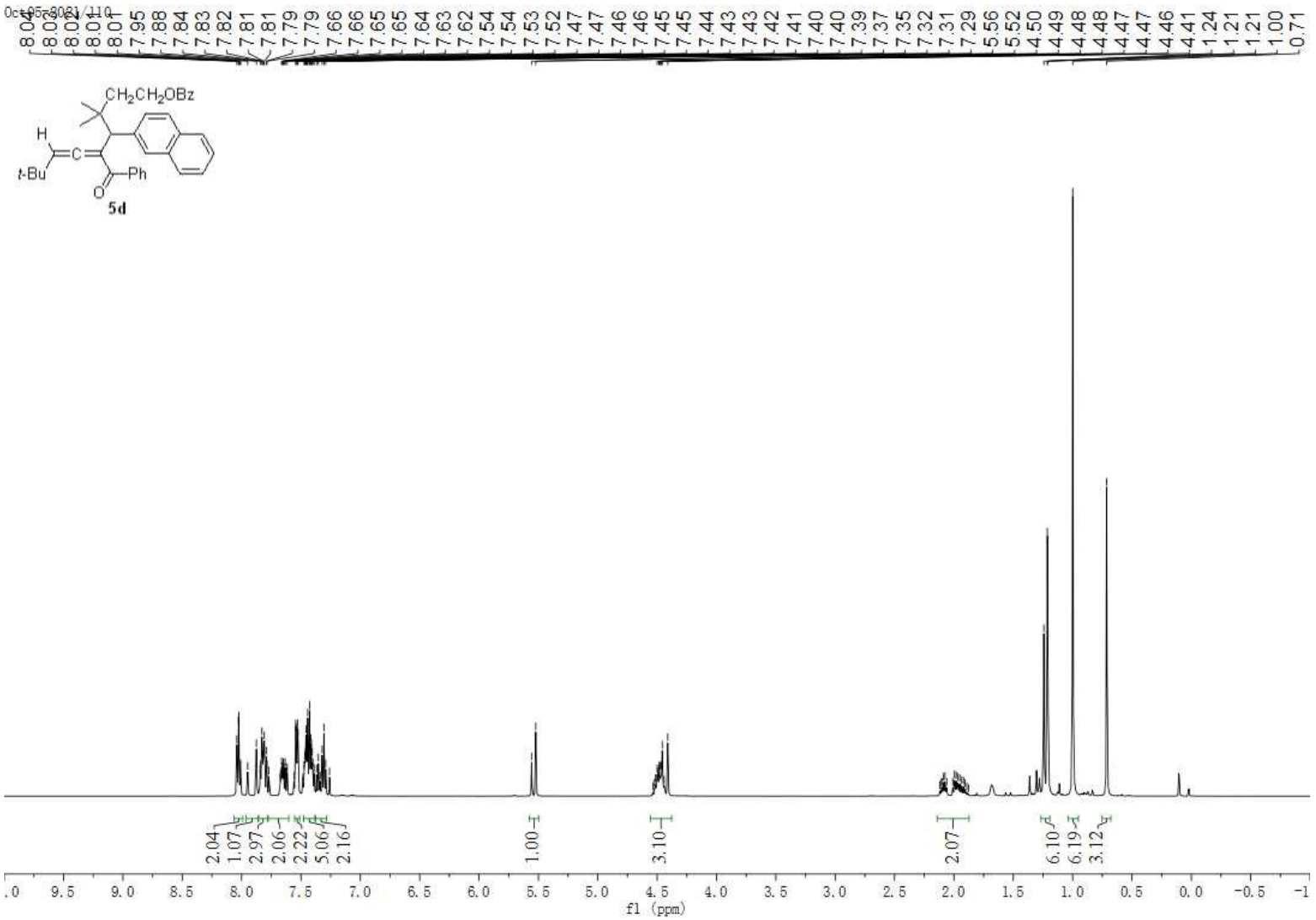

213.3
212.5
196.2
195.6
166.6
166.5
138.5
137.7
136.0
135.9
132.7
131.1
131.0
130.4
130.4
130.3
130.3
129.5
128.6
128.5
128.3
128.3
128.2
127.5
127.4
111.7
111.4
108.5
108.3
77.3
77.0
76.7
62.3
52.0
51.2
38.6
38.3
37.9
36.8
33.6
33.3
29.5
29.1
25.7
25.3
25.0
24.9
21.0
21.0
CH2CH2OBz
H
t-Bu
Me
Ph
O
5a
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

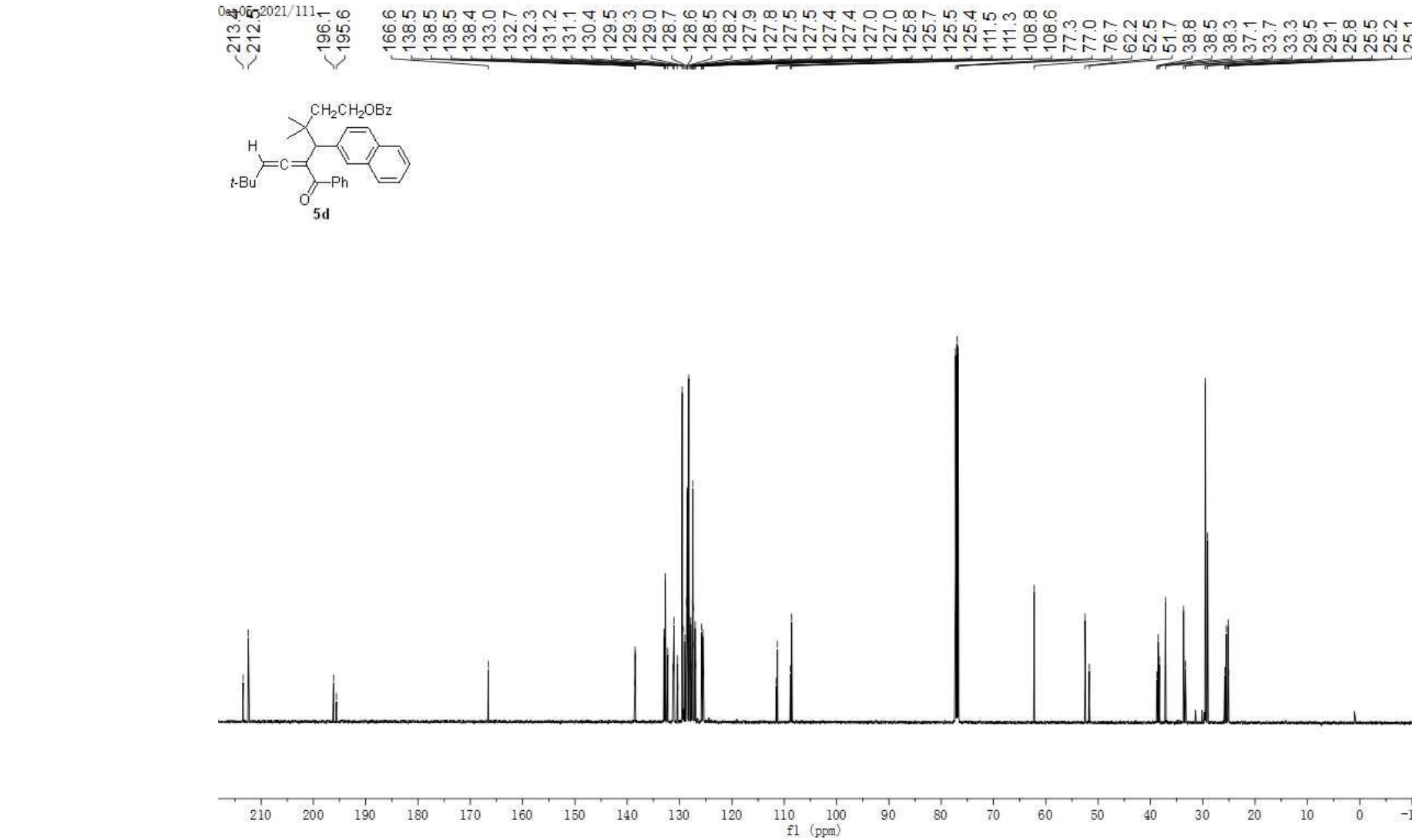

CH2CH2OBz
OMe
H
t-Bu
Ph
O
5b
2.01
3.12
7.23
2.04
0.99
2.07
1.04
3.10
2.16
6.25
7.30
2.10
f1 (ppm)

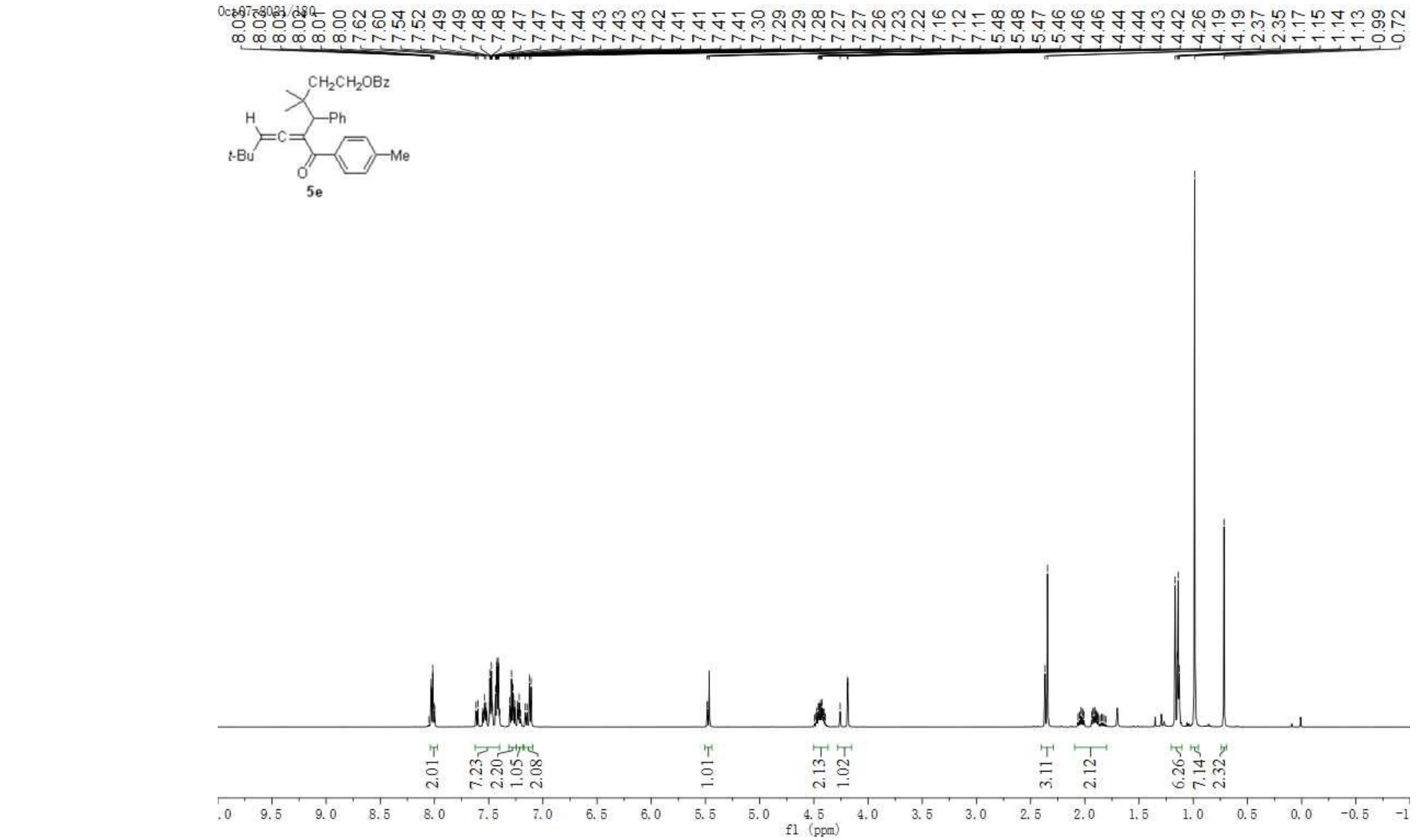

Oct-07-2021/21
213.3
212.3
196.2
195.6
166.6
166.6
158.2
158.2
138.5
138.5
133.0
132.9
132.7
131.4
131.3
131.2
131.0
130.4
130.4
129.5
128.7
128.5
128.3
127.5
127.4
113.0
112.9
111.8
111.5
108.6
108.4
77.3
77.0
76.7
62.3
55.2
55.1
51.6
50.8
38.6
38.3
38.0
36.8
33.6
33.3
29.5
29.1
25.7
25.3
25.0
24.9
CH2CH2OBz
OMe
H
t-Bu
Ph
O
5b
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-1
f1 (ppm)

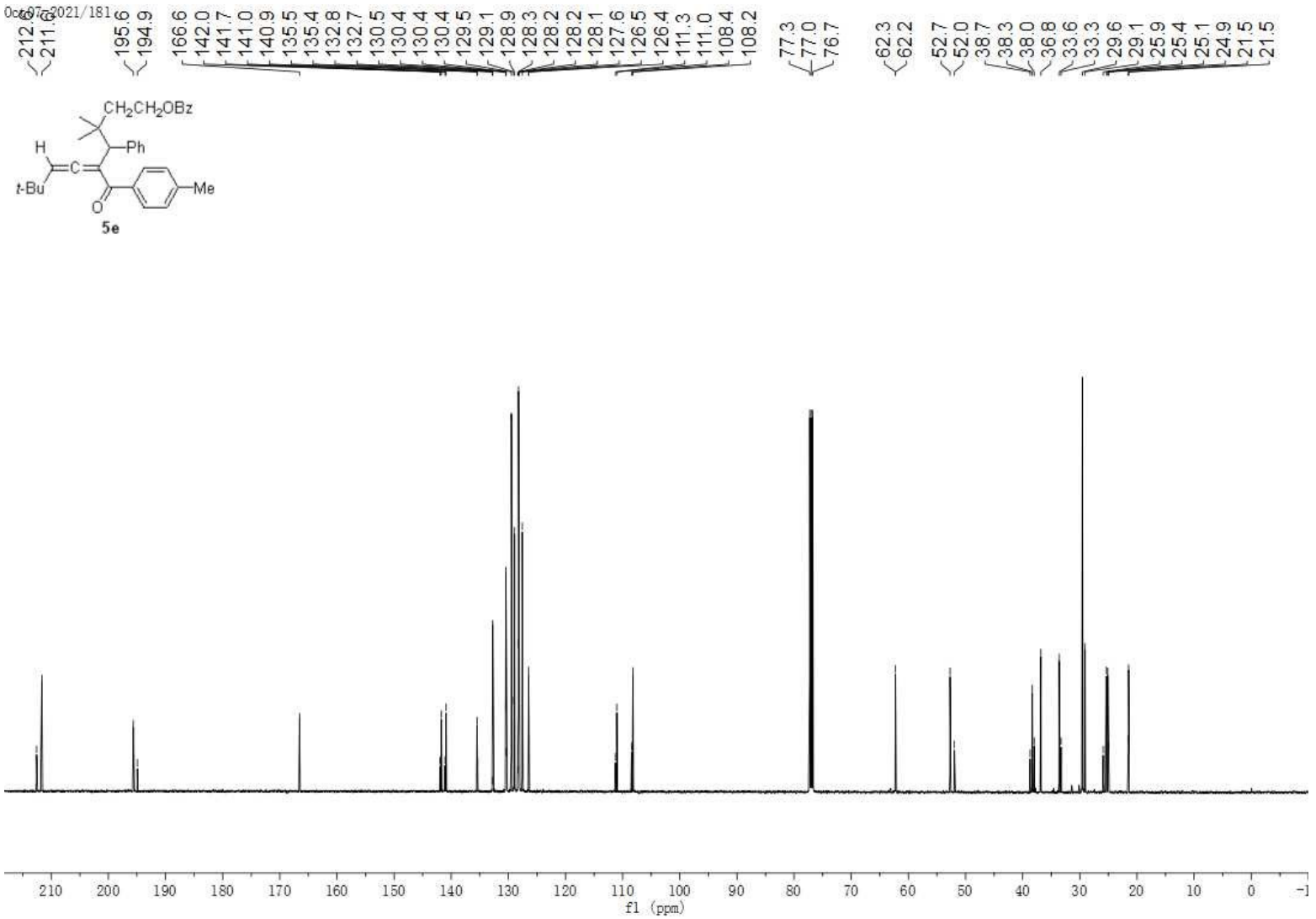

CH2CH2OBz
H
Cl
t-Bu
Ph
O
5c
2.10
3.14
7.03
2.14
0.98
2.15
1.01
2.18
6.16
6.71
2.47
f1 (ppm)

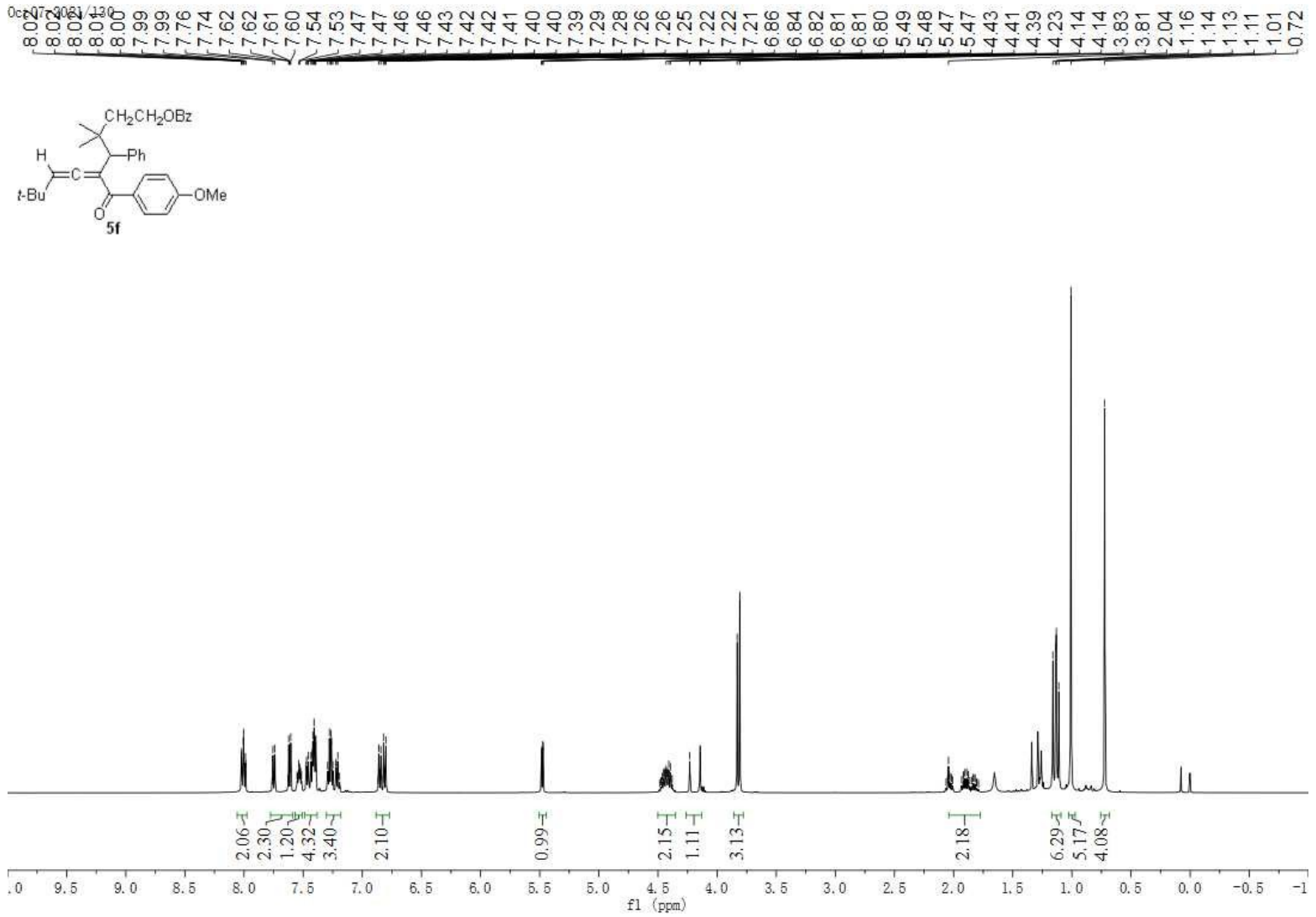

Oct-08-2021/71
213.2
212.3
195.9
195.3
166.5
166.5
139.5
139.4
138.3
138.2
132.8
132.4
132.3
131.7
131.6
131.3
131.1
130.3
130.3
129.5
128.6
128.5
128.3
128.3
127.8
127.7
127.6
127.5
111.1
111.0
109.0
108.7
77.3
77.0
76.7
62.1
51.7
50.9
38.6
38.3
37.9
36.7
33.7
33.3
29.5
29.1
25.6
25.3
24.9
24.8
CH2CH2OBz
H
Cl
t-Bu
Ph
O
5c
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-1
f1 (ppm)

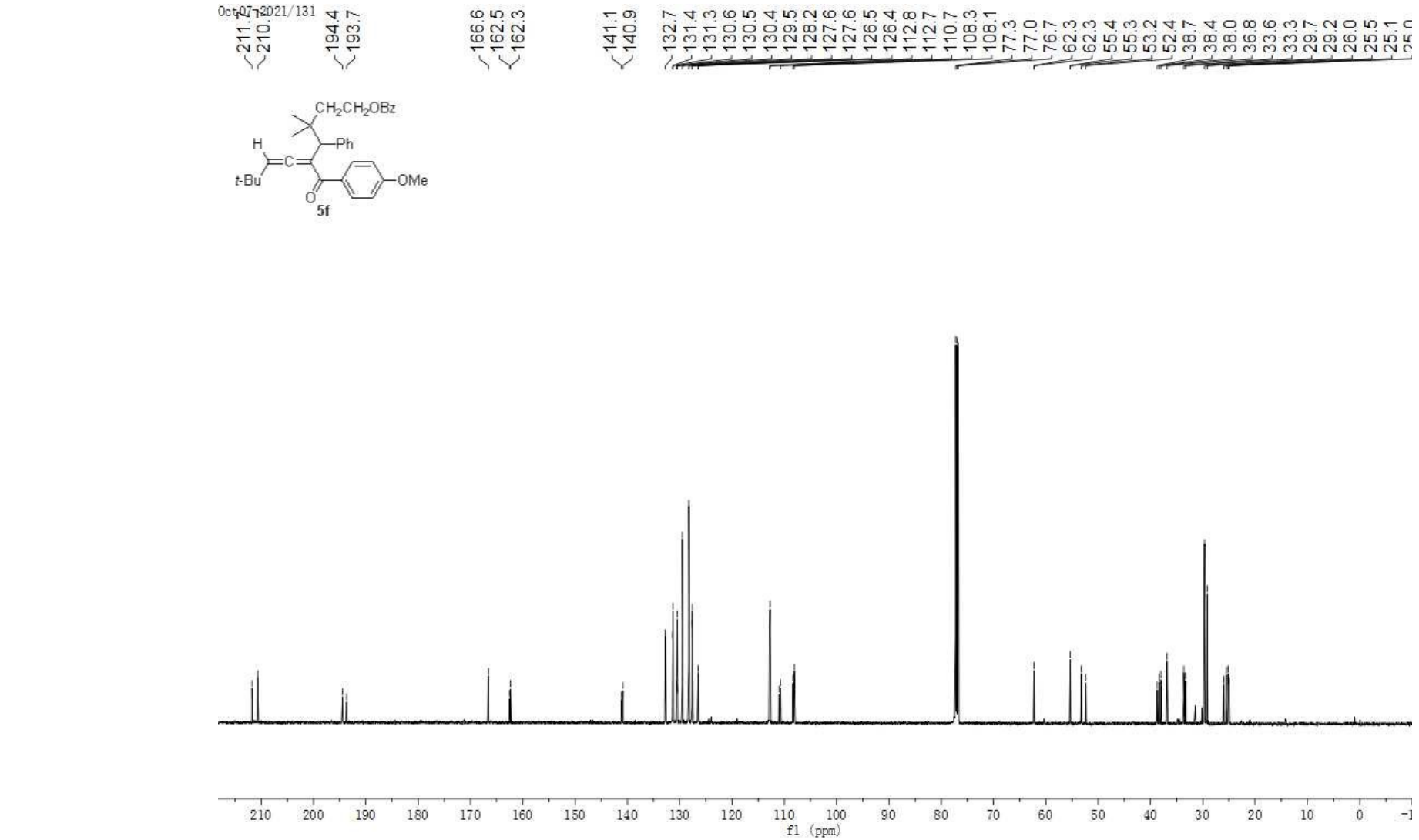

CH2CH2OBz
H
t-Bu
Ph
O
5d
fl (ppm)

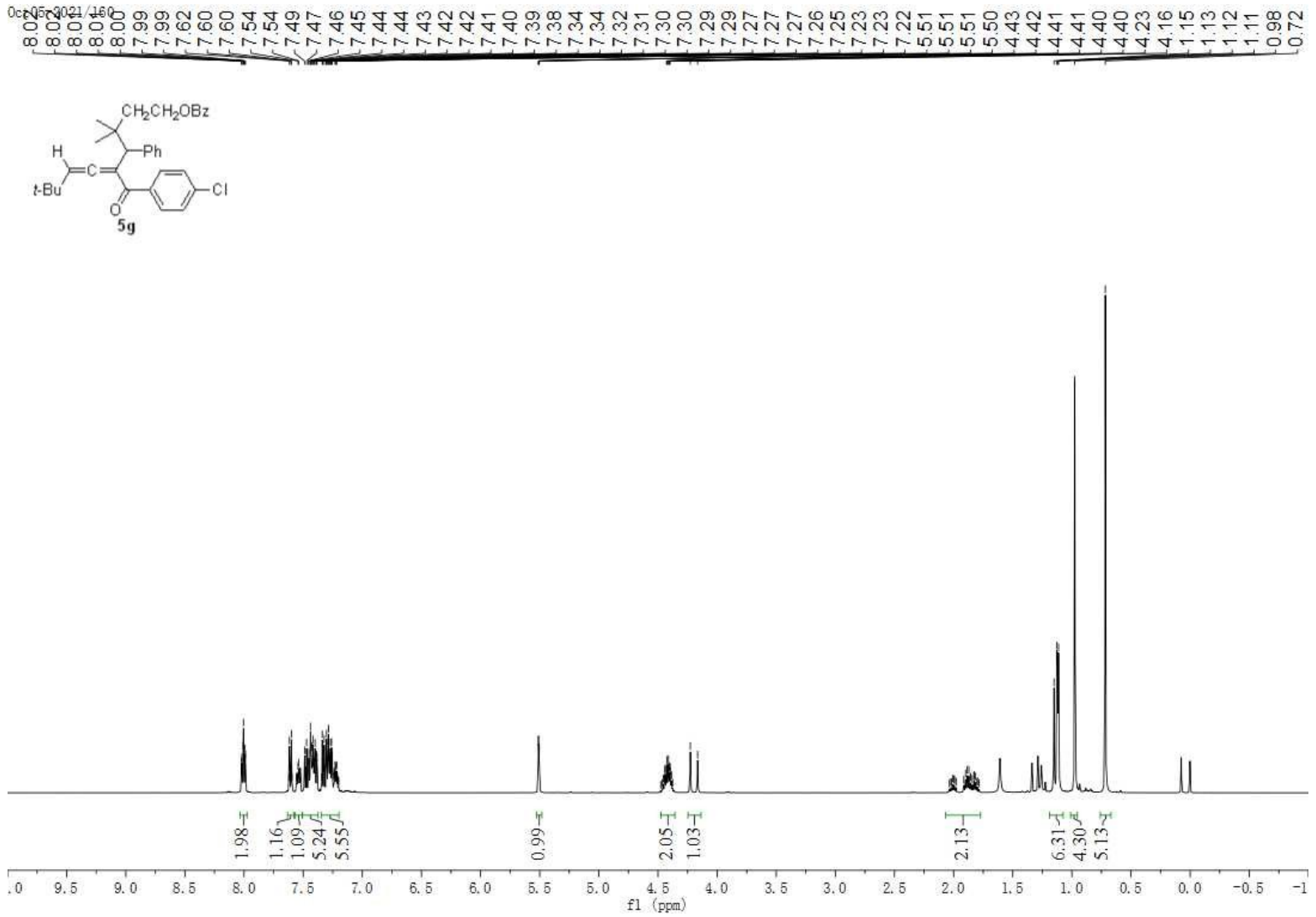

0ct 05 2021/111
213.4
212.2
196.1
195.6
166.6
138.5
138.5
138.5
138.4
133.0
132.7
132.3
131.2
131.1
130.4
129.5
129.3
129.0
128.7
128.6
128.5
128.2
127.9
127.8
127.5
127.5
127.4
127.4
127.0
127.0
125.8
125.7
125.5
125.4
111.5
111.3
108.8
108.6
77.3
77.0
76.7
62.2
52.5
51.7
38.8
38.5
38.3
37.1
33.7
33.3
29.5
29.1
25.8
25.5
25.2
CH2CH2OBz
H
t-Bu
Ph
O
5d
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

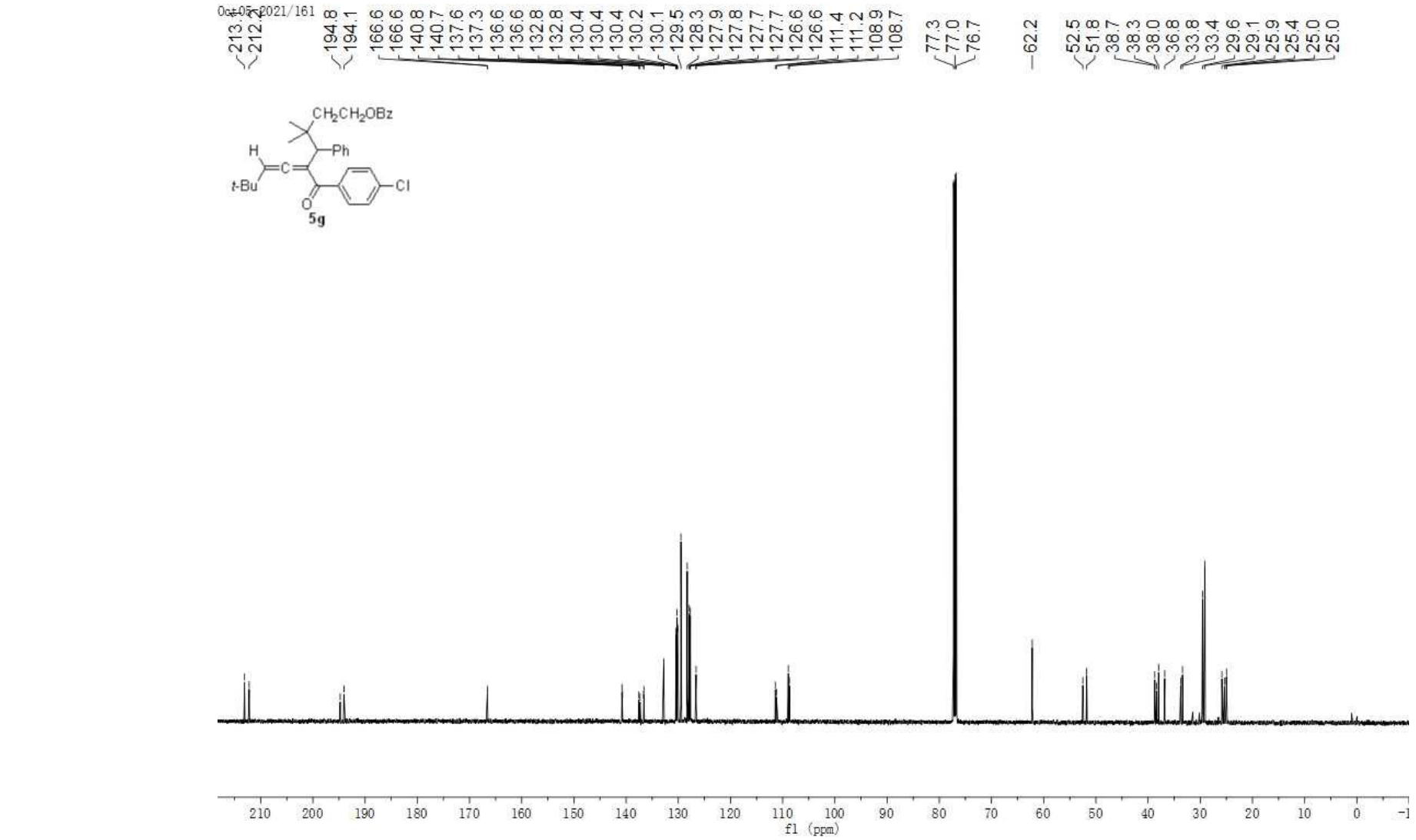

CH2CH2OBz
Ph
H
t-Bu
Me
O
5e
fl (ppm)

