Electronic Supplementary Material (ESI) for Green Chemistry

Lewis acid−surfactant-combined catalyzed synthesis of 4-aminocyclopentenones from glycals in water

*Siming Wang, Ronny William, Kim Kui Georgina Estelle Seah, and Xue-Wei Liu**

Contents

General considerations

Unless otherwise specified, all reactions were carried out under air atmosphere. The reagents and solvents were directly used from Sigma-Aldrich, Alfa Aesar and TCI without further purification unless noted. 3,4-di-*O*-methyl-L-rhamnal **1b**, 3,4-di-*O*-methyl-D-xylal **1c** and α, β-unsaturated aldehyde **16** were prepared according to the known procedure.[1] Reactions were monitored through thin layer chromatography [Merck 60 F254 precoated silica gel plate (0.2 mm thickness)]. Subsequent to elution, spots were visualized using UV radiation (254 nm) on Spectroline Model ENF-24061/F 254 nm. Further visualization was possible by using basic solution of potassium permanganate or acidic solution of Ceric molybdate as stain. Flash chromatography was performed using silica gel 60 with distilled solvents. HRMS spectra were recorded on a Waters Q-Tof permierTM mass Spectrometer. ^{1}H NMR and ^{13}C NMR spectra were recorded using Bruker Avance 300, 400 and 500 MHz spectrometers. Chemical shifts for ^{1}H NMR spectra are reported as δ in units of parts per million (ppm) downfield from $SiMe_4$ (δ 0.0) and relative to the signal of chloroform-d (δ 7.260, singlet). Multiplicities were given as: s (singlet); brs (broad singlet); d (doublet); t (triplet); q (quartet); dd (doublets of doublet); ddd (doublets of doublets of doublet); td (triplet of doublet); m (multiplets); ddt (doublet of doublet of triplet) and etc. Coupling constants are reported as a J value in Hz. Carbon nuclear magnetic resonance spectra (^{13}C NMR) are reported as δ in units of parts per million (ppm) downfield from $SiMe_4$ (δ 0.0) and relative to the signal of chloroform-d (δ 77.00, triplet). IR spectra were recorded using FTIR Restige-21 (Shimadzu). X-ray crystallographic data was collected by using a Bruker X8Apex diffractometer with Mo K/α radiation (graphite monochromator). Compound numbers used in the experimental section correspond to those employed in the main paper.

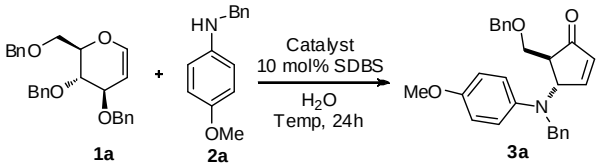
Experimental Procedure

General procedure for preparation of 4-aminocyclopentenones 1a

To a suspension of 3, 4, 6-tri-O-benzyl-D-glucal 1a (124.8 mg, 1.0 equiv, 0.3 mmol) and N-benzyl-4-methoxyaniline 2a (70.3 mg, 1.1 equiv, 0.33 mmol) in H_2O (8 mL) was added $InBr_3$ (32.0 mg, 0.3 equiv, 0.09 mmol) and sodium dodecylbenzene sulfonate (10.4 mg, 0.1 equiv, 0.03 mmol). The reaction mixture was stirred at room temperature for 10mins. The reaction mixture was then heated to 100 °C with good stirring for 24 h. Then the reaction mixture was extracted with EtOAc (3 × 50 mL), washed with 10% $NaHCO_3$ (2 × 50 mL) and brine (2 × 50 mL). The organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure to yield the crude residue as dark yellow oil. The crude residue was purified by flash column chromatography on silica gel (EtOAc:hexane = 1:20 to 1:4) to afford 3a in 81% yield as a yellow oil.

Reaction optimization

Table 1. Optimization of the reaction of glycal with secondary arylamine in water [a]

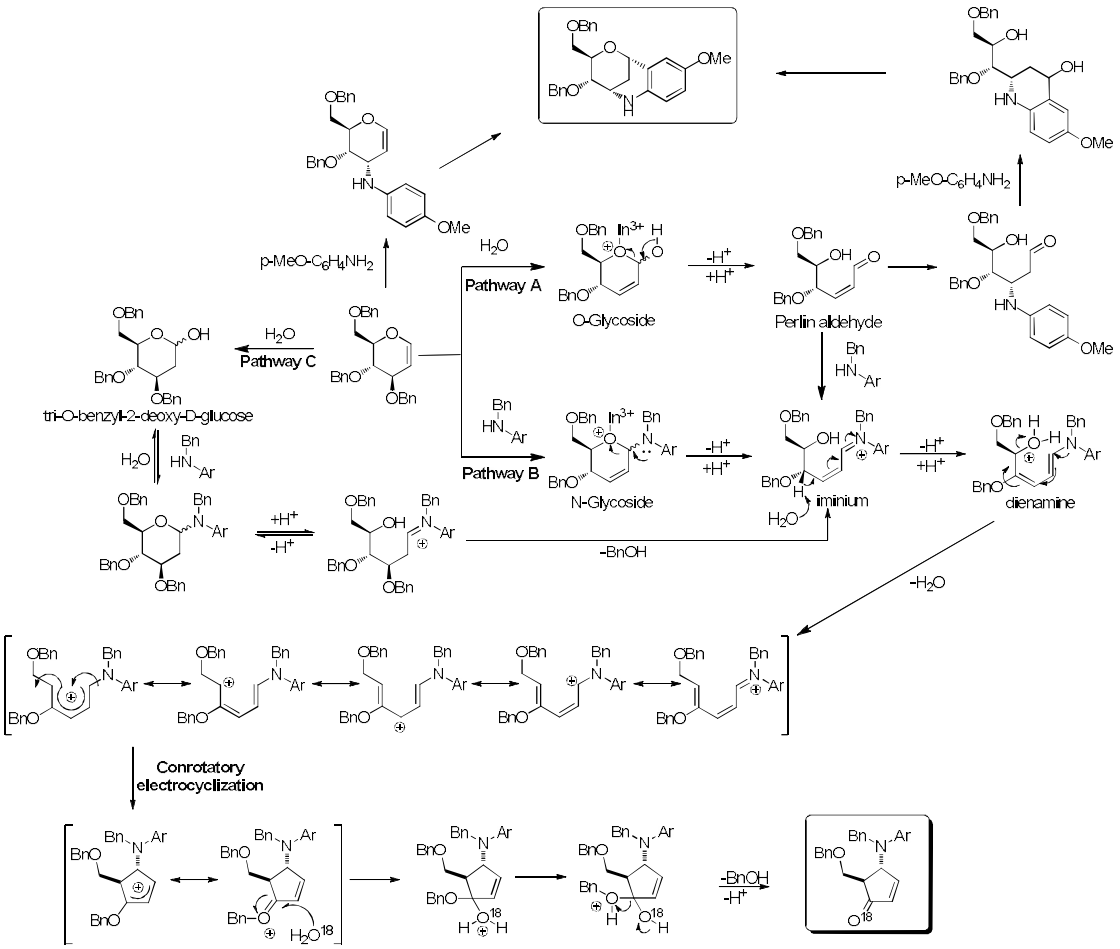


Entry	Catalyst (mol %)	Temp [°C]	Yield [%][b]
1	AgOTf (10)	100	47
2	$AlCl_3$ (10)	100	39
3	$AuCl_3$ (10)	100	53
4	$Cu(OTf)_2$ (10)	100	19
5	$Dy(OTf)_3$ (10)	100	0
6	$Yb(OTf)_3$ (10)	100	0
7	$FeCl_3$ (10)	100	46
8	$Sc(OTf)_3$ (10)	100	51
9	NaOTf (10)	100	0
10	$NiCl_2$ (10)	100	0
11	$ZnCl_2$ (10)	100	8
12	$TiCl_4$ (10)	100	0
13	$InCl_3$ (10)	100	44
14	$In(OTf)_3$ (10)	100	29
15	$InBr_3$ (10)	100	57
16	$InBr_3$ (20)	100	76
17	$InBr_3$ (30)	100	81
18	$InBr_3$ (30)	80	43
19	$InBr_3$ (30)	25	0
20[c]	$InBr_3$ (30)	100	0
21[d]	$InBr_3$ (30)	100	79
22	HOTf (10)	100	4
23	HCl (10)	100	trace

[a] Unless otherwise specified, all of the reactions were carried out using glycal **1a** (0.3 mmol, 1 equiv) and aniline **2a** (0.3 mmol, 1.1 equiv) with catalyst and SDBS (0.03 mmol, 0.1 equiv) in 8 mL of H_2O. [b] Isolated yield. [c] In the absence of SDBS. [d] The reaction was carried out in 8 mL CH_3CN/H_2O (9:1 v/v).

We chose 3, 4, 6-tri-*O*-benzyl-D-glucal 1a and *N*-benzyl-4-methoxyaniline 2a as model substrates and screened different metal salts in refluxing water (entries 1–15). Among the metal salts tested, $InBr_3$ proved to be a good candidate (entry 15). The investigation was carried out further on the effect of various catalysts loading and temperature to find out the best reaction conditions. This revealed that heating a mixture of 1a (1 equiv) and 2a (1.1 equiv) with 10 mol % of SDBS and 30 mol % of $InBr_3$ in water at 100 °C for 24 h gave the best result (entry 17). In the absence of SDBS, the starting material remained unreacted (entry 20).

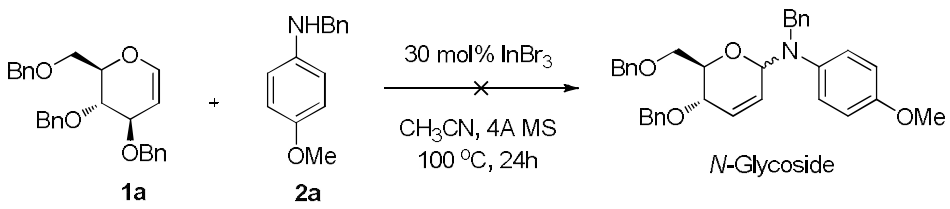
Mechanism study



Mechanism path way

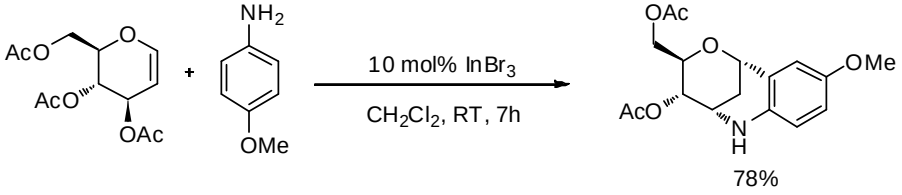
(I) No reaction occurred when the reaction was carried in anhydrous organic solvent showing that water plays a significant role in this transformation.

The reaction didn't proceed through pathway B since no *N*-Glycoside product has been observed.



(II) Treating of 1a with 4-methoxyaniline in refluxing H_2O, using 30 mol % of $InBr_3$ and 10 mol % of SDBS as catalyst, gave tetrahydroquinoline 6 in 23% yield.

The condensations of primary arylamines with 3,4,6-tri-*O*-acetyl-D-glucal have been mainly studied by Yadav's group.[2] They also demonstrated that the reaction can perform in water. However, 3,4,6-tri-*O*- benzyl-D-glucal did not react with aryl amines under their identical reaction conditions. Also, the reaction mechanism for this reaction is a matter of debate.[3]



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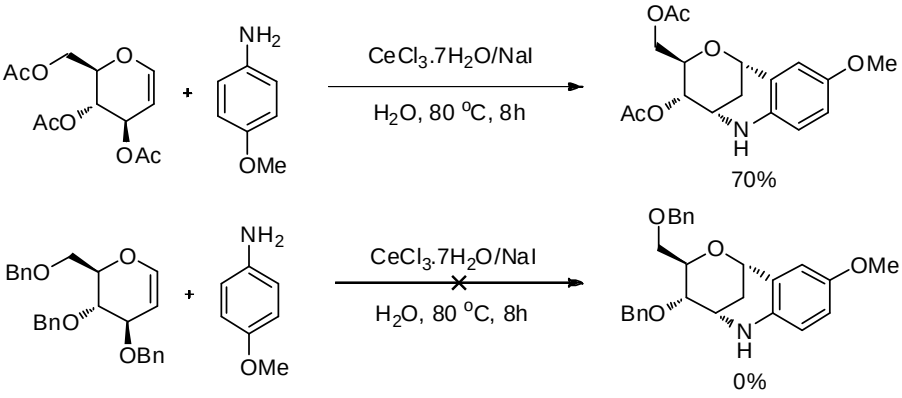

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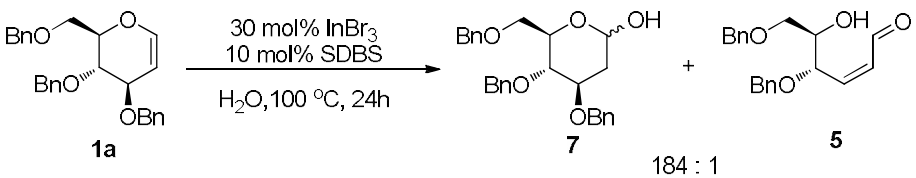
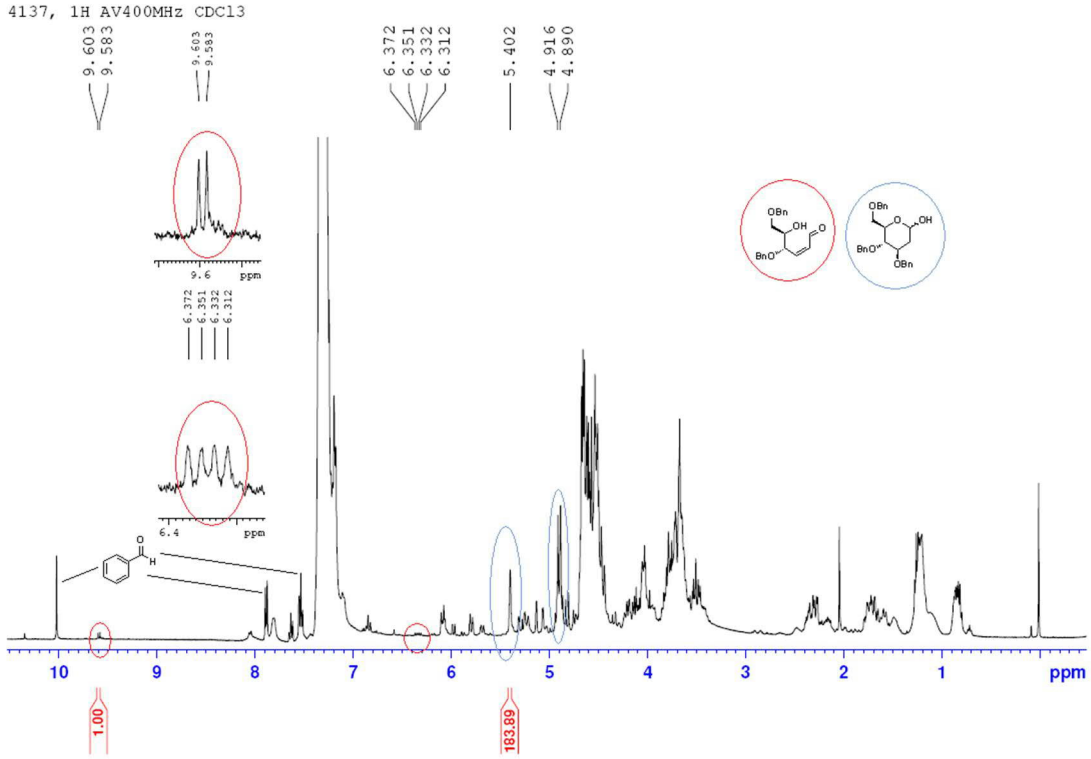
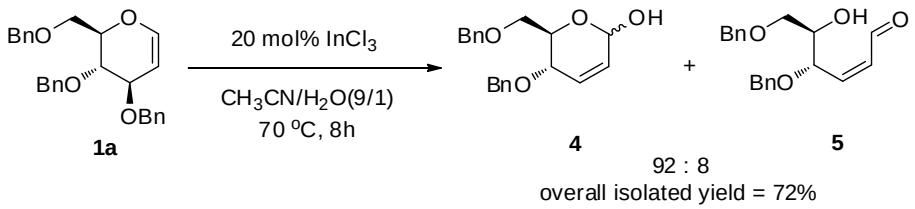
(III) In the presence of 10 mol % of SDBS and 30 mol % of $InBr_3$, 3, 4, 6-tri-*O*-benzyl-D-glucal 1a react with water to give tri-*O*-benzyl-2-deoxy-D-glucose 7 in 74% yield , along with a trace amount of α, β-unsaturated aldehyde 5 .



^{1}H NMR of the reaction crude mixture



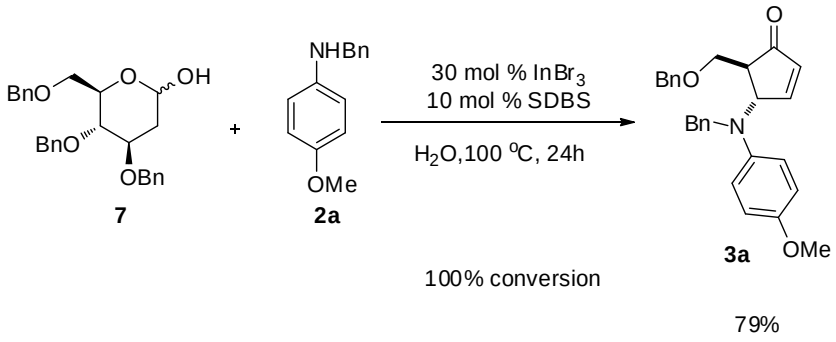
Ramesh[4] had reported that the reaction of 3, 4, 6-tri-O- benzyl-D-glucal with water, in acetonitrile as a solvent and 20 mol % $InCl_3$ as catalyst, gave hemiacetal 4 as the major product with trace amount of α, β-unsaturated aldehyde 5.



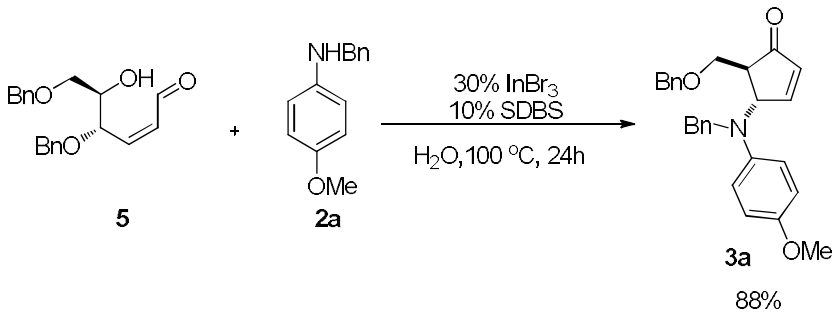
N.G. Ramesh et al. Tetrahedron 2011, 67, 769-776

(IV) We synthesized tri-*O*-benzyl-2-deoxy-D-glucose 7 and Perlin aldehyde 5 and tested their reactivity. 7 and 5 were identified as alternative reactants to 1a.

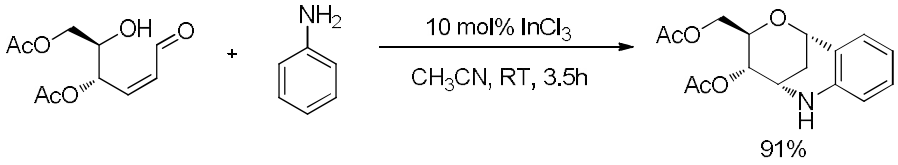
Treating of 7 with 2a in refluxing water, using 10 mol % SDBS and 30 mol % $InBr_3$ as catalyst, gave 3a in 79 % yield.



Treating of 5 with 2a in refluxing water, using 10 mol % SDBS and 30 mol % $InBr_3$ as catalyst, gave 3a in 88 % yield.



The cyclization of primary arylamines with Perlin aldehyde have been studied by Yadav's group.[5]



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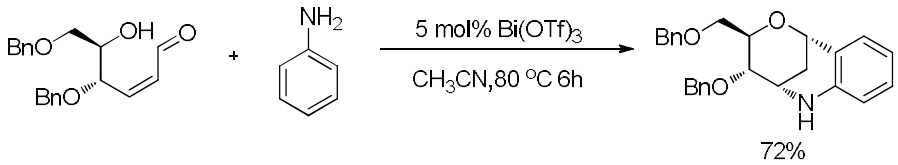

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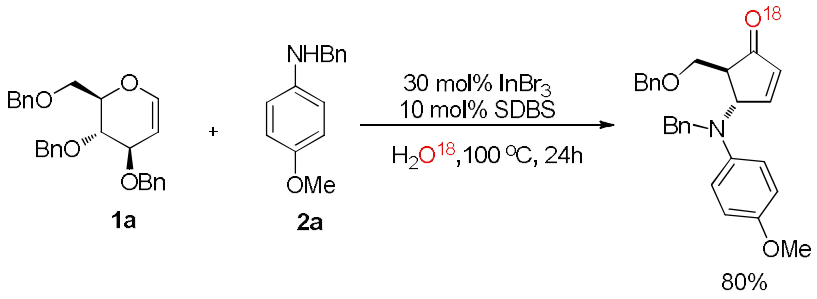
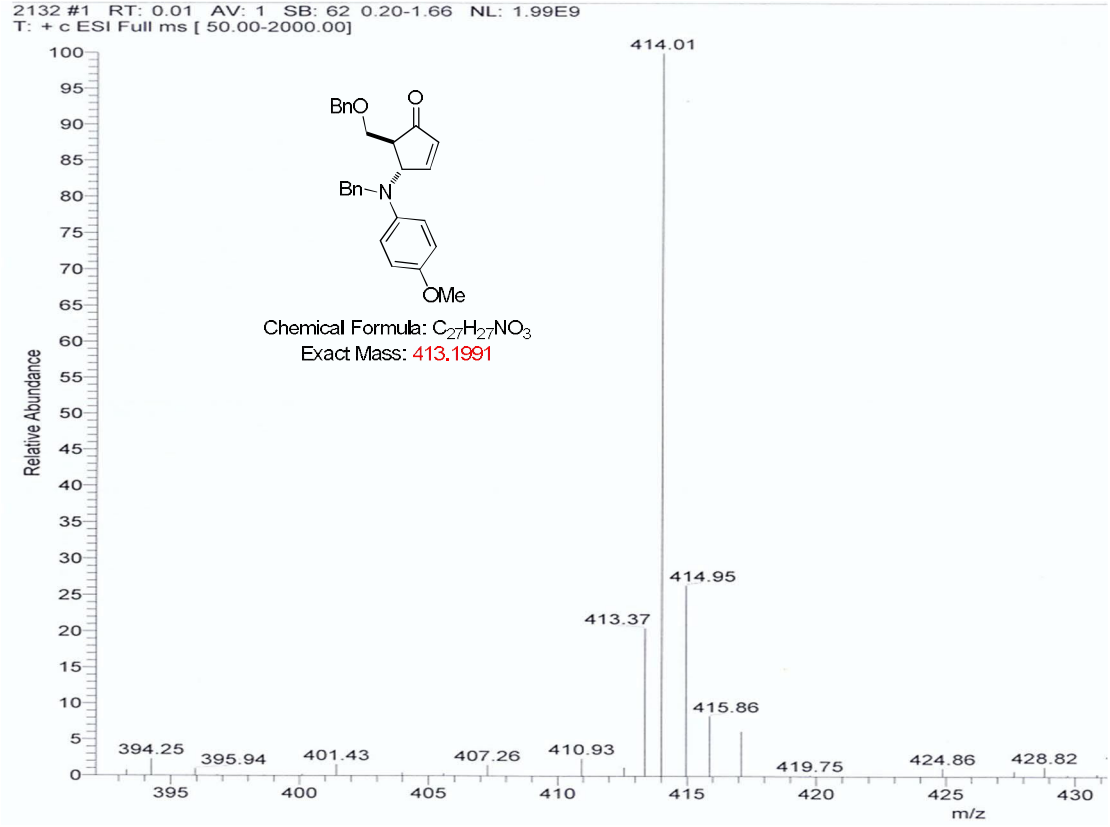
(V) Isotope labeling experiment demonstrated that water is involved in the reaction.