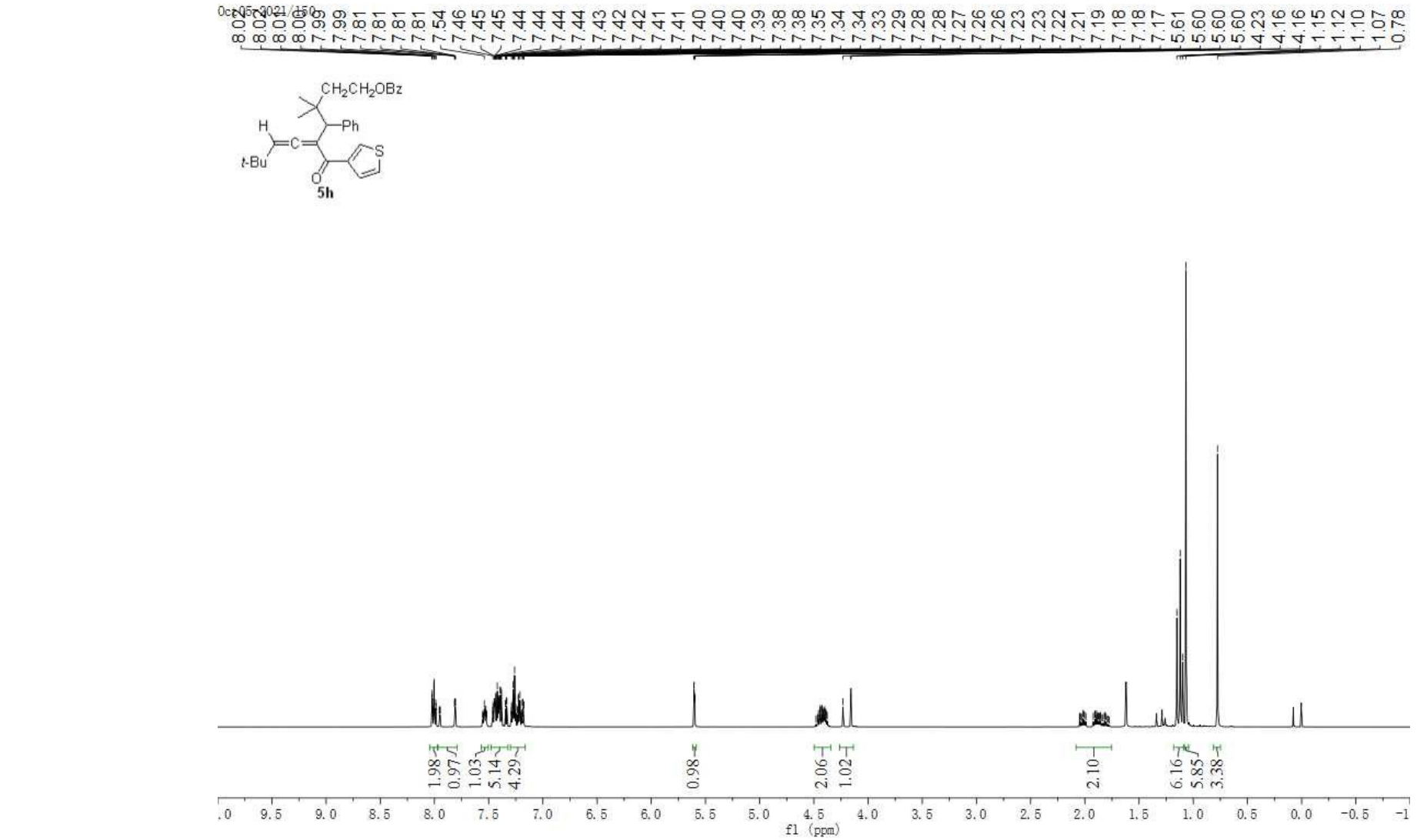

Oct 07 2021/181
212.6
211.6
195.6
194.9
166.6
142.0
141.7
141.0
140.9
135.5
135.4
132.8
132.7
130.5
130.4
130.4
130.4
129.5
129.1
128.9
128.3
128.2
128.2
128.1
127.6
126.5
126.4
111.3
111.0
108.4
108.2
77.3
77.0
76.7
62.3
62.2
52.7
52.0
38.7
38.3
38.0
36.8
33.6
33.3
29.6
29.1
25.9
25.4
25.1
24.9
21.5
21.5
CH2CH2OBz
Ph
H
t-Bu
Me
O
5e
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-1
f1 (ppm)

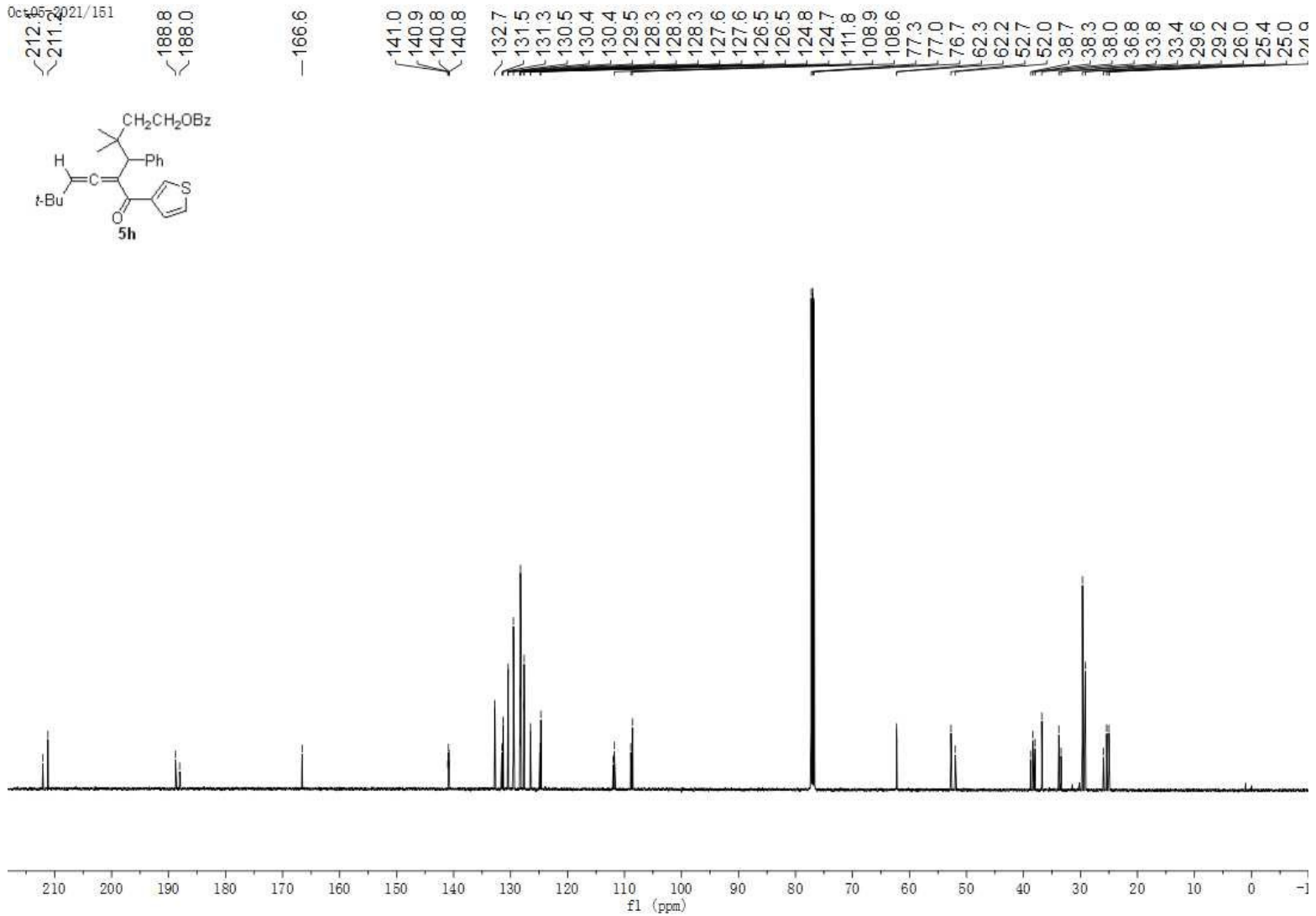

8.02 8.02 8.01 8.00 7.99 7.99 7.76 7.74 7.62 7.62 7.61 7.60 7.54 7.53 7.47 7.47 7.46 7.46 7.43 7.42 7.42 7.41 7.40 7.40 7.39 7.29 7.28 7.26 7.26 7.25 7.22 7.22 7.21 6.86 6.84 6.82 6.81 6.81 6.80 5.49 5.48 5.47 5.47 4.43 4.41 4.39 4.23 4.14 4.14 3.83 3.81 2.04 1.16 1.14 1.13 1.11 1.01 0.72
CH2CH2OBz
Ph
H
t-Bu
OMe
O
5f
2.06 2.30 1.20 4.32 3.40 2.10 0.99 2.15 1.11 3.13 2.18 6.29 5.17 4.08
f1 (ppm)

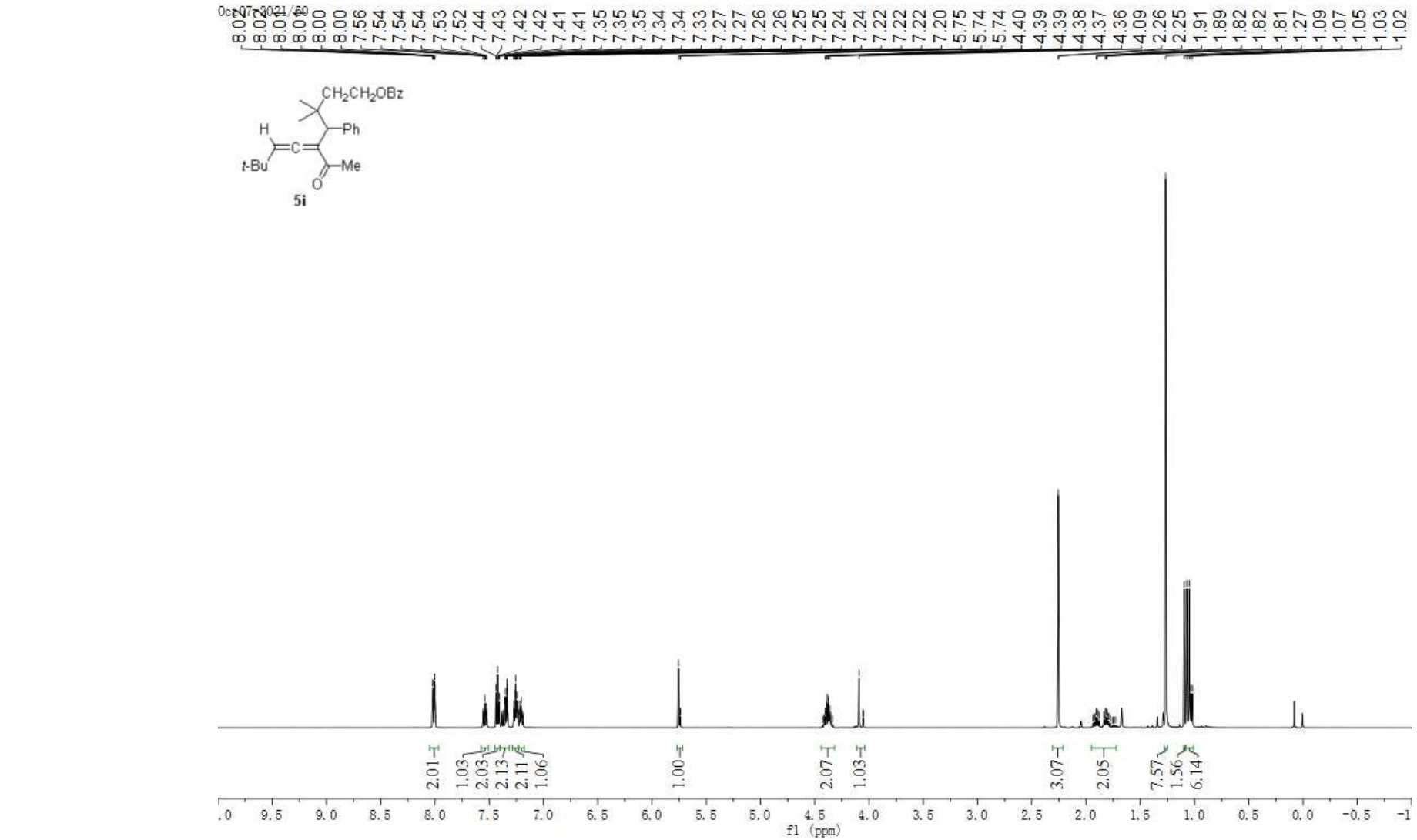

Oct-07-2021/131
211.7
210.1
194.4
193.7
166.6
162.5
162.3
141.1
140.9
132.7
131.4
131.3
130.6
130.5
130.4
129.5
128.2
127.6
127.6
126.5
126.4
112.8
112.7
110.7
108.3
108.1
77.3
77.0
76.7
62.3
62.3
55.4
55.3
53.2
52.4
38.7
38.4
38.0
36.8
33.6
33.3
29.7
29.2
26.0
25.5
25.1
CH2CH2OBz
Ph
H
t-Bu
OMe
O
5f
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

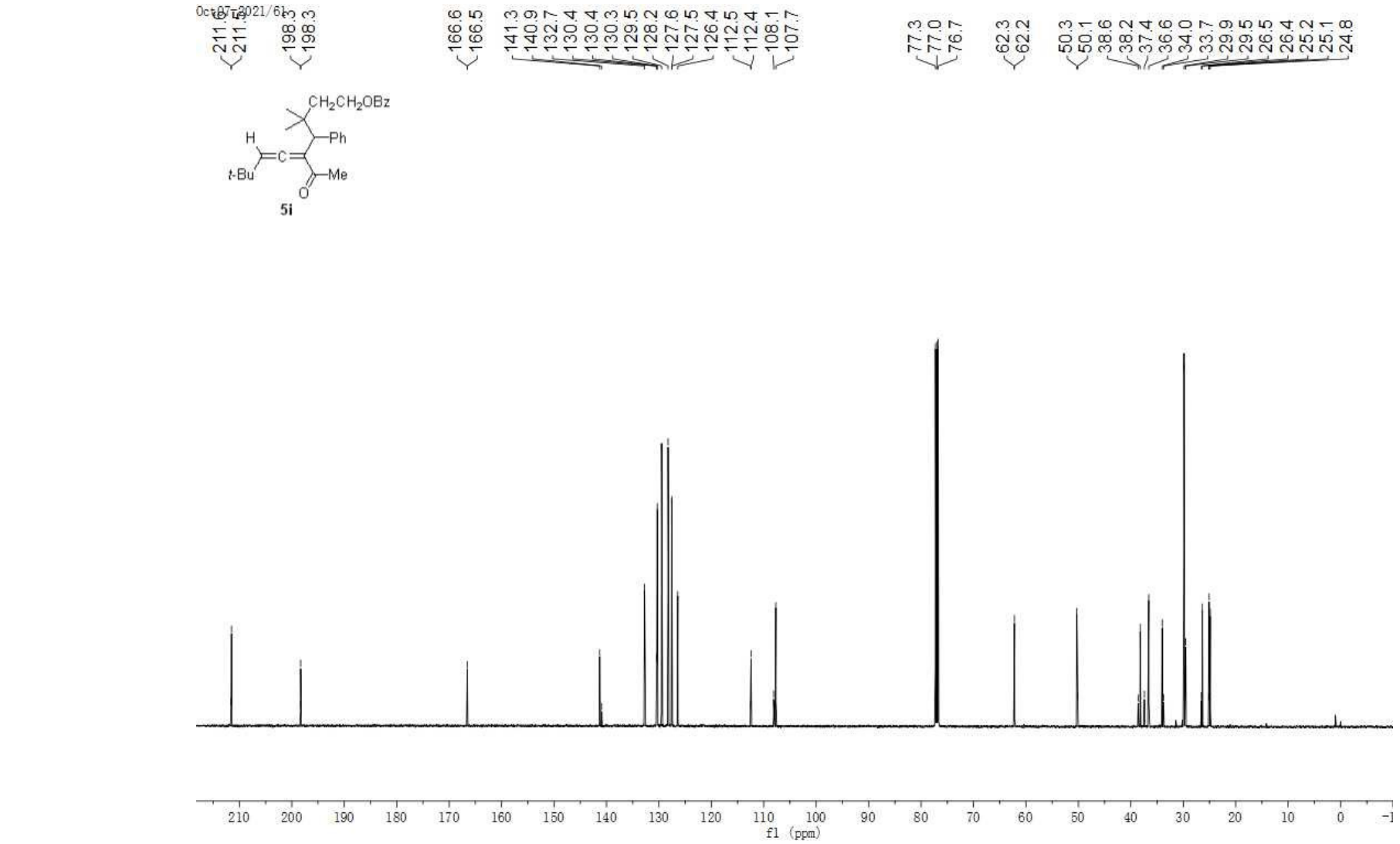

8.02 8.02 8.01 8.00 7.99 7.99 7.62 7.60 7.60 7.54 7.54 7.49 7.47 7.46 7.45 7.44 7.44 7.43 7.42 7.42 7.41 7.40 7.39 7.38 7.34 7.34 7.32 7.31 7.30 7.30 7.29 7.29 7.27 7.27 7.27 7.26 7.25 7.23 7.23 7.22 5.51 5.51 5.51 5.50 4.43 4.42 4.41 4.41 4.40 4.40 4.23 4.16 1.15 1.13 1.12 1.11 0.98 0.72
CH2CH2OBz
Ph
H
t-Bu
Cl
O
5g
1.98 1.16 1.09 5.24 5.55 0.99 2.05 1.03 2.13 6.31 4.30 5.13
f1 (ppm)

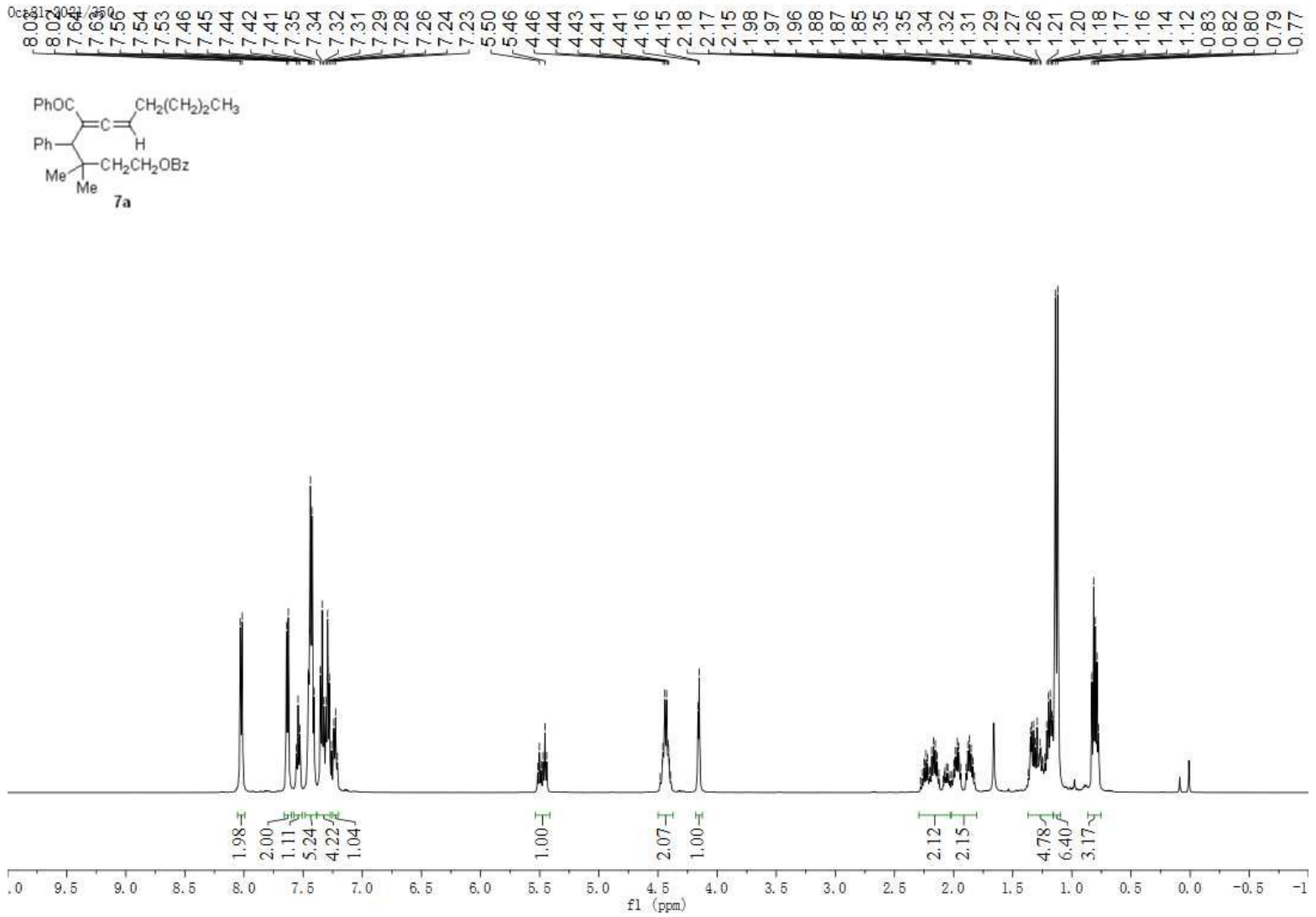

Oct-05-2021/161
213.2
212.2
194.8
194.1
166.6
166.6
140.8
140.7
137.6
137.3
136.6
136.6
132.8
132.8
130.4
130.4
130.4
130.2
130.1
129.5
128.3
127.9
127.8
127.7
127.7
126.6
126.6
111.4
111.2
108.9
108.7
77.3
77.0
76.7
62.2
52.5
51.8
38.7
38.3
38.0
36.8
33.8
33.4
29.6
29.1
25.9
25.4
25.0
25.0
CH2CH2OBz
Ph
H
t-Bu
Cl
O
5g
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-1
f1 (ppm)

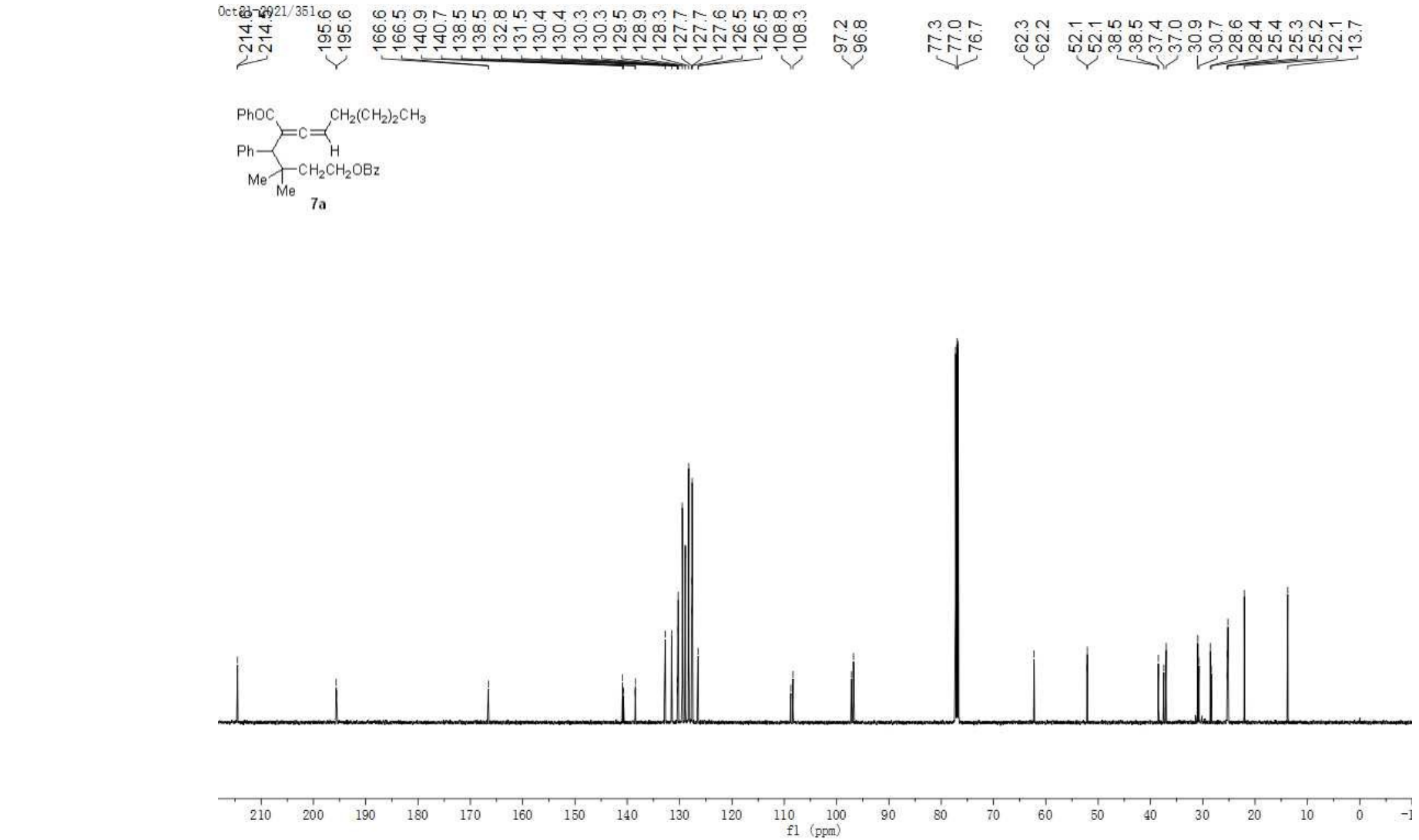

CH2CH2OBz
Ph
H
t-Bu
S
O
5h
f1 (ppm)

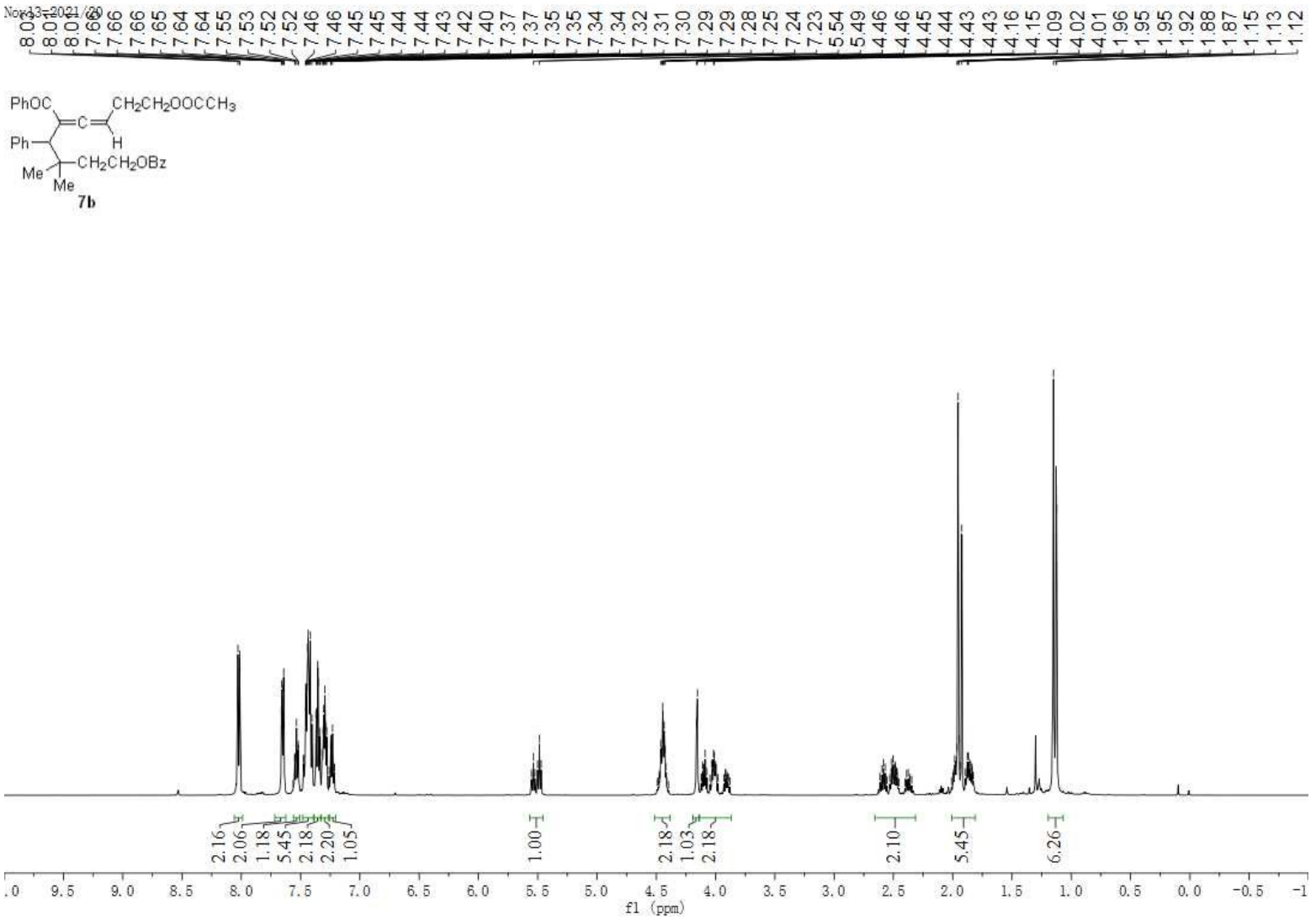

Oct-05-2021/151
212.2
211.4
188.8
188.0
166.6
141.0
140.9
140.8
140.8
132.7
131.5
131.3
130.5
130.4
130.4
129.5
128.3
128.3
128.3
127.6
127.6
126.5
126.5
124.8
124.7
111.8
108.9
108.6
77.3
77.0
76.7
62.3
62.2
52.7
52.0
38.7
38.3
38.0
36.8
33.8
33.4
29.6
29.2
26.0
25.4
25.0
CH2CH2OBz
Ph
H
t-Bu
S
O
5h
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

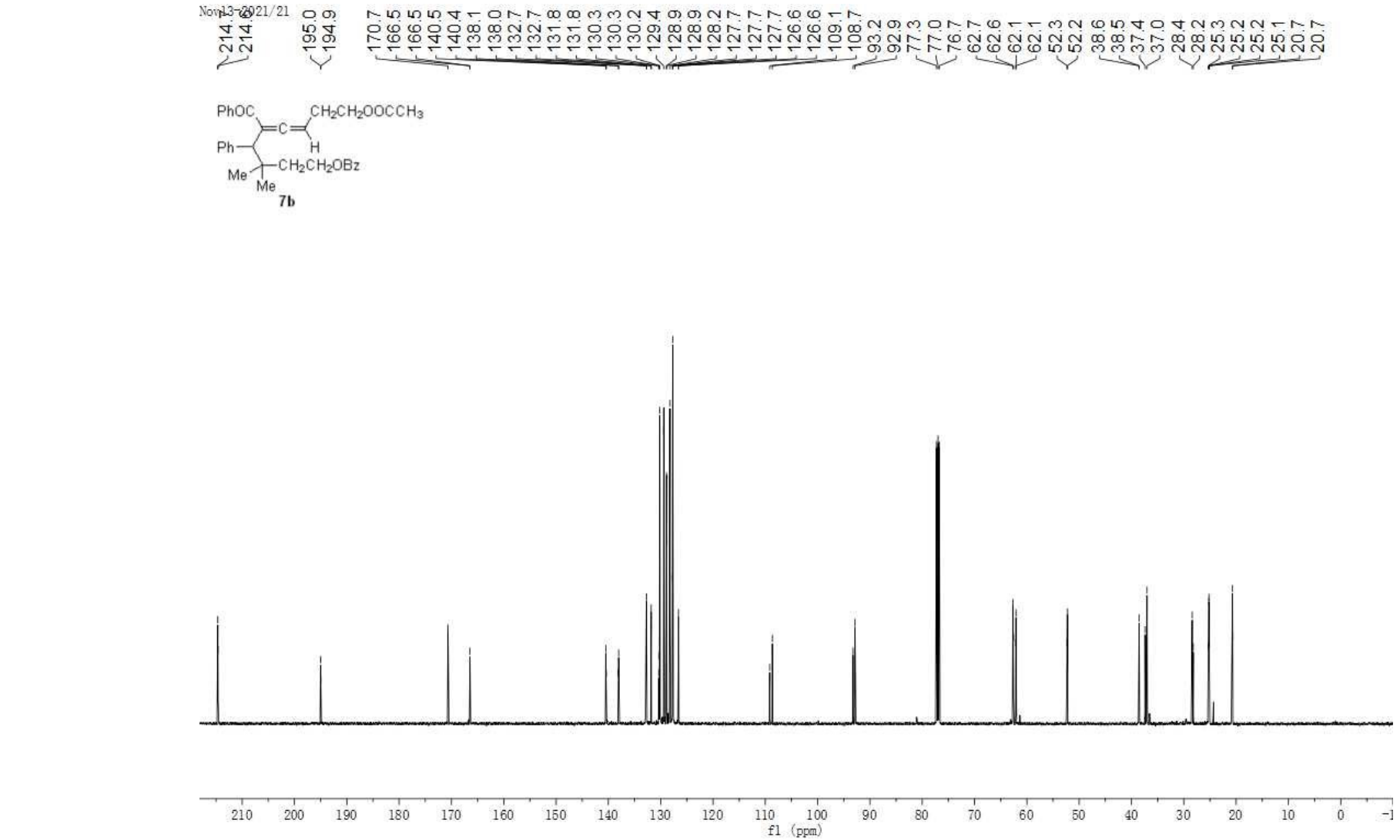

CH2CH2OBz
Ph
H
t-Bu
Me
O
5i
f1 (ppm)