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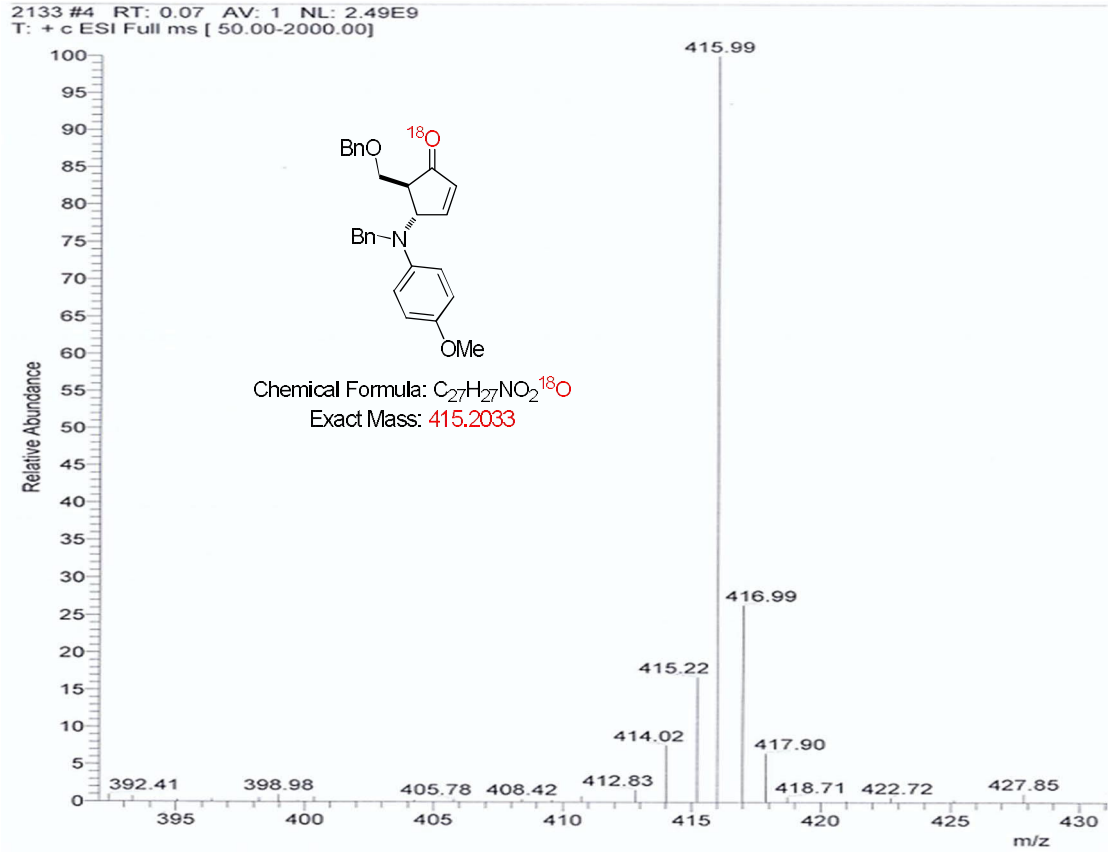
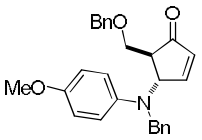
T: + c ESI Full ms [50.00-2000.00]
BnO
O
Bn
N
OMe
Chemical Formula: C27H27NO3
Exact Mass: 413.1991
Relative Abundance
m/z
414.01
414.95
413.37
415.86
394.25
395.94
401.43
407.26
410.93
419.75
424.86
428.82


2133 #4 RT: 0.07 AV: 1 NL: 2.49E9
T: + c ESI Full ms [50.00-2000.00]
BnO
18O
Bn
N
OMe
Chemical Formula: C27H27NO2 18O
Exact Mass: 415.2033
Relative Abundance
m/z
415.99
416.99
415.22
414.02
417.90
392.41
398.98
405.78
408.42
412.83
418.71
422.72
427.85

Characterization Data for the Isolated Products

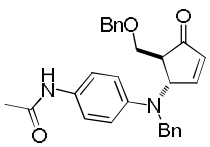
4-(benzyl(4-methoxyphenyl)amino)-5-((benzyloxy)methyl)cyclopent-2-enone (3a)



3a

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 78%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.65 (dd, *J*=6.0, 2.0 Hz, 1H), 7.36-7.20 (m, 10H), 6.79 - 6.77 (m, 2H), 6.72-6.70 (m, 2H), 6.28 (dd, *J*=5.6, 2.0 Hz, 1H), 5.27 (q, *J*=2.4 Hz, 1H), 4.55 (d, *J*=12.0, 1H), 4.46 (d, *J*=12.0, 1H), 4.32-4.25 (m, 2H), 3.92 (dd, *J*=9.6, 3.6 Hz, 1H), 3.72 (s, 3 H), 3.71 (dd, *J*=9.2, 3.6 Hz, 1H), 2.47 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 206.3, 163.9, 153.1, 142.5, 139.4, 138.0, 135.2, 128.6, 128.4, 127.8, 127.7, 127.0, 126.7, 117.4, 114.6, 73.4, 67.2, 63.3, 55.6, 51.7, 50.9; IR(NaCl): 3048, 1713, 1512, 1244, 1028, 746 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{27}H_{28}NO_3$ $[M+H]^+$ 414.2069 , found, 414.2067.

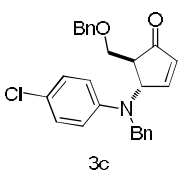
N-(4-(benzyl(5-((benzyloxy)methyl)-4-oxocyclopent-2-en-1-yl)amino) phenyl)acetamide (3b)



3b

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 68%. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.61 (dd, *J*=6.0, 2.0 Hz, 1H), 7.36-7.18 (m, 12H), 6.75-6.73 (m, 2H), 6.31 (dd, *J*=5.5, 2.0 Hz, 1H), 5.43 (d, *J*=2.0 Hz, 1H), 4.56 (d, *J*=12.0, 1H), 4.47 (d, *J*=12.0, 1H), 4.36 (d, *J*=12.0, 1H), 3.96 (dd, *J*=9.5, 3.0 Hz, 1H), 3.73 (dd, *J*=9.5, 3.5 Hz, 1H), 2.46 (m, 1 H), 2.12 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ = 206.1, 168.2, 163.4, 145.6, 139.0, 137.9, 135.4, 129.0, 128.7, 128.5, 127.8, 127.0, 126.2, 122.1, 114.6, 73.5, 66.9, 62.0, 51.3, 50.7, 24.3; IR(NaCl): 3027, 1713, 1706, 1532, 1155, 1032, 743 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{28}H_{29}N_2O_3$ $[M+H]^+$ 441.2178 , found, 441.2173.

4-(benzyl(4-chlorophenyl)amino)-5-((benzyloxy)methyl)cyclopent-2-enone (3c)

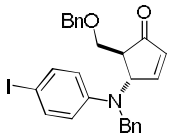


3c

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 70%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.59 (dd, *J*=5.6, 2.0 Hz, 1H), 7.38-7.18 (m, 10H), 7.07-7.04 (m, 2H), 6.70-6.68 (m, 2H), 6.33 (dd, *J*=5.6, 2.0 Hz, 1H), 5.45 (d, *J*=2.4 Hz, 1H), 4.59 (d, *J*=12.0 Hz, 1H), 4.47 (d, *J*=12.0 Hz, 1H), 4.37 (d, *J*=17.2 Hz, 1H), 4.29 (d, *J*=17.6 Hz, 1H), 3.97 (dd, *J*=9.2, 3.2 Hz,

1H), 3.74 (dd, *J*=9.6, 3.6 Hz, 1H), 2.44 (m 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 205.7, 162.9, 147.1, 138.5, 137.8, 135.6, 129.1, 128.8, 128.5, 127.9, 127.2, 126.1, 122.9, 115.1, 73.5, 66.8, 61.7, 51.4, 50.3; IR(NaCl): 3030, 1715, 1595, 1496, 1101 732, 698 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{26}H_{25}ClNO_2$ $[M+H]^+$ 418.1574 , found, 418.1570.

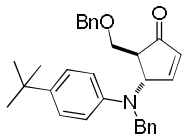
4-(benzyl(4-iodophenyl)amino)-5-((benzyloxy)methyl)cyclopent-2-enone (3d)



3d

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 76%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.57 (dd, *J*=6.0, 2.0 Hz, 1H), 7.38-7.17 (m, 14H), 6.56-6.54 (m, 2H), 6.33 (dd, *J*=6.8, 2.0 Hz, 1H), 5.46 (d, *J*=2.4 Hz, 1H), 4.58 (d, *J*=12.0, 1H), 4.47 (d, *J*=12.0 Hz, 1H), 4.36 (d, *J*=17.6, 1H), 4.28 (d, *J*=17.6Hz, 1H), 3.97 (dd, J=9.2, 3.2 Hz, 1H), 3.74 (dd, J=9.2, 3.2 Hz, 1H), 2.45 (m 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 205.6, 162.7, 148.1, 138.4, 137.9, 137.8, 135.7, 128.8, 128.5, 127.9, 127.2, 126.0, 116.0, 79.2, 73.5, 66.8, 61.3, 51.4, 50.1; IR(NaCl): 3031, 1629, 1493, 1205, 1026, 731, 696 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{26}H_{25}INO_2$ $[M+H]^+$ 510.0930 , found, 510.0928.

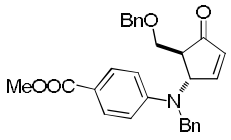
4-(benzyl(4-(tert-butyl)phenyl)amino)-5-((benzyloxy)methyl)cyclopent-2-enone (3e)



3e

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 68%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.61 (dd, *J*=5.6, 2.0 Hz, 1H), 7.38 - 7.20 (m, 10H), 7.17-7.13 (m, 2H), 6.75-6.71 (m, 2H), 6.31 (dd, *J*=6.0, 2.0 Hz, 1H), 5.49 (d, *J*=2.4 Hz, 1H), 4.59 (d, *J*=12.0, 1H), 4.48 (d, *J*=12.4, 1H), 4.37 (d, *J*=17.6 Hz, 1H), 4.30 (d, *J*=17.6 Hz, 1H), 3.97 (dd, *J*=9.2, 2.8 Hz, 1H), 3.77 (dd, *J*=9.2, 3.2 Hz, 1H), 2.45 (m 1H), 1.26 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 206.3, 163.7, 146.3, 140.8, 139.6, 138.0, 135.4, 128.7, 128.5, 127.9, 127.8, 127.0, 126.2, 126.2, 113.5, 73.5, 66.7, 61.3, 51.3, 50.8, 33.8, 31.5; IR(NaCl): 3061, 1715, 1612, 1517, 1364, 1026, 732, 698 cm^{-1};HRMS (ESI):*m/z* calcd for $C_{30}H_{34}NO_2$ $[M+H]^+$ 440.2590 , found, 440.2584.

Methyl 4-(benzyl(5-((benzyloxy)methyl)-4-oxocyclopent-2-en-1-yl)amino)benzoate (3f)

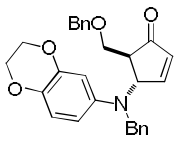


3f

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 29%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.83 (d, *J*=9.2 Hz, 2H), 7.57 (dd,

J=6.0, 2.4 Hz, 1H), 7.39-7.24 (m, 8H), 7.19 (d, *J*=7.2 Hz, 2H), 6.78 (d, *J*=9.2 Hz, 2H), 6.36 (dd, *J*=5.6, 2.0 Hz, 1H), 5.64 (q, *J*=2.4 Hz, 1H), 4.60 (d, *J*=12.0, 1H), 4.50 (d, *J*=12.0, 1H), 4.43-4.41 (m, 2H), 4.01 (dd, *J*=9.6, 3.2 Hz, 1H), 3.85 (s, 3H), 3.77 (dd, *J*=9.6, 3.6 Hz, 1H), 2.48 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 205.4, 167.0, 162.2, 152.0, 137.9, 137.7, 135.9, 131.5, 128.9, 128.5, 127.9, 127.3, 125.9, 119.0, 112.2, 73.6, 66.6, 60.8, 51.7, 51.6, 49.9; IR(NaCl): 3051, 1723, 1712, 1532, 1343, 1026, 735 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{28}H_{28}NO_4$ $[M+H]^+$ 442.2018 , found, 442.2015.

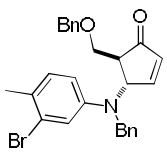
4-(benzyl(2,3-dihydrobenzo[b][1,4]dioxin-6-yl)amino)-5-((benzyloxy) methyl)cyclopent-2-enone (3g)



3g

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 70%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.64 (dd, *J*=6.0, 2.0 Hz, 1H), 7.36-7.20 (m, 10H), 6.68 (d, *J*=8.8, 1H), 6.42 (d, *J*=2.8, 1H), 6.37 (dd, *J*=8.8, 3.2 Hz, 1H), 6.29 (dd, *J*=6.0, 2.0 Hz, 1H), 5.29 (d, *J*=2.0 Hz, 1H), 4.56 (d, *J*=12.0 Hz, 1H), 4.49(d, *J*=12.0 Hz, 1H), 4.31-4.17 (m, 6H), 3.95 (dd, *J*=9.2, 3.2 Hz, 1H), 3.74 (dd, *J*=9.2, 3.2 Hz, 1H), 2.47 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 206.3, 163.7, 143.9, 143.5, 139.3, 138.0, 136.7, 135.2, 128.6, 128.4, 127.8, 127.7, 127.0, 126.5, 117.5, 109.0, 104.7, 73.4, 67.0, 64.7, 64.2, 62.8, 51.5, 51.0; IR(NaCl): 3026, 1712, 1498, 1304, 1033, 737 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{28}H_{28}NO_4$ $[M+H]^+$ 442.2018 , found, 442.2013.

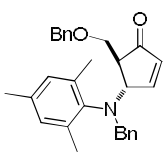
4-(benzyl(3-bromo-4-methylphenyl)amino)-5-((benzyloxy)methyl)cycl opent-2-enone (3h)



3h

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 71%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.57 (dd, *J*=5.6, 2.0 Hz, 1H), 7.36-7.19 (m, 10H), 7.13 (d, *J*=2.8, 1H), 6.96 (d, *J*=8.4 Hz, 1H), 6.62 (dd, *J*=8.4, 2.8 Hz, 1H), 6.30 (dd, *J*=5.6, 2.0 Hz, 1H), 5.44 (d, *J*=2.4 Hz, 1H), 4.54 (s, 2H), 4.35 (d, *J*=17.2, 1H), 4.28 (d, *J*=17.6, 1H), 3.98 (dd, *J*=9.6, 3.2 Hz, 1H), 3.74 (dd, *J*=9.6, 3.6 Hz, 1H), 2.45 (m, 1H), 2.26 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 205.7, 162.9, 147.8, 138.7, 137.9, 135.5, 131.1, 128.8, 128.4, 127.8, 127.8, 127.2, 127.1, 126.2, 125.7, 117.7, 113.4, 73.5, 67.0, 61.8, 51.4, 50.4, 21.6; IR(NaCl): 3028, 1715, 1606, 1502, 1205, 1028, 752 cm^{-1};HRMS (ESI):*m/z* calcd for $C_{27}H_{27}BrNO_2$ $[M+H]^+$ 476.1225 , found, 476.1220.

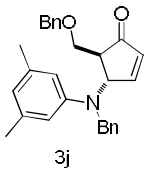
4-(benzyl(mesityl)amino)-5-((benzyloxy)methyl)cyclopent-2-enone (3i)



3i

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 72%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.37 (dd, J=6.0, 2.4 Hz, 1H), 7.30 - 7.10 (m, 10H), 6.78 (s, 2H), 6.12 (dd, J=5.6, 1.6 Hz, 1H), 4.61 (q, J=2.0 Hz, 1H), 4.45 (d, J=12.4 1H), 4.37 (d, J=12.4 1H), 4.24 (d, J=14.0 1H), 4.19 (d, J=14.4 1H), 3.76 (dd, J=9.2, 4.0 Hz, 1H), 3.50 (dd, J=9.2, 3.2 Hz, 1H), 2.60 (m, 1H), 2.25 (s, 3H), 2.23 (s, 3H), 2.10 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 207.5, 164.6, 144.2, 140.6, 138.1, 137.5, 137.0, 135.2, 133.8, 130.0, 129.7, 128.9, 128.3,128.2, 127.5, 127.0, 73.2, 67.9, 66.2, 56.3, 52.9, 20.8, 20.0, 19.9; IR(NaCl): 3028, 1715, 1479, 1454, 1113, 698 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{29}H_{32}NO_2$ $[M+H]^+$ 426.2433 , found, 426.2429.

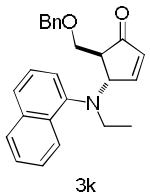
4-(benzyl(3,5-dimethylphenyl)amino)-5-((benzyloxy)methyl)cyclopent-2-enone (3j)



3j

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 80%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.60 (dd, *J*=5.6, 2.0 Hz, 1H), 7.34-7.22 (m, 10H), 6.50 (s, 2H), 6.45 (s, 1H), 6.30 (dd, *J*=6.0, 2.0 Hz, 1H), 5.53 (d, *J*=2.4 Hz, 1H), 4.55 (d, *J*=12.0 Hz, 1H), 4.52 (d, *J*=12.0 Hz, 1H), 4.39 (d, *J*=17.6 Hz, 1H), 4.31 (d, *J*=17.6 Hz, 1H), 3.99 (dd, *J*=9.6, 3.2 Hz, 1H), 3.76 (dd, *J*=9.6, 3.6 Hz, 1H), 2.47 (m, 1 H), 2.20 (s, 6 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 206.2, 163.6, 149.0, 139.6, 139.0, 138.0, 135.3, 128.7, 128.4, 127.7, 127.6, 127.0, 126.2, 120.2, 111.8, 73.5, 67.1, 61.3, 51.4, 50.6, 21.8; IR(NaCl): 3029, 1713, 1509, 1341, 1018, 747 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{28}H_{30}NO_2$ $[M+H]^+$ 412.2277 , found, 412.2275.

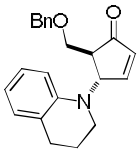
5-((benzyloxy)methyl)-4-(ethyl(naphthalen-1-yl)amino)cyclopent-2-enone (3k)



3k

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 28%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.38 (d, *J*=8 Hz, 1H), 7.86-7.80 (m, 2H), 7.65-7.48 (m, 1H), 7.46-7.40 (m, 2H), 7.40-7.36 (m, 1H), 7.20-7.19 (m, 3H), 6.96-6.95 (m, 2H), 6.27 (d, *J*=6.0 Hz, 1H), 4.76 (s, 1H), 4.31 (d, *J*=12.0 Hz, 1H), 4.19 (d, *J*=12.0 Hz, 1H), 3.77 (dd, *J*=9.2, 3.6 Hz, 1H), 3.40 (brs, 1H), 3.26-3.19 (m, 1H), 3.17-3.08 (m, 1H), 2.61 (m, 1H), 1.01 (t, *J*=14, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 207.1, 164.2, 145.3, 137.9, 135.0, 134.9, 131.8, 128.3, 128.2, 127.4, 127.4, 126.0, 125.8, 125.3, 124.9, 123.8, 119.7, 73.2, 67.8, 67.3, 49.5, 42.8, 13.4; IR(NaCl): 3031, 1712, 1524, 1345, 1134, 752 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{25}H_{26}NO_2$ $[M+H]^+$ 372.1964, found, 372.1958.

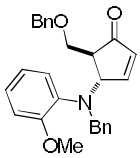
5-((benzyloxy)methyl)-4-(3,4-dihydroquinolin-1(2H)-yl)cyclopent-2-enone (3l)



3l

The title compound was prepared according to the general procedure. The product was obtained as brown oil. Yield: 36%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.64 (dd, *J*=5.6, 2.0 Hz, 1H), 7.36-7.26 (m, 5H), 6.98-6.93 (m, 2H), 6.80 (d, *J*=8.4 Hz, 1H), 6.64-6.62 (m, 1H), 6.36 (dd, *J*=6.0, 2.0 Hz, 1H), 5.43 (d, *J*=2.4 Hz, 1H), 4.61 (d, *J*=12.0, 1H), 4.48 (d, *J*=12.0, 1H), 4.02 (dd, *J*=9.2, 2.8 Hz, 1H), 3.75 (dd, *J*=9.2, 3.2 Hz, 1H), 3.09-3.04 (m, 2H), 2.78-2.74 (m, 2H), 2.51 (m, 1H), 1.93-1.89 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 206.4, 164.7, 144.9, 137.9, 135.1, 129.7, 128.4, 127.9, 127.8, 127.2, 123.2, 116.9, 111.3, 73.5, 67.1, 60.3, 49.9, 43.7, 28.1, 22.3; IR(NaCl): 3064, 1715, 1601, 1495, 1103, 744 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{22}H_{24}NO_2$ $[M+H]^+$ 334.1807, found, 334.1800.

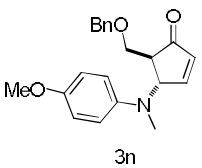
4-(benzyl(2-methoxyphenyl)amino)-5-((benzyloxy)methyl)cyclopent-2-enone (3m)



3m

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 68%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.71 (dd, *J*=6.0, 2.4 Hz, 1H), 7.29-7.12 (m, 10H), 7.00-6.96 (m, 2H), 6.83 (d, *J*=7.6, 1H), 6.78-6.74 (m, 1H), 6.16 (dd, *J*=6.0, 2.0 Hz, 1H), 4.91 (q, *J*=2.4 Hz, 1H), 4.41 (d, *J*=12.4, 1H), 4.35 (d, *J*=12.4, 1H), 4.41 (d, *J*=15.2, 1H), 4.25 (d, *J*=15.2, 1H), 3.83-3.79 (m, 4H), 3.55 (dd, *J*=9.2, 3.6 Hz, 1H), 2.59 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 207.3, 165.1, 154.7, 139.6, 138.2, 137.7, 134.1, 128.3, 128.2, 127.9, 127.4, 126.8, 125.0, 124.5, 120.6, 111.9, 73.2, 67.6, 65.7, 55.3, 52.8, 50.4; IR(NaCl): 3041, 1713, 1506, 1357, 1042, 733 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{27}H_{28}NO_3$ $[M+H]^+$ 414.2069, found, 414.2064.