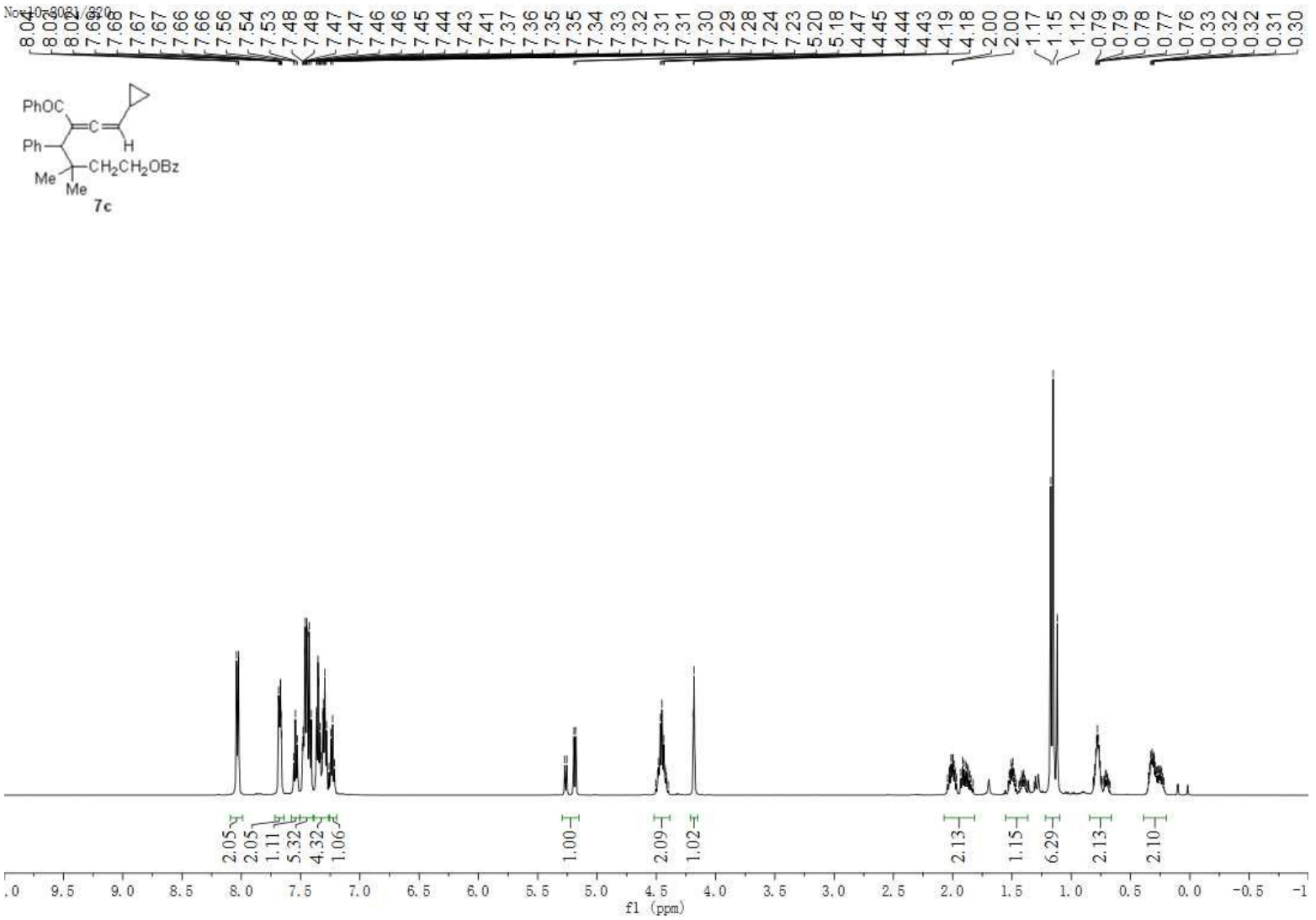

211.6
211.3
198.3
198.3
166.6
166.5
141.3
140.9
132.7
130.4
130.4
130.3
129.5
128.2
127.6
127.5
126.4
112.5
112.4
108.1
107.7
77.3
77.0
76.7
62.3
62.2
50.3
50.1
38.6
38.2
37.4
36.6
34.0
33.7
29.9
29.5
26.5
26.4
25.2
25.1
24.8
CH2CH2OBz
Ph
H
t-Bu
Me
O
5i
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

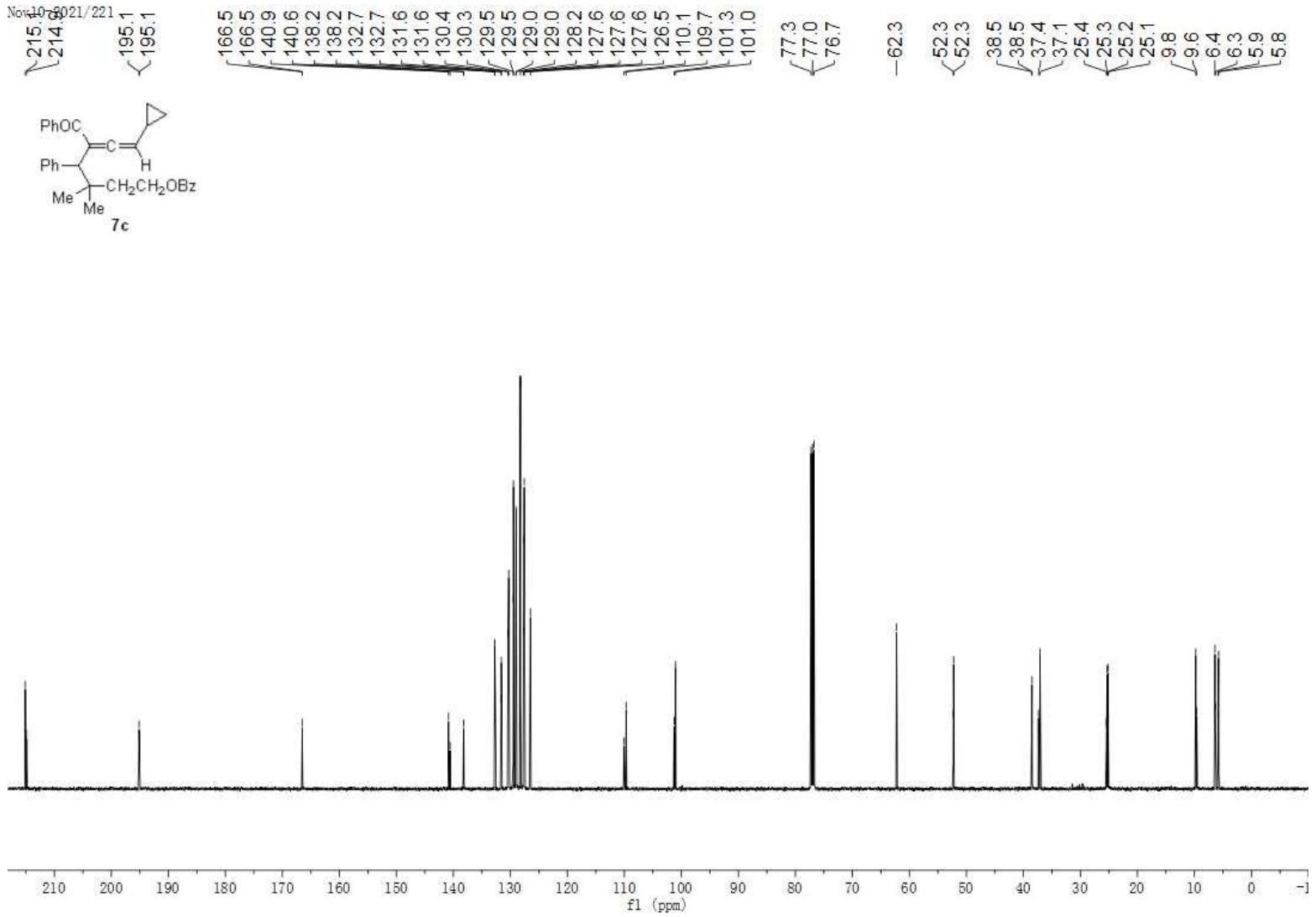

8.02
8.01
7.64
7.63
7.56
7.54
7.53
7.46
7.45
7.44
7.42
7.41
7.35
7.34
7.32
7.31
7.29
7.28
7.26
7.24
7.23
5.50
5.46
5.46
4.44
4.43
4.41
4.41
4.16
4.15
2.18
2.17
2.15
1.98
1.97
1.96
1.88
1.87
1.85
1.35
1.35
1.34
1.32
1.31
1.29
1.27
1.26
1.21
1.20
1.18
1.17
1.16
1.14
1.12
0.83
0.82
0.80
0.79
0.77
PhOC
CH2(CH2)2CH3
Ph
H
Me
CH2CH2OBz
Me
7a
1.98
2.00
1.11
5.24
4.22
1.04
1.00
2.07
1.00
2.12
2.15
4.78
6.40
3.17
f1 (ppm)

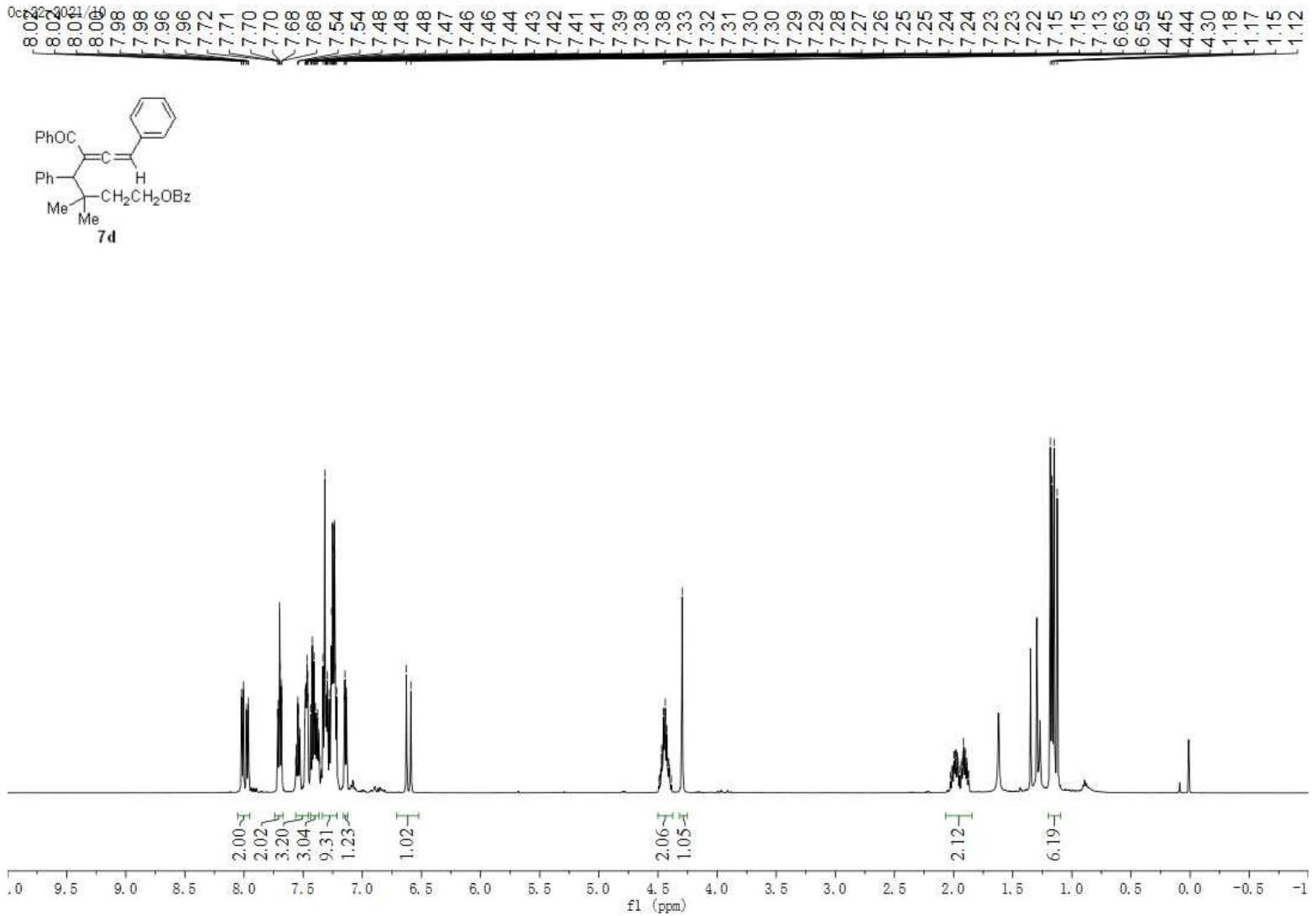

Oct21-2021/351
214.4
214.4
195.6
195.6
166.6
166.5
140.9
140.7
138.5
138.5
132.8
131.5
130.4
130.4
130.3
130.3
129.5
128.9
128.3
127.7
127.7
127.6
126.5
126.5
108.8
108.3
97.2
96.8
77.3
77.0
76.7
62.3
62.2
52.1
52.1
38.5
38.5
37.4
37.0
30.9
30.7
28.6
28.4
25.4
25.3
25.2
22.1
13.7
PhOC
CH2(CH2)2CH3
Ph
H
Me
CH2CH2OBz
Me
7a
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-1
f1 (ppm)

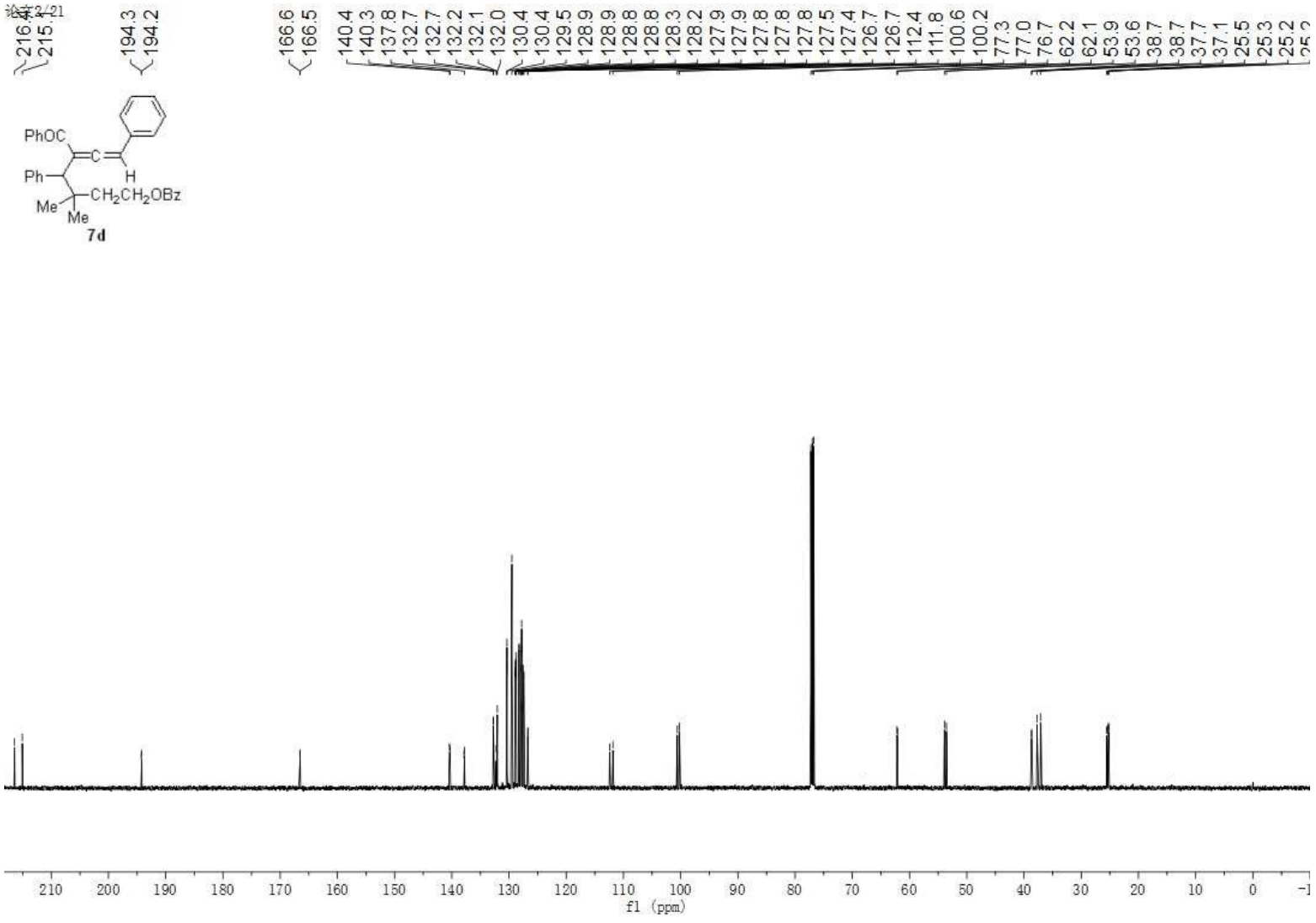

8.01
8.01
8.00
7.66
7.66
7.65
7.64
7.64
7.55
7.53
7.52
7.52
7.46
7.46
7.45
7.45
7.44
7.44
7.43
7.42
7.40
7.37
7.37
7.35
7.35
7.34
7.34
7.32
7.31
7.30
7.29
7.29
7.28
7.25
7.24
7.23
5.54
5.49
4.46
4.46
4.45
4.44
4.43
4.43
4.16
4.15
4.09
4.02
4.01
1.96
1.95
1.95
1.92
1.88
1.87
1.15
1.13
1.12
PhOC
CH2CH2OOCCH3
Ph
H
Me
CH2CH2OBz
Me
7b
2.16
2.06
1.18
5.45
2.18
2.20
1.05
1.00
2.18
1.03
2.18
2.10
5.45
6.26
f1 (ppm)

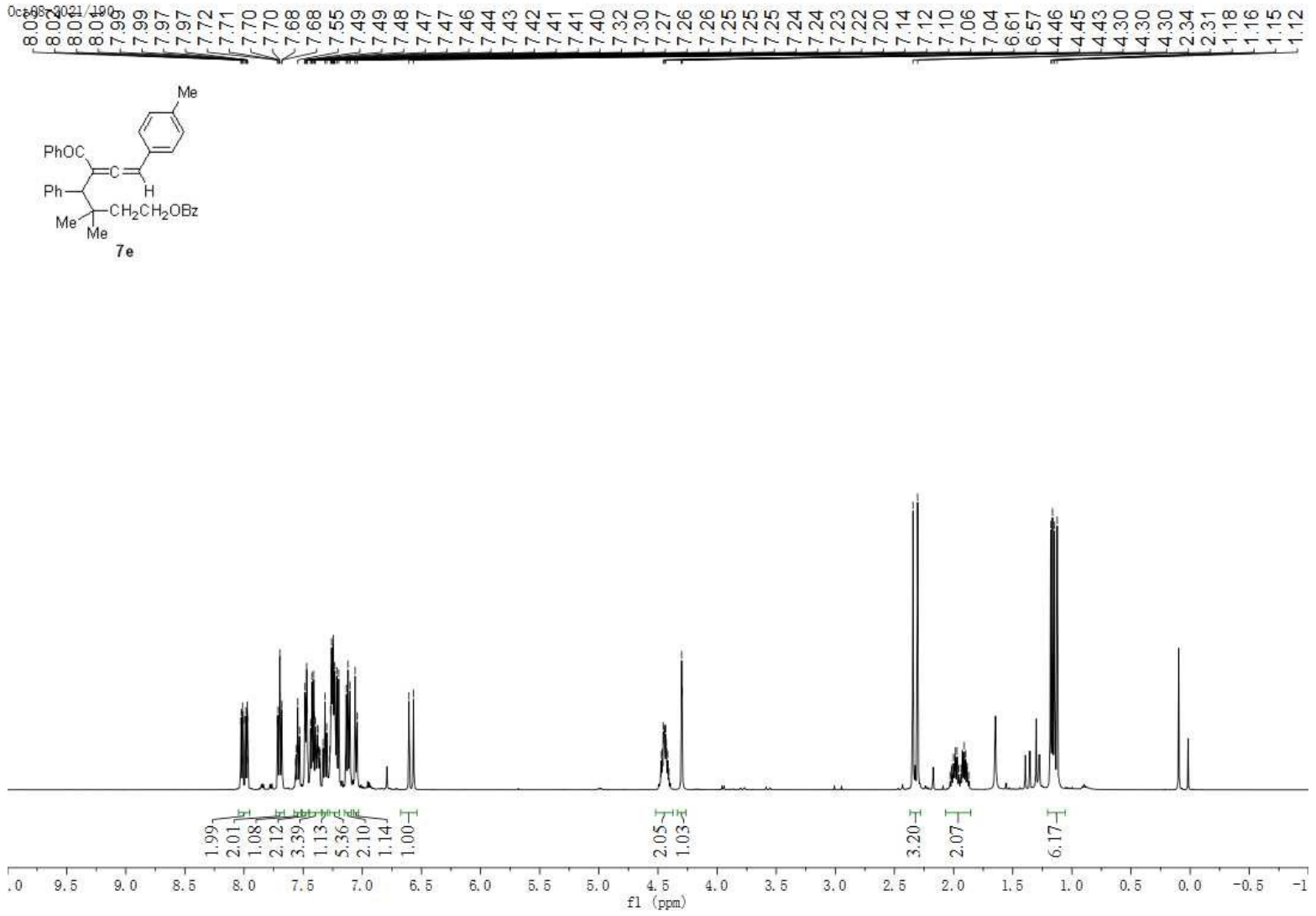

Nov-13-2021/21
214.4
214.2
195.0
194.9
170.7
166.5
166.5
140.5
140.4
138.1
138.0
132.7
132.7
131.8
131.8
130.3
130.3
130.2
129.4
128.9
128.9
128.2
127.7
127.7
127.7
126.6
126.6
109.1
108.7
93.2
92.9
77.3
77.0
76.7
62.7
62.6
62.1
62.1
52.3
52.2
38.6
38.5
37.4
37.0
28.4
28.2
25.3
25.2
25.2
25.1
20.7
20.7
PhOC
CH2CH2OOCCH3
Ph
H
Me
CH2CH2OBz
Me
7b
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-1
f1 (ppm)

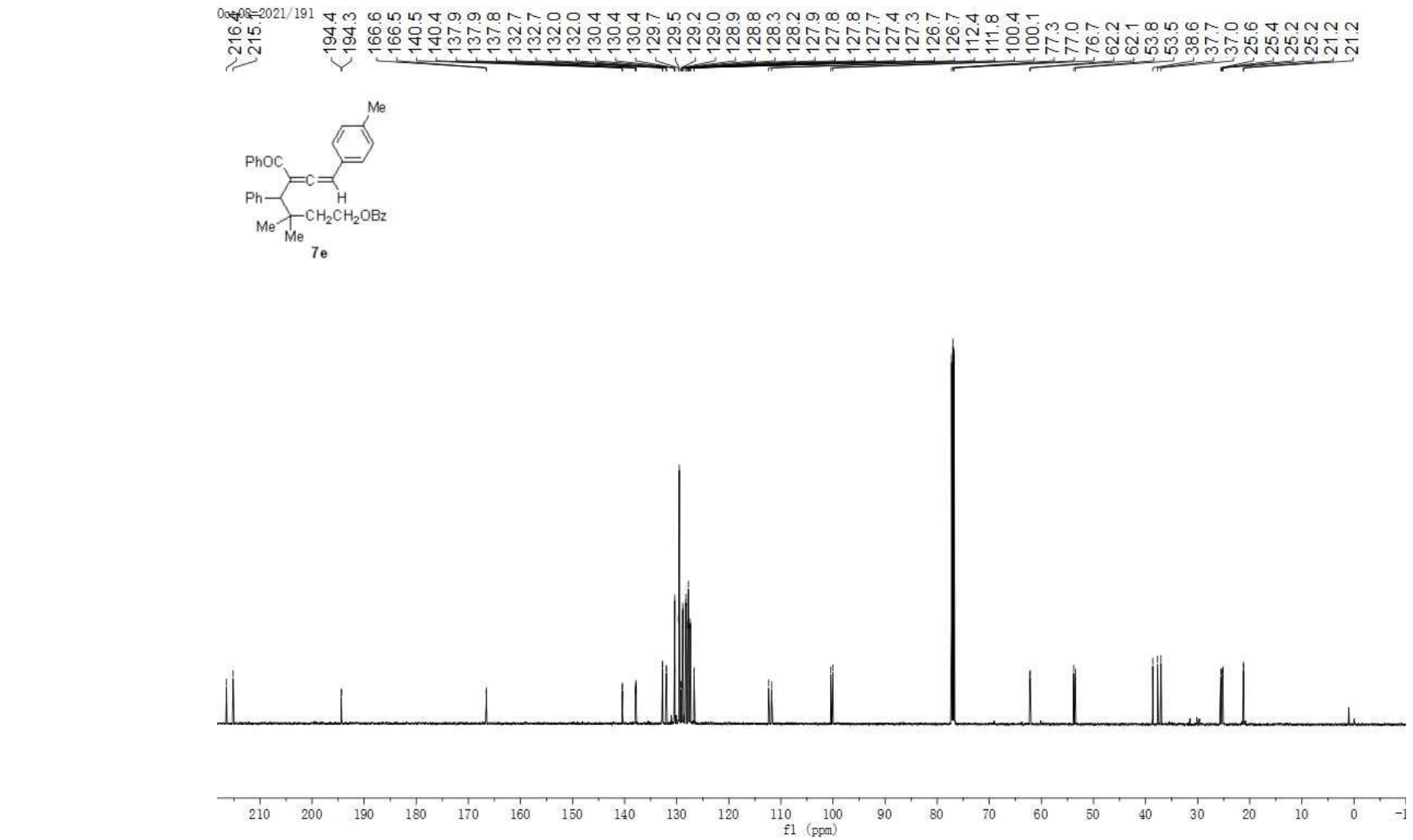

8.04 8.03 8.03 7.68 7.67 7.67 7.66 7.66 7.56 7.54 7.53 7.48 7.48 7.47 7.47 7.46 7.46 7.45 7.44 7.43 7.41 7.37 7.36 7.35 7.35 7.34 7.33 7.32 7.31 7.31 7.30 7.29 7.28 7.24 7.23 5.20 5.18 4.47 4.45 4.44 4.43 4.19 4.18 2.00 2.00 1.17 1.15 1.12 0.79 0.79 0.78 0.77 0.76 0.33 0.32 0.32 0.31 0.30
PhOC
Ph
Me
Me
CH2CH2OBz
H
7c
2.05 2.05 1.11 5.32 4.32 1.06 1.00 2.09 1.02 2.13 1.15 6.29 2.13 2.10
f1 (ppm)

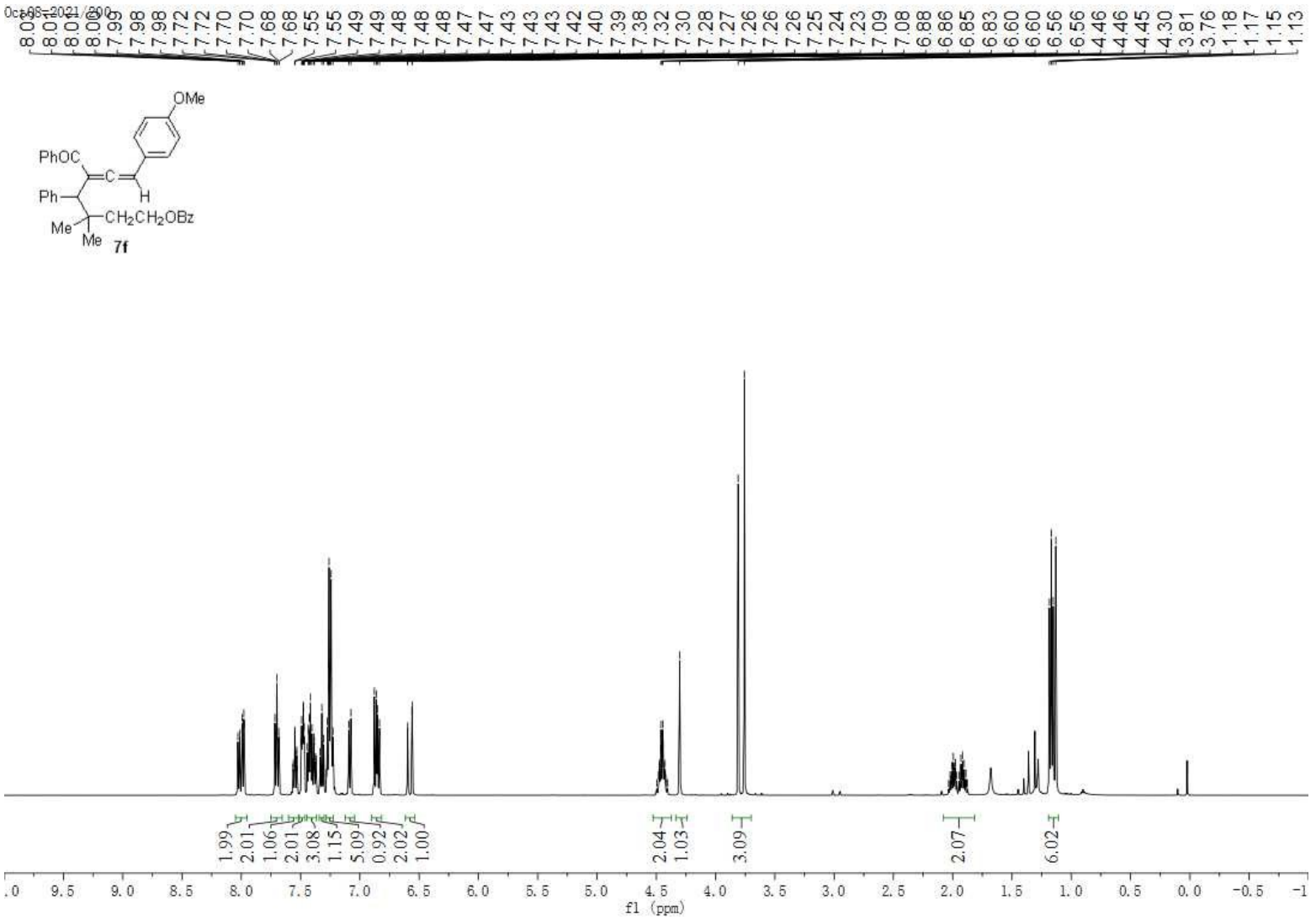

Nov-10-2021/221
215.4
214.4
195.1
195.1
166.5
166.5
140.9
140.6
138.2
138.2
132.7
132.7
131.6
131.6
130.4
130.3
129.5
129.5
129.0
129.0
128.2
127.6
127.6
127.6
126.5
110.1
109.7
101.3
101.0
77.3
77.0
76.7
62.3
52.3
52.3
38.5
38.5
37.4
37.1
25.4
25.3
25.2
25.1
9.8
9.6
6.4
6.3
5.9
5.8
PhOC
Ph
Me
Me
CH2CH2OBz
H
7c
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-1
f1 (ppm)

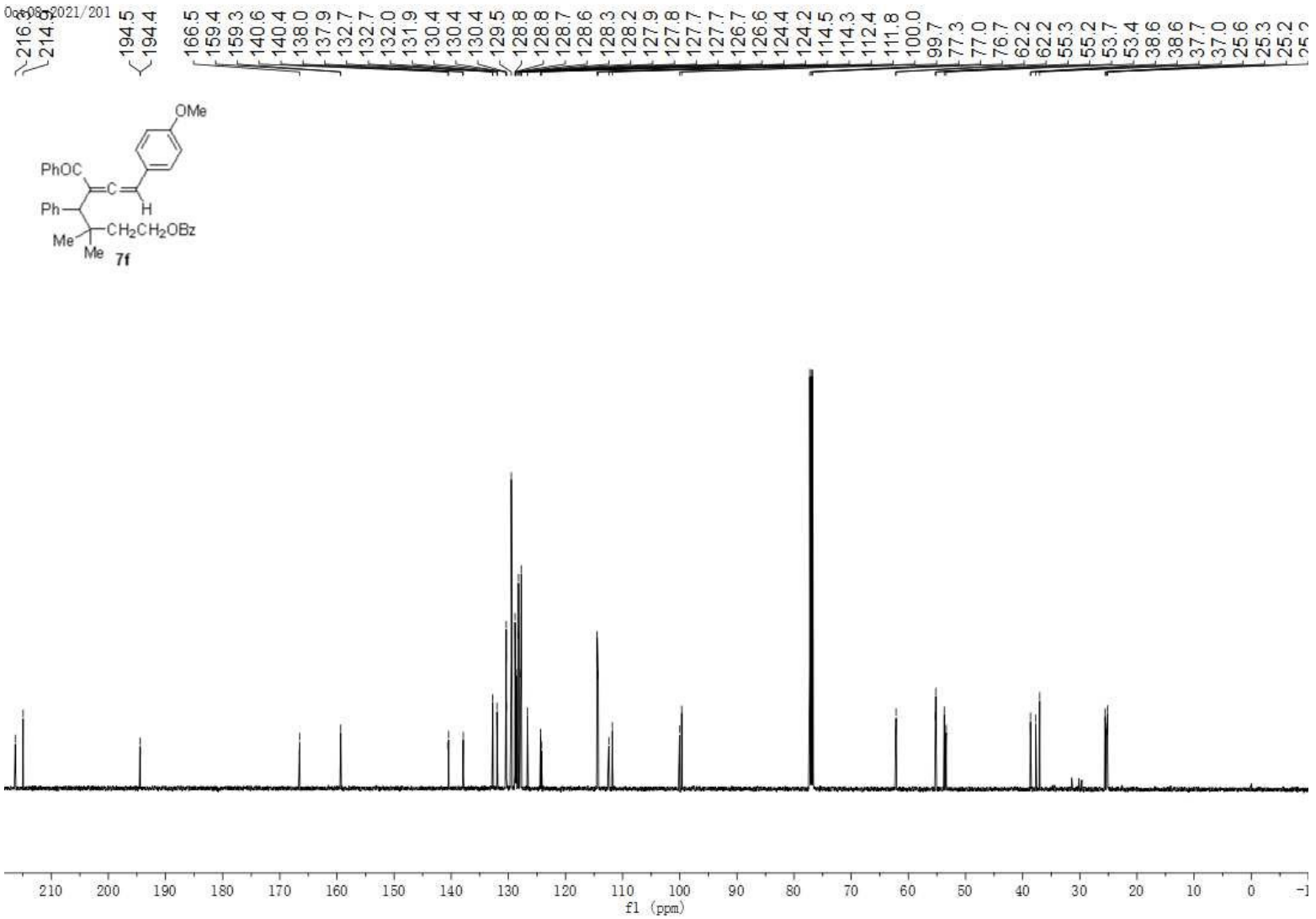

8.02 8.02 8.01 8.00 7.98 7.98 7.96 7.96 7.72 7.71 7.70 7.70 7.68 7.68 7.54 7.54 7.48 7.48 7.48 7.47 7.46 7.46 7.44 7.43 7.42 7.41 7.41 7.39 7.38 7.38 7.33 7.32 7.31 7.30 7.30 7.29 7.29 7.28 7.27 7.26 7.25 7.25 7.24 7.24 7.23 7.23 7.22 7.15 7.15 7.13 6.63 6.59 4.45 4.44 4.30 1.18 1.17 1.15 1.12
PhOC
Ph
H
CH2CH2OBz
Me
Me
7d
2.00 2.02 3.20 3.04 9.31 1.23 1.02 2.06 1.05 2.12 6.19
f1 (ppm)