5-((benzyloxy)methyl)-4-((4-methoxyphenyl)(methyl)amino)cyclopent-2-enone (3n)

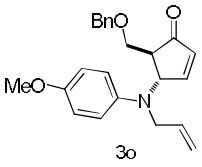


3n

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 77%. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.65 (dd, *J*=5.5, 2.0 Hz, 1H), 7.36-7.26 (m, 5H), 6.84-6.78 (m, 4H), 6.33 (dd, *J*=6.0, 2.0 Hz, 1H), 5.18 (d, *J*=2.0 Hz, 1H), 4.54 (d, *J*=12.5, 1H), 4.42 (d, *J*=12.5, 1H), 3.92 (dd, *J*=9.0, 3.0 Hz, 1H), 3.75 (s, 3H), 3.58 (dd, *J*=9.5, 3.5 Hz, 1H), 2.44 (m, 1H); ^{13}C NMR (125 MHz, $CDCl_3$): δ = 206.5, 164.3, 153.0, 143.9, 138.0, 135.0, 128.4, 127.8, 127.7, 116.7, 114.7, 73.3, 67.2, 64.2, 55.7, 49.2, 33.6; IR(NaCl): 3029, 1713,

1635, 1510, 1244, 1103 734, 698 cm $^{-1}$; HRMS (ESI):*m/z* calcd for $C_{21}H_{24}NO_3$ $[M+H]^+$ 338.1756, found, 338.1752.

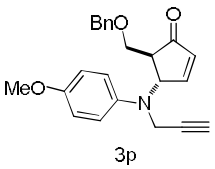
4-(allyl(4-methoxyphenyl)amino)-5-((benzyloxy)methyl)cyclopent-2-enone (3o)



3o

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 76%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.64 (dd, *J*=6.0, 2.4 Hz, 1H), 7.36-7.25 (m, 5H), 6.81-6.74 (m, 4H), 6.31 (dd, *J*=6.0, 2.0 Hz, 1H), 5.86-5.77 (m, 1H), 5.22-5.17 (m, 2H), 5.16-5.10 (m, 1H), 4.56 (d, *J*=12.0, 1H), 4.46 (d, *J*=12.0, 1H), 3.94 (dd, *J*=9.2 3.2 Hz, 1H), 3.77 (s, 3H), 3.69-3.65 (m, 3H), 2.45 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 206.5, 164.0, 153.0, 142.4, 138.0, 135.8, 135.0, 128.4, 127.8, 127.7, 117.2, 116.4, 114.6, 73.4, 67.0, 63.0, 55.7, 50.9, 50.3; IR(NaCl): 3033, 1841, 1713, 1645, 1523, 1028, 699 cm $^{-1}$; HRMS (ESI):*m/z* calcd for $C_{23}H_{26}NO_3$ $[M+H]^+$ 364.1913, found, 364.1907.

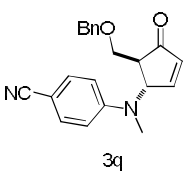
5-((benzyloxy)methyl)-4-((4-methoxyphenyl)(prop-2-yn-1-yl)amino)cyclopent-2-enone (3p)



3p

The title compound was prepared according to the general procedure. The product was obtained as brown oil. Yield: 72%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.75 (dd, J=6.0, 2.4 Hz, 1H), 7.38-7.26 (m, 5H), 6.97 - 6.93 (m, 2H), 6.81 - 6.78 (m, 2H), 6.34 (dd, J=5.6, 2.0 Hz, 1H), 5.15 (q, J=2.4 Hz, 1H), 4.57 (d, J=12.0 Hz, 1H), 4.45 (d, J=12.0 Hz, 1H), 3.92 (dd, J=9.6 Hz, 3.6 Hz, 1H), 3.87 (d, J=2.4 Hz, 1H), 3.85 (d, J=2.4 Hz, 1H), 3.77 (s, 3H), 3.69 (dd, J=9.2, 3.6 Hz, 1H), 2.65 (m, 1H), 2.23 (t, J=2.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 206.4, 163.5, 154.0, 141.4, 138.0, 135.3, 128.4, 127.9, 127.7, 118.8, 114.6, 81.2, 73.4, 73.0, 67.2, 63.5, 55.6, 50.6, 38.4; IR(NaCl): 3248, 2107, 1713, 1689, 1512, 1244, 1133, 724 cm $^{-1}$; HRMS (ESI):*m/z* calcd for $C_{23}H_{24}NO_3$ $[M+H]^+$ 362.1756, found, 362.1751.

4-((5-((benzyloxy)methyl)-4-oxocyclopent-2-en-1-yl)(methyl)amino)benzonitrile (3q)

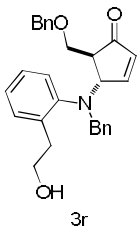


3q

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 32%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.54 (dd, *J*=5.6, 2.0 Hz, 1H), 7.40-7.32 (m, 5H), 7.28-7.25 (m, 2H), 6.77 (d, *J*=9.2, 2H), 6.41 (dd, *J*=6.0, 2.0 Hz, 1H), 5.41 (d, *J*=2.4 Hz, 1H), 4.59 (d, *J*=12.0, 1H), 4.43 (d, *J*=12.0, 1H), 3.97 (dd, *J*=9.2, 3.2 Hz, 1H), 3.68 (dd, *J*=9.2, 3.6 Hz, 1H), 2.77 (s, 3H), 2.40 (m,

1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 205.1, 162.3, 151.9,137.5, 135.9, 133.6,128.5, 128.0, 120.1, 112.3, 99.2, 73.6, 66.4, 60.8, 50.8, 32.3; IR(NaCl): 3039, 2243, 1712, 1607, 1324, 1024, 756 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{21}H_{21}N_2O_2$ $[M+H]^+$ 333.1603, found, 333.1597.

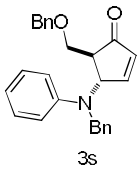
4-(benzyl(2-(2-hydroxyethyl)phenyl)amino)-5-((benzyloxy)methyl)cyclopent-2-enone (3r)



3r

The title compound was prepared according to the general procedure. The product was obtained as brown oil. Yield: 51%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.77(dd, J=6.0, 2.4 Hz, 1H), 7.31-7.01 (m, 14H), 6.27 (dd, *J*=5.6, 1.6 Hz, 1H), 4.60 (q, *J*=2.4 Hz, 1H), 4.42 (d, *J*=12.0, 1H), 4.33 (d, *J*=12.0, 1H), 4.16 (m, 2H), 3.82 (dd, J=9.6, 4.0 Hz, 1H), 3.69 - 3.65 (m, 2H), 3.53 (dd, *J*=9.2, 3.6 Hz, 1H), 3.02- 2.97 (m, 1H), 2.94-2.89 (m, 1H), 2.62 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 206.7, 163.5, 148.0, 138.5, 137.8, 136.2, 135.0, 130.4, 128.8, 128.3, 128.3, 127.6, 127.2, 126.9, 125.5, 124.8, 73.3, 67.8, 67.3, 63.0, 54.0, 49.7, 33.7; IR(NaCl): 3417, 1747, 1713, 1643, 1454, 1220, 1074, 738 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{28}H_{30}NO_3$ $[M+H]^+$ 428.2226, found, 428.2220.

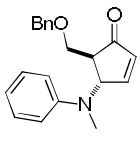
4-(benzyl(phenyl)amino)-5-((benzyloxy)methyl)cyclopent-2-enone (3s)



3s

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 71%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.61 (dd, J=5.6, 2.0 Hz, 1H), 7.36-7.27 (m, 7H), 7.24-7.22 (m, 3H), 7.19-7.12 (m, 2H), 6.80 (d, *J*=8.0 Hz, 2H), 6.76 (t, *J*=7.2 Hz, 1H), 6.31 (dd, *J*=6.0, 2.0 Hz, 1H), 5.52 (q, *J*=2.4 Hz, 1H), 4.58 (d, *J*=12.0 Hz, 1H), 4.48 (d, *J*=12.0 Hz, 1H), 4.40 (d, *J*=17.2 Hz, 1H), 4.32 (d, *J*=17.2 Hz, 1H), 3.97 (dd, *J*=9.2, 3.2 Hz, 1H), 3.76 (dd, *J*=9.6, 3.6 Hz, 1H), 2.47 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 206.1, 163.4, 148.6, 139.2, 137.9, 135.5, 129.4, 128.7, 128.5, 127.9, 127.8, 127.0, 126.2, 118.1, 113.9, 73.5, 66.9, 61.4, 51.4, 50.5; IR(NaCl): 3030, 1715, 1637, 1599, 1504, 1205, 1021, 742 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{26}H_{26}NO_2$ $[M+H]^+$ 384.1964, found, 384.1961.

5-((benzyloxy)methyl)-4-(methyl(phenyl)amino)cyclopent-2-enone (3t)

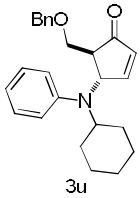


3t

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 82%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.61 (dd, *J*=6.0, 2.0 Hz, 1H), 7.36-7.26 (m, 5H),

7.24-7.18 (m, 2H), 6.86 - 6.83 (m, 2H), 6.79 - 6.75 (m, 1H), 6.35 (dd, *J*=6.0, 2.0 Hz, 1H), 5.39 (d, *J*=2.0 Hz, 1H), 4.56 (d, *J*=12.0, 1H), 4.45 (d, *J*=12.0, 1H), 3.97 (dd, *J*=9.2, 3.2 Hz, 1H), 3.66 (dd, *J*=9.6, 3.6 Hz, 1H), 2.70 (s, 3H), 2.43 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 206.3, 164.2, 149.5, 137.9, 135.2, 129.4, 128.4, 127.9, 127.8, 118.0, 113.7, 73.4, 66.9, 62.1, 50.0, 32.5; IR(NaCl): 3062, 1713, 1588, 1278, 956, 746 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{20}H_{22}NO_2$ $[M+H]^+$ 308.1651, found, 308.1645.

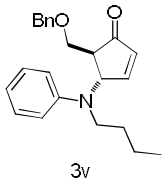
5-((benzyloxy)methyl)-4-(cyclohexyl(phenyl)amino)cyclopent-2-enone (3u)



3u

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 53%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.75 (dd, *J*=5.6, 1.6 Hz, 1H), 7.40-7.26 (m, 5H), 7.15-7.11 (m, 2H), 6.79-6.75 (m, 3H), 6.30 (dd, *J*=6.0, 2.4 Hz, 1H), 4.92 (m, 1H), 4.59 (d, *J*=12.0 Hz, 1H), 4.45 (d, *J*=12.0 Hz, 1H), 3.94 (dd, *J*=9.2, 2.4 Hz, 1H), 3.63 (dd, *J*=9.2, 2.8 Hz, 1H), 3.43 (m, 1H), 2.75 (m, 1H), 1.91-1.76 (m, 5H), 1.50-1.31 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 206.0, 169.3, 147.8, 138.0, 133.6, 129.0, 128.3, 128.0, 127.7, 119.2, 117.7, 73.5, 65.6, 59.4, 58.5, 49.9, 32.3, 31.7, 26.3, 26.0, 25.7; IR(NaCl): 3051, 1712, 1611, 1445, 1138, 739 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{25}H_{30}NO_2$ $[M+H]^+$ 376.2277, found, 376.2270.

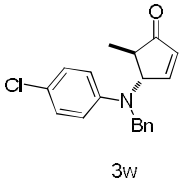
5-((benzyloxy)methyl)-4-(butyl(phenyl)amino)cyclopent-2-enone (3v)



3v

The title compound was prepared according to the general procedure. The product was obtained as brown oil. Yield: 69%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.66 (dd, *J*=6.0, 2.4 Hz, 1H), 7.40-7.27 (m, 5H), 7.20 (dd, *J*=8.8, 7.2 Hz, 2H), 6.83 (d, *J*=8.4 Hz, 2H), 6.77 (dd, *J*=5.6, 2.0 Hz, 1H), 6.35 (dd, *J*=5.6, 2.0 Hz, 1H), 5.29 (d, *J*=2.4, 1H), 4.57 (d, *J*=12.0 Hz, 1H), 4.45 (d, *J*=12.0 Hz, 1H), 3.97 (dd, *J*=9.2, 3.2 Hz, 1H), 3.69 (dd, *J*=9.6, 3.6 Hz, 1H), 3.15 - 2.96 (m, 2H), 2.46 (m, 1H), 1.60-1.44 (m, 2H), 1.31 (m, 2H), 0.92 (t, *J*=7.6 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 206.4, 164.5, 148.2, 138.0, 134.9, 129.3, 128.4, 127.8, 127.7, 117.9, 114.5, 73.4, 66.9, 62.6, 51.2, 46.3, 31.0, 20.3, 13.9; IR(NaCl): 3033, 1713, 1521, 1455, 1154, 741 cm $^{-1}$; HRMS (ESI):*m/z* calcd for $C_{23}H_{28}NO_2$ $[M+H]^+$ 350.2120, found, 350.2115.

4-(benzyl(4-chlorophenyl)amino)-5-methylcyclopent-2-enone (3w)

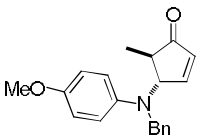


3w

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 70%. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.55 (dd, J=6.0, 2.0 Hz, 1H), 7.34 - 7.31 (m, 2H), 7.26-7.22 (m, 3H), 7.15 – 7.13 (m, 2H), 6.75-6.72 (m, 2H), 6.34 (dd, J=5.5, 2.0 Hz, 1H), 4.85 (d, J=2.5 Hz, 1H), 4.38 (d, J=17.5, 1H),

4.32 (d, J=17.5, 1H), 2.42 (dq, J=7.0, 3.0 Hz, 1H), 1.32 (d, J=7.5 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ = 208.1, 161.2, 147.2, 138.5, 135.5, 129.2, 128.8, 127.2, 126.1, 123.3, 115.5, 67.5, 50.6, 45.7, 14.4; IR(NaCl): 3062, 1713, 1595, 1497, 1452, 1163, 810 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{19}H_{19}ClNO$ $[M+H]^+$ 312.1155, found, 312.1150.

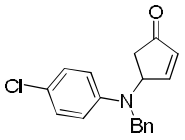
4-(benzyl(4-methoxyphenyl)amino)-5-methylcyclopent-2-enone (3x)



3x

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 80%. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.62 (dd, J=5.5, 2.0 Hz, 1H), 7.31-7.26 (m, 4H), 7.25-7.23 (m, 1H), 6.86 - 6.78 (m, 4H), 6.28 (dd, J=6.0, 2.0 Hz, 1H), 4.66 (q, J=2.5 Hz, 1H), 4.34 (d, J=16.5, 1H), 4.29 (d, J=16.0, 1H), 3.74 (s, 3H), 2.43 (dq, J=7.0, 3.0 Hz, 1H), 1.28 (d, J=7.5 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ = 208.8, 162.2, 153.4, 142.7, 139.4, 134.9, 128.6, 127.0, 126.8, 118.2, 114.7, 69.2, 55.6, 52.1, 45.2, 14.4; IR(NaCl): 3038, 1713, 1533, 1341, 1024, 776 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{20}H_{22}NO_2$ $[M+H]^+$ 308.1651, found, 308.1644.

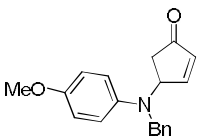
4-(benzyl(4-chlorophenyl)amino)cyclopent-2-enone (3y)



3y

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 76%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.56 (dd, J=5.6, 2.4 Hz, 1H), 7.34-7.26 (m, 2H), 7.25-7.22 (m, 3H), 7.16-7.13 (m, 2H), 6.72-6.68 (m, 2H), 6.30 (dd, J=6.0, 2.0 Hz, 1H), 5.21 (dd, J=6.4, 2.4 Hz, 1H), 4.36 (q, J=17.6 Hz, 2H), 2.90 (dd, J=18.8, 6.4 Hz, 1H), 2.30 (dd, J=18.8, 2.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 206.3, 162.4, 147.4, 138.8, 136.4, 129.2, 128.9, 127.2, 126.1, 123.4, 115.3, 59.4, 50.7, 39.7; IR(NaCl): 3053, 1713, 1492, 1322, 1123, 741 cm $^{-1}$; HRMS (ESI):*m/z* calcd for $C_{18}H_{17}ClNO$ $[M+H]^+$ 298.0999, found, 298.0991.

4-(benzyl(4-methoxyphenyl)amino)cyclopent-2-enone (3z)

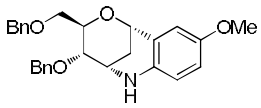


3z

The title compound was prepared according to the general procedure. The product was obtained as yellowish oil. Yield: 81%. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.60 (dd, J=5.6, 2.4 Hz, 1H), 7.33-7.21 (m, 5 H), 6.79 (s, 4H), 6.24 (dd, J=5.6, 2.0 Hz, 1H), 5.08-5.03 (m, 1H), 4.30 (q, J=16.8 Hz, 2H), 3.74 (s, 3H), 2.80 (dd, J=18.8, 6.4 Hz, 1H), 2.34 (dd, J=18.8, 2.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 206.9, 163.6, 153.4, 142.8, 139.6, 135.9, 128.6, 127.0, 126.7, 117.7, 114.7, 60.6, 55.6,

52.2, 39.2; IR(NaCl): 3029, 1712, 1602, 1342, 1118, 696 cm $^{-1}$; HRMS (ESI):*m/z* calcd for $C_{19}H_{20}NO_2$ $[M+H]^+$ 294.1494, found, 294.1489.

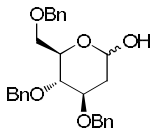
(2S,3S,4R,6S)-3-(benzyloxy)-4-((benzyloxy)methyl)-8-methoxy-2,3,4,6-tetrahydro-1H-2,6-methanobenzo[c][1,5]oxazocine (6)



6

The product was obtained as brown oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.34-7.22 (m, 10H), 6.75 (dd, *J*=8.5, 3.0 Hz, 1H), 6.70 (d, *J*=3.0, 1H), 6.55 (d, *J*=8.5, 1H), 4.72 (brs, 1H), 4.63 (d, *J*=12.5, 1H), 4.56 (d, *J*=11.5, 1H), 4.46 (d, *J*=7.0, 1H), 4.44 (d, *J*=6.0, 1H), 3.73 (s, 3H), 3.71 (brs, 1H), 3.66-3.63 (m, 2H), 3.54 (dd, *J*=6.0, 2.0 Hz, 1H), 3.40 (dd, *J*=3.5, 2.0 Hz, 1H), 3.38 (dd, *J*=3.5, 2.5 Hz, 1H), 2.20 (dt, *J*=13.5, 3.0 Hz, 1H), 2.01 (ddd, *J*=13.5, 4.5, 2.0 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$): δ = 151.8, 139.8, 138.3, 138.1, 128.5, 128.3, 128.0, 127.9, 127.9, 127.6, 120.8, 116.6, 115.1, 114.7, 77.2, 73.5, 71.7, 70.0, 69.2, 68.6, 55.8, 46.2, 28.3; IR(NaCl): 3373, 2939, 1558, 1374, 1134, 841 cm $^{-1}$; HRMS (ESI):*m/z* calcd for $C_{27}H_{30}NO_4$ $[M+H]^+$ 432.2175, found, 432.2169.

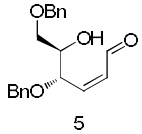
(4R,5S,6R)-4,5-bis(benzyloxy)-6-((benzyloxy)methyl)tetrahydro-2H-pyran-2-ol (7)



7

The product was obtained as white solid. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.37-7.28 (m, 13H), 7.21-7.20 (m, 2H), 5.40 (s, 1H), 4.93 (d, *J*=11.5 Hz, 1H), 4.70-4.51 (m, 6H), 4.09-4.04 (m, 2H), 3.73-3.61 (m, 2H), 3.52-3.46 (m, 1H), 3.35 (s, 1H), 2.31 (d, *J*=12.5, 5.0 Hz, 1H), 1.72 (dt, *J*=12.5, 3.5 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$): δ = 138.7, 138.5, 137.9, 128.4, 128.4, 128.4, 128.1, 128.0, 127.8, 127.7, 127.7, 92.1, 78.6, 75.0, 73.5, 71.8, 70.7, 69.4, 35.6; IR(NaCl): 3394, 3028, 1452, 1363, 1095, 1076, 696 cm^{-1}; HRMS (ESI):*m/z* calcd for $C_{27}H_{31}O_5$ $[M+H]^+$ 435.2171, found, 435.2164.

(4S,5R,Z)-4,6-bis(benzyloxy)-5-hydroxyhex-2-enal (5)



5

The title compound was prepared according to the ref 1. The product was obtained as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 9.61 (d, *J*=7.6 Hz, 1H), 7.38-7.29 (m, 10H), 6.91 (dd, *J*=15.6, 6.0 Hz, 1H), 6.37 (dd, *J*=16.0, 8.0 Hz, 1H), 4.63 (d, *J*=11.2 Hz, 1H), 4.52 (s, 2H), 4.43 (d, *J*=11.2 Hz, 1H), 4.21 (t, *J*=5.6, 1H), 3.95-3.90 (m, 1H), 3.64-3.56 (m, 2H), 2.51 (d, *J*=5.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 193.3,

153.7, 137.5, 137.2, 133.9, 128.6, 128.5, 128.4, 128.1, 128.0, 128.0, 127.9, 78.5, 73.6, 72.3, 72.0, 70.1; IR(NaCl): 3415, 2868, 1715, 1692, 1454, 1273m 1097, 698 cm $^{-1}$; HRMS (ESI):*m/z* calcd for $C_{20}H_{23}O_4$ $[M+H]^+$ 327.1596, found, 327.1591.

References

[1] a) F. Gonzalez, S. Lesage, A. S. Perlin, *Carbohydr. Res*. **1975**, 42, 267-274; b) J. Wengel, J. Lau, E. B. Pedersen, *Synthesis.* **1989**, 829–831.

[2] a) J. S. Yadav, B. V. S. Reddy, K. V. Rao, K. S. Raj, A. R. Prasad, S. K. Kumar, A. C. Kunwar, P. Jayaprakash, B. Jagannath, *Angew. Chem. Int. Ed.* **2003**, 42, 5198-5201; b) J. S. Yadav, B. V. S. Reddy, M. Srinivas, B. Padmavani, *Tetrahedron.* **2004**, 60, 3261-3266.