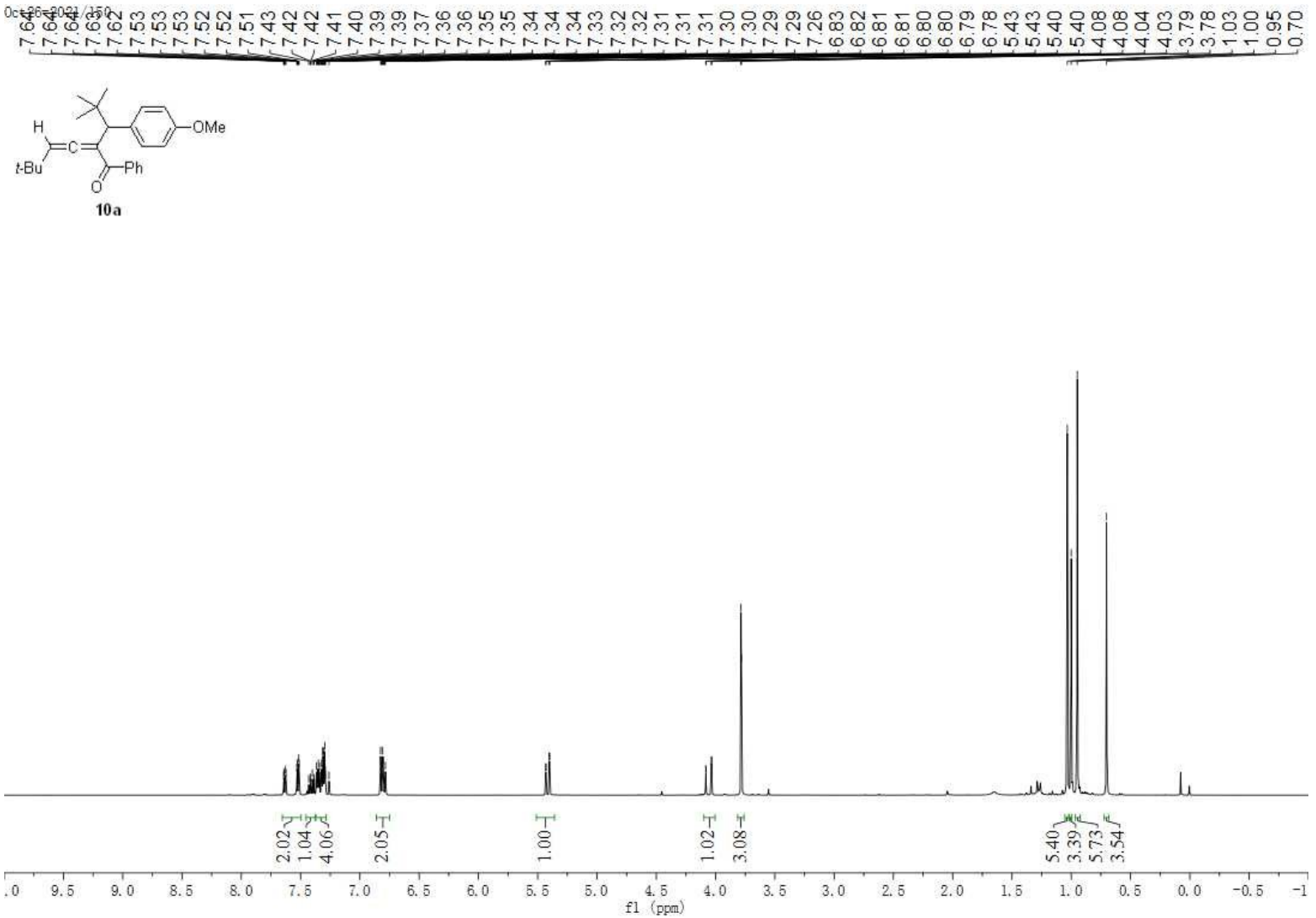

216.4
215.1
194.3
194.2
166.6
166.5
140.4
140.3
137.8
132.7
132.7
132.2
132.1
132.0
130.4
130.4
129.5
128.9
128.9
128.8
128.8
128.3
128.2
127.9
127.9
127.8
127.8
127.8
127.5
127.4
126.7
126.7
112.4
111.8
100.6
100.2
77.3
77.0
76.7
62.2
62.1
53.9
53.6
38.7
38.7
37.7
37.1
25.5
25.3
25.2
PhOC
Ph
Me
Me
CH2CH2OBz
H
7d
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

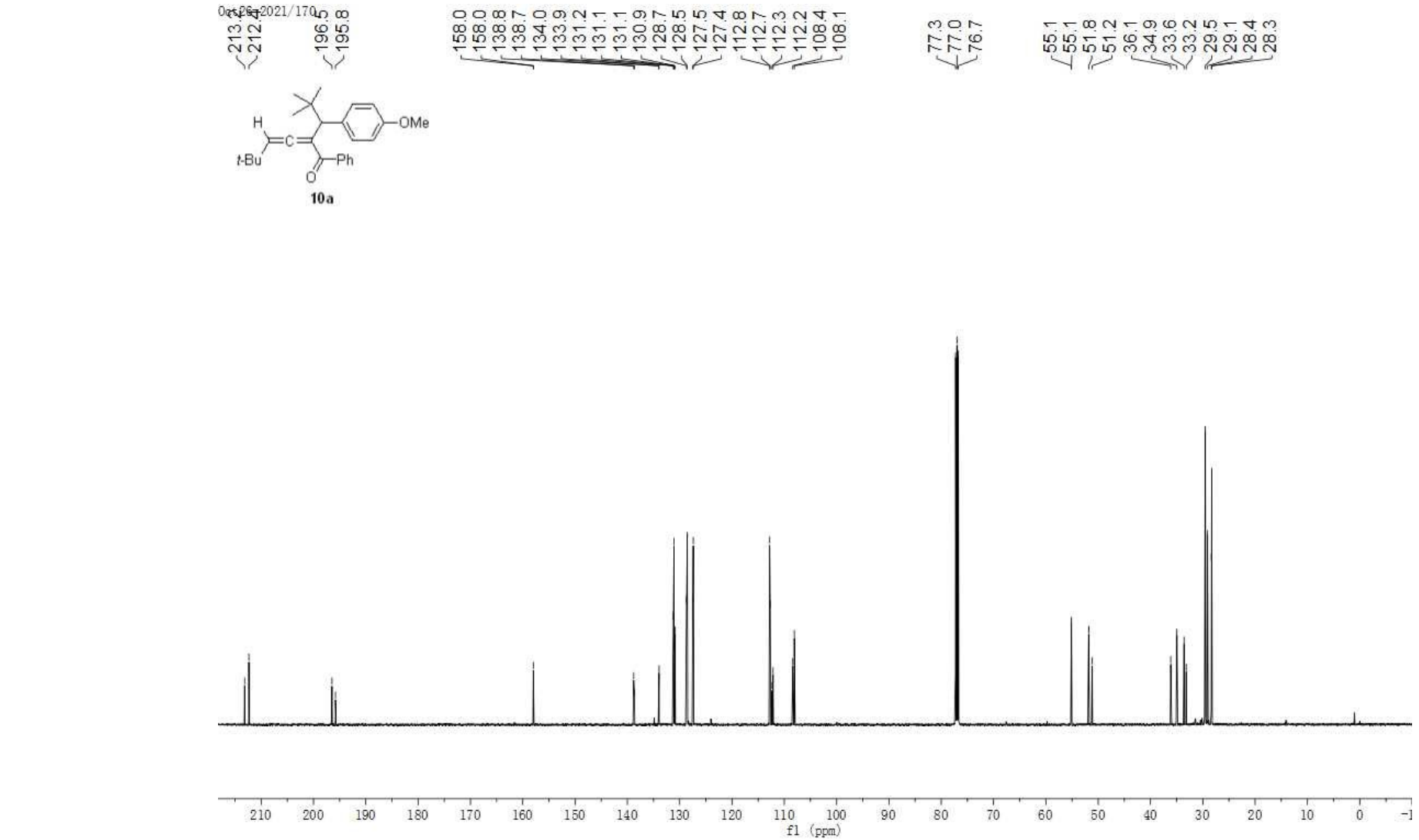

Oct-08-2021/190
8.03 8.02 8.01 8.01 7.99 7.99 7.97 7.97 7.72 7.71 7.70 7.70 7.68 7.68 7.55 7.49 7.49 7.48 7.47 7.47 7.46 7.44 7.43 7.42 7.41 7.41 7.40 7.32 7.30 7.27 7.26 7.26 7.25 7.25 7.25 7.24 7.24 7.23 7.22 7.20 7.14 7.12 7.10 7.06 7.04 6.61 6.57 4.46 4.45 4.43 4.30 4.30 4.30 2.34 2.31 1.18 1.16 1.15 1.12
Me
PhOC
C
H
Ph
CH2CH2OBz
Me
Me
7e
1.99 2.01 1.08 2.12 3.39 1.13 5.36 2.10 1.14 1.00
2.05 1.03
3.20
2.07
6.17
f1 (ppm)

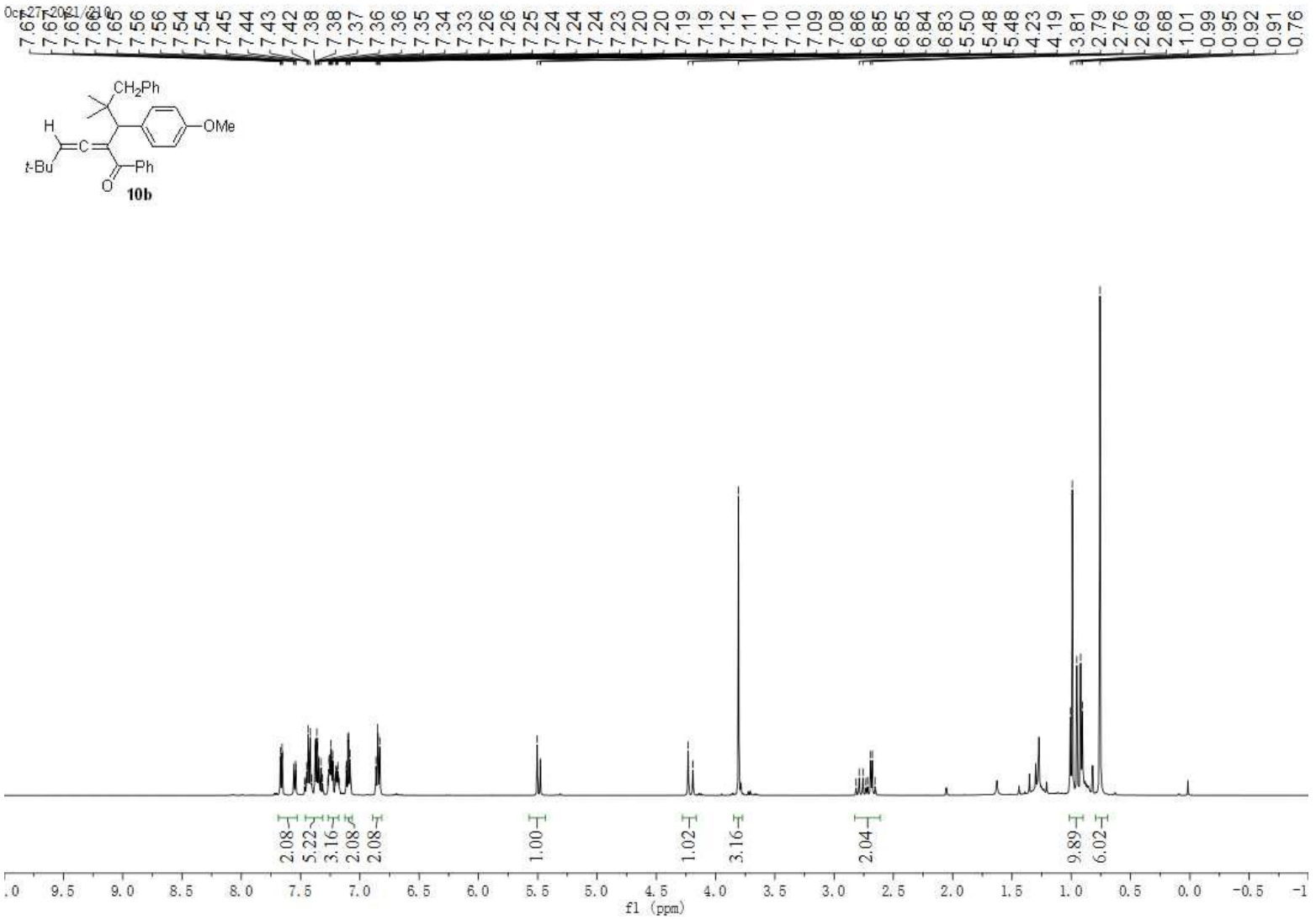

Oct-08-2021/191
216.4
215.5
194.4
194.3
166.6
166.5
140.5
140.4
137.9
137.9
137.8
132.7
132.7
132.0
132.0
130.4
130.4
130.4
129.7
129.5
129.2
129.0
128.9
128.8
128.3
128.2
127.9
127.8
127.8
127.7
127.4
127.3
126.7
126.7
112.4
111.8
100.4
100.1
77.3
77.0
76.7
62.2
62.1
53.8
53.5
38.6
37.7
37.0
25.6
25.4
25.2
25.2
21.2
21.2
Me
PhOC
C
H
Ph
Me
CH2CH2OBz
Me
7e
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-1
f1 (ppm)

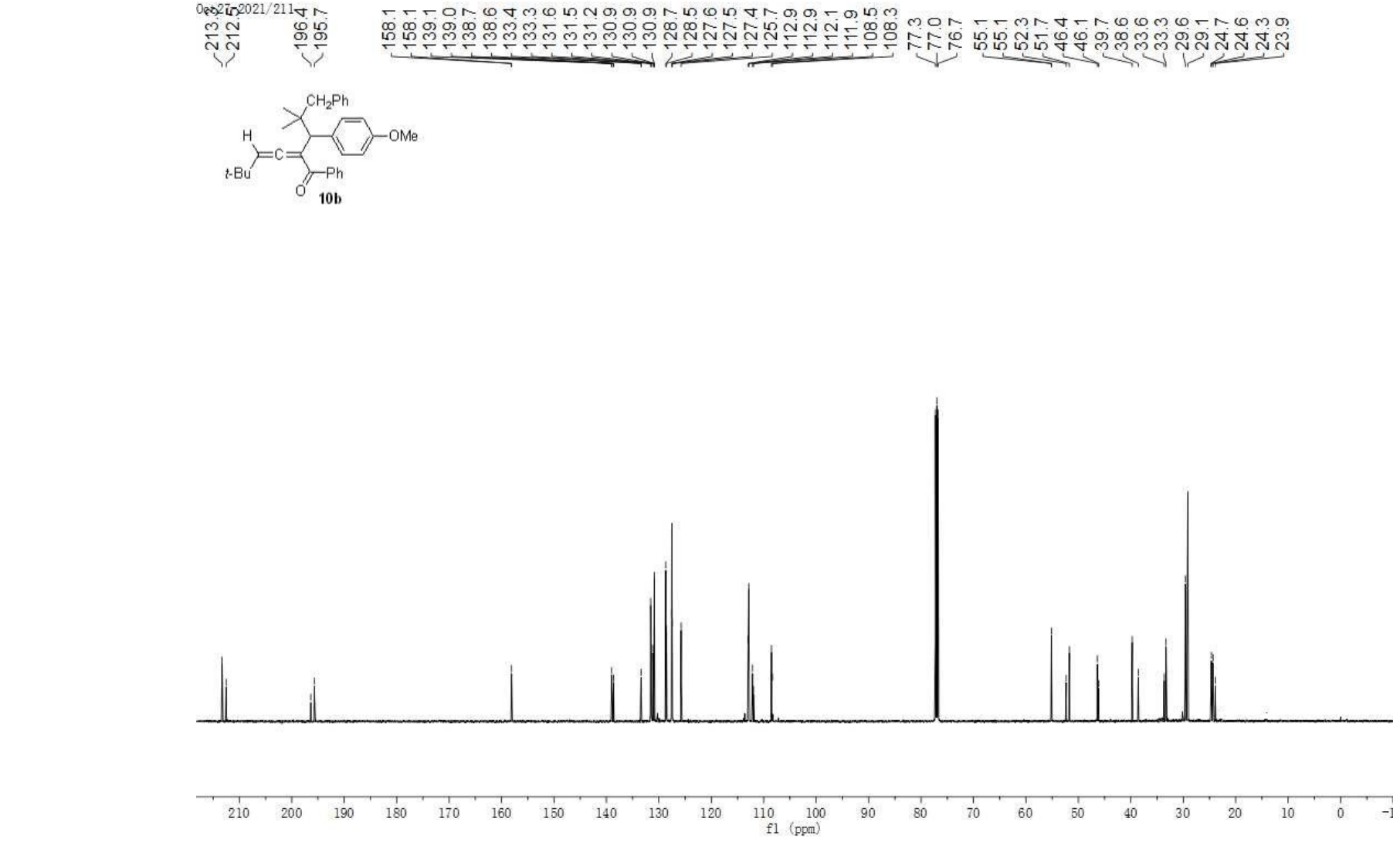

OMe
PhOC
Ph
Me
Me
CH2CH2OBz
H
7f
1.99
2.01
1.06
2.01
3.08
1.15
5.09
0.92
2.02
1.00
2.04
1.03
3.09
2.07
6.02
f1 (ppm)

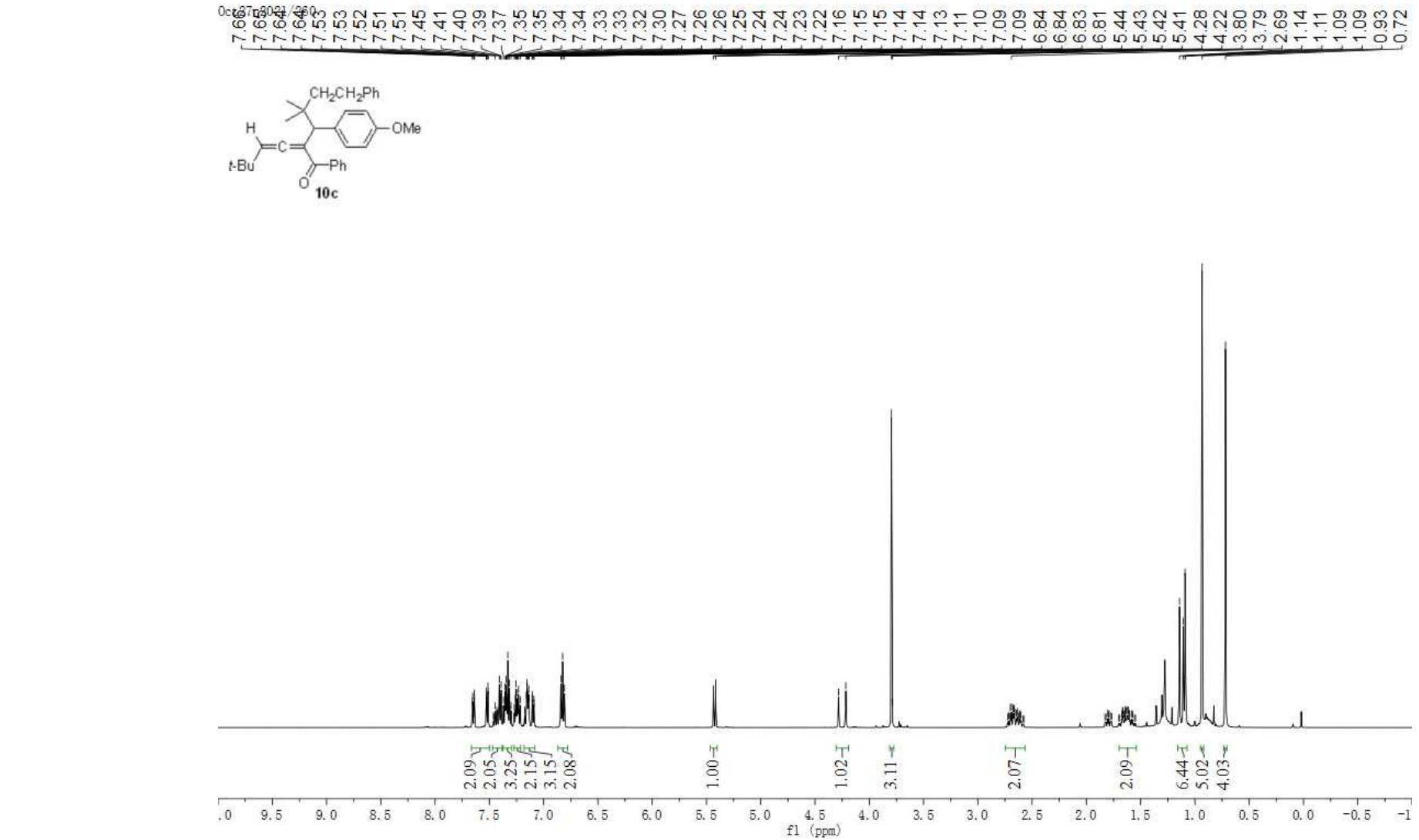

Oct 08 2021/201
216.5
214.5
194.5
194.4
166.5
159.4
159.3
140.6
140.4
138.0
137.9
132.7
132.7
132.0
131.9
130.4
130.4
130.4
129.5
128.8
128.8
128.7
128.6
128.3
128.2
127.9
127.8
127.7
127.7
126.7
126.6
124.4
124.2
114.5
114.3
112.4
111.8
100.0
99.7
77.3
77.0
76.7
62.2
62.2
55.3
55.2
53.7
53.4
38.6
38.6
37.7
37.0
25.6
25.3
25.2
OMe
PhOC
C
H
Ph
CH2CH2OBz
Me
Me
7f
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

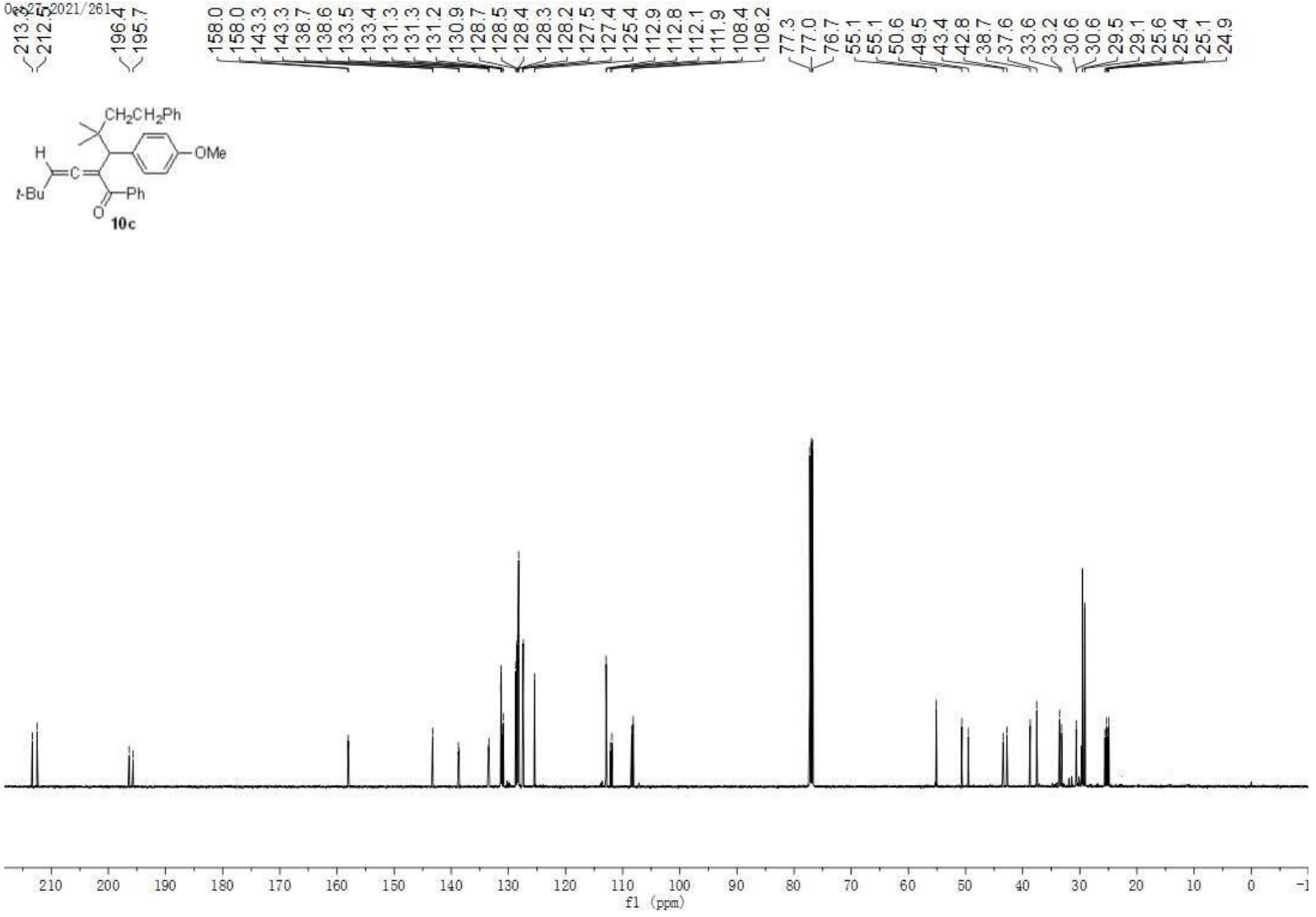

7.64 7.64 7.64 7.63 7.62 7.53 7.53 7.53 7.52 7.52 7.51 7.43 7.42 7.42 7.41 7.40 7.39 7.39 7.37 7.36 7.36 7.35 7.35 7.34 7.34 7.34 7.33 7.32 7.32 7.31 7.31 7.30 7.30 7.29 7.29 7.26 6.83 6.82 6.81 6.81 6.80 6.80 6.79 6.78 5.43 5.43 5.40 5.40 4.08 4.08 4.04 4.03 3.79 3.78 1.03 1.00 0.95 0.70
H
t-Bu
OMe
Ph
O
10a
2.02
1.04
4.06
2.05
1.00
1.02
3.08
5.40
3.39
5.73
3.54
f1 (ppm)

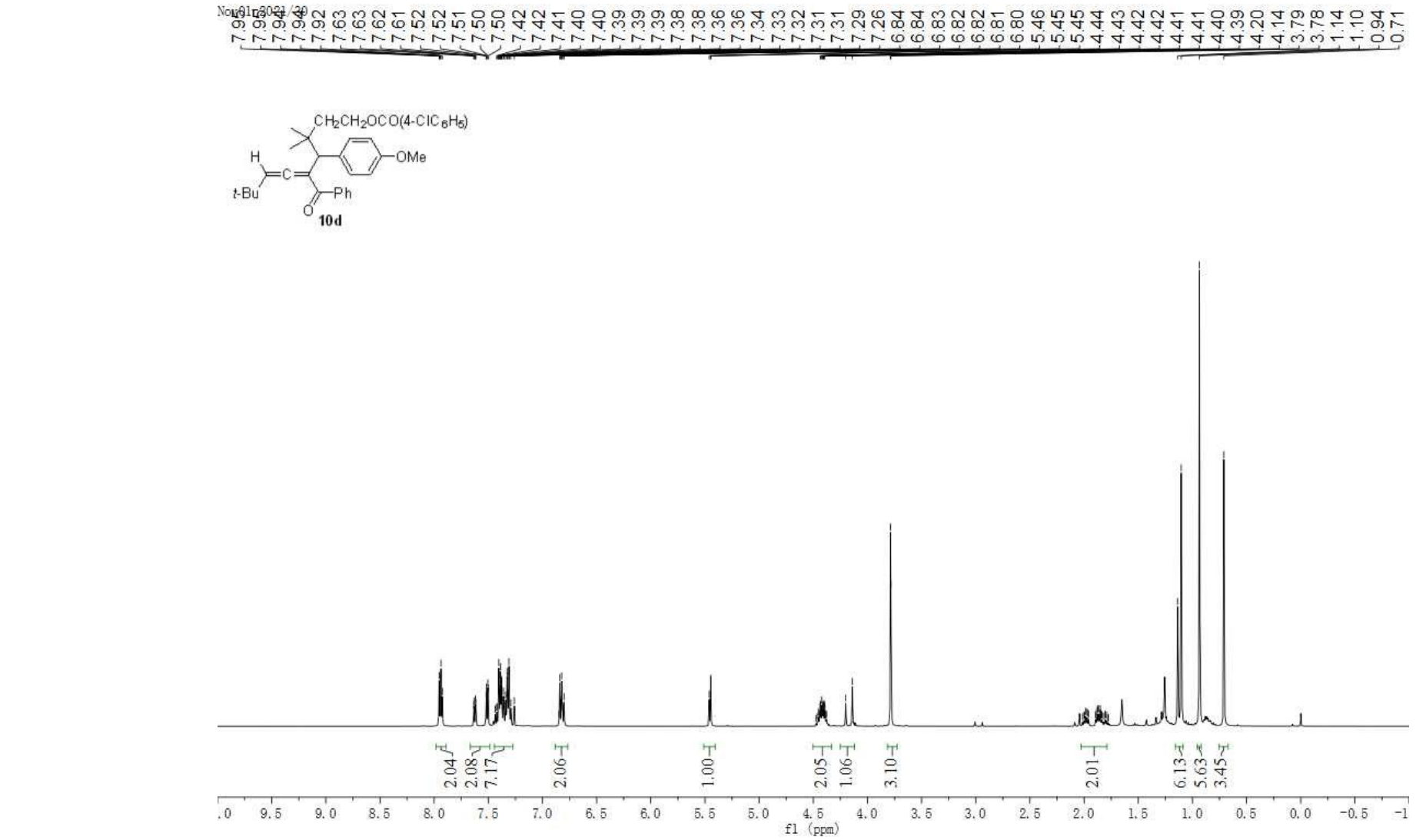

Oct 26 2021/170
213.7
212.7
196.5
195.8
158.0
158.0
138.8
138.7
134.0
133.9
131.2
131.1
131.1
130.9
128.7
128.5
127.5
127.4
112.8
112.7
112.3
112.2
108.4
108.1
77.3
77.0
76.7
55.1
55.1
51.8
51.2
36.1
34.9
33.6
33.2
29.5
29.1
28.4
28.3
H
t-Bu
OMe
Ph
O
10a
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