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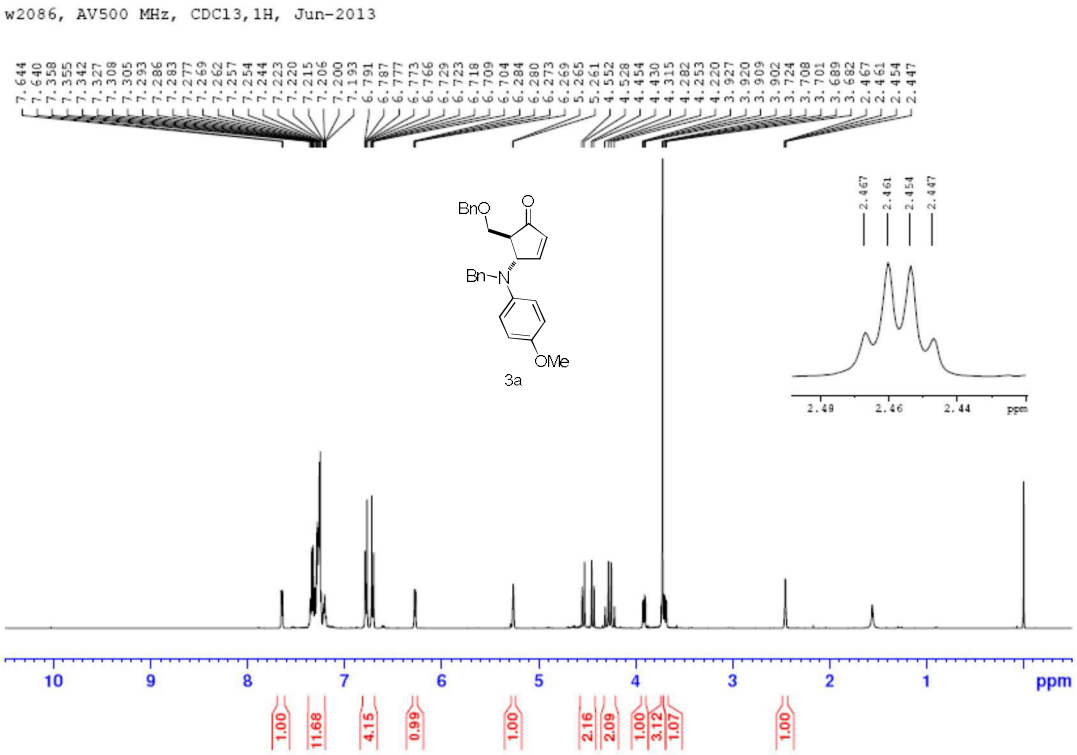
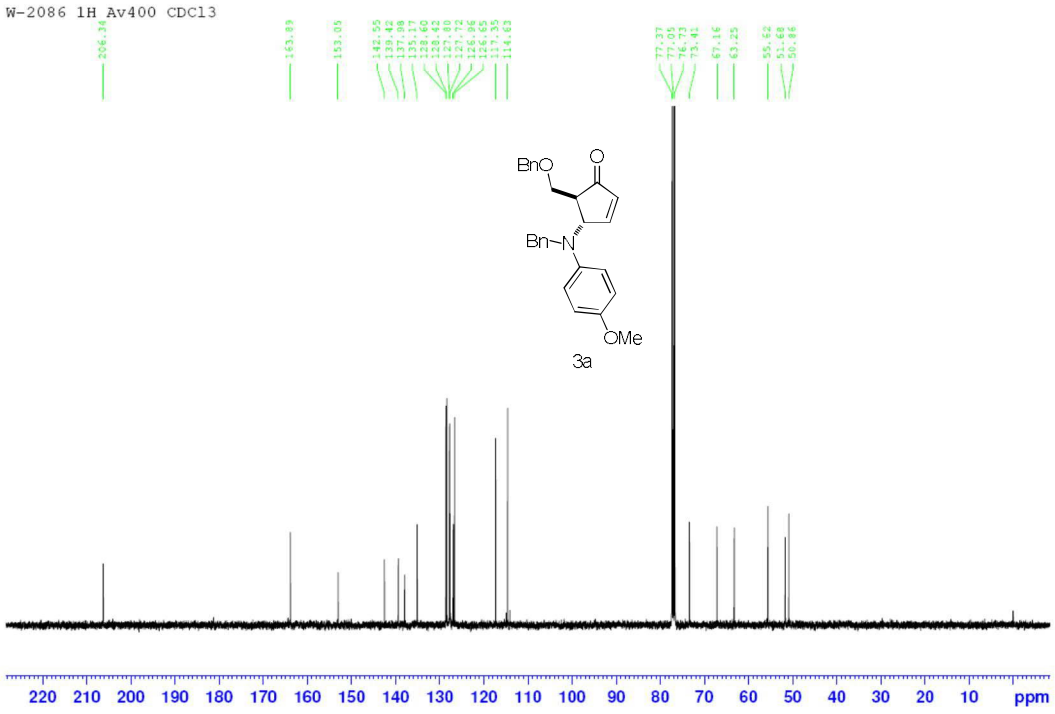
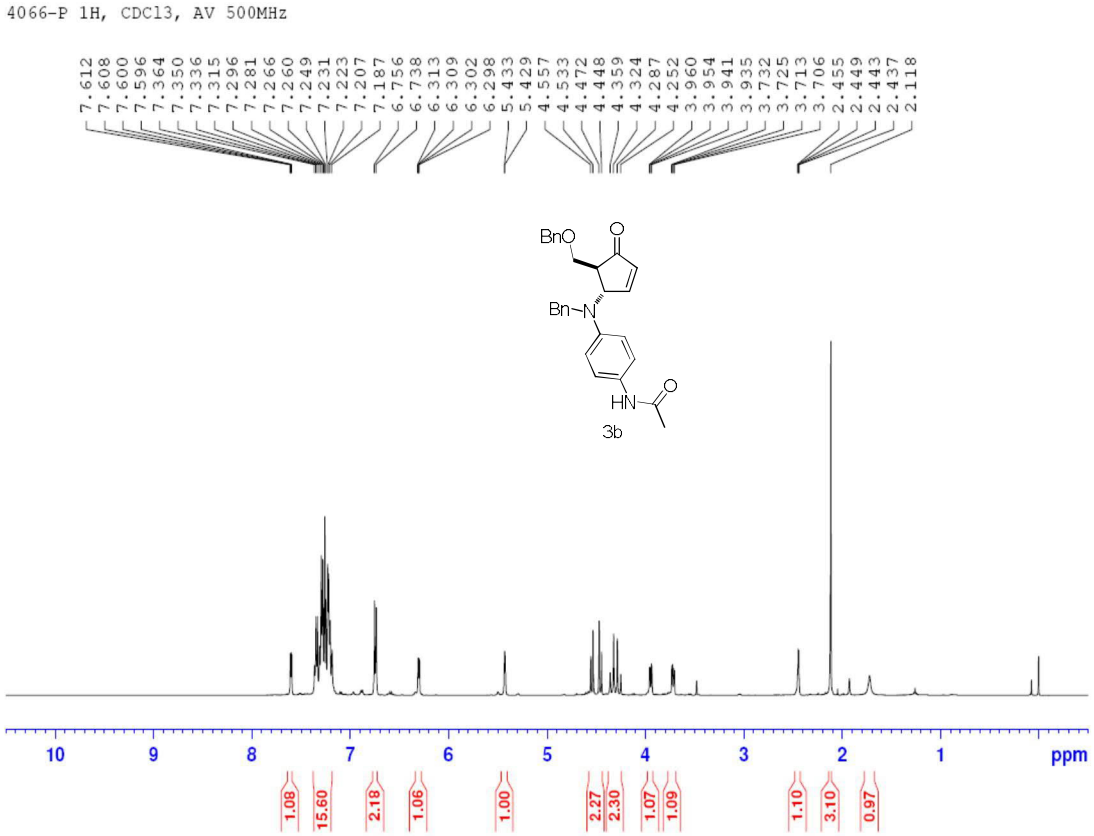
NMR Spectra of the Isolated Products



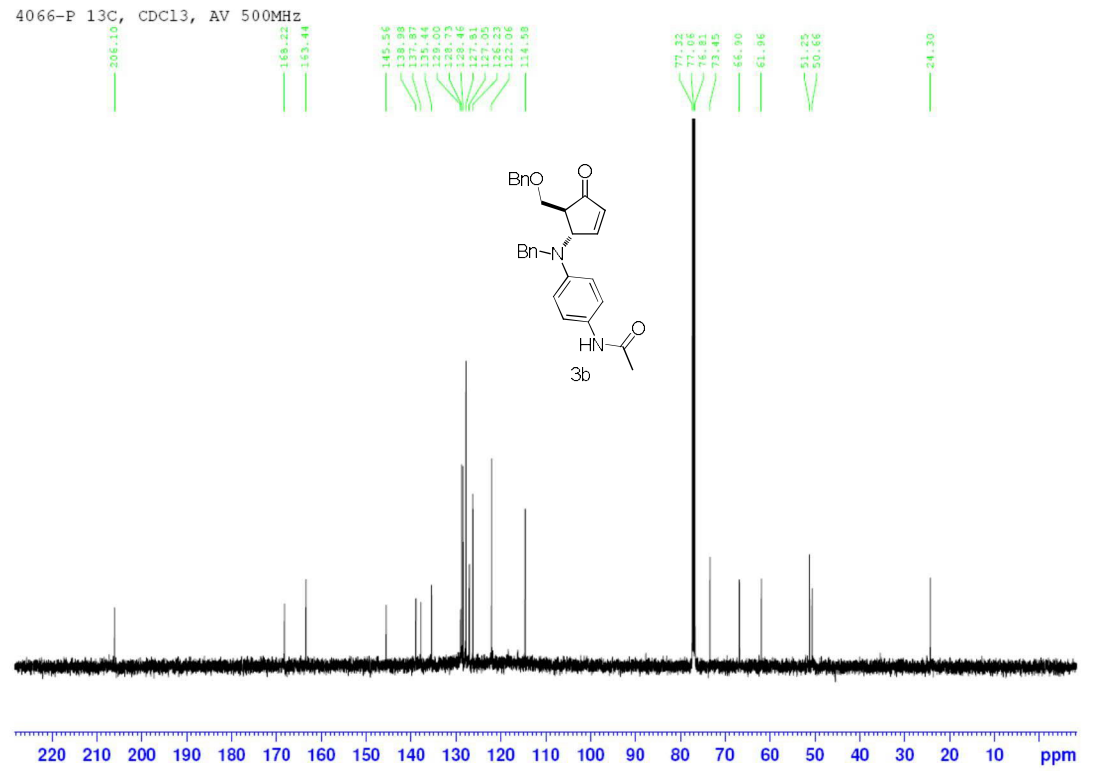
[1] H NMR of compound 3a



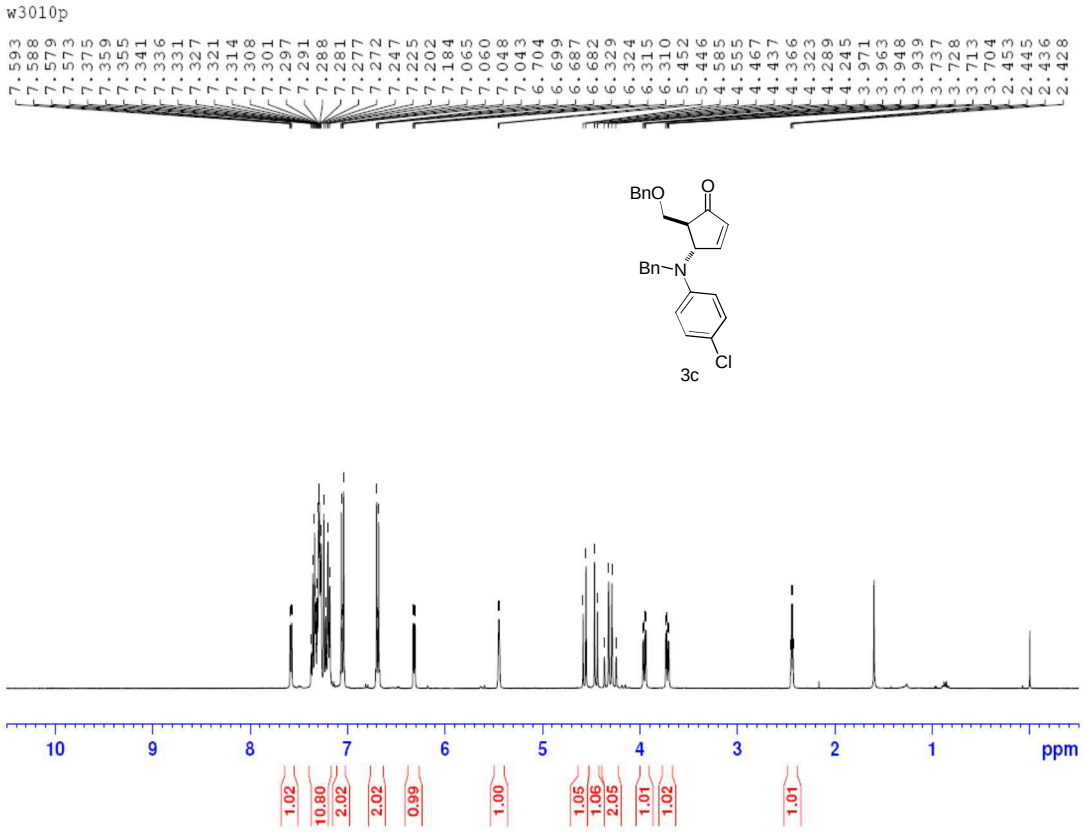
[13] C NMR of compound 3a



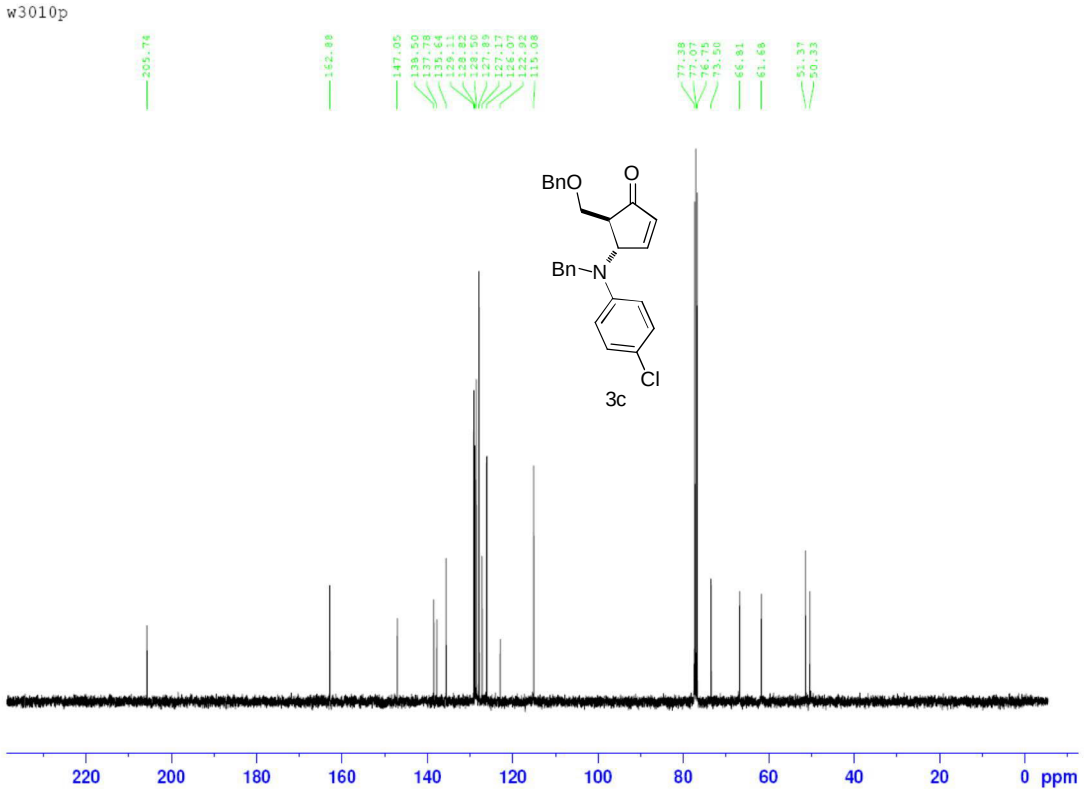
[1] H NMR of compound 3b



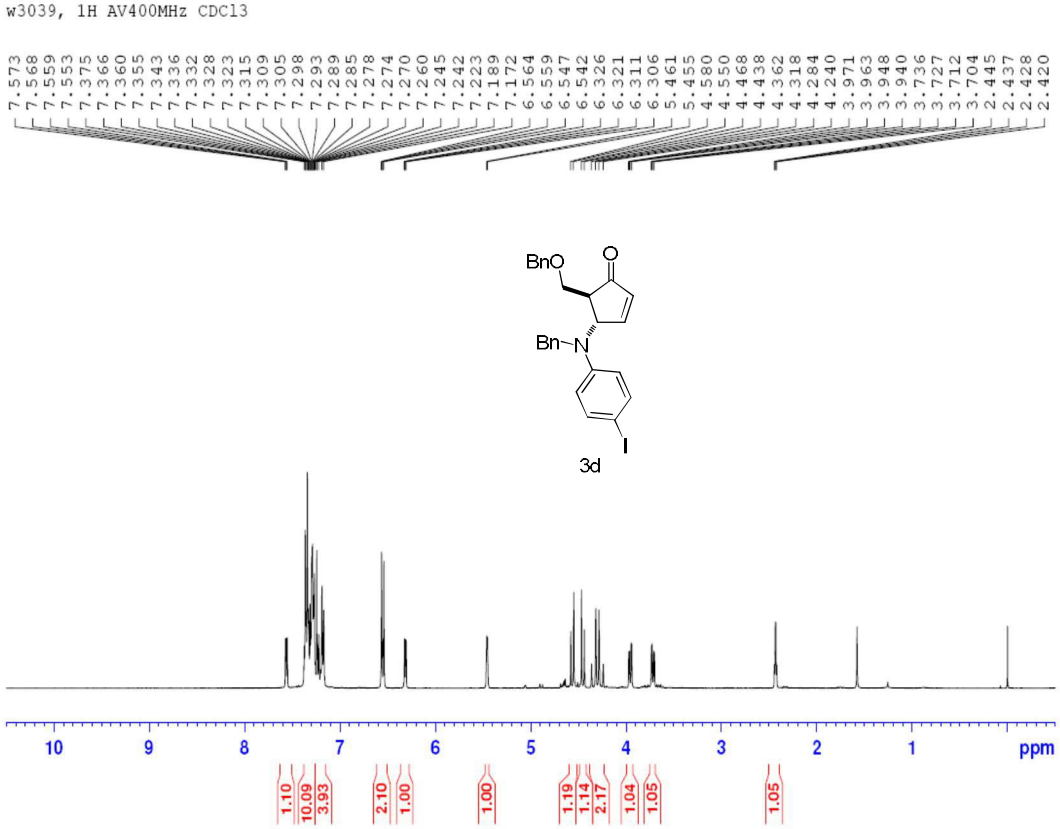
[13] C NMR of compound 3b



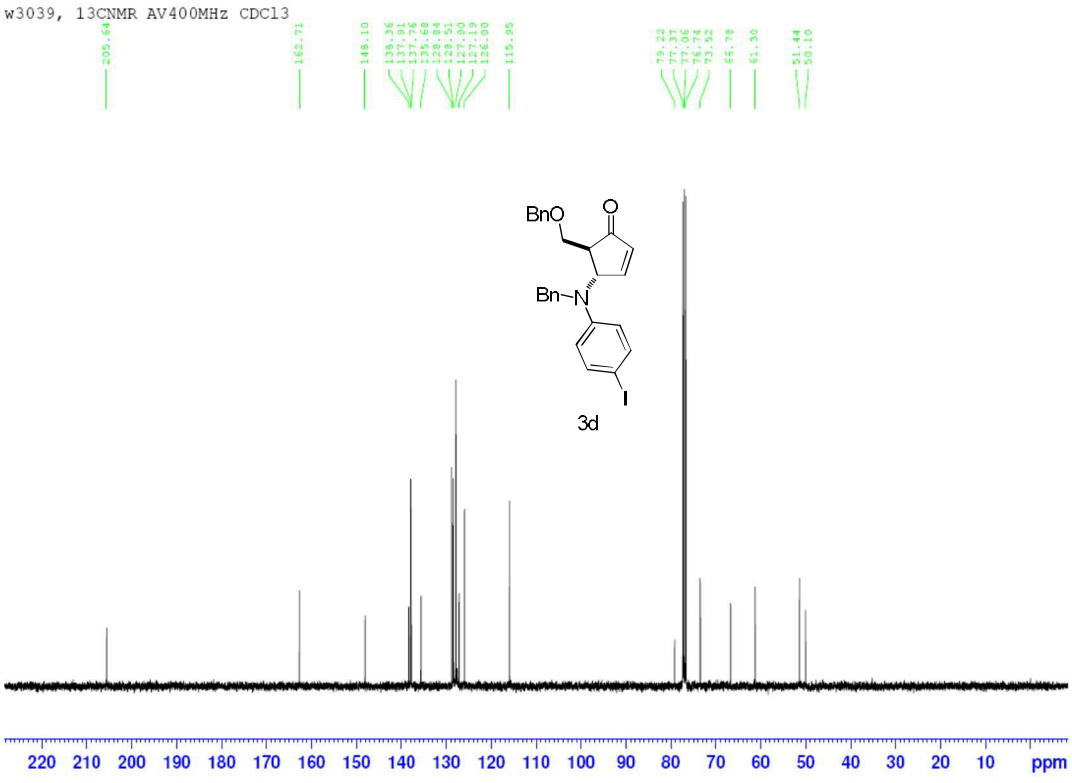
[1] H NMR of compound 3c



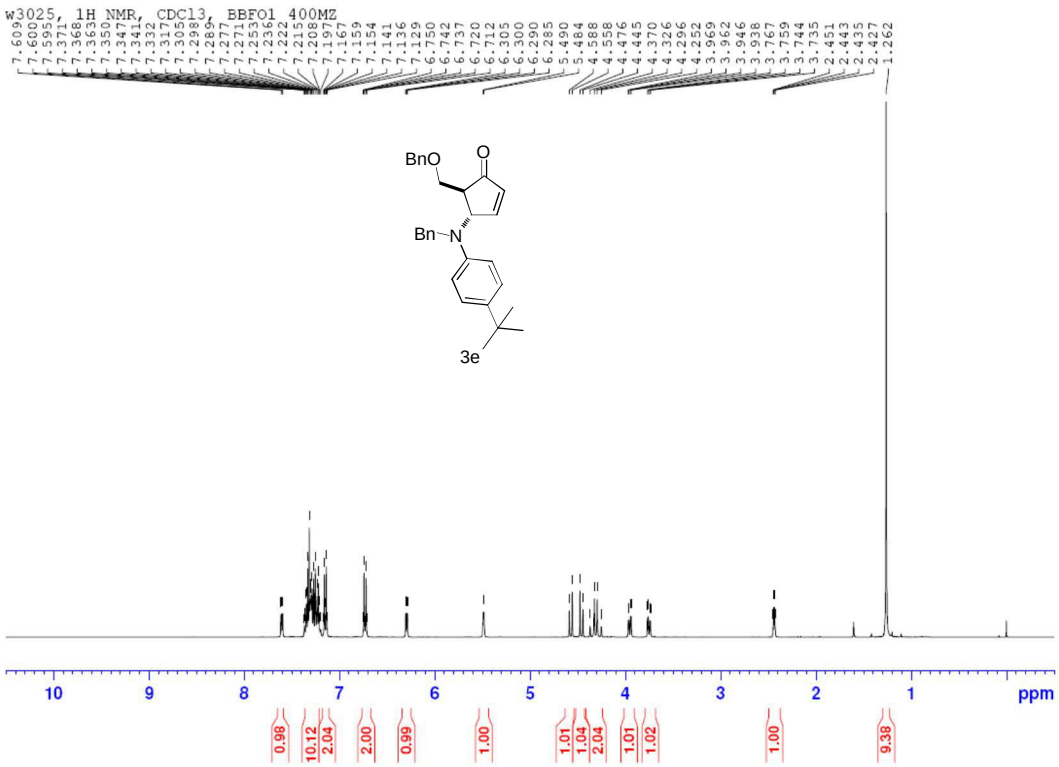
[13] C NMR of compound 3c



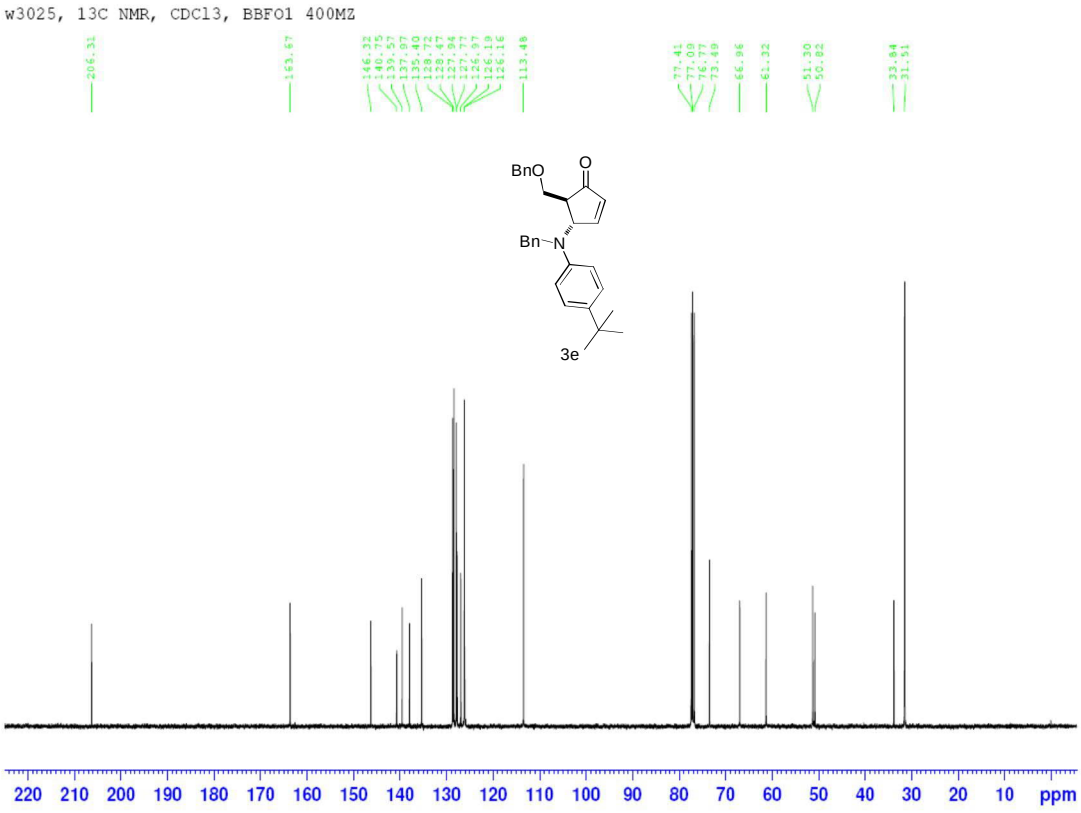
[1] H NMR of compound 3d



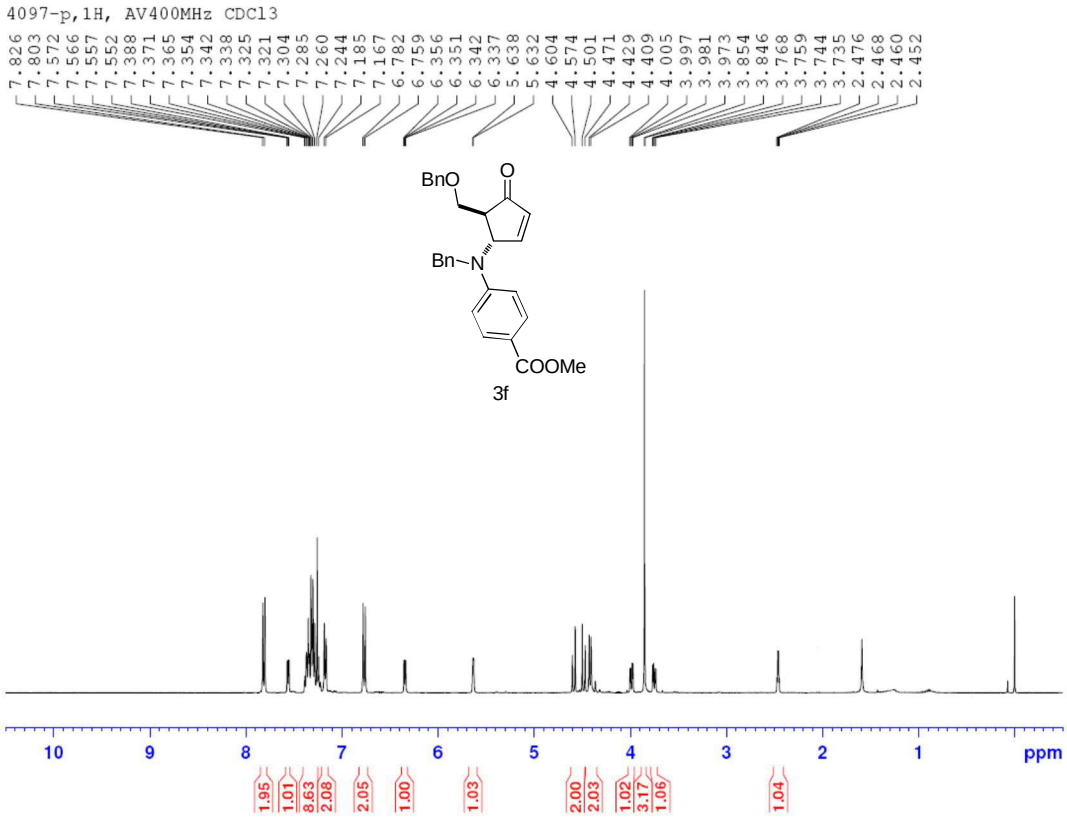
[13] C NMR of compound 3d



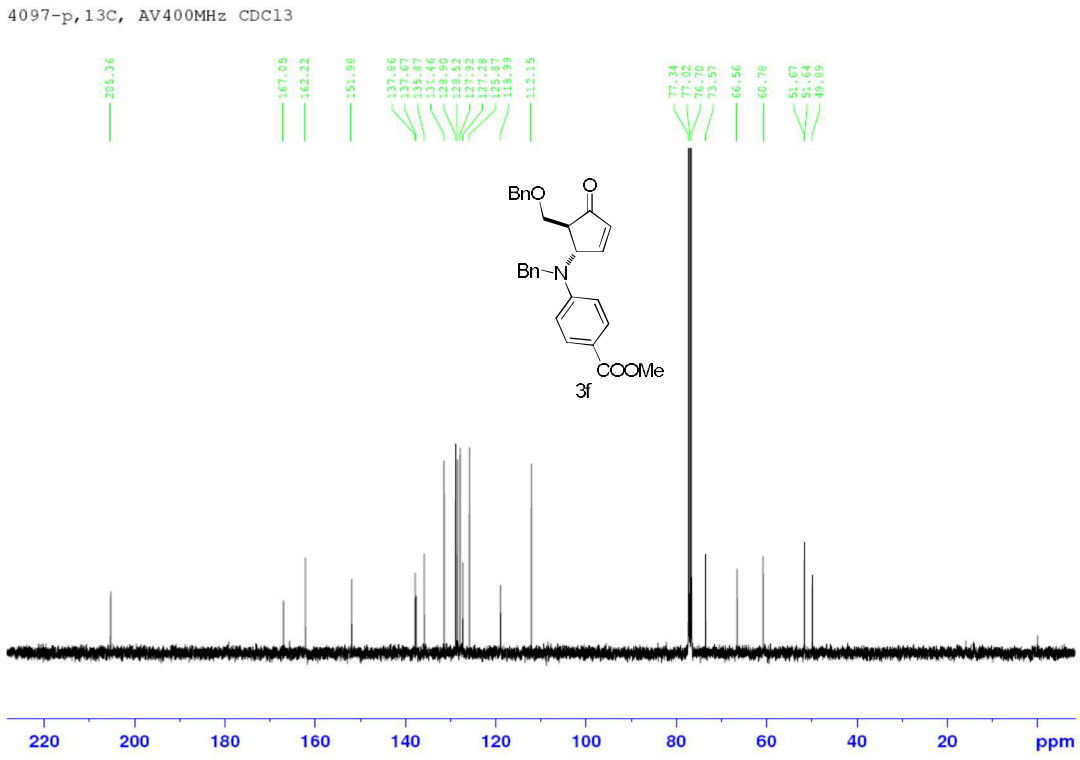
[1] H NMR of compound 3e



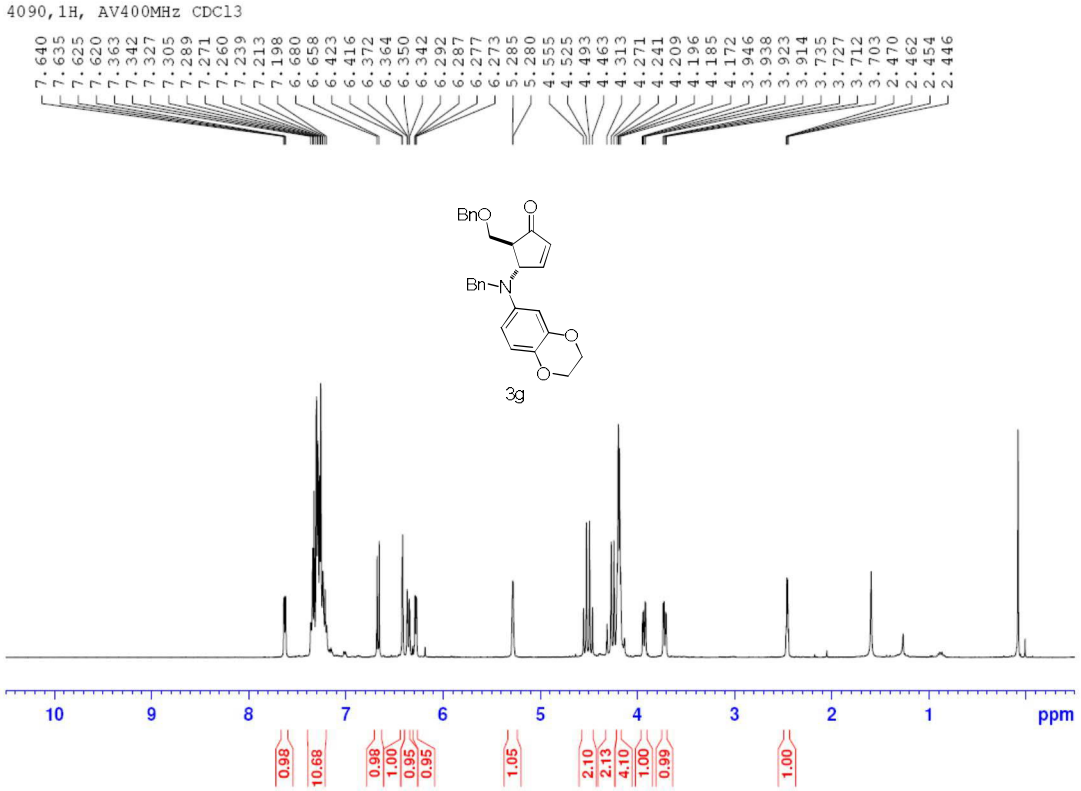