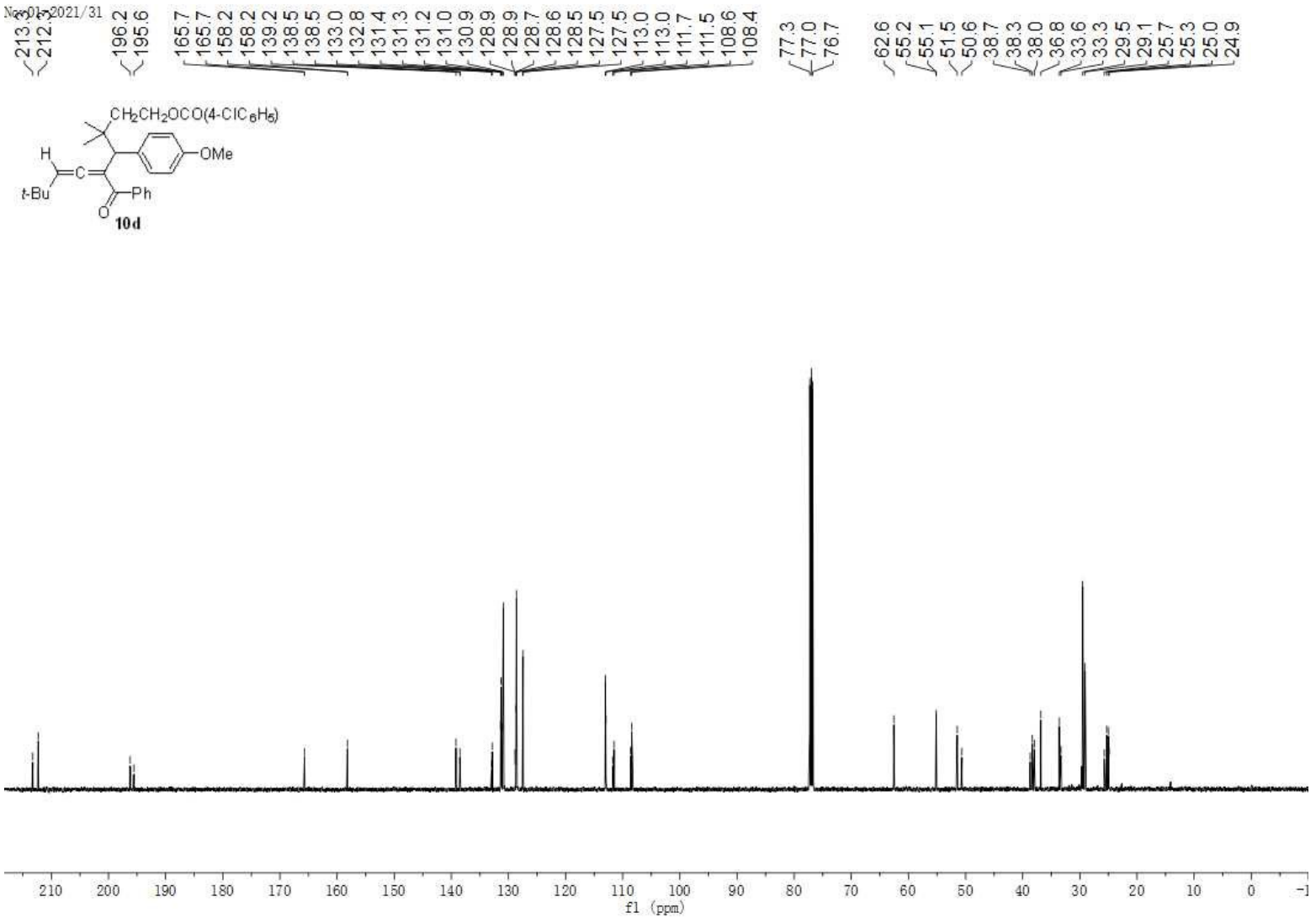

CH2Ph
H
OMe
t-Bu
Ph
O
10b
2.08
5.22
3.16
2.08
2.08
1.00
1.02
3.16
2.04
9.89
6.02
f1 (ppm)

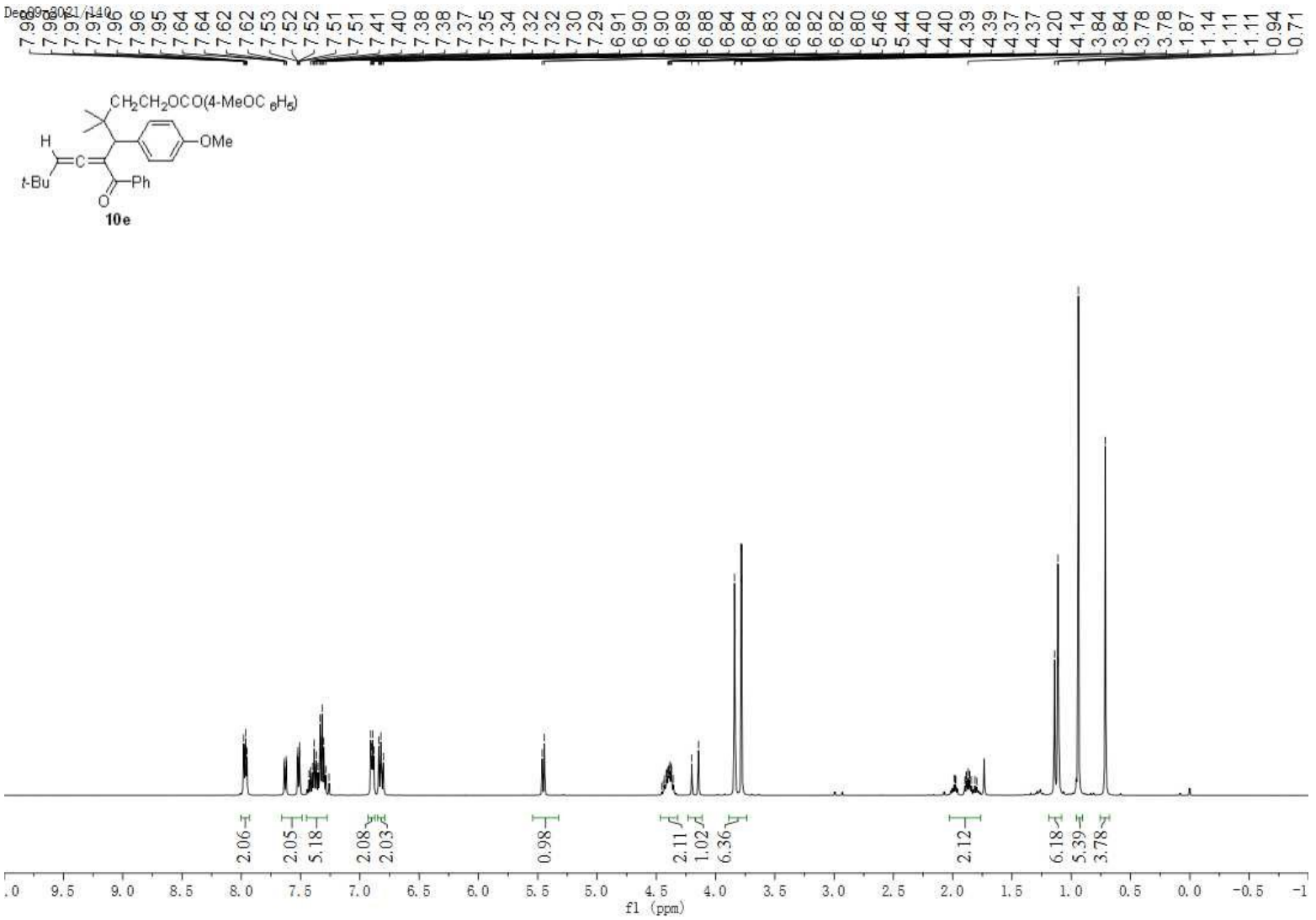

213.6
212.5
196.4
195.7
158.1
158.1
139.1
139.0
138.7
138.6
133.4
133.3
131.6
131.5
131.2
130.9
130.9
130.9
128.7
128.5
127.6
127.5
127.4
125.7
112.9
112.9
112.1
111.9
108.5
108.3
77.3
77.0
76.7
55.1
55.1
52.3
51.7
46.4
46.1
39.7
38.6
33.6
33.3
29.6
29.1
24.7
24.6
24.3
23.9
CH2Ph
H
OMe
t-Bu
Ph
O
10b
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

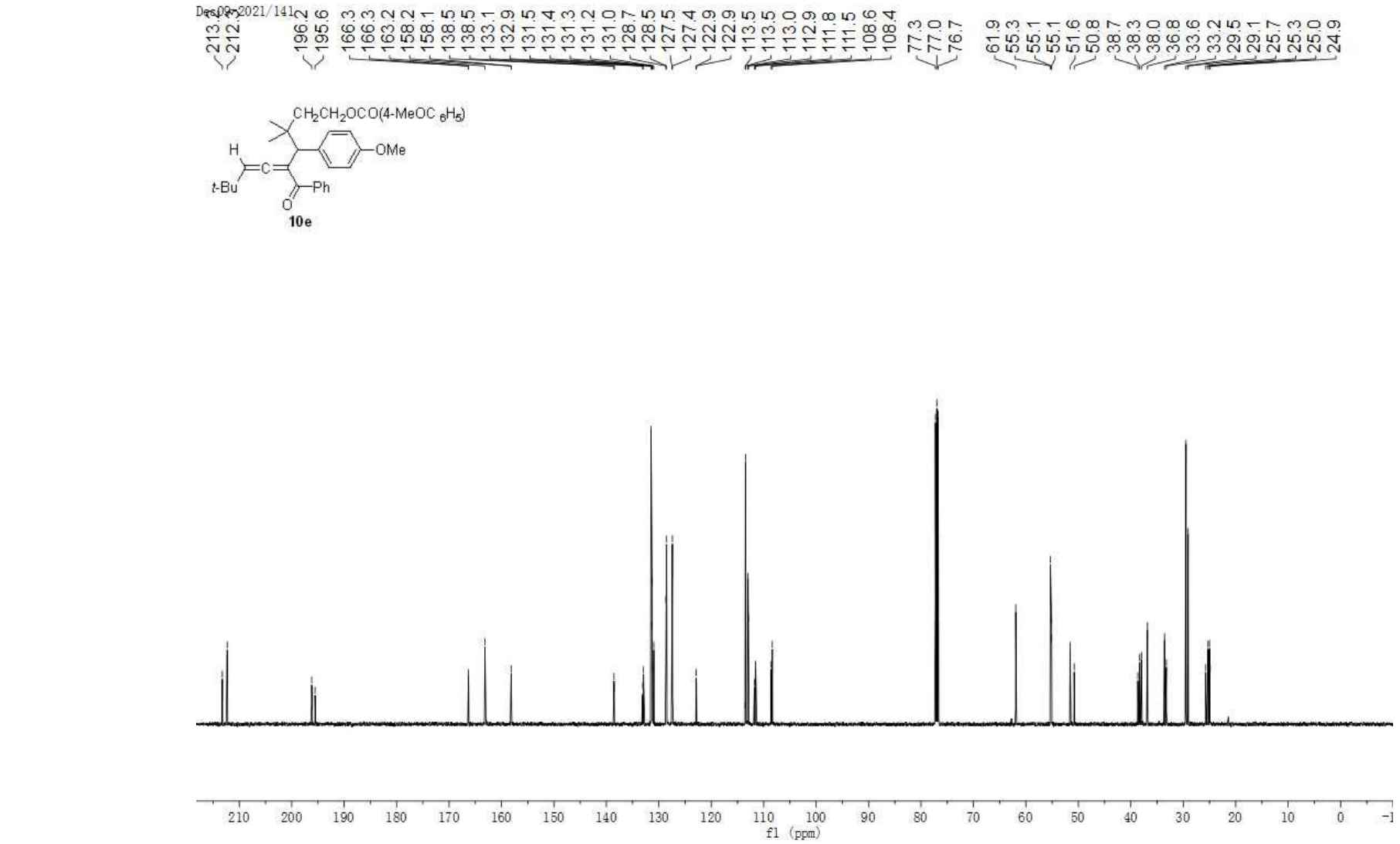

7.66 7.65 7.64 7.64 7.53 7.53 7.52 7.51 7.51 7.45 7.41 7.40 7.39 7.37 7.35 7.35 7.34 7.34 7.33 7.33 7.32 7.30 7.27 7.26 7.26 7.25 7.24 7.24 7.23 7.22 7.16 7.15 7.15 7.14 7.14 7.13 7.11 7.10 7.09 7.09 6.84 6.84 6.83 6.81 5.44 5.43 5.42 5.41 4.28 4.22 3.80 3.79 2.69 1.14 1.11 1.09 1.09 0.93 0.72
CH2CH2Ph
H
OMe
t-Bu
Ph
O
10c
2.09 2.05 3.25 2.15 3.15 2.08 1.00 1.02 3.11 2.07 2.09 6.44 5.02 4.03
f1 (ppm)

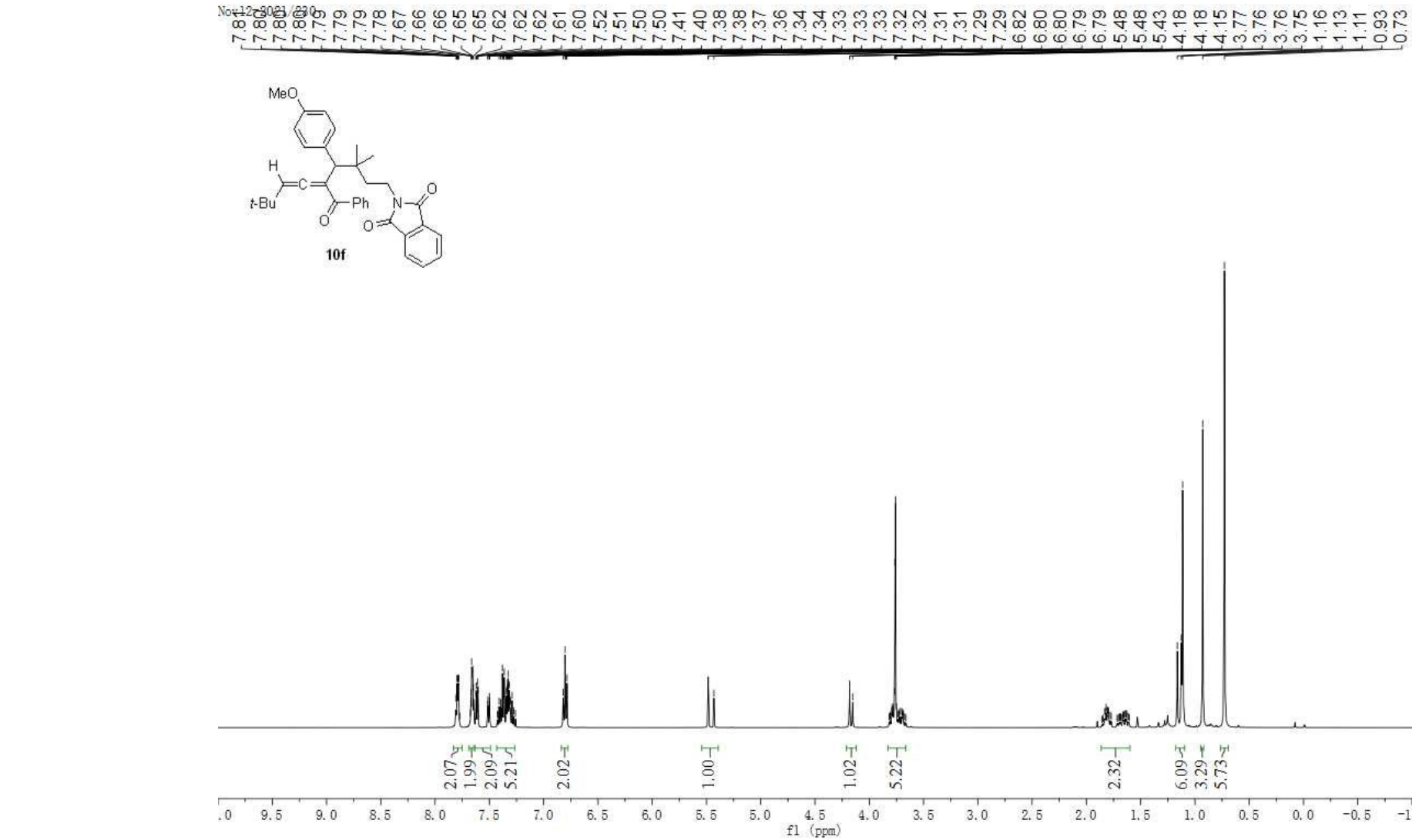

Oct 27 2021/261
213.6
212.5
196.4
195.7
158.0
158.0
143.3
143.3
138.7
138.6
133.5
133.4
131.3
131.3
131.2
130.9
128.7
128.5
128.4
128.3
128.2
127.5
127.4
125.4
112.9
112.8
112.1
111.9
108.4
108.2
77.3
77.0
76.7
55.1
55.1
50.6
49.5
43.4
42.8
38.7
37.6
33.6
33.2
30.6
30.6
29.5
29.1
25.6
25.4
25.1
24.9
CH2CH2Ph
H
OMe
t-Bu
Ph
O
10c
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

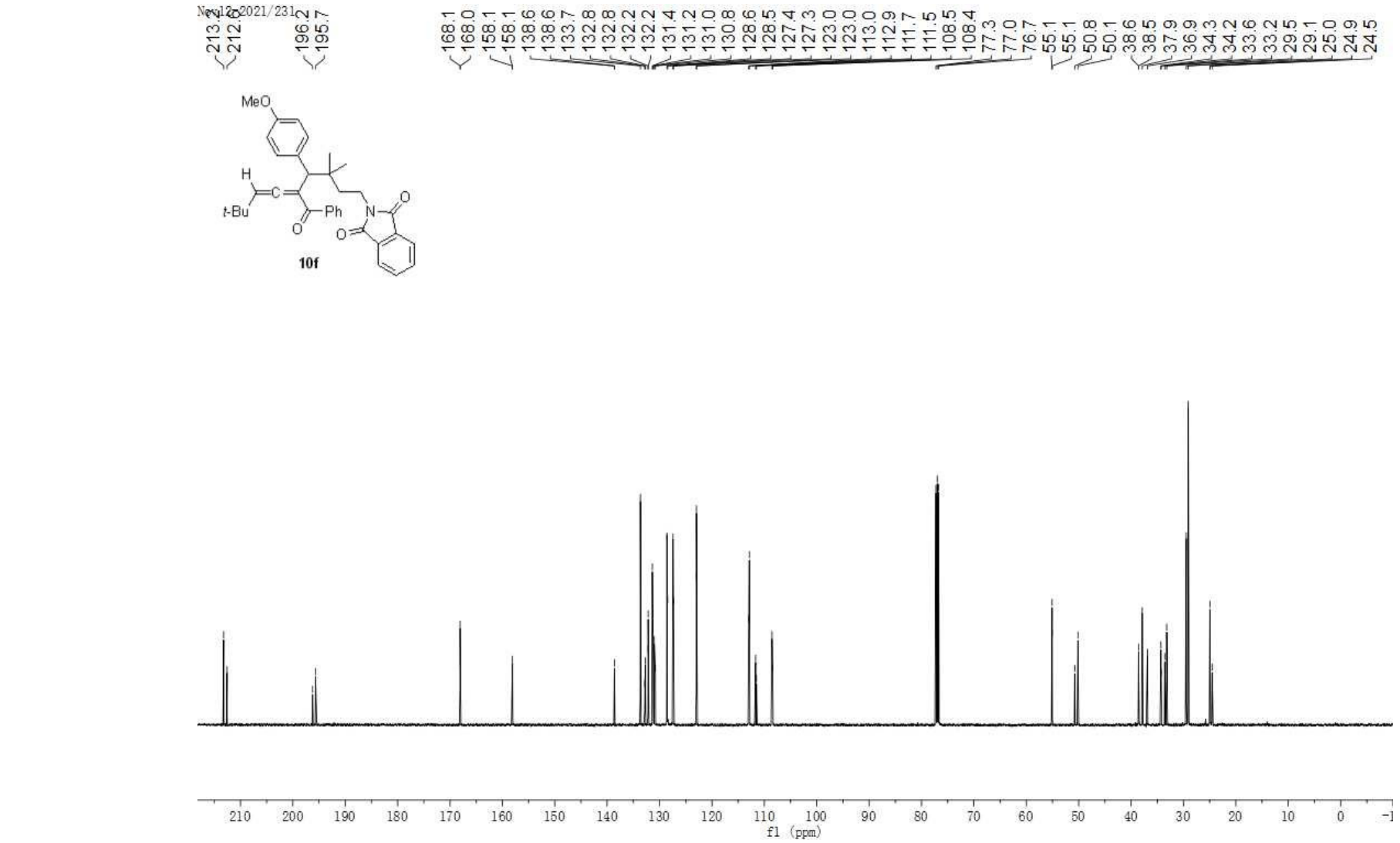

CH2CH2OCO(4-ClC6H5)
H
OMe
t-Bu
Ph
O
10d
fl (ppm)

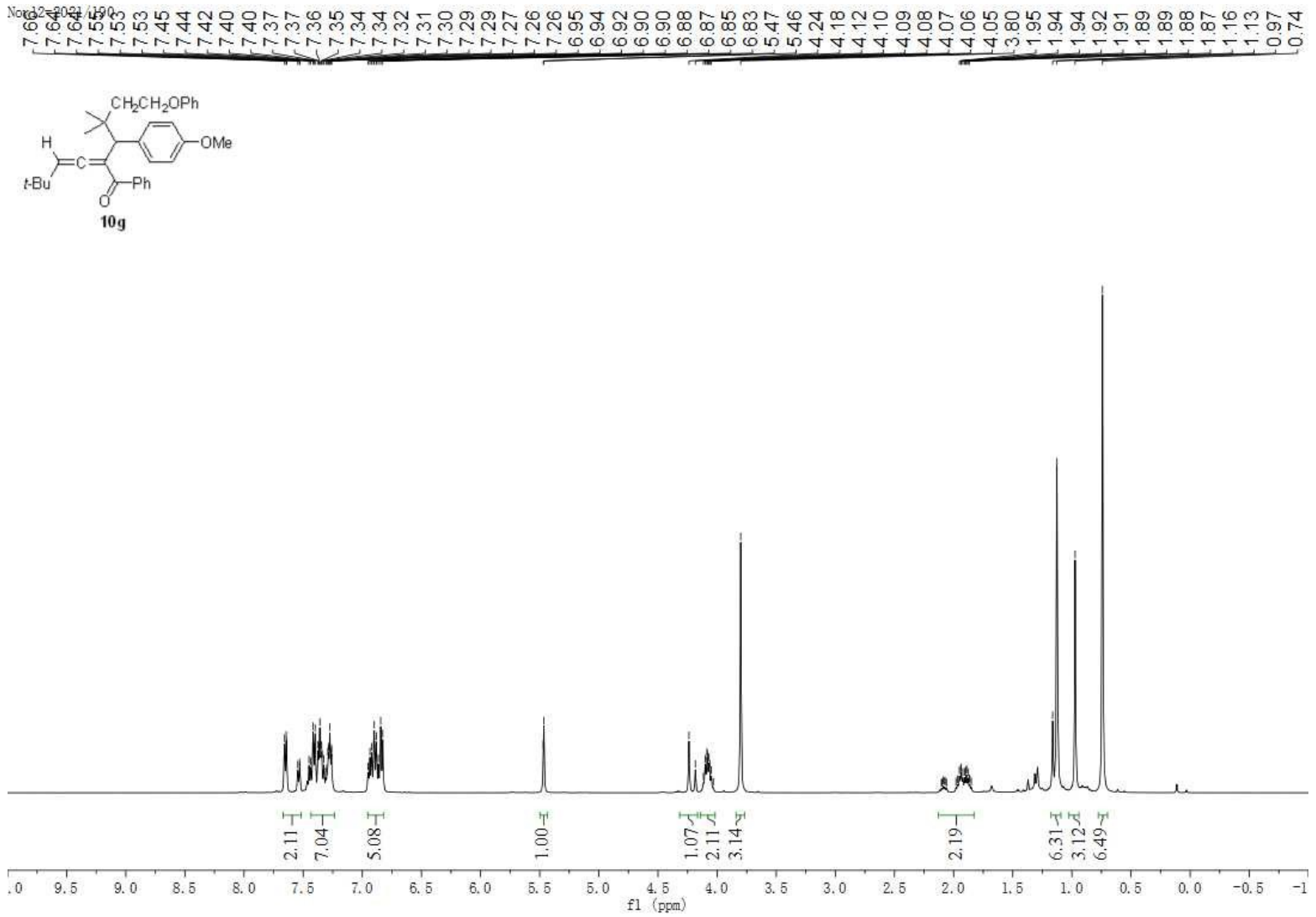

Nov 01 2021/31
213.3
212.3
196.2
195.6
165.7
165.7
158.2
158.2
139.2
138.5
138.5
133.0
132.8
131.4
131.3
131.2
131.0
130.9
128.9
128.9
128.7
128.6
128.5
127.5
127.5
113.0
113.0
111.7
111.5
108.6
108.4
77.3
77.0
76.7
62.6
55.2
55.1
51.5
50.6
38.7
38.3
38.0
36.8
33.6
33.3
29.5
29.1
25.7
25.3
25.0
24.9
CH2CH2OCO(4-ClC6H5)
OMe
H
C
t-Bu
Ph
O
10d
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-1
f1 (ppm)

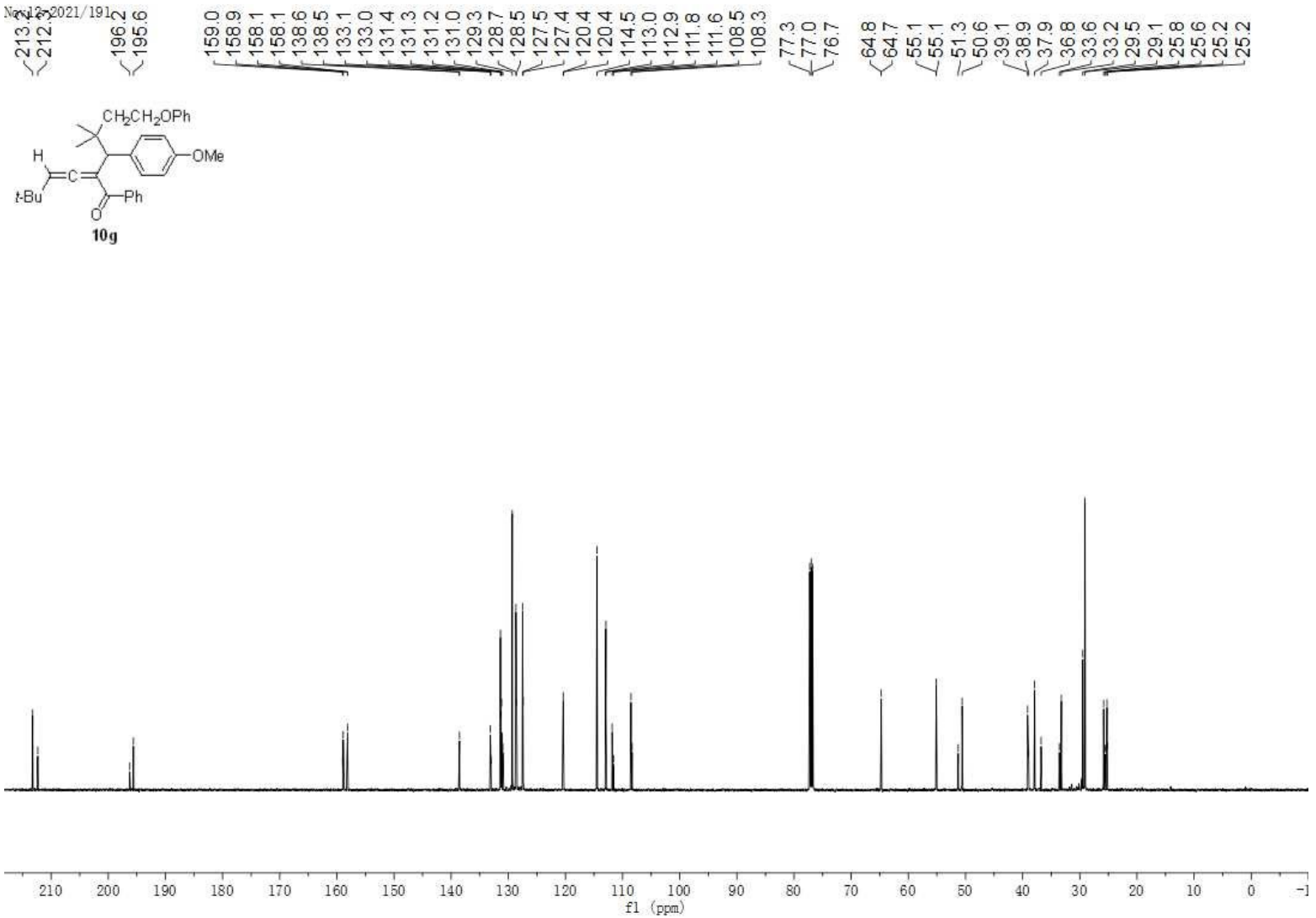

CH2CH2OCO(4-MeOC6H5)
OMe
H
t-Bu
Ph
O
10e
2.06
2.05
5.18
2.08
2.03
0.98
2.11
1.02
6.36
2.12
6.18
5.39
3.78
f1 (ppm)

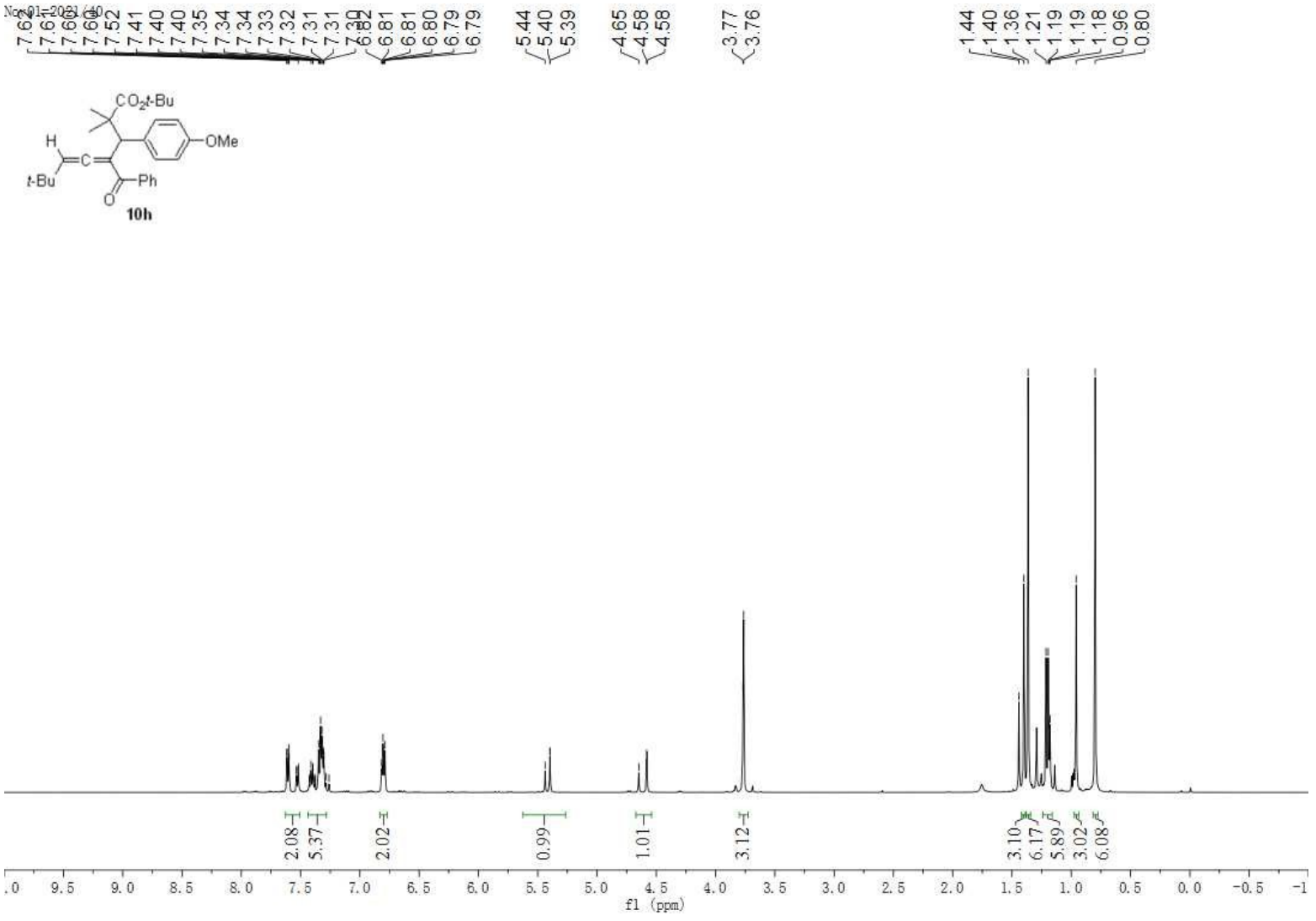

Dec 09 2021/141
213.2
212.3
196.2
195.6
166.3
166.3
163.2
158.2
158.1
138.5
138.5
133.1
132.9
131.5
131.4
131.3
131.2
131.0
128.7
128.5
127.5
127.4
122.9
122.9
113.5
113.5
113.0
112.9
111.8
111.5
108.6
108.4
77.3
77.0
76.7
61.9
55.3
55.1
55.1
51.6
50.8
38.7
38.3
38.0
36.8
33.6
33.2
29.5
29.1
25.7
25.3
25.0
24.9
CH2CH2OCO(4-MeOC6H5)
H
OMe
t-Bu
Ph
O
10e
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-1
f1 (ppm)