[13] C NMR of compound 3e



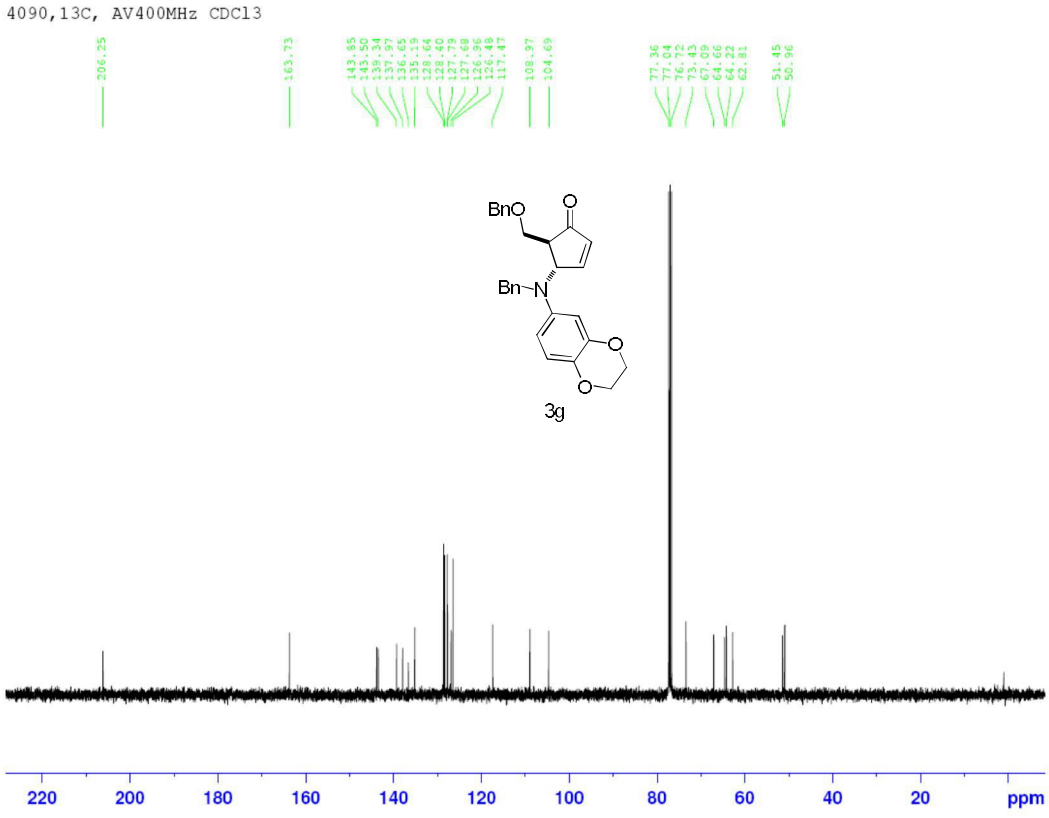
[1] H NMR of compound 3f



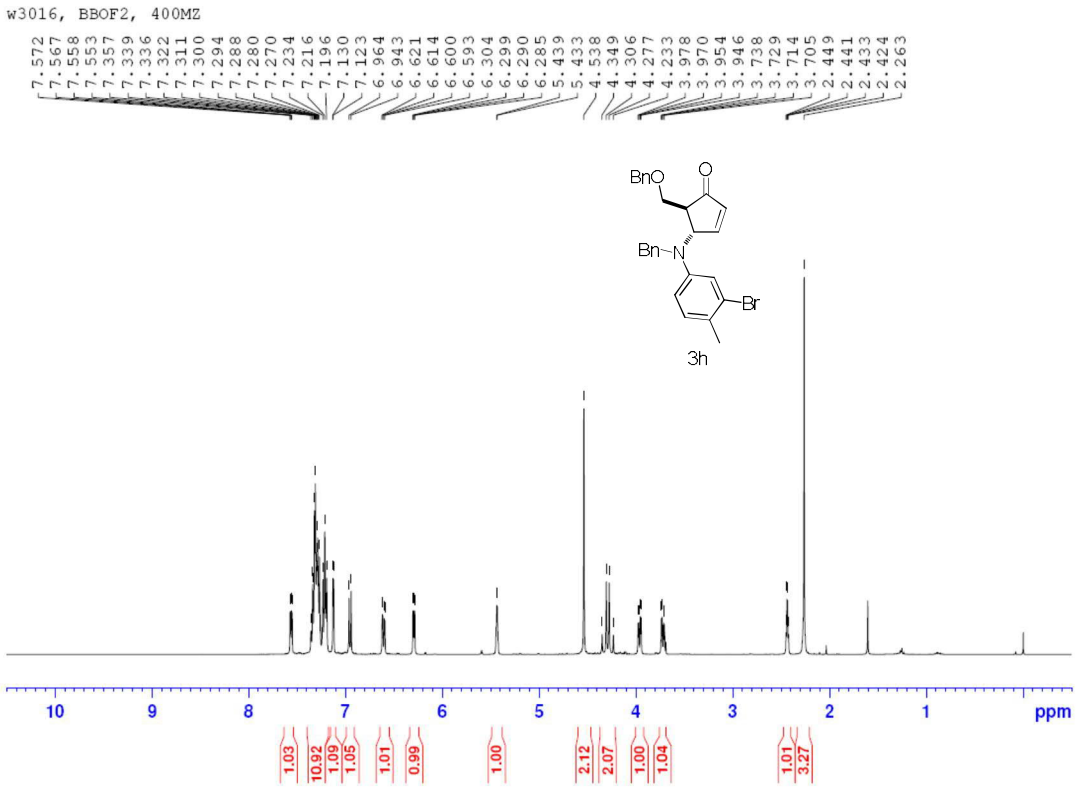
[13] C NMR of compound 3f



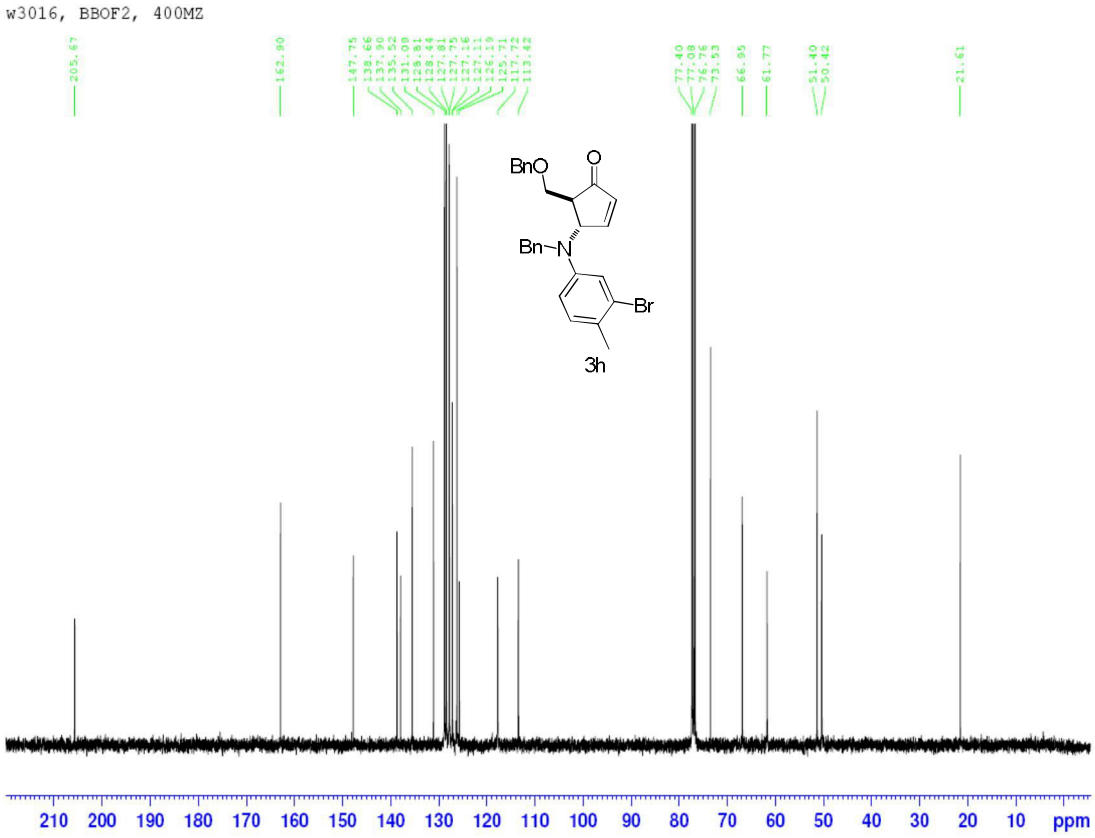
[1] H NMR of compound 3g



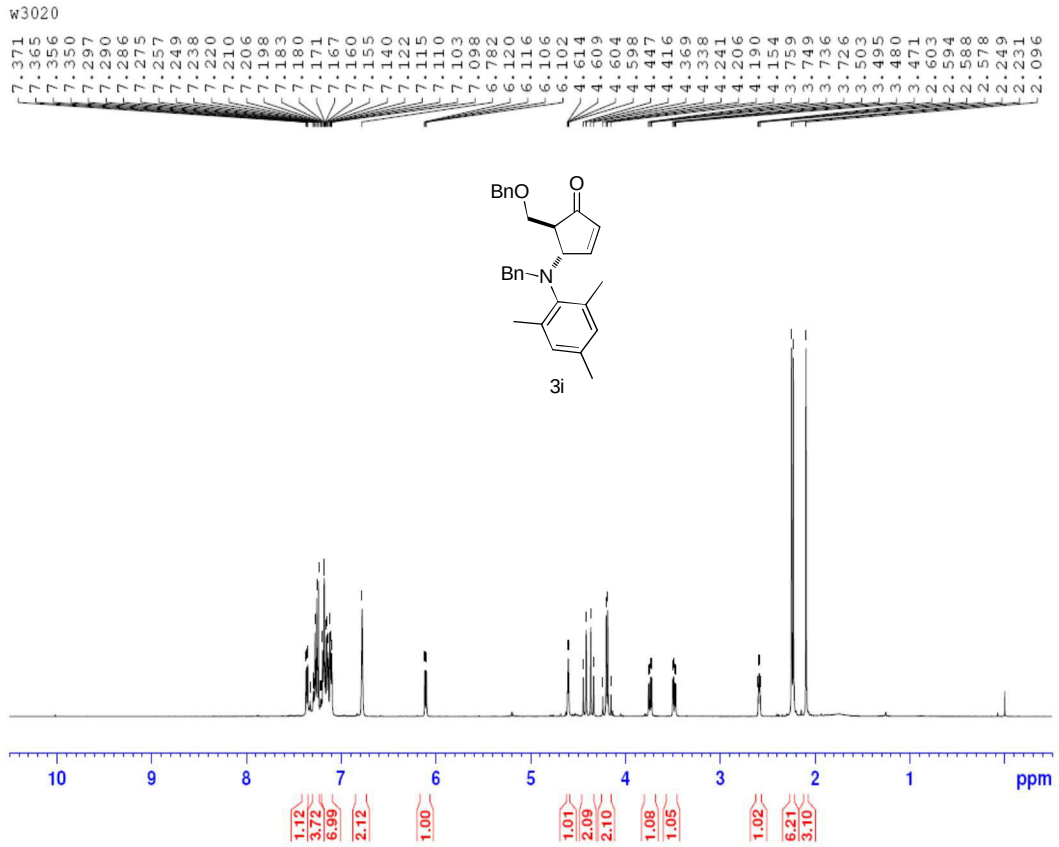
[13] C NMR of compound 3g



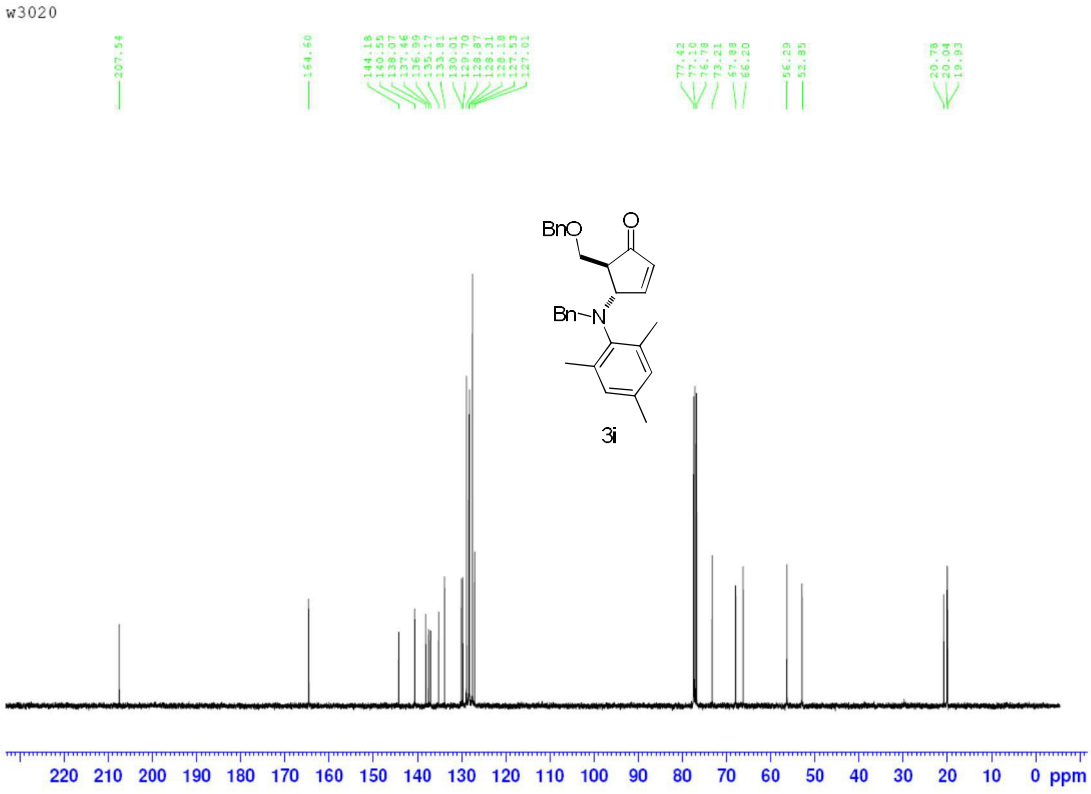
[1] H NMR of compound 3h



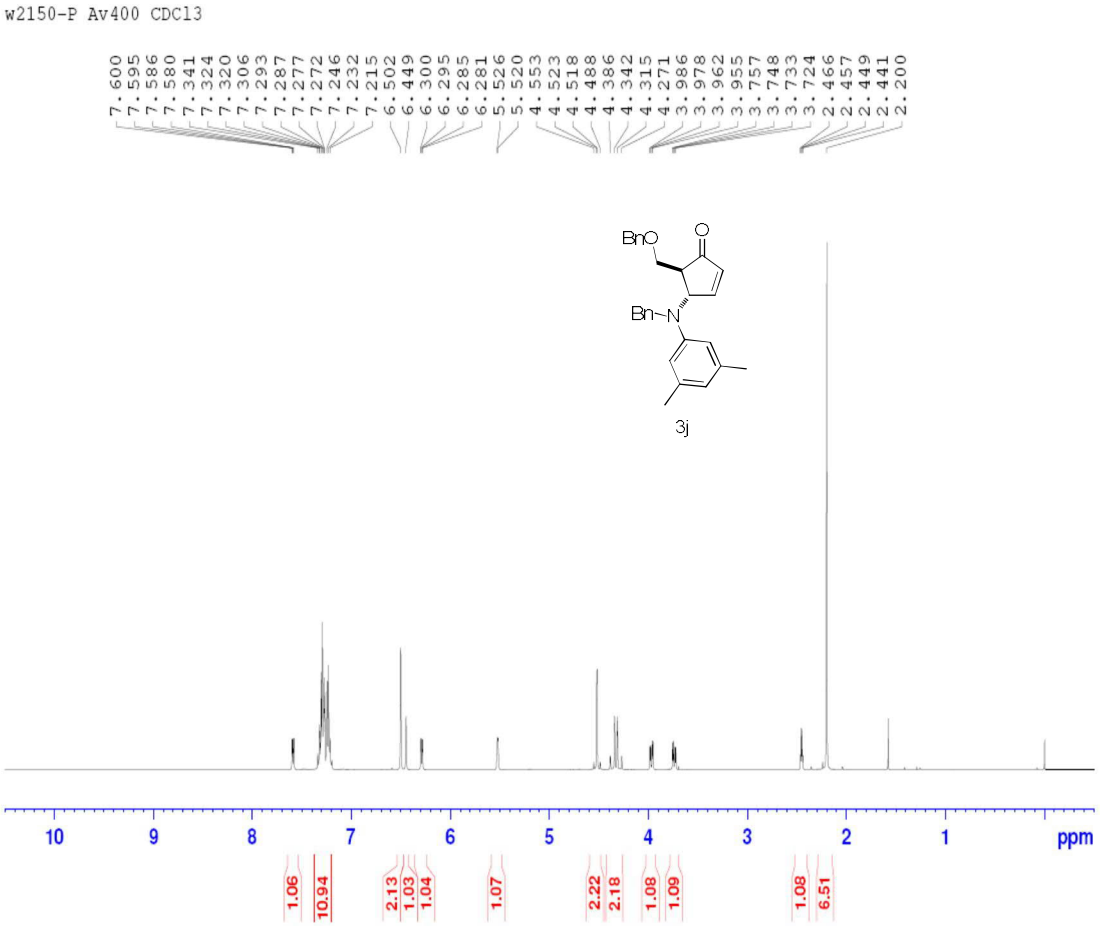
[13] C NMR of compound 3h



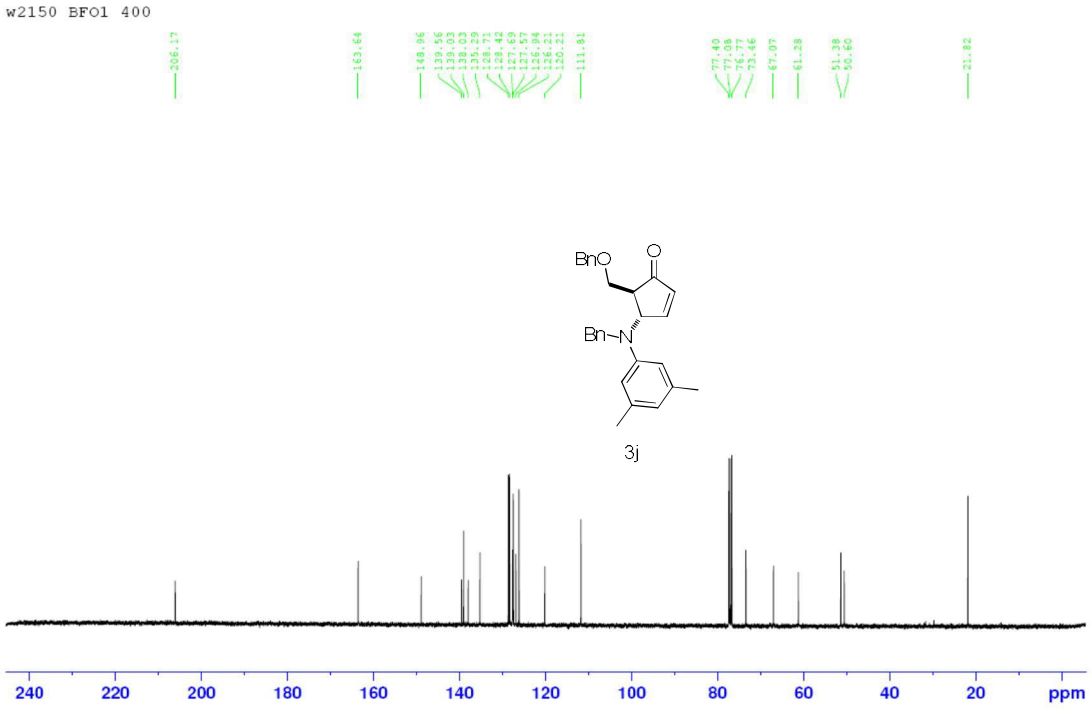
[1] H NMR of compound 3i



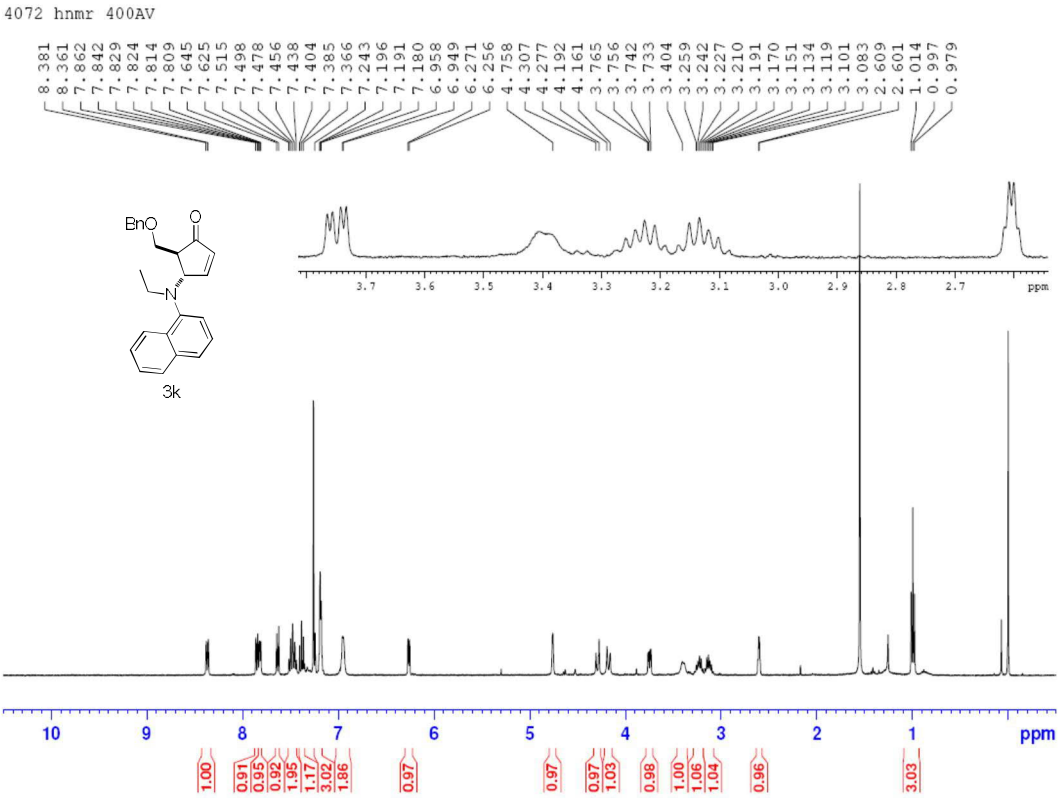
[13] C NMR of compound 3i



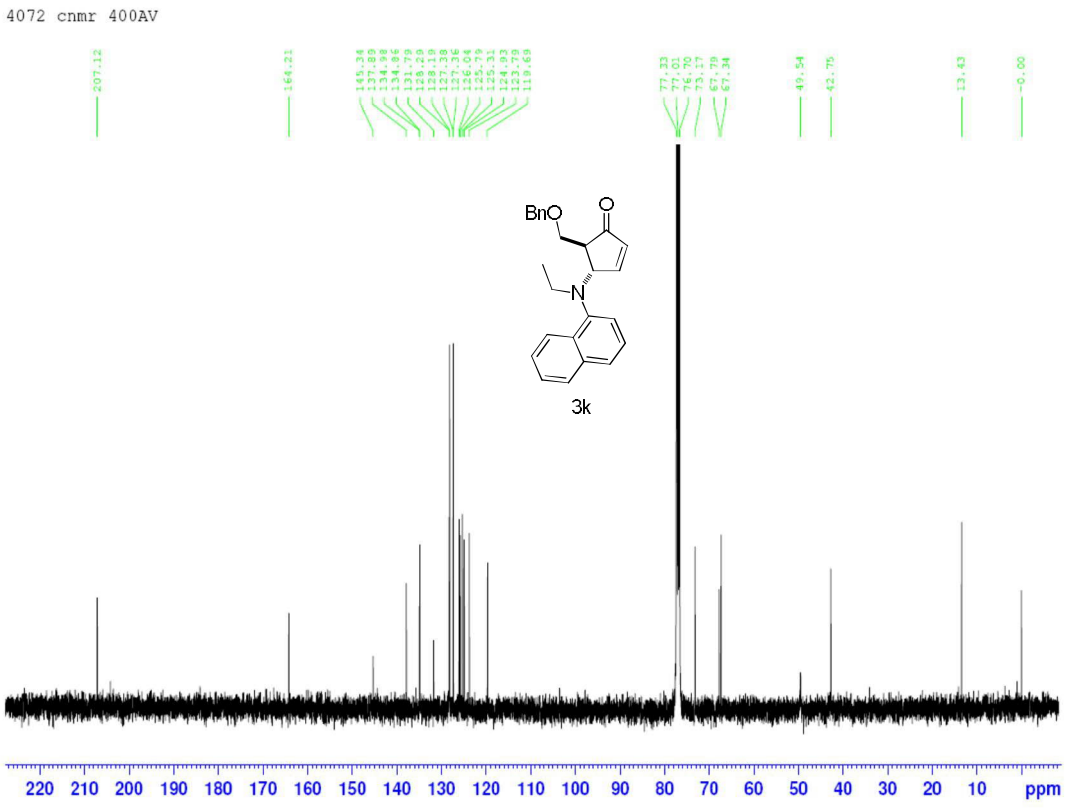
[1] H NMR of compound 3j



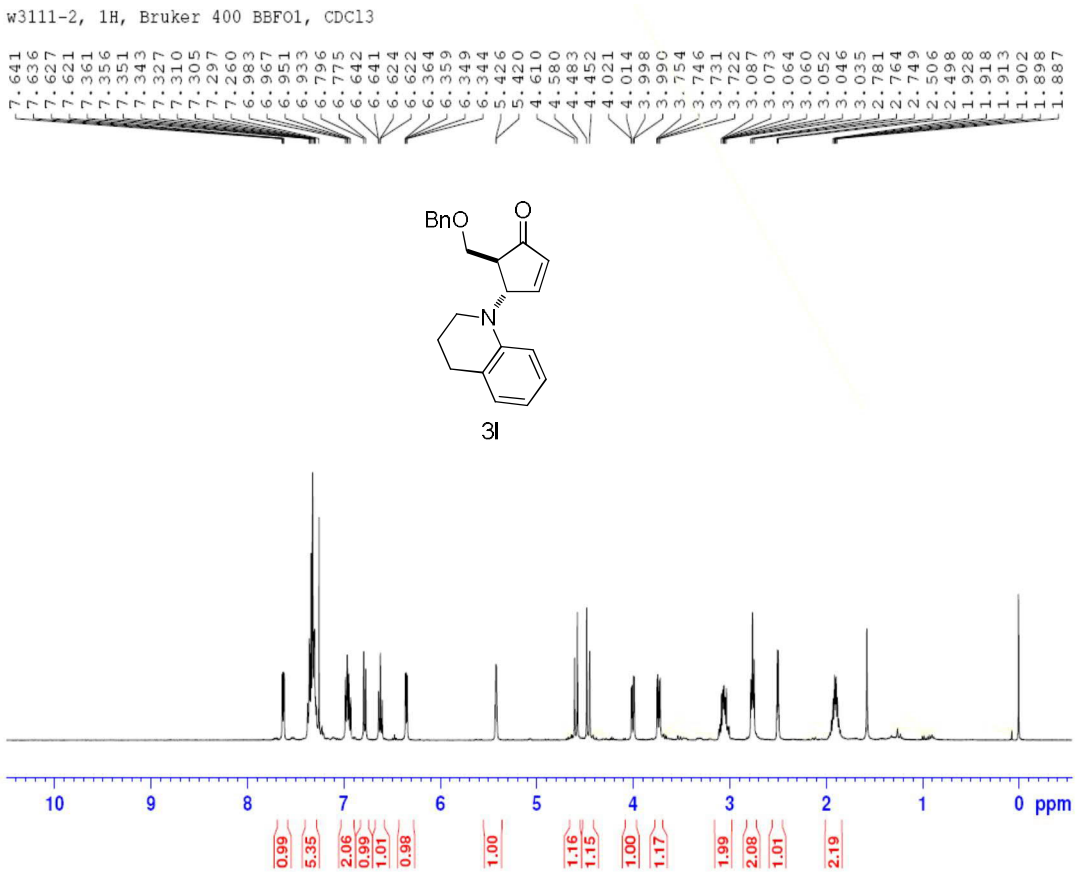
[13] C NMR of compound 3j



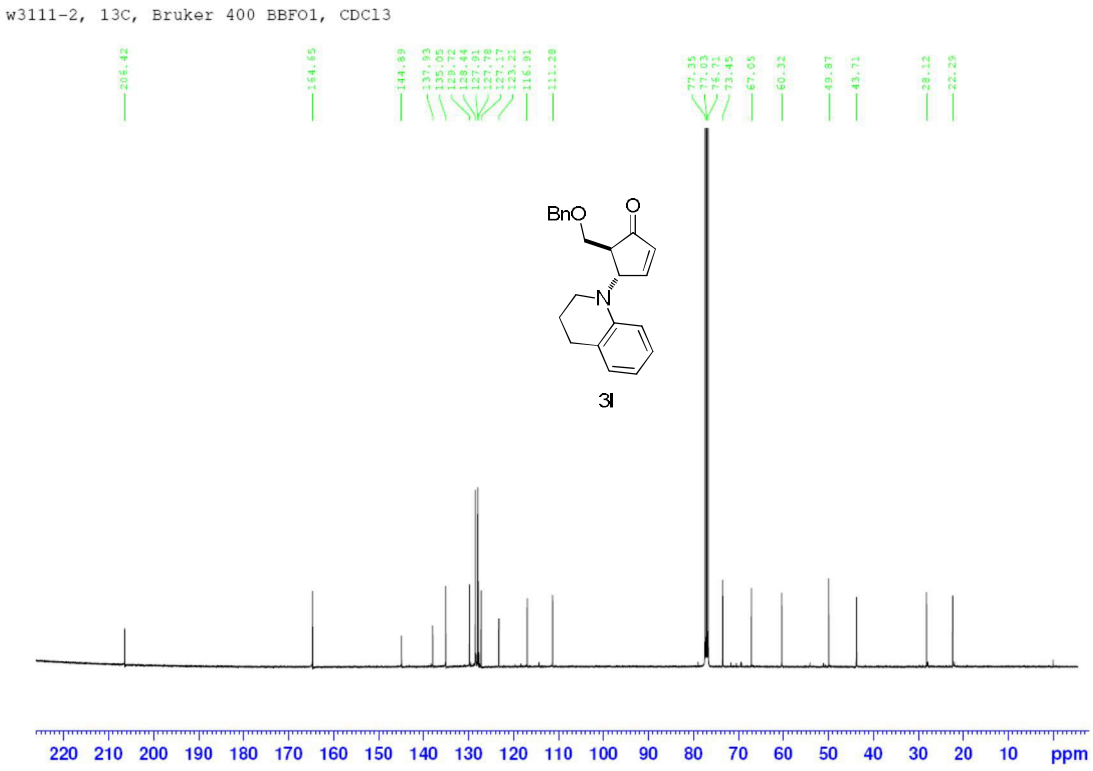
[1] H NMR of compound 3k



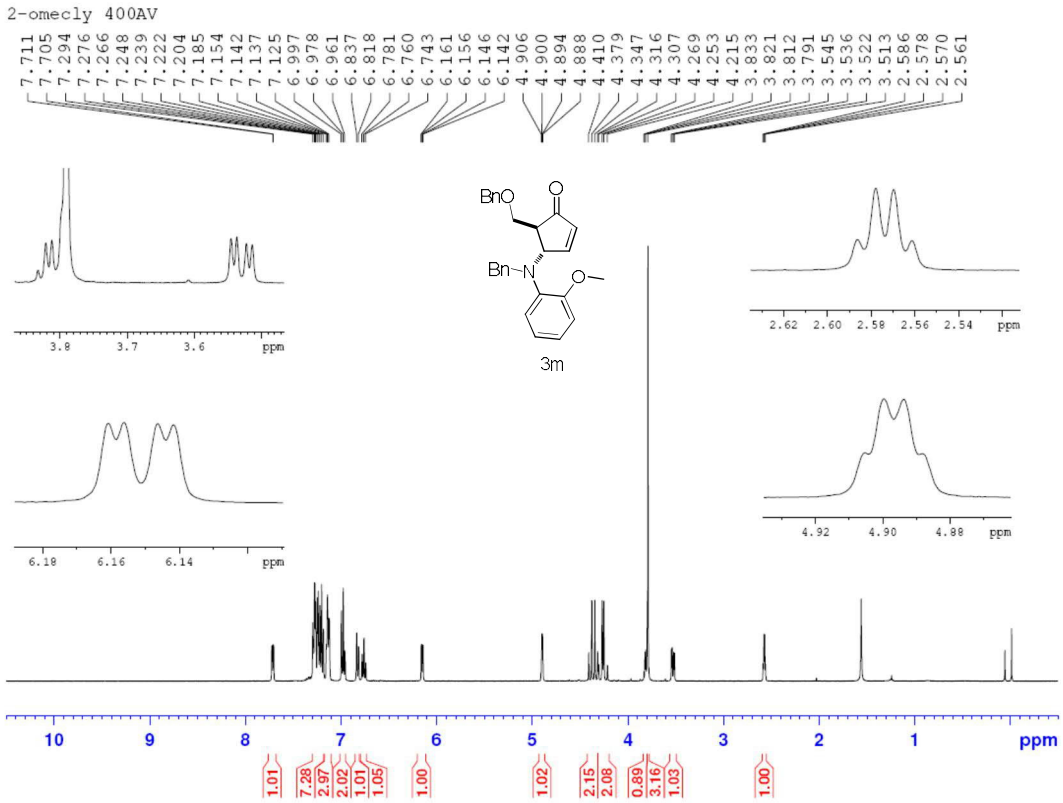
[13] C NMR of compound 3k



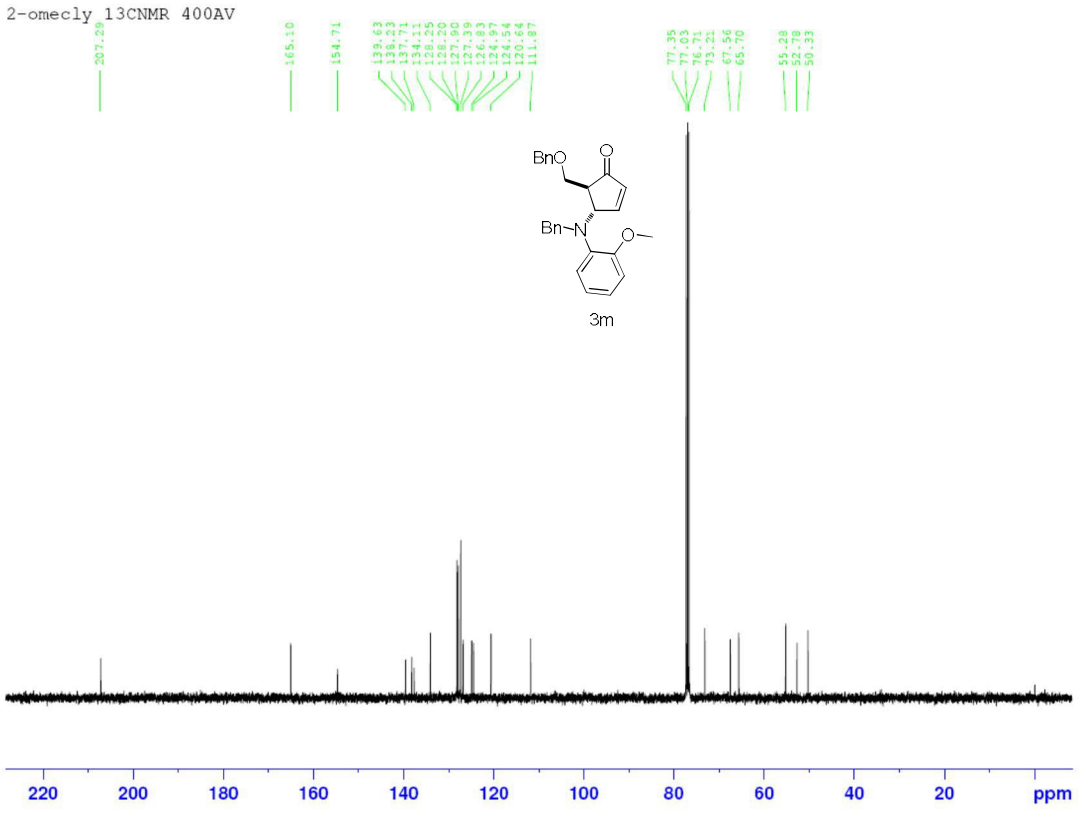
[1] H NMR of compound 3l



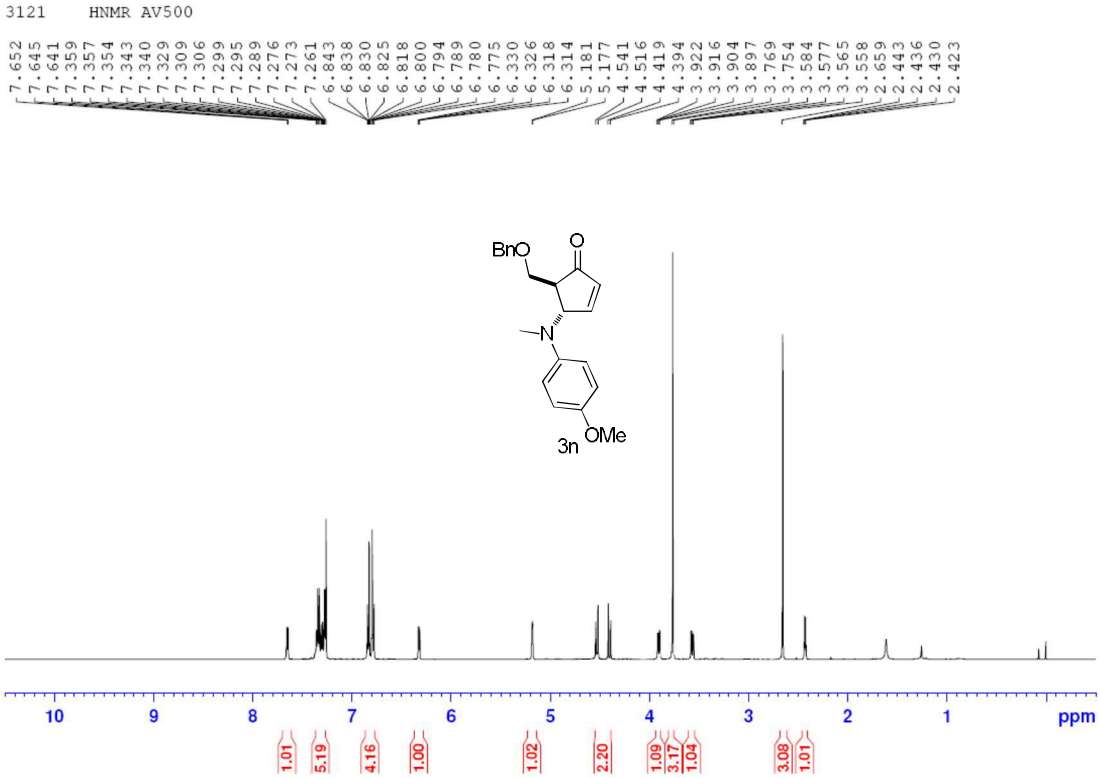
[13] C NMR of compound 3l



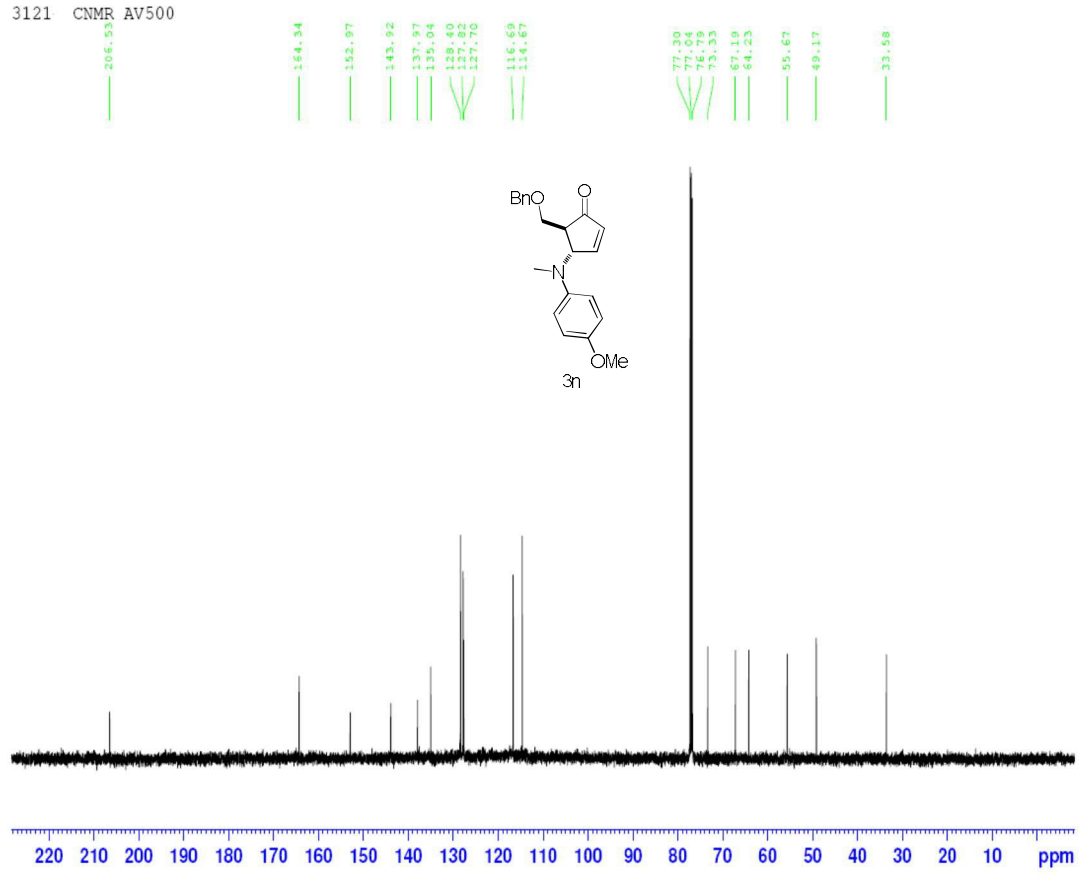
[1] H NMR of compound 3m



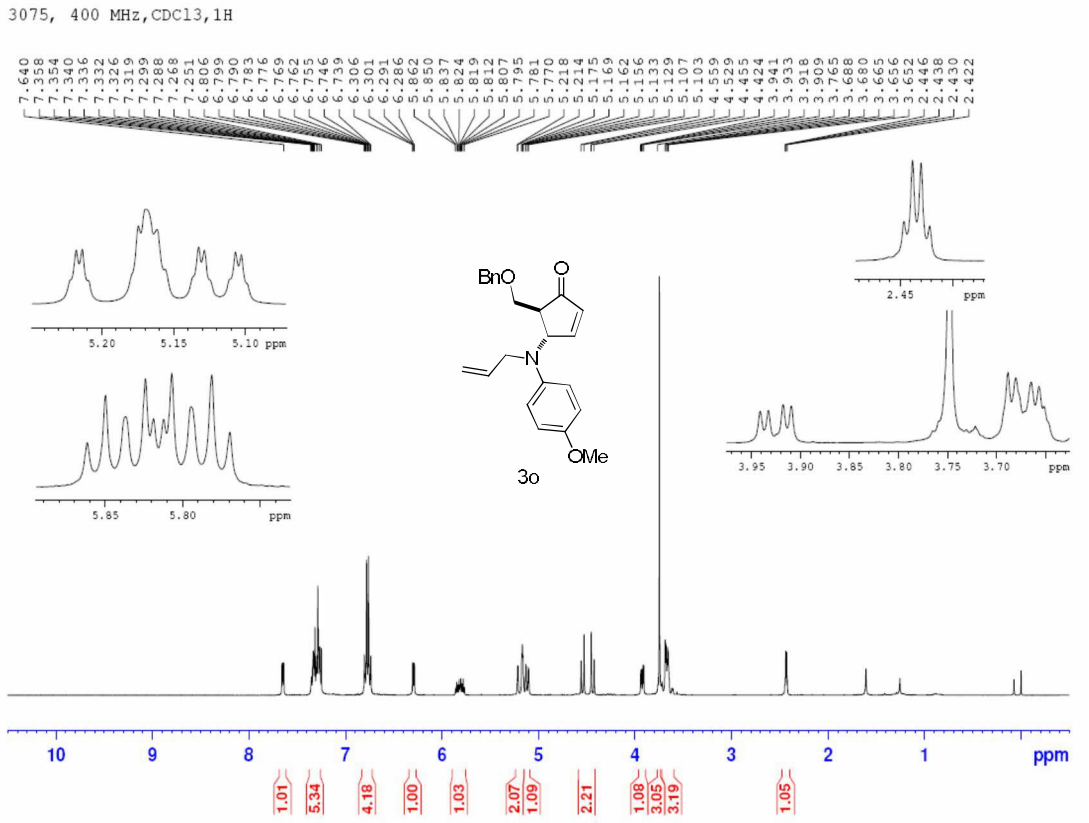
[13] C NMR of compound 3m



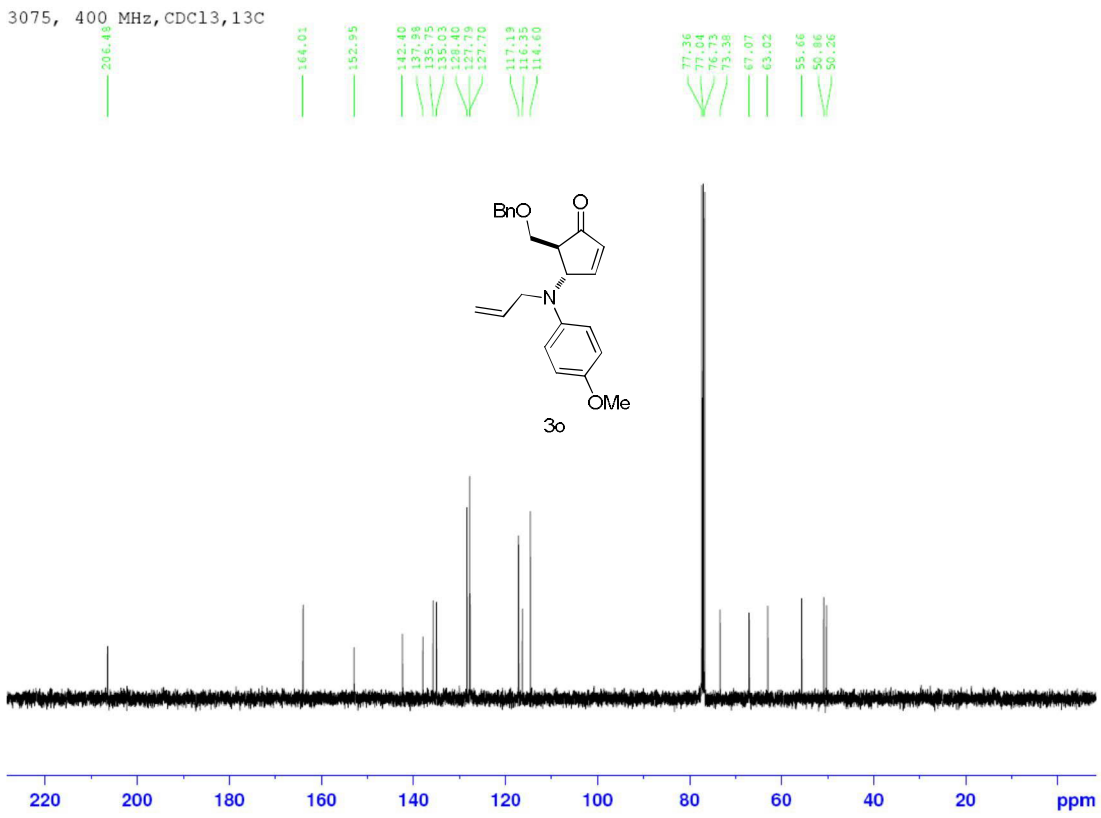
[1] H NMR of compound 3n



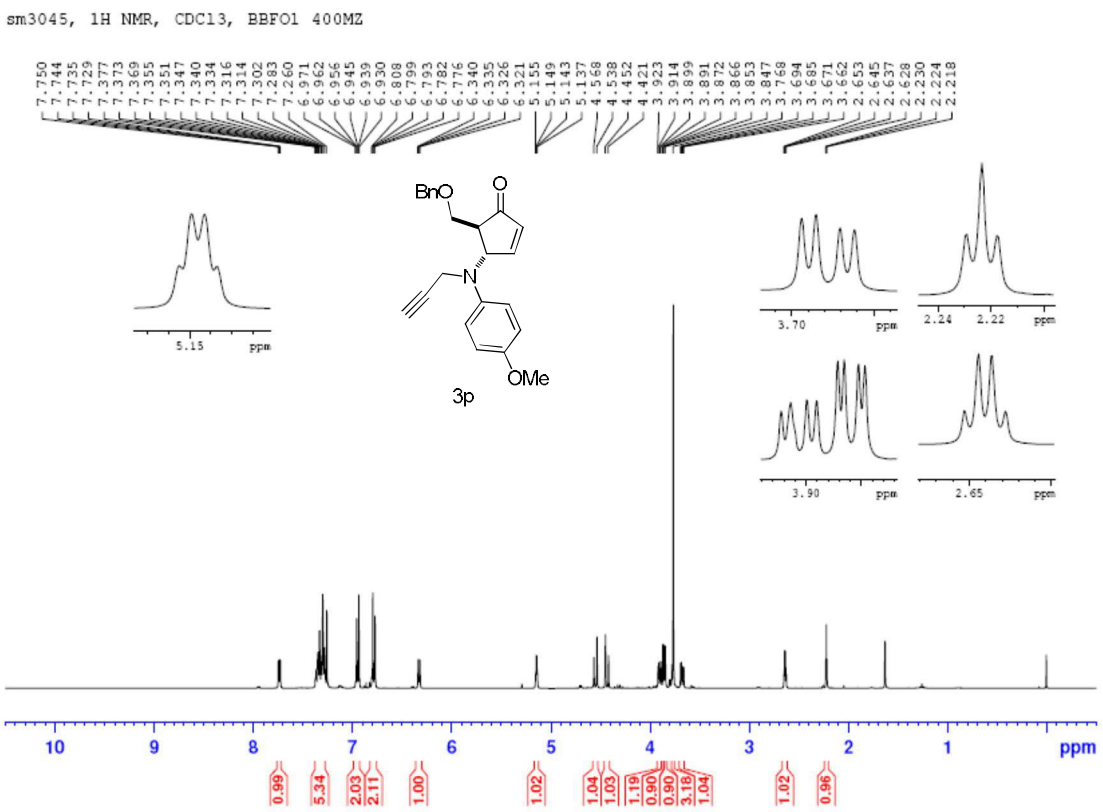
[13] C NMR of compound 3n



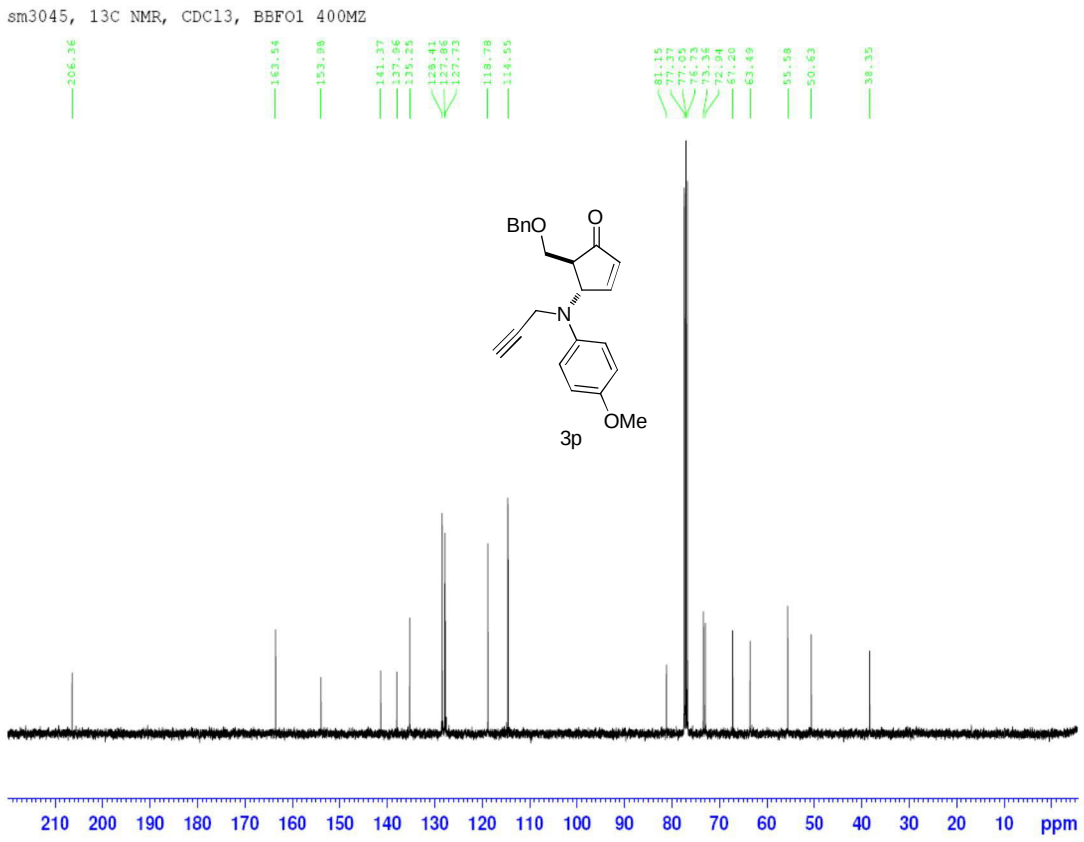