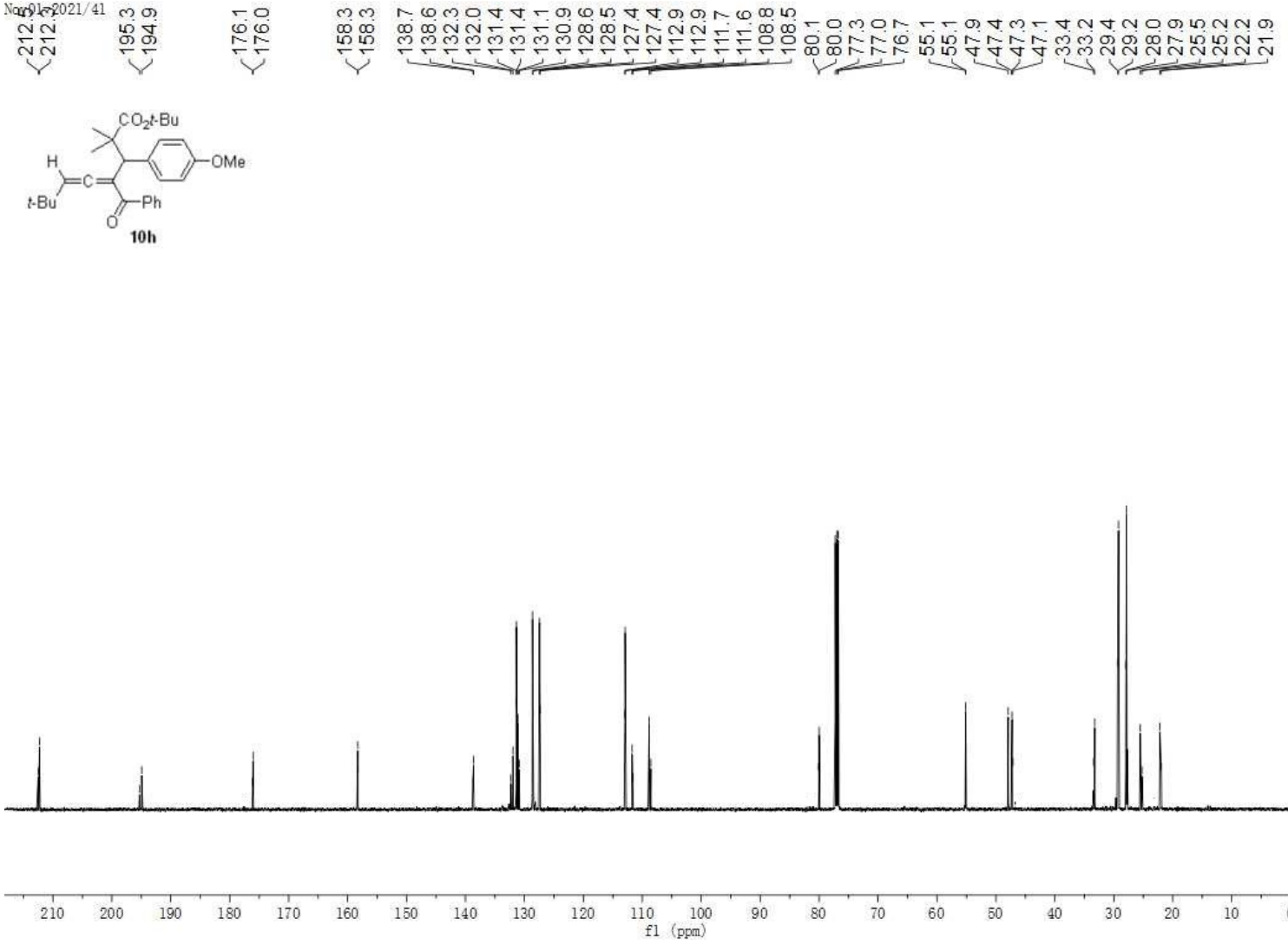

MeO
H
t-Bu
Ph
O
O
O
N
10f
fl (ppm)

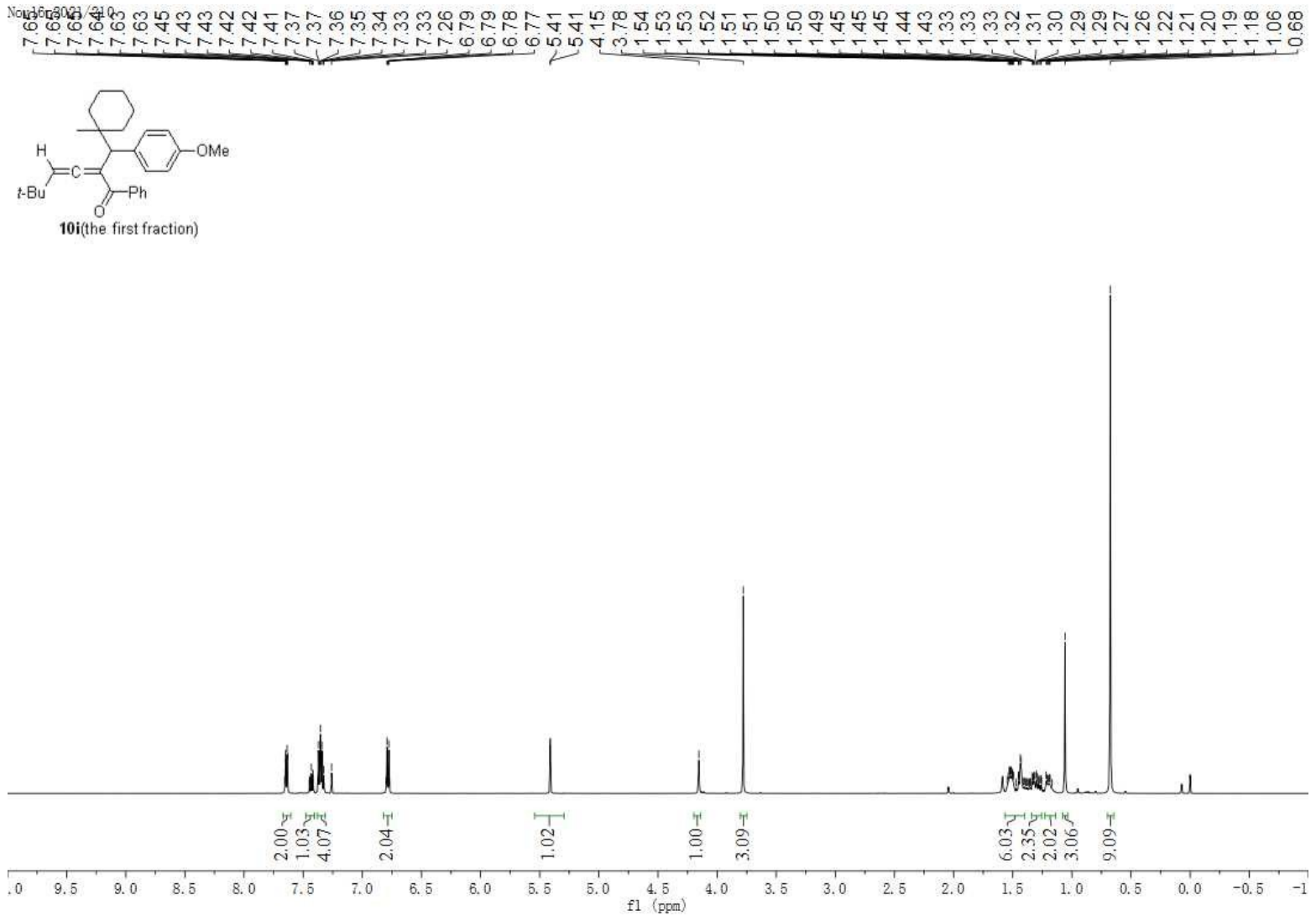

Nov12 2021/231
213.2
212.6
196.2
195.7
168.1
168.0
158.1
158.1
138.6
138.6
133.7
132.8
132.8
132.2
132.2
131.4
131.2
131.0
130.8
128.6
128.5
127.4
127.3
123.0
123.0
113.0
112.9
111.7
111.5
108.5
108.4
77.3
77.0
76.7
55.1
55.1
50.8
50.1
38.6
38.5
37.9
36.9
34.3
34.2
33.6
33.2
29.5
29.1
25.0
24.9
24.5
MeO
H
t-Bu
Ph
O
N
O
O
10f
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-1
f1 (ppm)

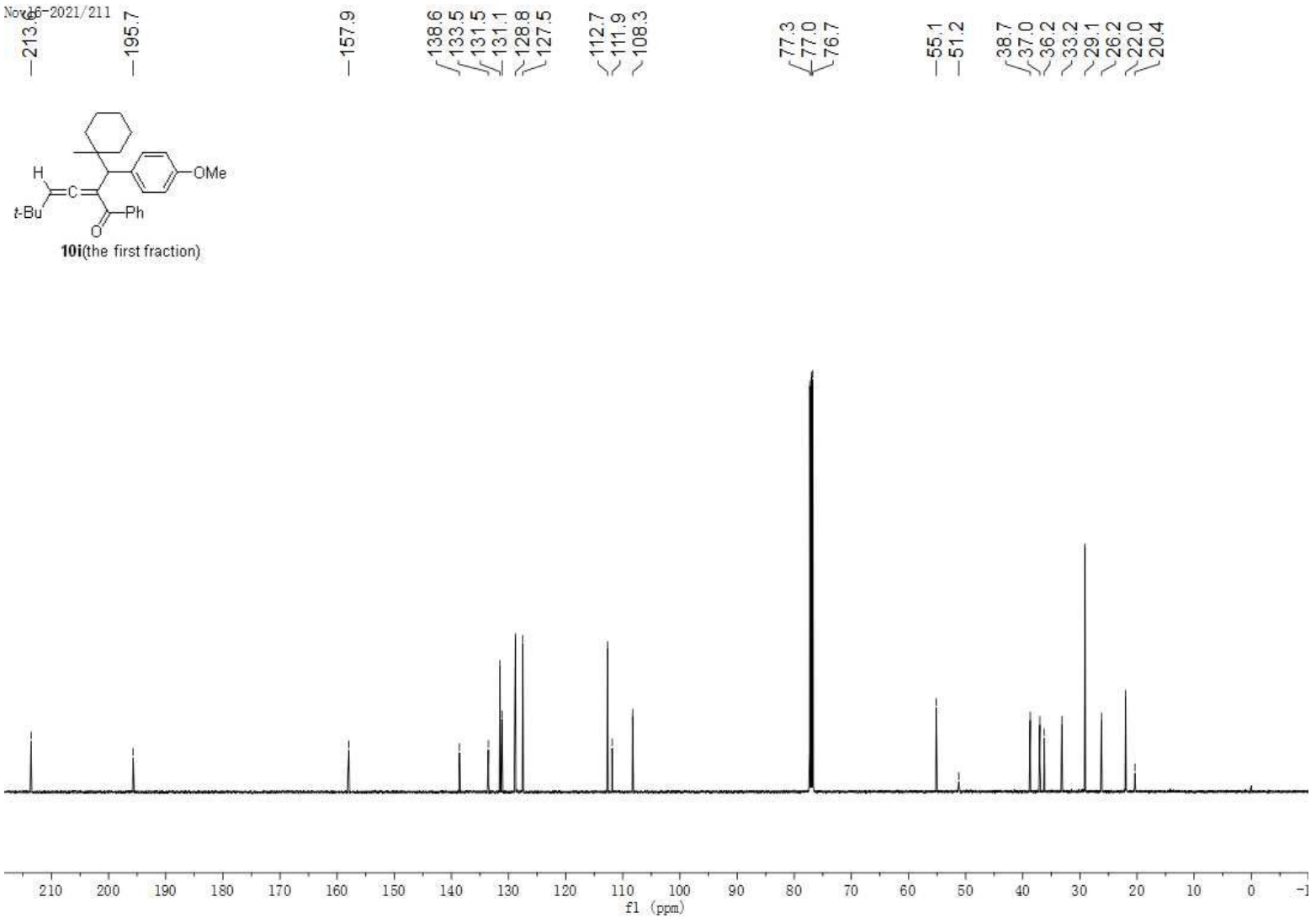

7.66 7.64 7.64 7.55 7.53 7.53 7.45 7.44 7.42 7.40 7.40 7.37 7.37 7.36 7.35 7.34 7.34 7.32 7.31 7.30 7.29 7.29 7.27 7.26 7.26 6.95 6.94 6.92 6.90 6.90 6.88 6.87 6.85 6.83 5.47 5.46 4.24 4.18 4.12 4.10 4.09 4.08 4.07 4.06 4.05 3.80 1.95 1.94 1.94 1.92 1.91 1.89 1.89 1.88 1.87 1.16 1.13 0.97 0.74
CH2CH2OPh
OMe
H
t-Bu
Ph
O
10g
2.11
7.04
5.08
1.00
1.07
2.11
3.14
2.19
6.31
3.12
6.49
f1 (ppm)

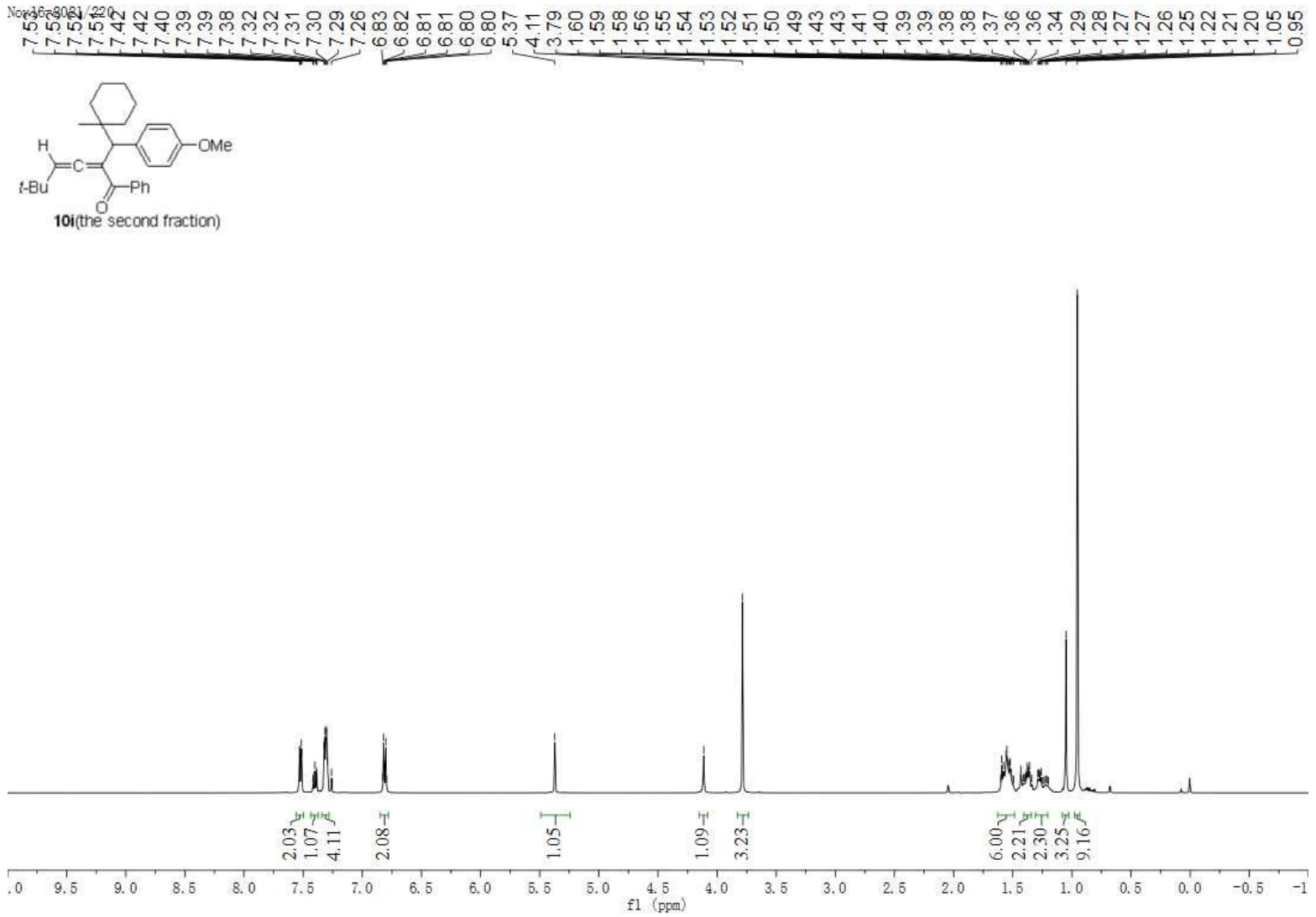

213.2
212.3
196.2
195.6
159.0
158.9
158.1
158.1
138.6
138.5
133.1
133.0
131.4
131.3
131.2
131.0
129.3
128.7
128.5
127.5
127.4
120.4
120.4
114.5
113.0
112.9
111.8
111.6
108.5
108.3
77.3
77.0
76.7
64.8
64.7
55.1
55.1
51.3
50.6
39.1
38.9
37.9
36.8
33.6
33.2
29.5
29.1
25.8
25.6
25.2
25.2
CH2CH2OPh
OMe
H
t-Bu
Ph
O
10g
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

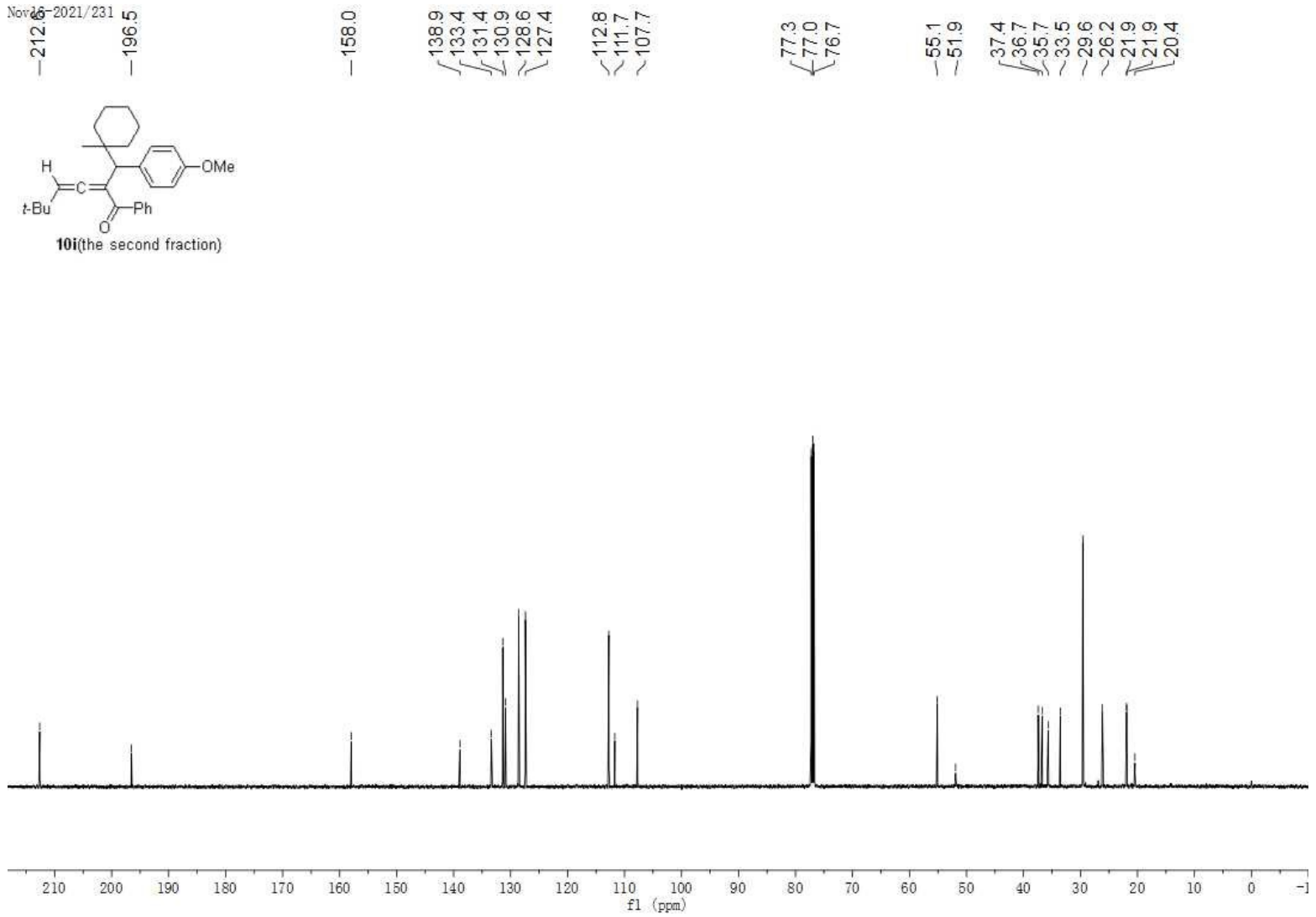

7.62
7.61
7.60
7.60
7.52
7.41
7.40
7.40
7.35
7.34
7.34
7.33
7.32
7.31
7.31
7.30
6.82
6.81
6.81
6.80
6.79
6.79
5.44
5.40
5.39
4.65
4.58
4.58
3.77
3.76
1.44
1.40
1.36
1.21
1.19
1.19
1.18
0.96
0.80
CO2t-Bu
OMe
H
C
t-Bu
Ph
O
10h
2.08
5.37
2.02
0.99
1.01
3.12
3.10
6.17
5.89
3.02
6.08
f1 (ppm)

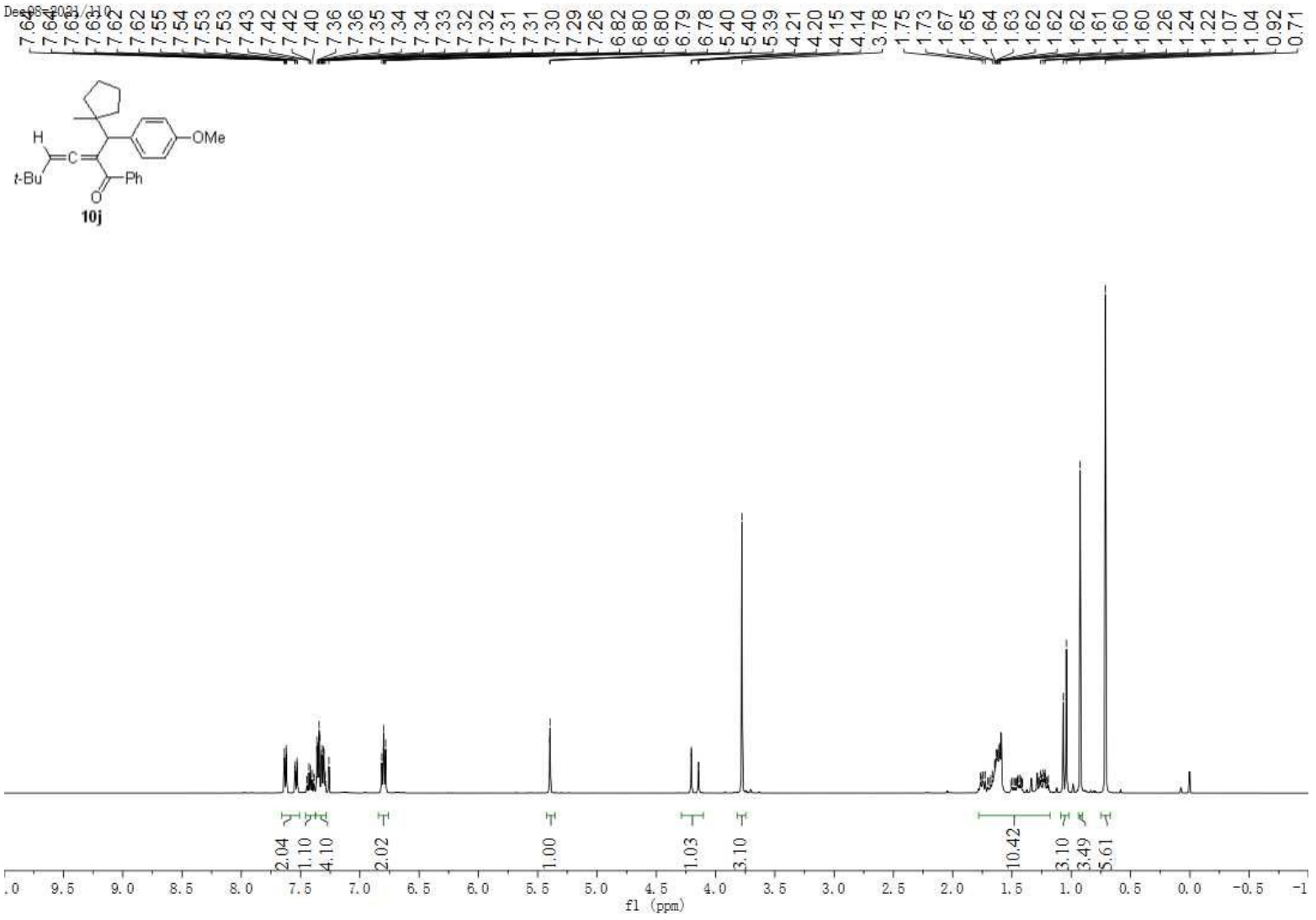

Nov 01 2021/41
212.5
212.2
195.3
194.9
176.1
176.0
158.3
158.3
138.7
138.6
132.3
132.0
131.4
131.4
131.1
130.9
128.6
128.5
127.4
127.4
112.9
112.9
111.7
111.6
108.8
108.5
80.1
80.0
77.3
77.0
76.7
55.1
55.1
47.9
47.4
47.3
47.1
33.4
33.2
29.4
29.2
28.0
27.9
25.5
25.2
22.2
21.9
CO2t-Bu
OMe
H
t-Bu
Ph
O
10h
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-1
f1 (ppm)

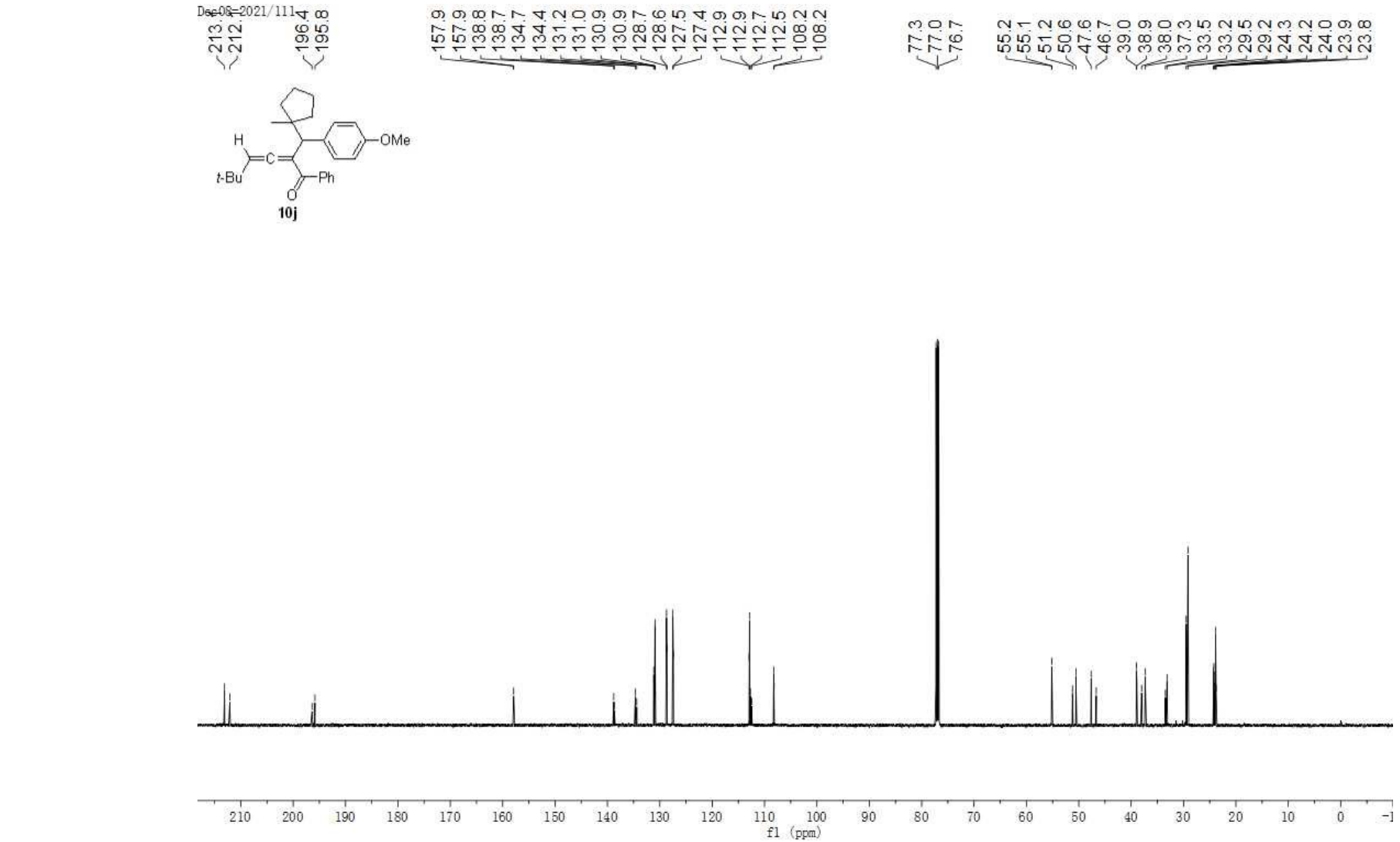

7.65 7.65 7.64 7.64 7.63 7.63 7.45 7.43 7.43 7.42 7.42 7.41 7.37 7.37 7.36 7.35 7.34 7.33 7.33 7.26 6.79 6.79 6.78 6.77 5.41 5.41 4.15 3.78 1.54 1.53 1.53 1.52 1.51 1.51 1.50 1.50 1.49 1.45 1.45 1.45 1.44 1.43 1.33 1.33 1.33 1.32 1.31 1.30 1.29 1.29 1.27 1.26 1.22 1.21 1.20 1.19 1.18 1.06 0.68
H
C
t-Bu
OMe
Ph
O
10i(the first fraction)
2.00
1.03
4.07
2.04
1.02
1.00
3.09
6.03
2.35
2.02
3.06
9.09
f1 (ppm)

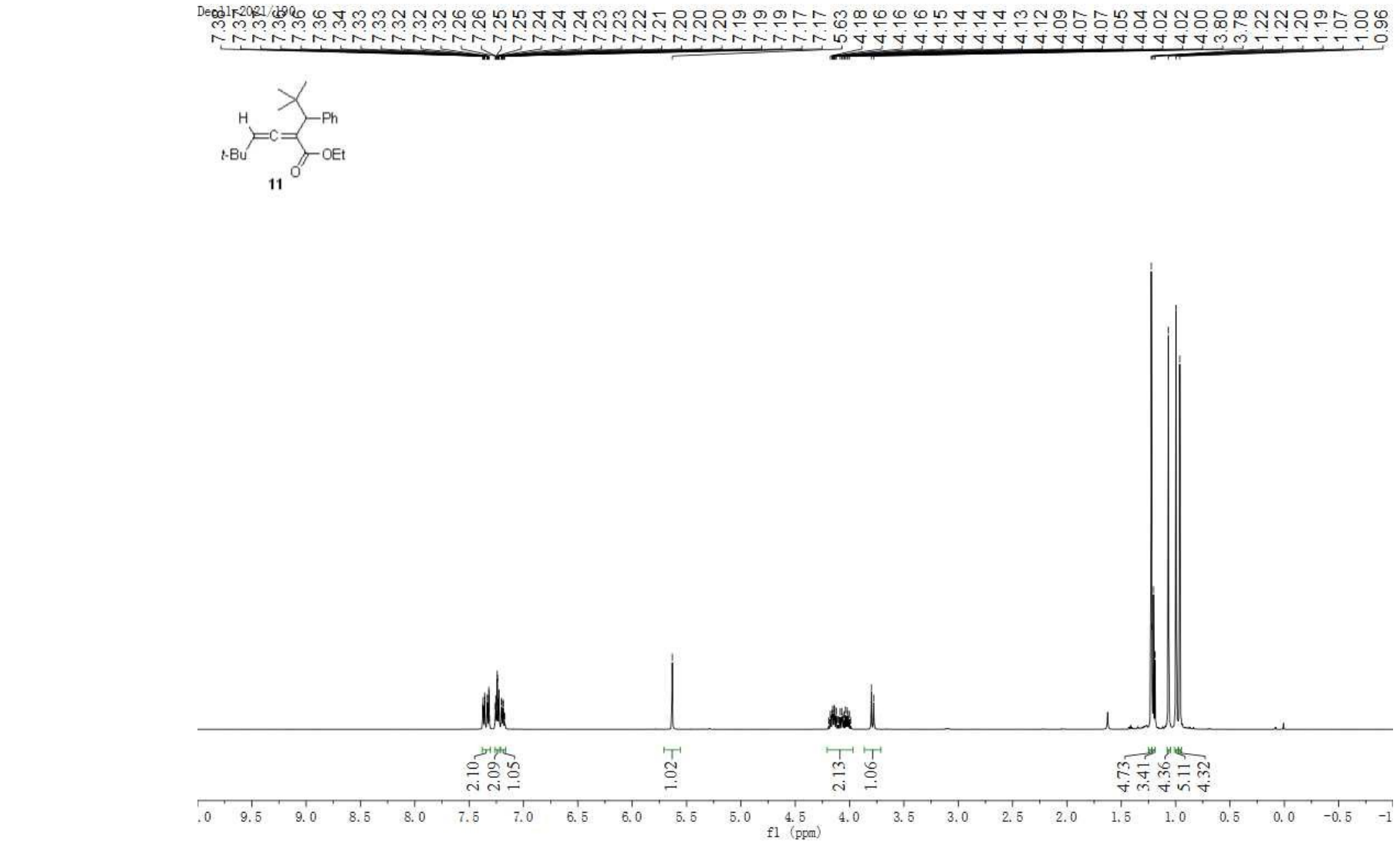

Nov16-2021/211
213.6
195.7
157.9
138.6
133.5
131.5
131.1
128.8
127.5
112.7
111.9
108.3
77.3
77.0
76.7
55.1
51.2
38.7
37.0
36.2
33.2
29.1
26.2
22.0
20.4
H
C
t-Bu
Ph
O
OMe
10i(the first fraction)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -1
f1 (ppm)

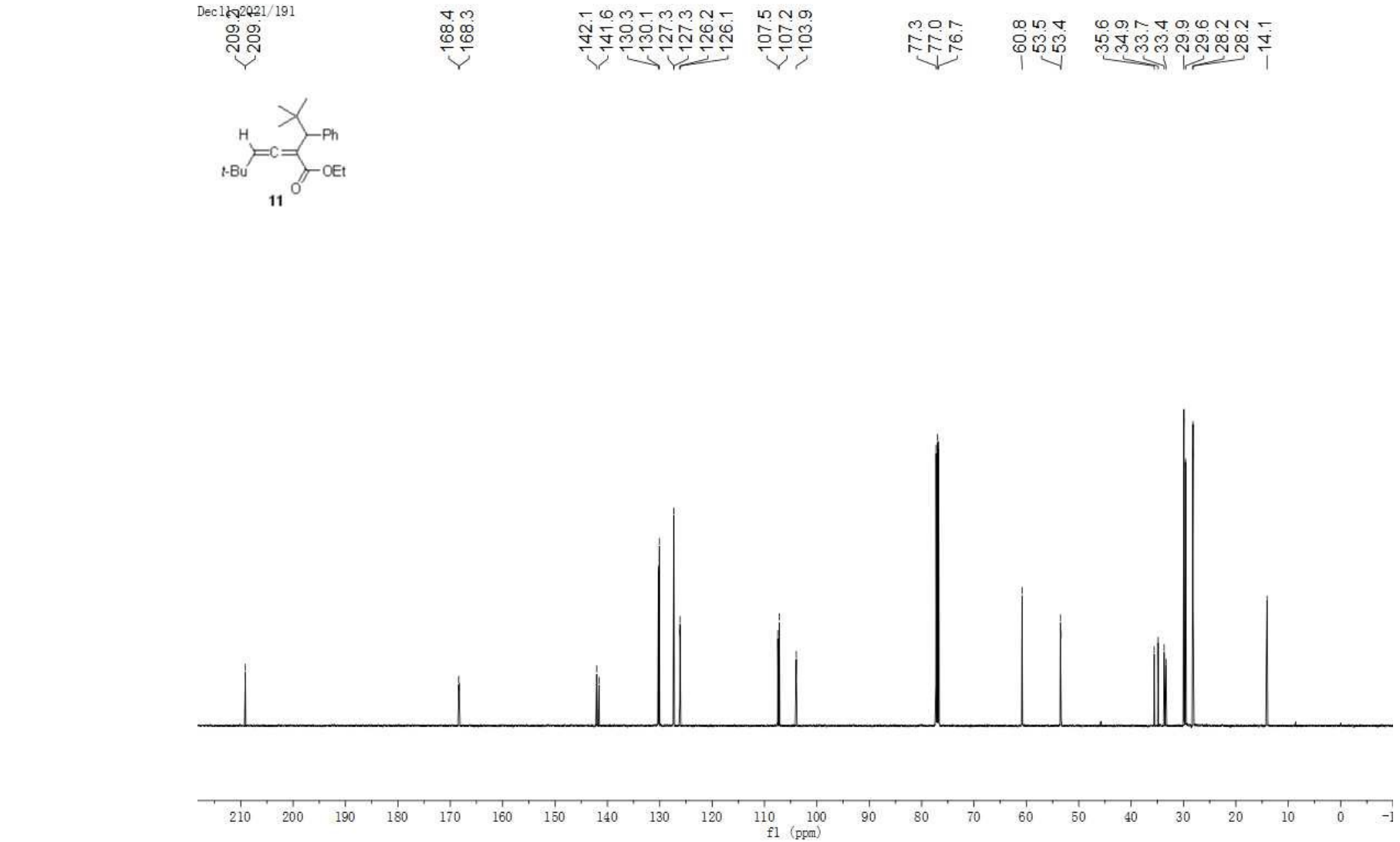

7.53 7.52 7.51 7.42 7.42 7.40 7.39 7.39 7.38 7.32 7.32 7.31 7.30 7.29 7.26
6.83 6.82 6.81 6.81 6.80 6.80
5.37
4.11 3.79
1.60 1.59 1.58 1.56 1.55 1.54 1.53 1.52 1.51 1.50 1.49 1.43 1.43 1.41 1.40 1.39 1.39 1.38 1.38 1.37 1.36 1.36 1.34 1.29 1.28 1.27 1.27 1.26 1.25 1.22 1.21 1.20 1.05 0.95
H
t-Bu
C
OMe
Ph
O
10i(the second fraction)
2.03 1.07 4.11 2.08 1.05 1.09 3.23 6.00 2.21 2.30 3.25 9.16
f1 (ppm)

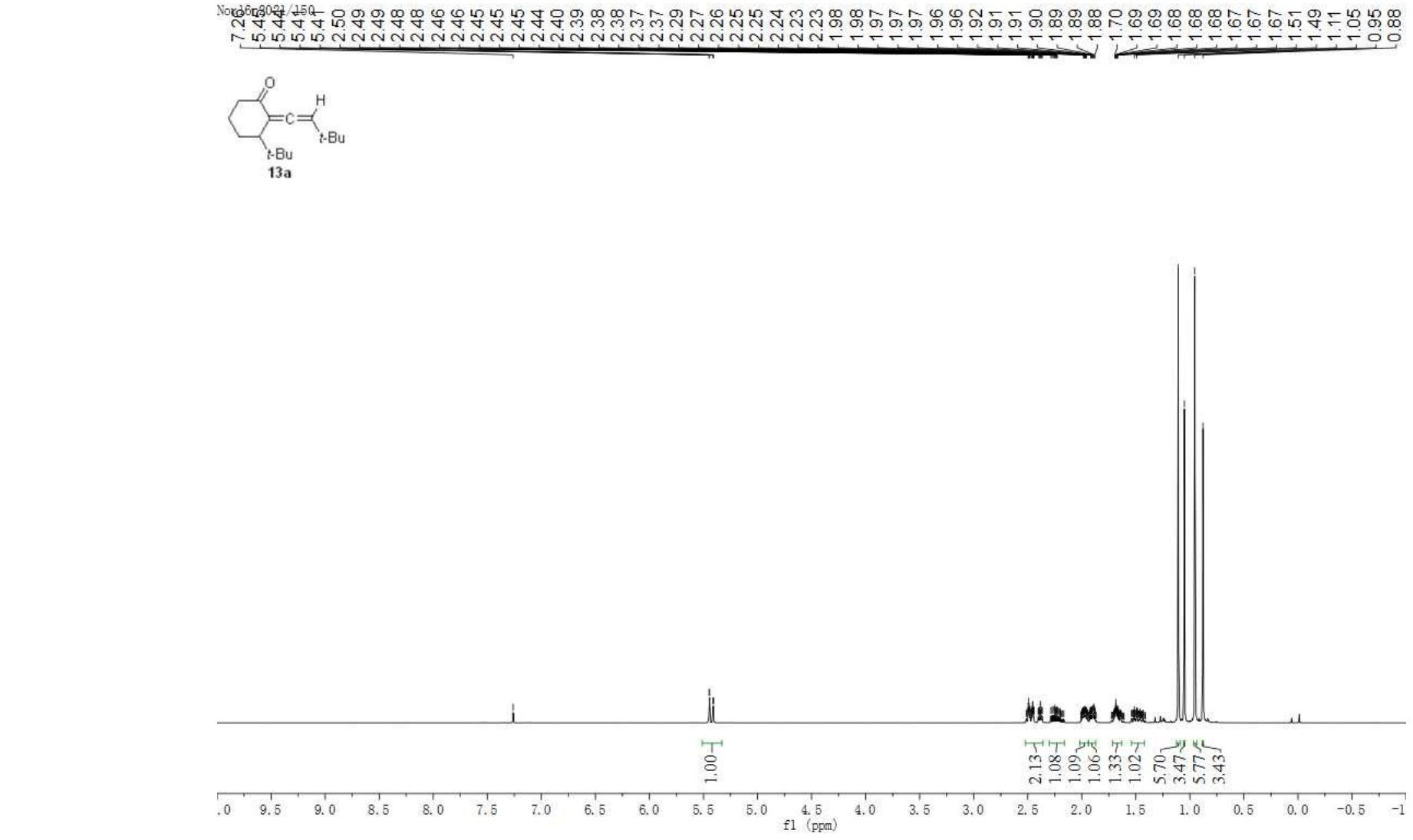

Nov 18 2021/231
212.6
196.5
158.0
138.9
133.4
131.4
130.9
128.6
127.4
112.8
111.7
107.7
77.3
77.0
76.7
55.1
51.9
37.4
36.7
35.7
33.5
29.6
26.2
21.9
21.9
20.4
H
t-Bu
C
OMe
Ph
O
10i(the second fraction)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -1
f1 (ppm)

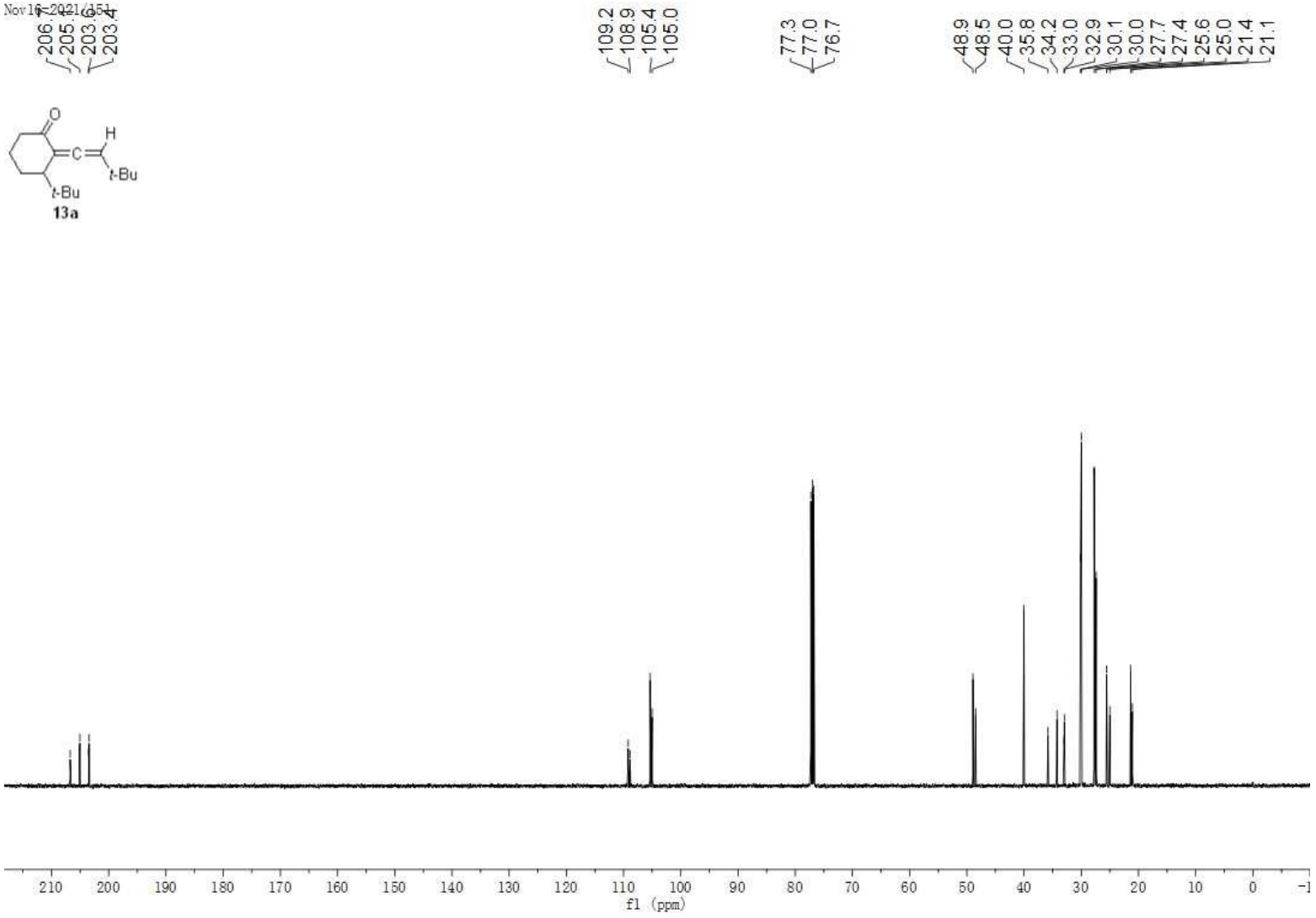

7.64 7.64 7.63 7.62 7.62 7.55 7.54 7.53 7.53 7.43 7.42 7.42 7.40 7.36 7.36 7.35 7.34 7.34 7.33 7.32 7.32 7.31 7.31 7.30 7.29 7.26 6.82 6.80 6.80 6.79 6.78 5.40 5.40 5.39 4.21 4.20 4.15 4.14 3.78 1.75 1.73 1.67 1.65 1.64 1.63 1.62 1.62 1.62 1.61 1.60 1.60 1.26 1.24 1.22 1.07 1.04 0.92 0.71
H
C
t-Bu
OMe
Ph
O
10j
2.04 1.10 4.10 2.02 1.00 1.03 3.10 10.42 3.10 3.49 5.61
f1 (ppm)

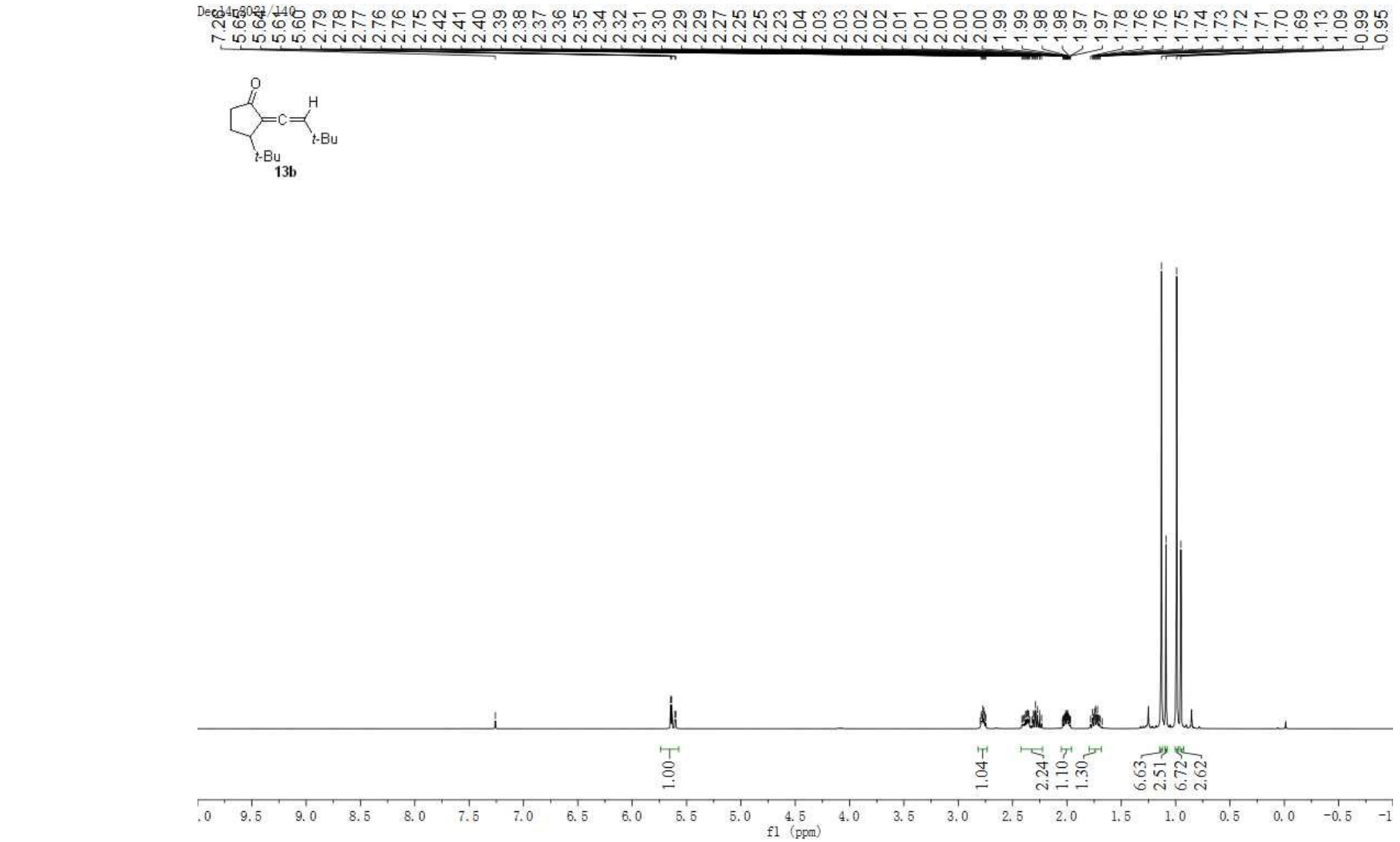

Dec08-2021/111
213.4
212.2
196.4
195.8
157.9
157.9
138.8
138.7
134.7
134.4
131.2
131.0
130.9
130.9
128.7
128.6
127.5
127.4
112.9
112.9
112.7
112.5
108.2
108.2
77.3
77.0
76.7
55.2
55.1
51.2
50.6
47.6
46.7
39.0
38.9
38.0
37.3
33.5
33.2
29.5
29.2
24.3
24.2
24.0
23.9
23.8
H
C
t-Bu
OMe
Ph
O
10j
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-1
f1 (ppm)

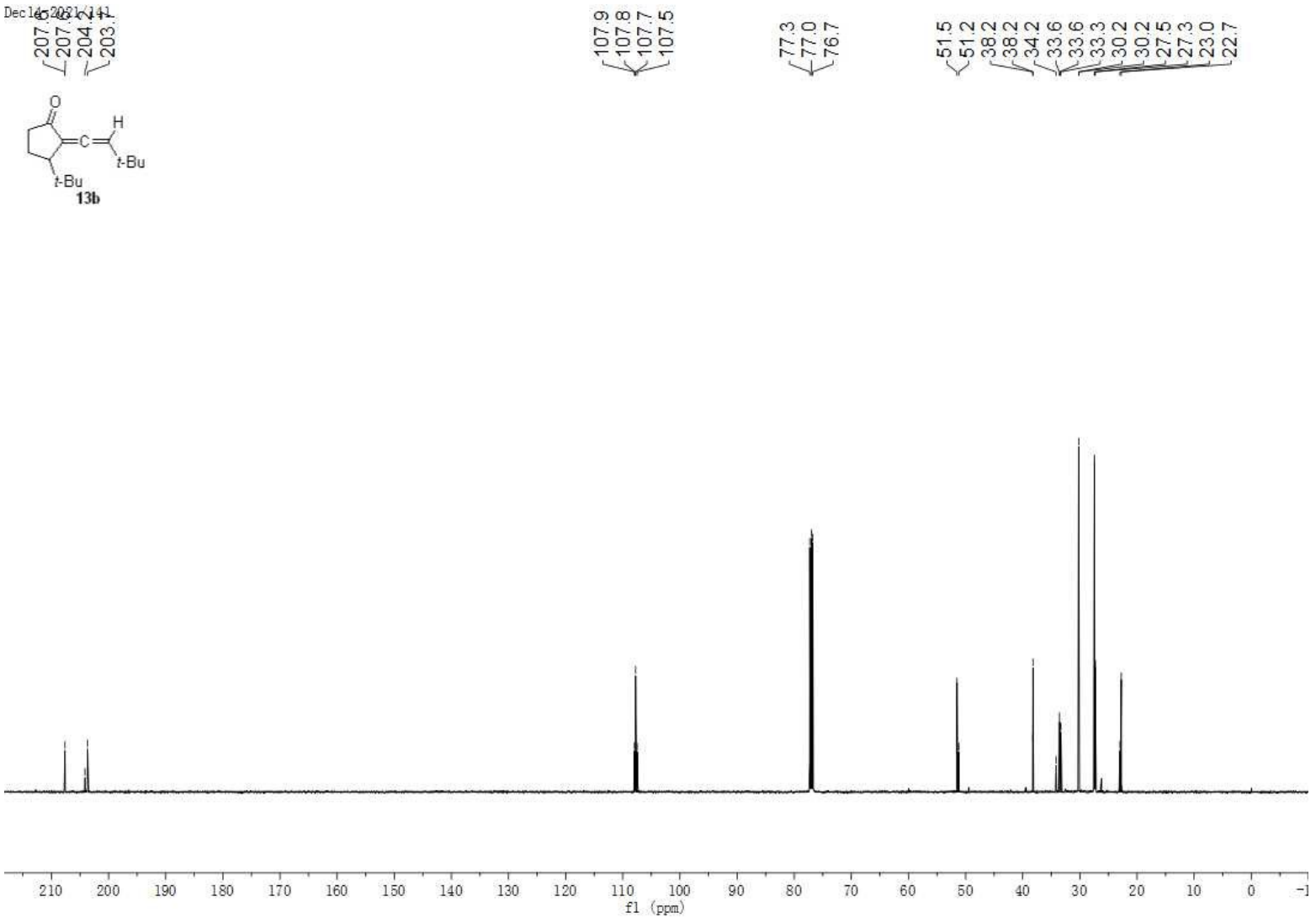

Dec11-2021/190
7.31 7.31 7.30 7.30 7.36 7.36 7.34 7.33 7.33 7.32 7.32 7.32 7.26 7.26 7.25 7.25 7.24 7.24 7.24 7.23 7.23 7.22 7.21 7.20 7.20 7.20 7.19 7.19 7.19 7.17 5.63 4.18 4.16 4.16 4.16 4.15 4.14 4.14 4.14 4.13 4.12 4.09 4.07 4.07 4.05 4.04 4.02 4.02 4.00 3.80 3.78 1.22 1.22 1.20 1.19 1.07 1.00 0.96
H
Ph
t-Bu
OEt
O
11
2.10
2.09
1.05
1.02
2.13
1.06
4.73
3.41
4.36
5.11
4.32
f1 (ppm)

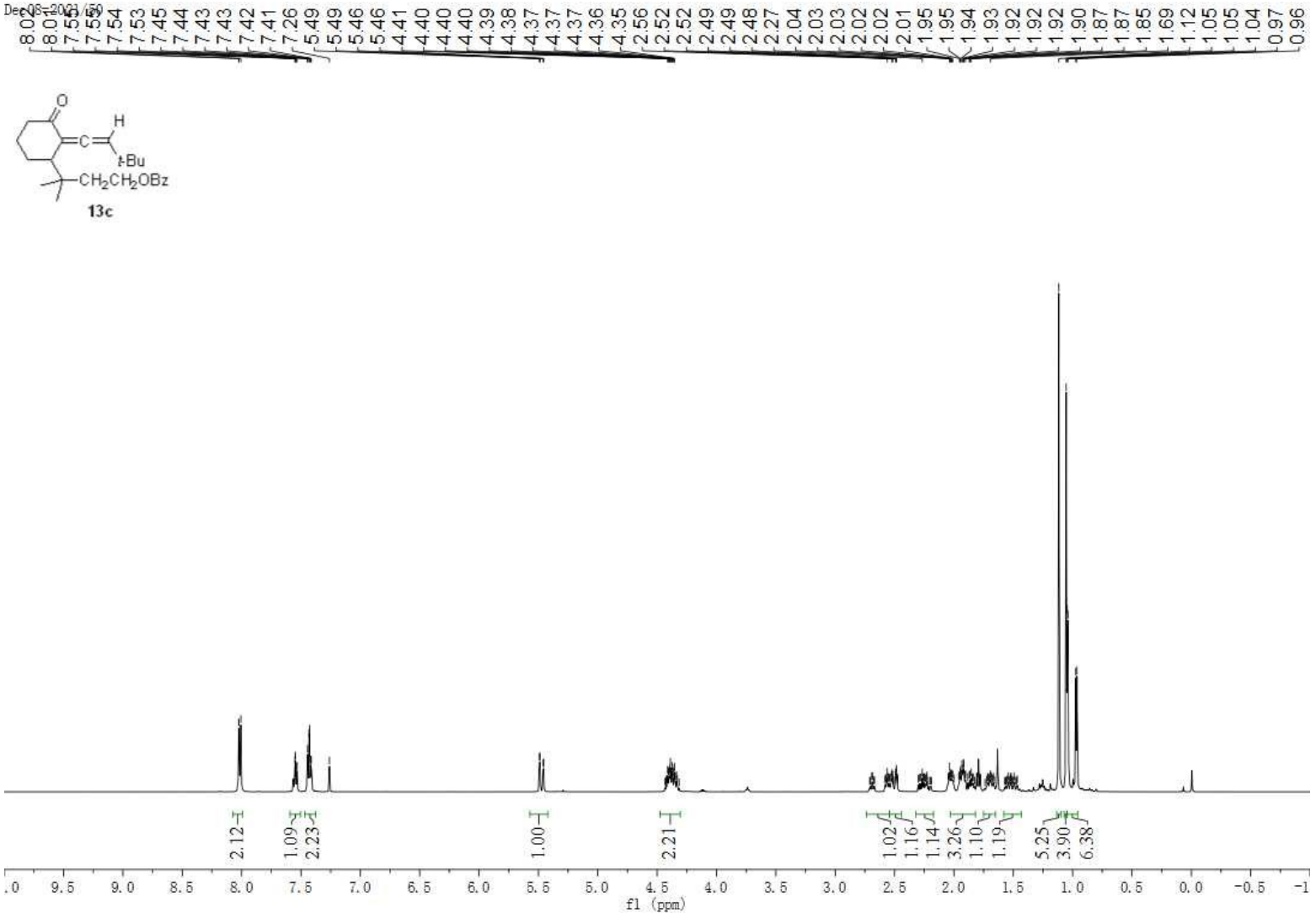

Dec1s2021/191
209.4
209.1
168.4
168.3
142.1
141.6
130.3
130.1
127.3
127.3
126.2
126.1
107.5
107.2
103.9
77.3
77.0
76.7
60.8
53.5
53.4
35.6
34.9
33.7
33.4
29.9
29.6
28.2
28.2
14.1
H
Ph
t-Bu
OEt
O
11
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

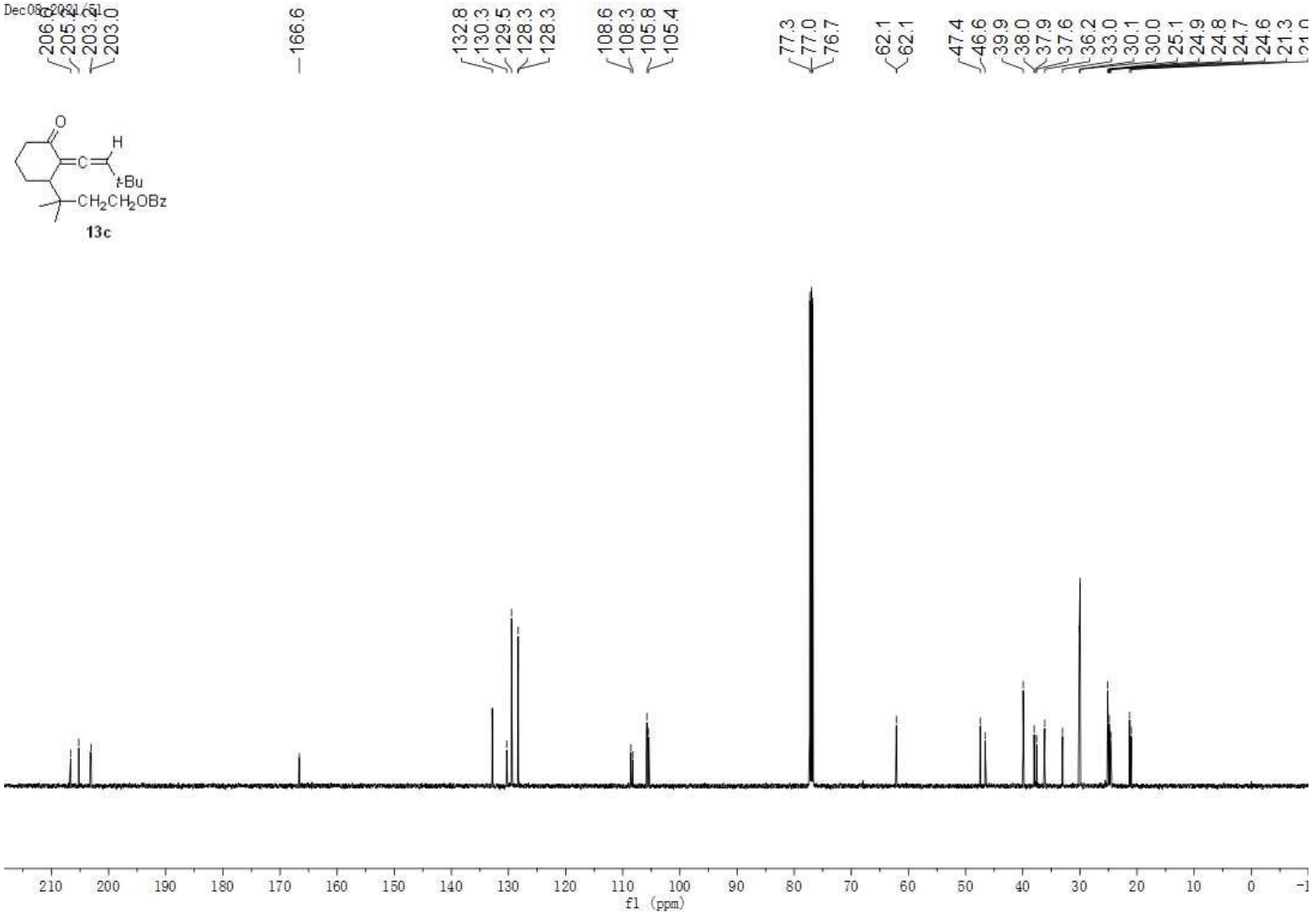

7.26
5.45
5.44
5.41
5.41
2.50
2.49
2.49
2.48
2.48
2.46
2.46
2.45
2.45
2.45
2.44
2.40
2.39
2.38
2.38
2.37
2.37
2.29
2.27
2.26
2.25
2.25
2.24
2.23
2.23
1.98
1.98
1.97
1.97
1.97
1.96
1.96
1.92
1.91
1.91
1.90
1.89
1.89
1.88
1.70
1.69
1.69
1.68
1.68
1.68
1.67
1.67
1.67
1.51
1.49
1.11
1.05
0.95
0.88
O
H
t-Bu
t-Bu
13a
1.00
2.13
1.08
1.09
1.06
1.33
1.02
5.70
3.47
5.77
3.43
f1 (ppm)

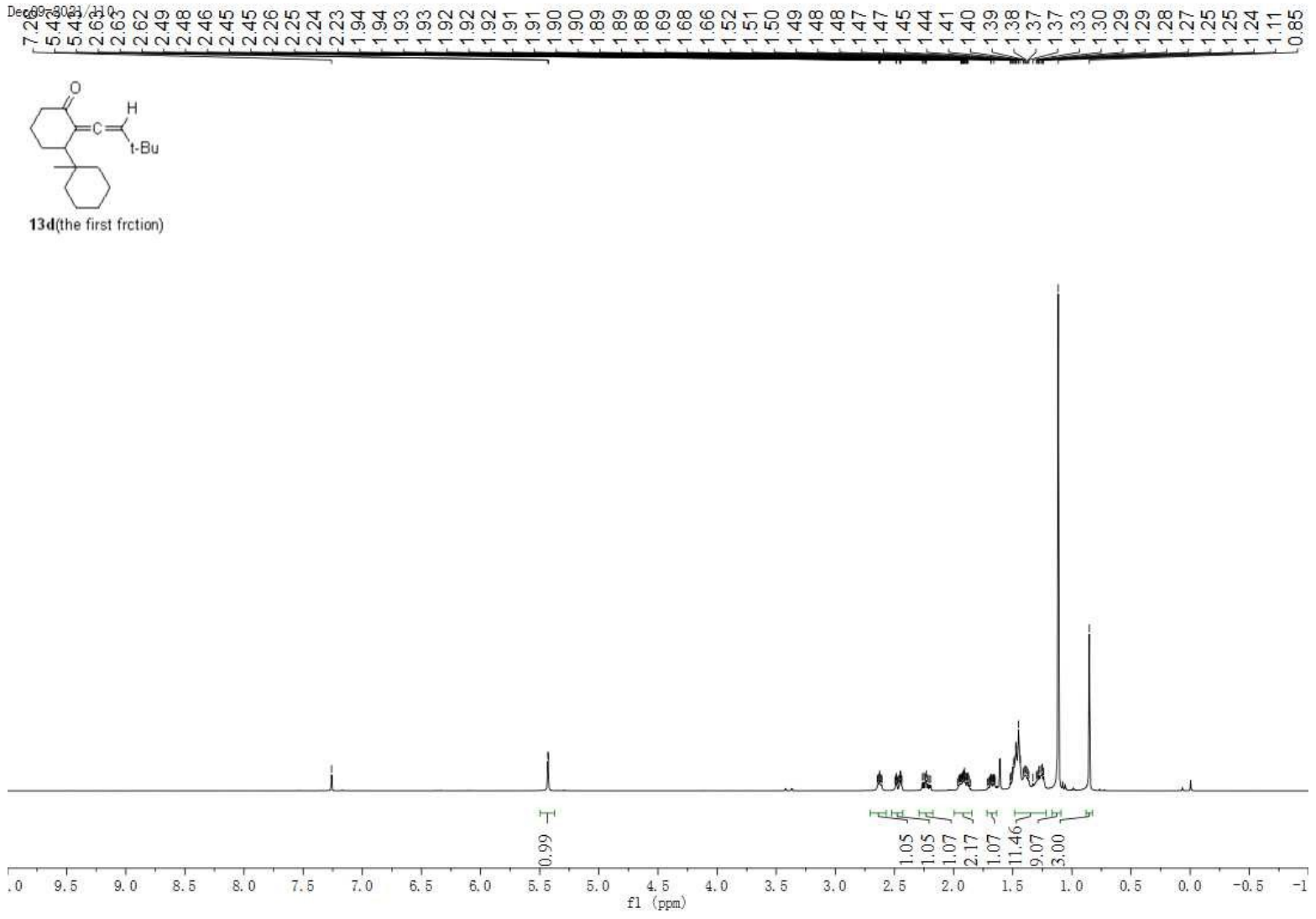

206.7
205.4
203.6
203.4
109.2
108.9
105.4
105.0
77.3
77.0
76.7
48.9
48.5
40.0
35.8
34.2
33.0
32.9
30.1
30.0
27.7
27.4
25.6
25.0
21.4
21.1
O
H
t-Bu
t-Bu
13a
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

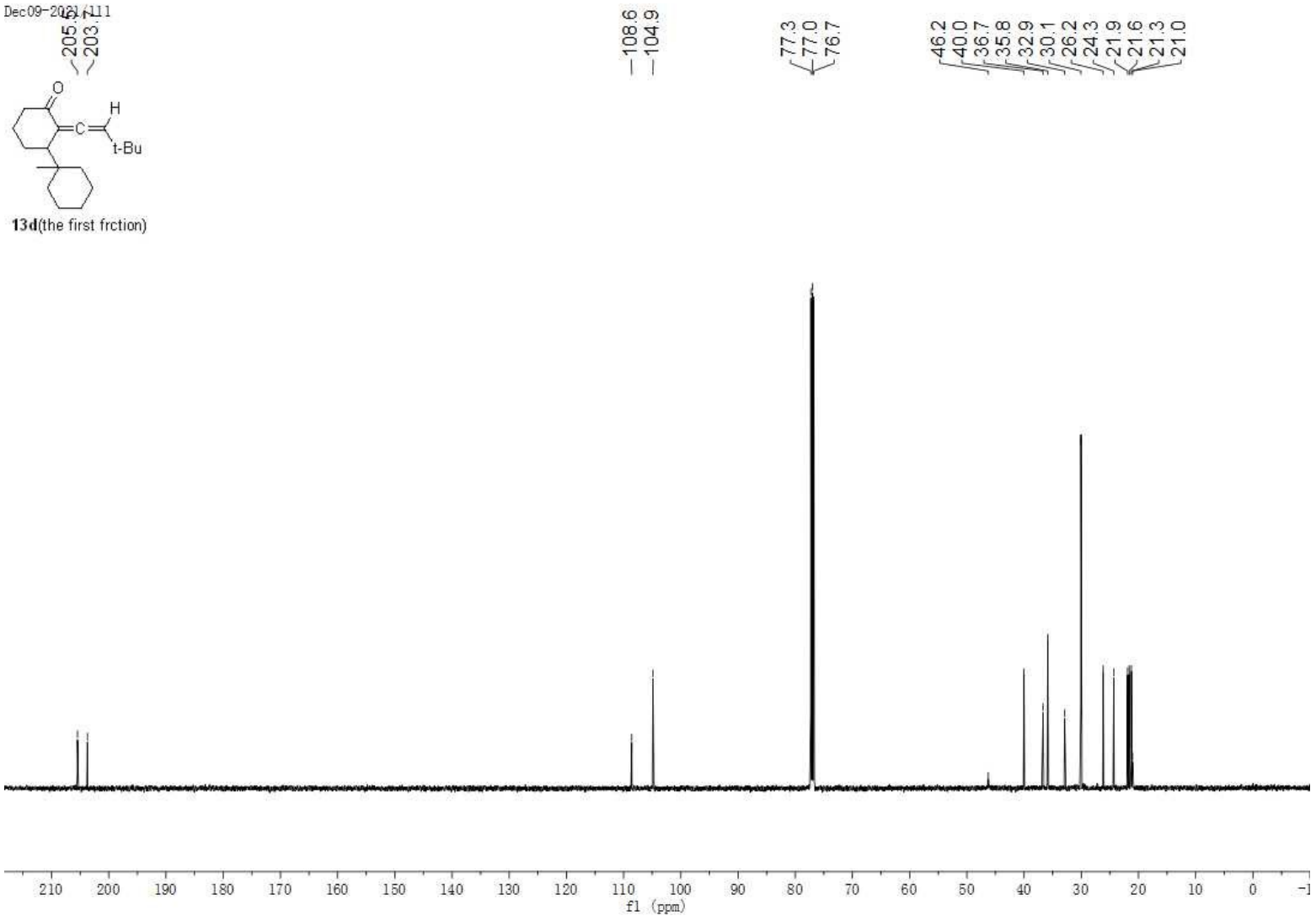

7.26
5.65
5.64
5.61
5.60
2.79
2.78
2.77
2.76
2.76
2.75
2.42
2.41
2.40
2.39
2.38
2.37
2.36
2.35
2.34
2.32
2.31
2.30
2.29
2.29
2.27
2.25
2.25
2.23
2.04
2.03
2.03
2.02
2.02
2.01
2.01
2.00
2.00
2.00
1.99
1.99
1.98
1.98
1.97
1.97
1.78
1.76
1.76
1.75
1.74
1.73
1.72
1.71
1.70
1.69
1.13
1.09
0.99
0.95
O
H
t-Bu
t-Bu
13b
1.00
1.04
2.24
1.10
1.30
6.63
2.51
6.72
2.62
f1 (ppm)

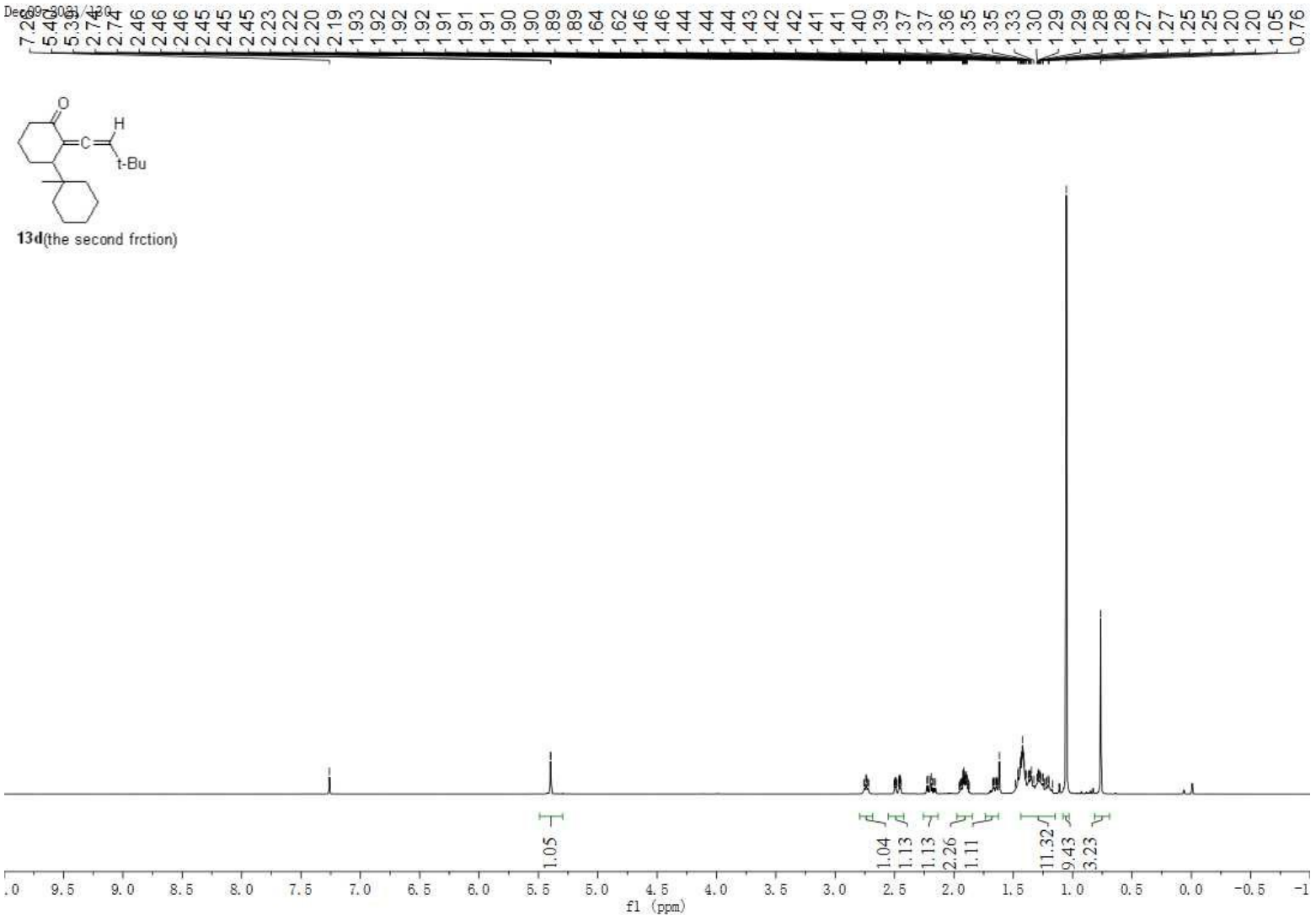

Dec 14 2021 (14)
207.6
207.2
204.4
203.1
107.9
107.8
107.7
107.5
77.3
77.0
76.7
51.5
51.2
38.2
38.2
34.2
33.6
33.6
33.3
30.2
30.2
27.5
27.3
23.0
22.7
O
H
C
t-Bu
t-Bu
13b
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.02 8.01 7.55 7.54 7.53 7.45 7.44 7.43 7.43 7.42 7.41 7.26 5.49 5.49 5.46 5.46 4.41 4.40 4.40 4.40 4.39 4.38 4.37 4.37 4.37 4.36 4.35 2.56 2.52 2.52 2.49 2.49 2.48 2.27 2.04 2.03 2.03 2.02 2.02 2.01 1.95 1.95 1.94 1.93 1.92 1.92 1.92 1.90 1.87 1.87 1.85 1.69 1.12 1.05 1.05 1.04 0.97 0.96
O
H
t-Bu
CH2CH2OBz
13c
2.12 1.09 2.23 1.00 2.21 1.02 1.16 1.14 3.26 1.10 1.19 5.25 3.90 6.38
f1 (ppm)

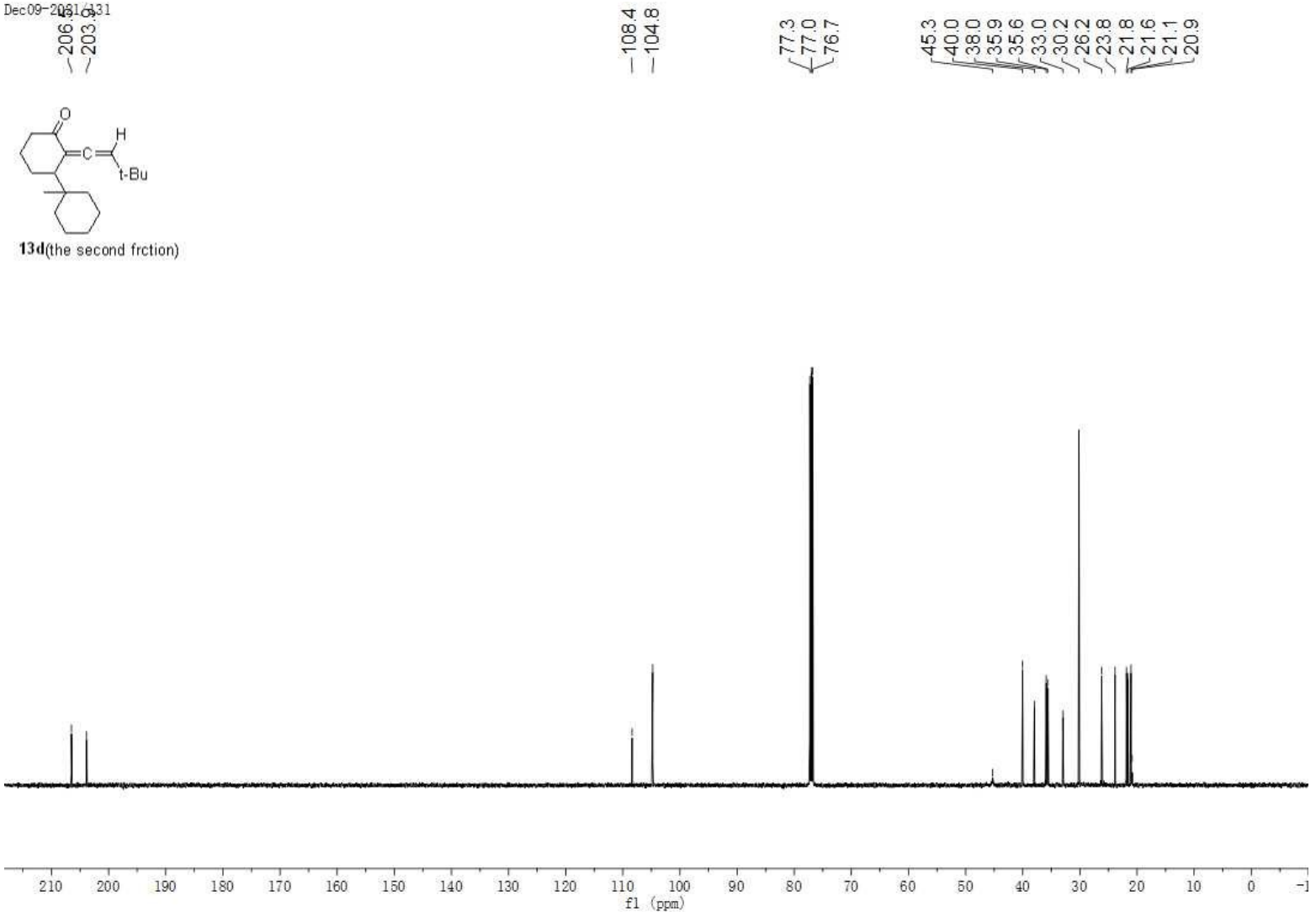

206.6
205.4
203.4
203.0
166.6
132.8
130.3
129.5
128.3
128.3
108.6
108.3
105.8
105.4
77.3
77.0
76.7
62.1
62.1
47.4
46.6
39.9
38.0
37.9
37.6
36.2
33.0
30.1
30.0
25.1
24.9
24.8
24.7
24.6
21.3
O
H
t-Bu
CH2CH2OBz
13c
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

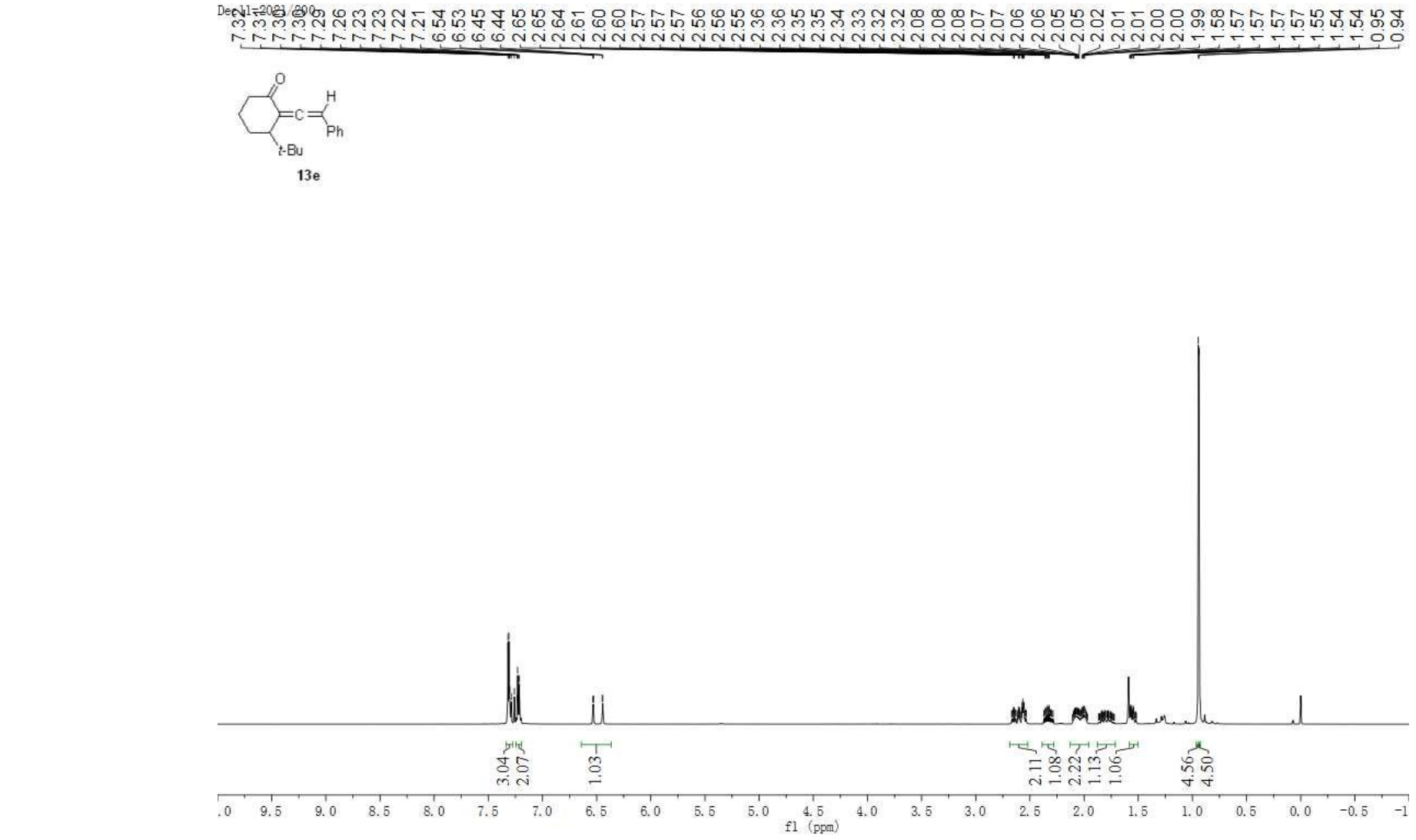

7.26
5.42
5.41
2.63
2.63
2.62
2.49
2.48
2.46
2.45
2.45
2.26
2.25
2.24
2.23
1.94
1.94
1.93
1.93
1.92
1.92
1.92
1.91
1.91
1.90
1.90
1.89
1.89
1.88
1.69
1.68
1.66
1.52
1.51
1.50
1.49
1.48
1.48
1.47
1.47
1.45
1.44
1.41
1.40
1.39
1.38
1.37
1.37
1.33
1.30
1.29
1.29
1.28
1.27
1.25
1.25
1.24
1.11
0.85
O
H
C
t-Bu
13d(the first frction)
0.99
1.05
1.05
1.07
2.17
1.07
11.46
9.07
3.00
f1 (ppm)

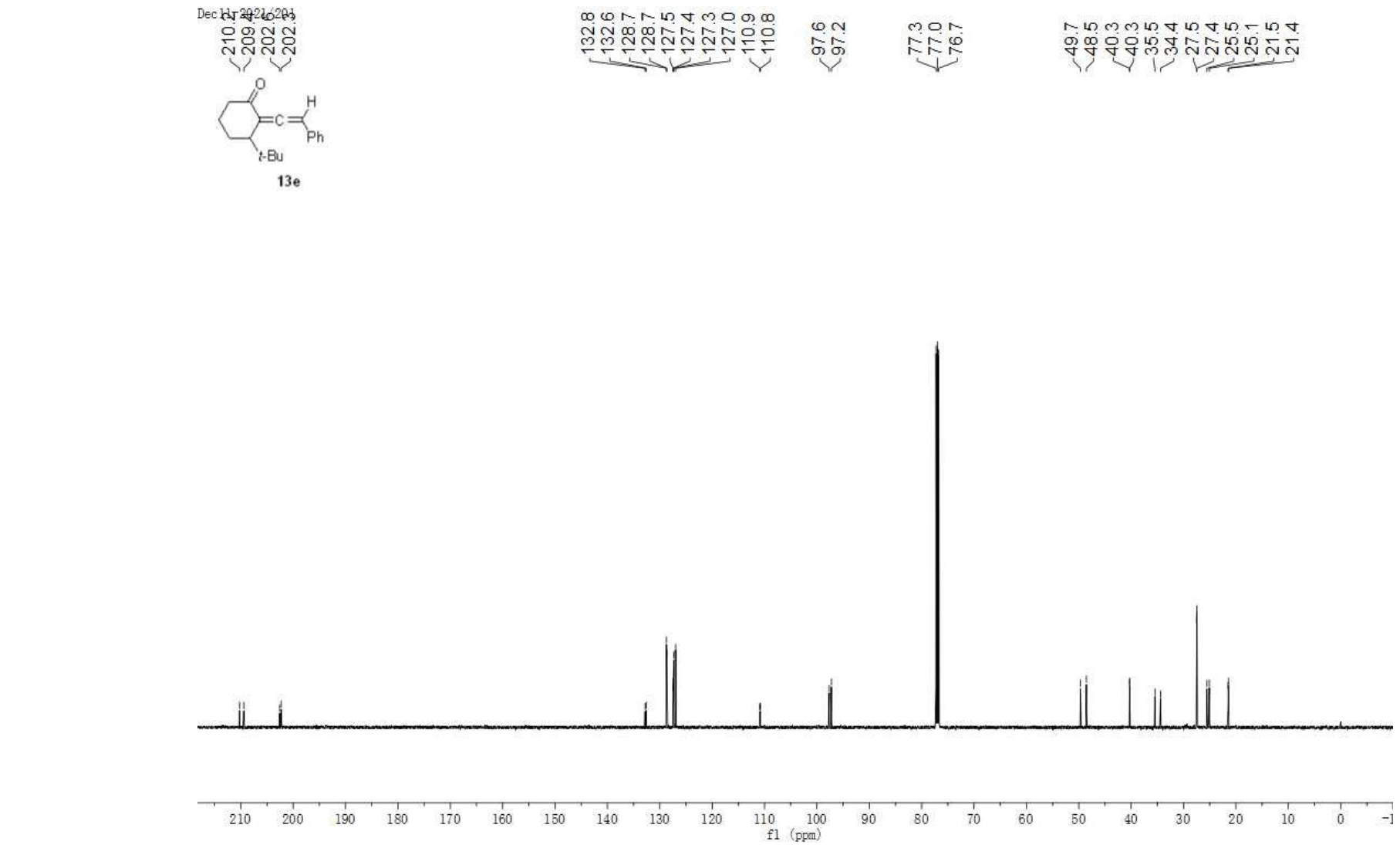

Dec09-2021-111
205.7
203.1
O
H
C
t-Bu
13d(the first frction)
108.6
104.9
77.3
77.0
76.7
46.2
40.0
36.7
35.8
32.9
30.1
26.2
24.3
21.9
21.6
21.3
21.0
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

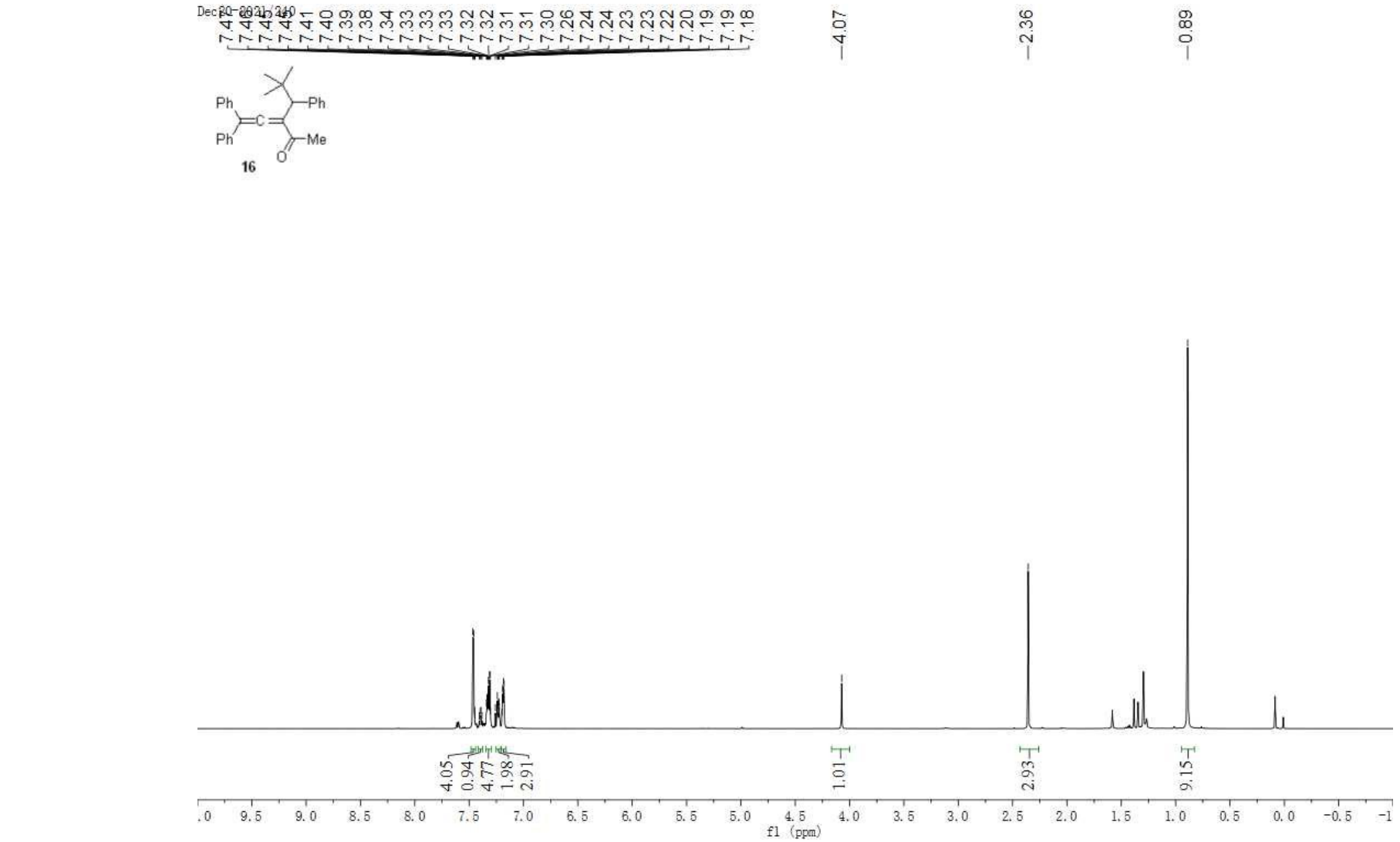


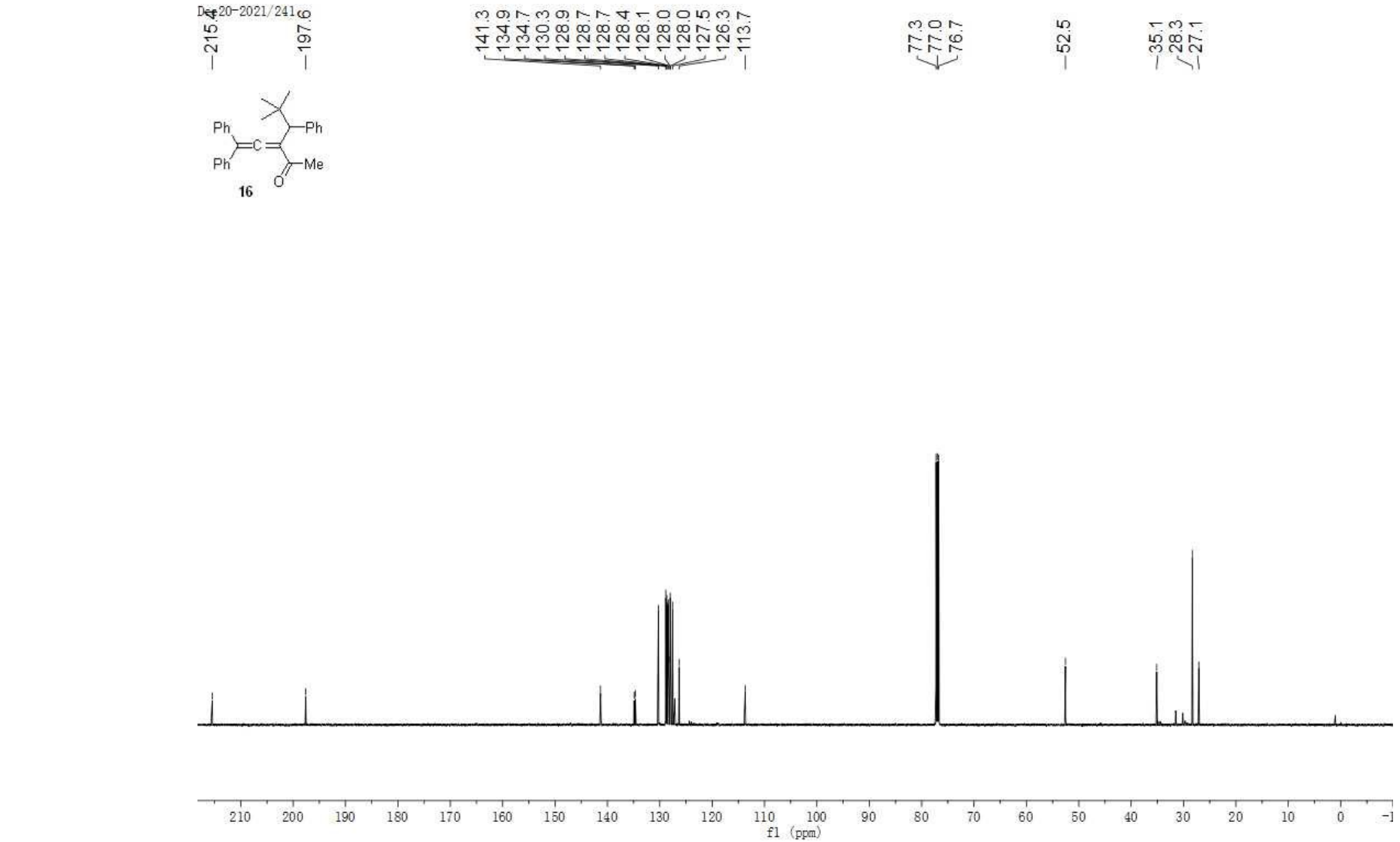

**13d**(the second frction)


Dec09-2011/131
206.3
203.3
108.4
104.8
77.3
77.0
76.7
45.3
40.0
38.0
35.9
35.6
33.0
30.2
26.2
23.8
21.8
21.6
21.1
20.9
O
H
C
t-Bu
13d(the second frction)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.32 7.31 7.30 7.29 7.26 7.23 7.23 7.22 7.21 6.54 6.53 6.45 6.44 2.65 2.65 2.64 2.61 2.60 2.60 2.57 2.57 2.57 2.56 2.56 2.55 2.36 2.36 2.35 2.35 2.34 2.33 2.32 2.32 2.08 2.08 2.08 2.07 2.07 2.06 2.06 2.05 2.05 2.02 2.01 2.01 2.00 2.00 1.99 1.58 1.57 1.57 1.57 1.57 1.55 1.54 1.54 0.95 0.94
O
H
C
Ph
t-Bu
13e
3.04
2.07
1.03
2.11
1.08
2.22
1.13
1.06
4.56
4.50
f1 (ppm)


210.4
209.6
202.6
202.3
132.8
132.6
128.7
128.7
127.5
127.4
127.3
127.0
110.9
110.8
97.6
97.2
77.3
77.0
76.7
49.7
48.5
40.3
40.3
35.5
34.4
27.5
27.4
25.5
25.1
21.5
21.4
O
H
C
Ph
t-Bu
13e
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


Dec 20 2021 240
7.47
7.46
7.45
7.45
7.41
7.40
7.39
7.38
7.34
7.33
7.33
7.33
7.32
7.32
7.31
7.31
7.30
7.26
7.24
7.24
7.23
7.23
7.22
7.20
7.19
7.19
7.18
4.07
2.36
0.89
Ph
Ph
Ph
Me
O
16
4.05
0.94
4.77
1.98
2.91
1.01
2.93
9.15
f1 (ppm)


Dec20-2021/241
215.4
197.6
141.3
134.9
134.7
130.3
128.9
128.7
128.7
128.4
128.1
128.0
128.0
127.5
126.3
113.7
77.3
77.0
76.7
52.5
35.1
28.3
27.1
Ph
Ph
Ph
Me
O
16
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-1
f1 (ppm)