[1] H NMR of compound 3o



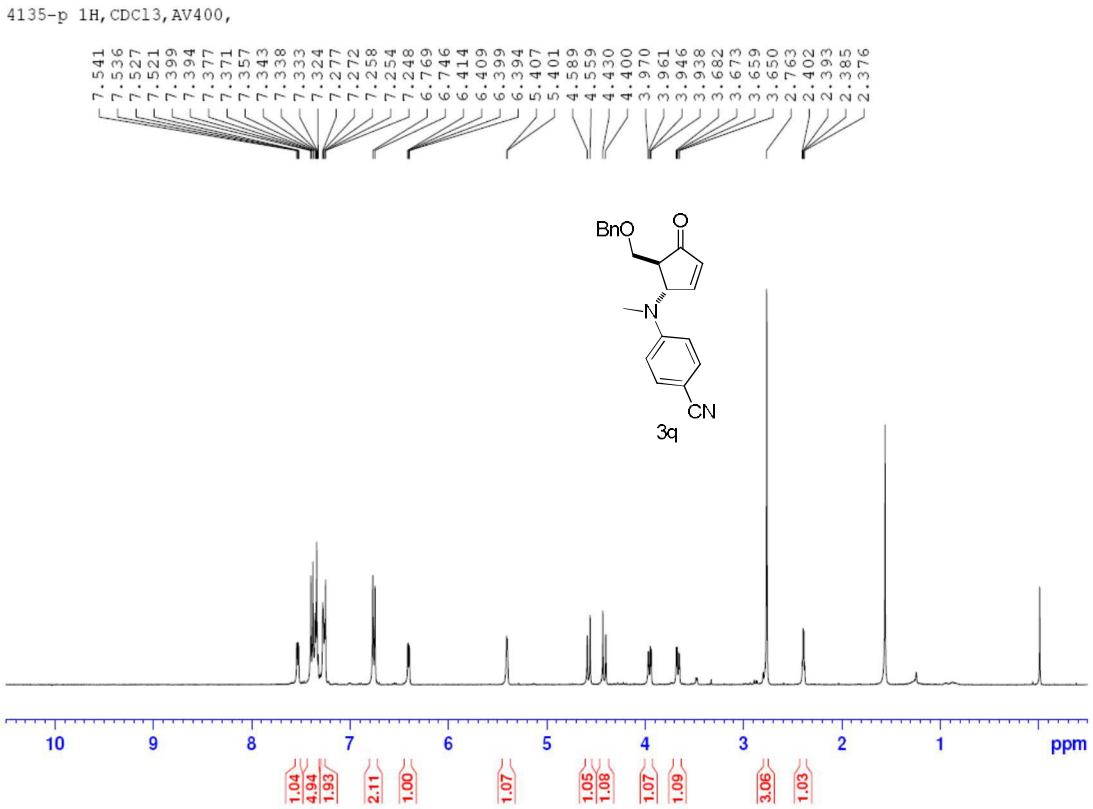
[13] C NMR of compound 3o



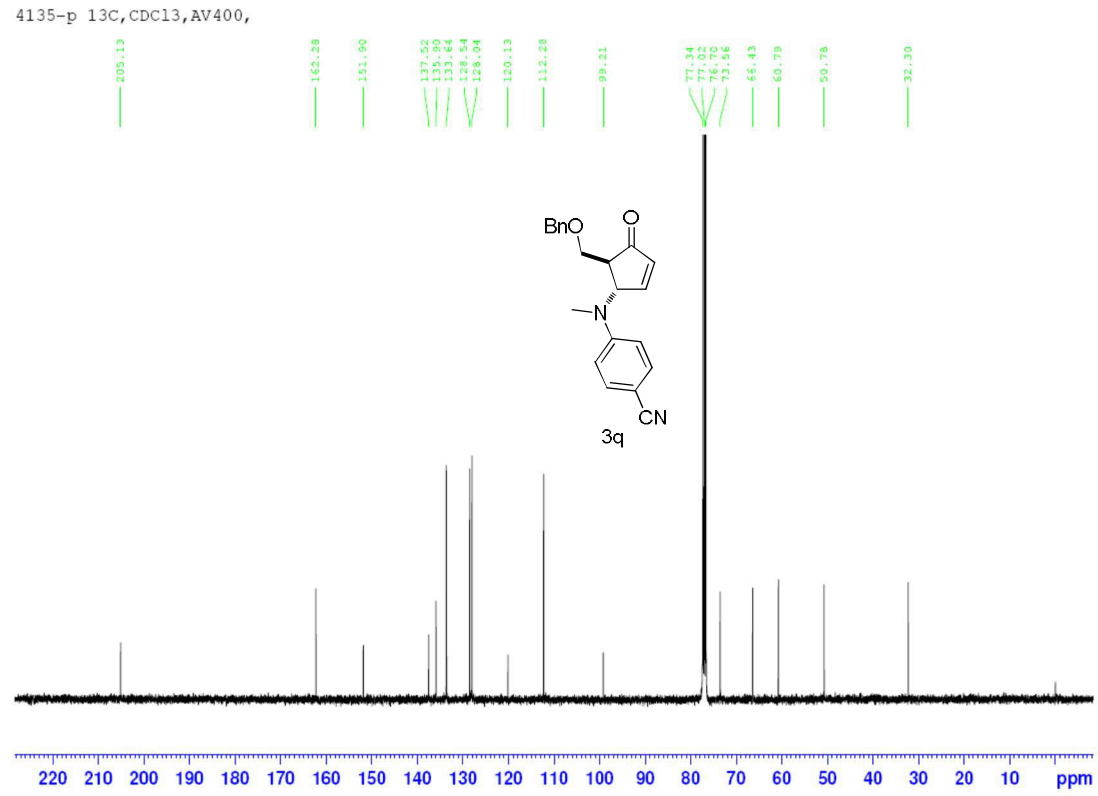
[1] H NMR of compound 3p



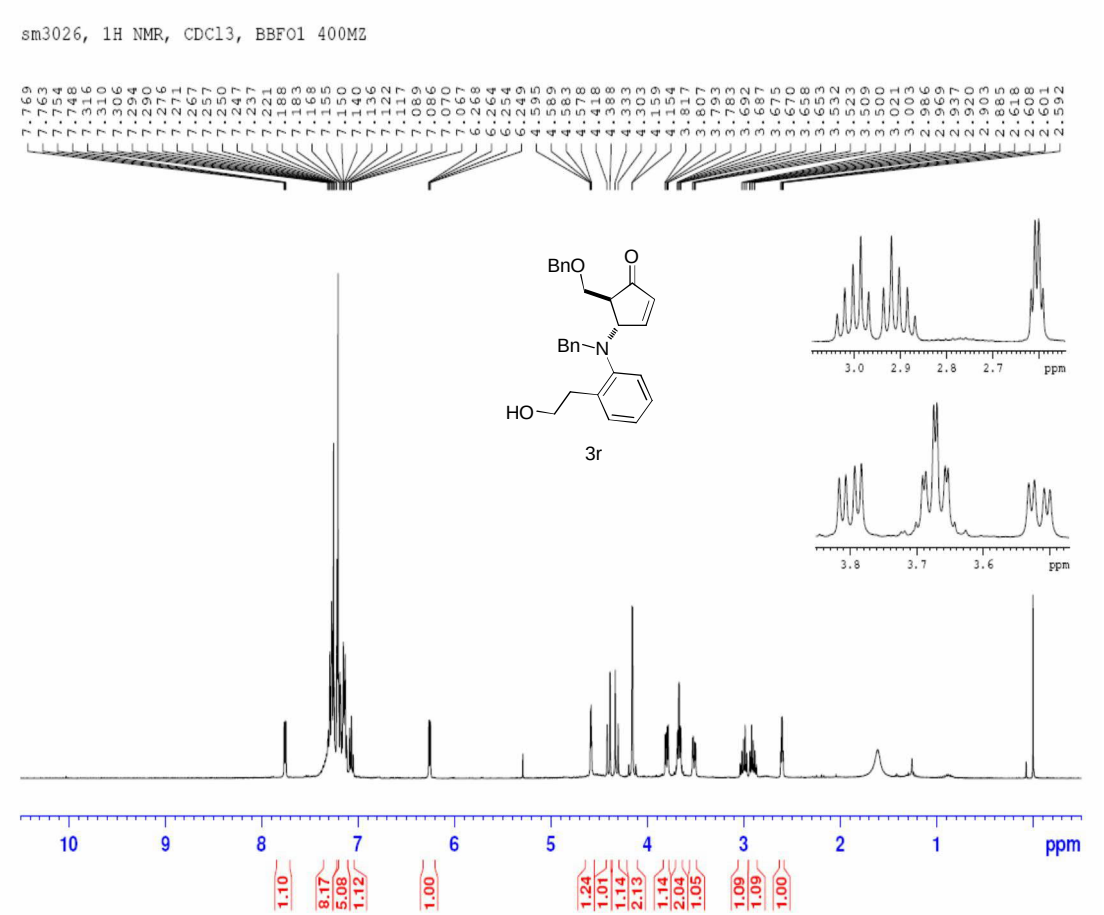
[13] C NMR of compound 3p



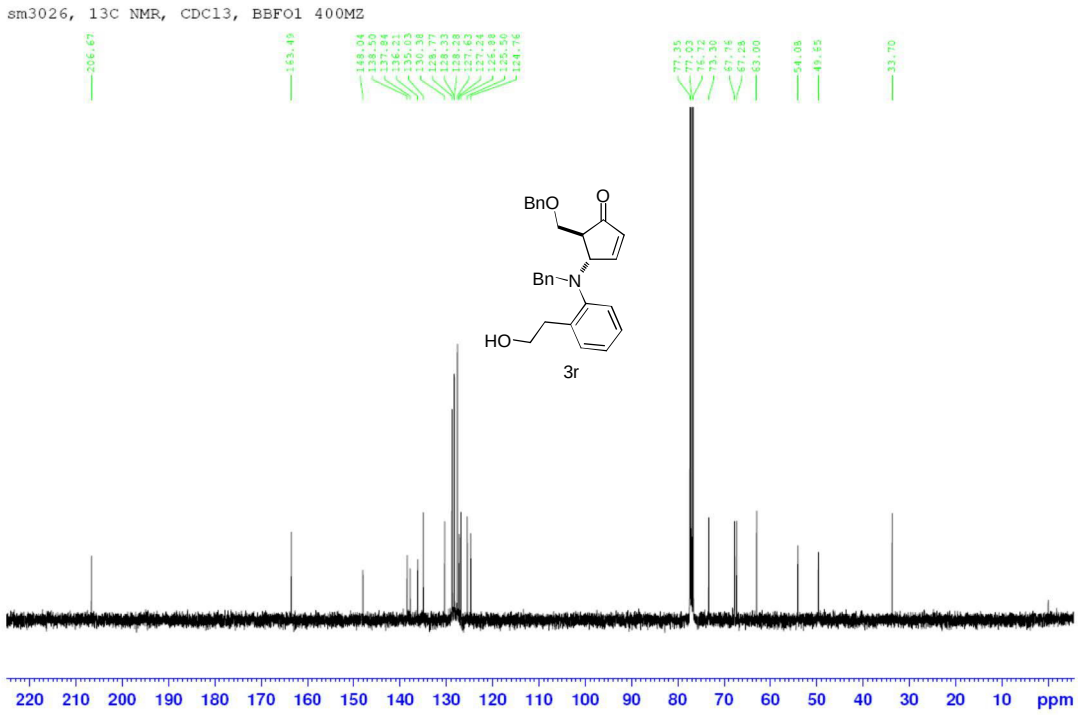
[1] H NMR of compound 3q



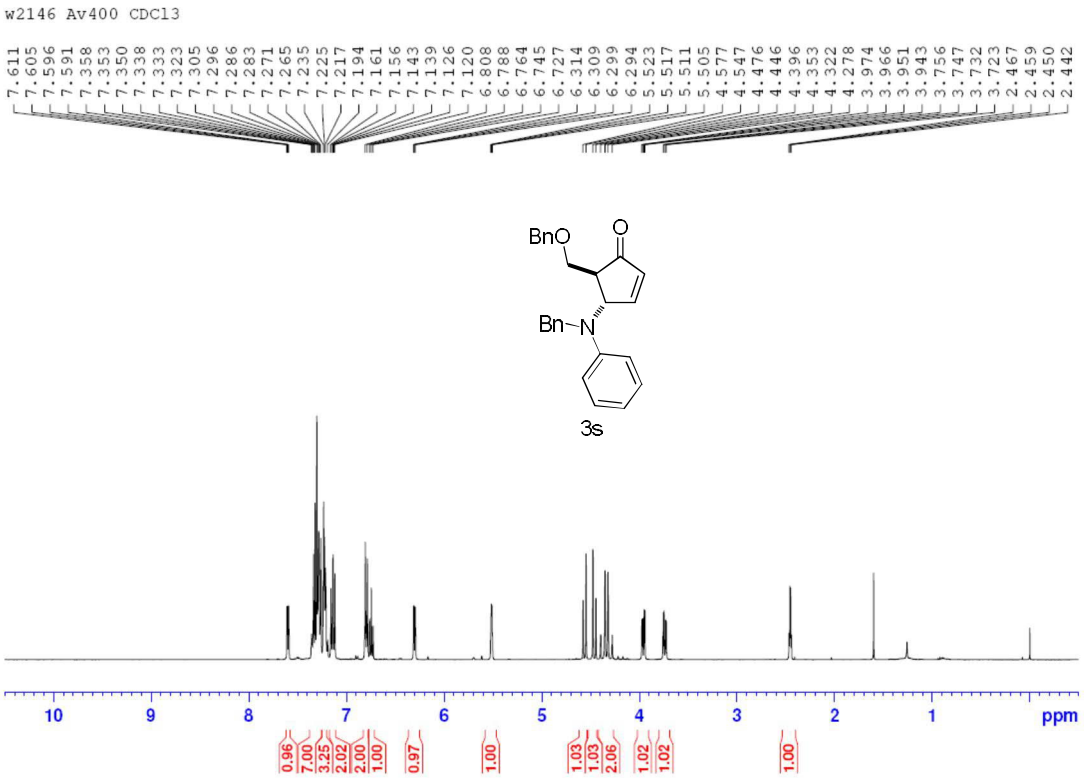
[13] C NMR of compound 3q



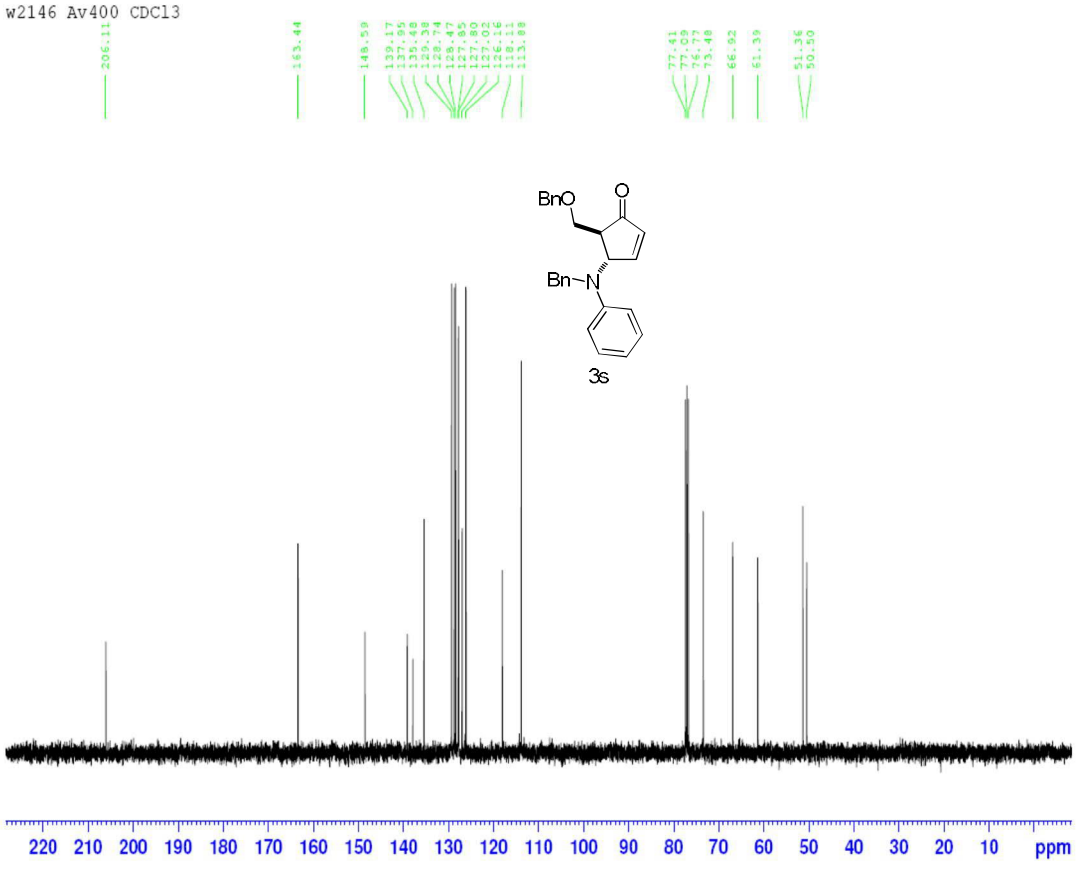
[1] H NMR of compound 3r



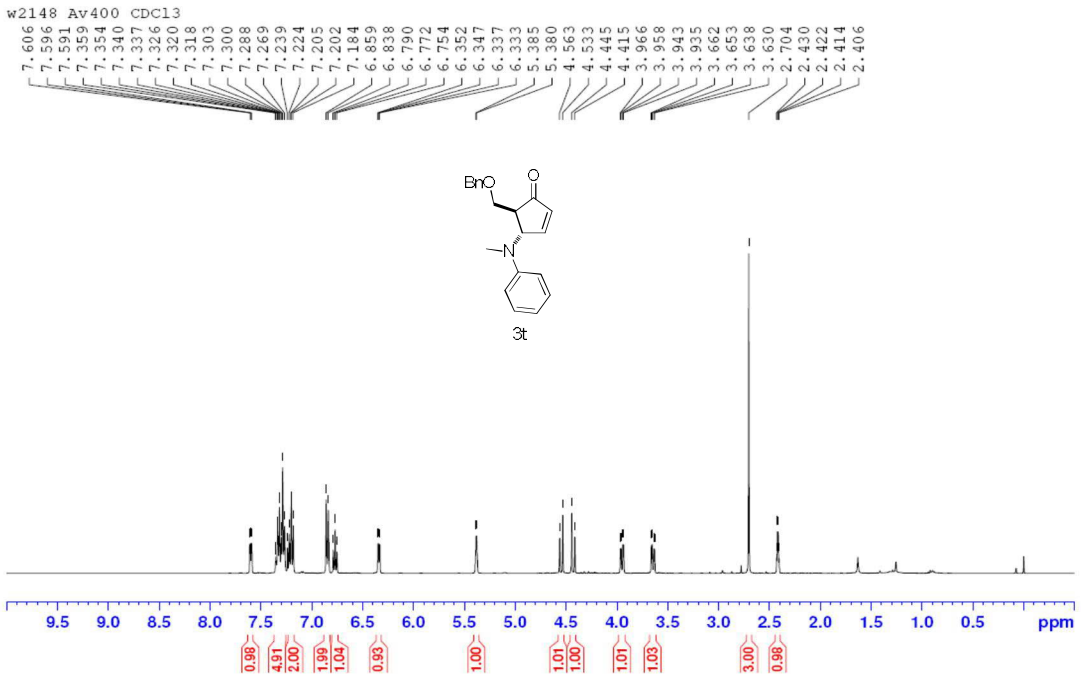
[13] C NMR of compound 3r



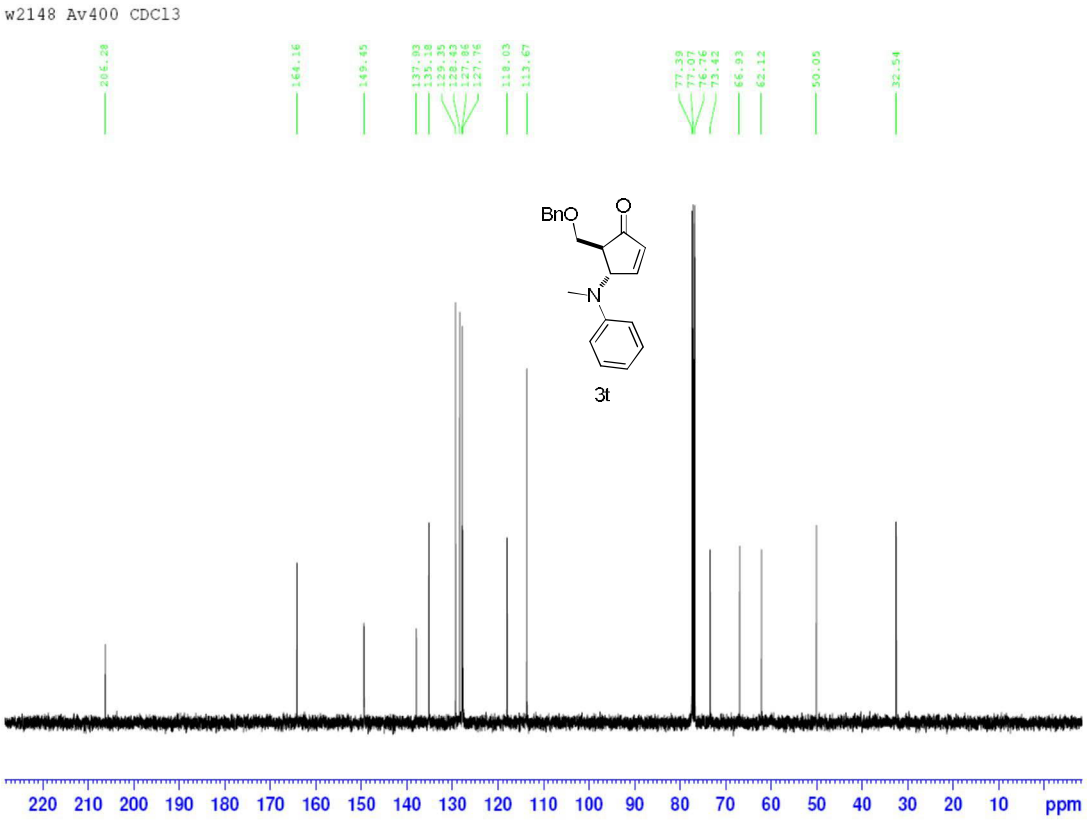
[1] H NMR of compound 3s



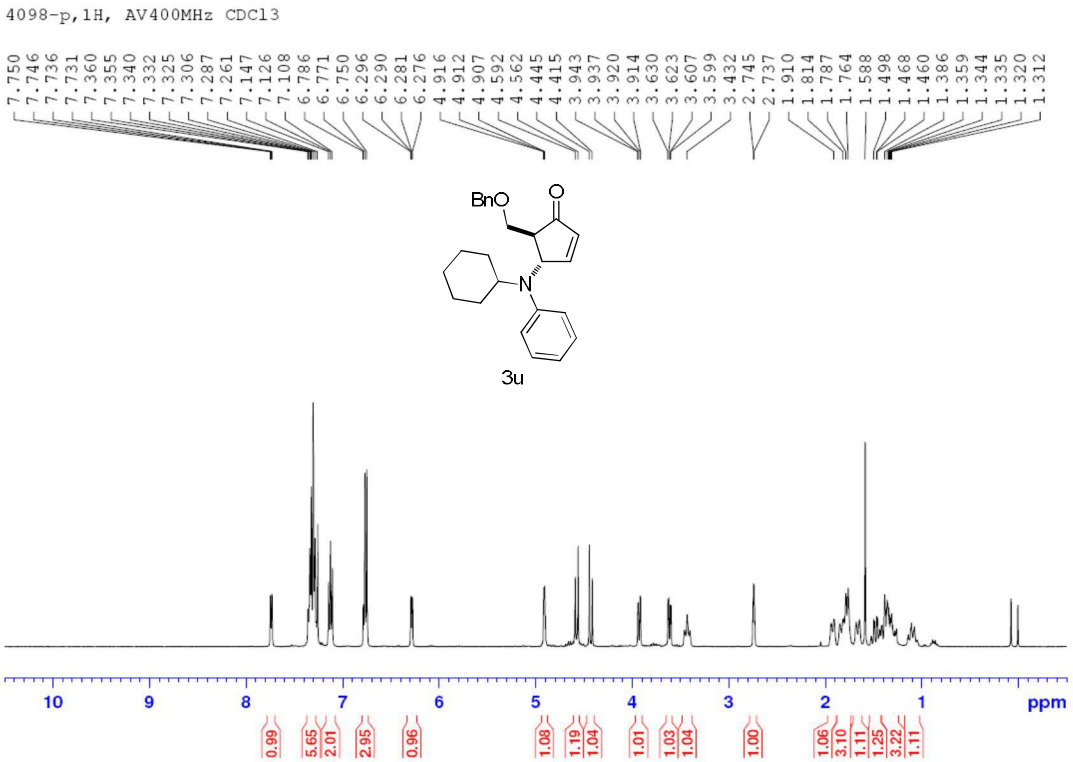
[13] C NMR of compound 3s



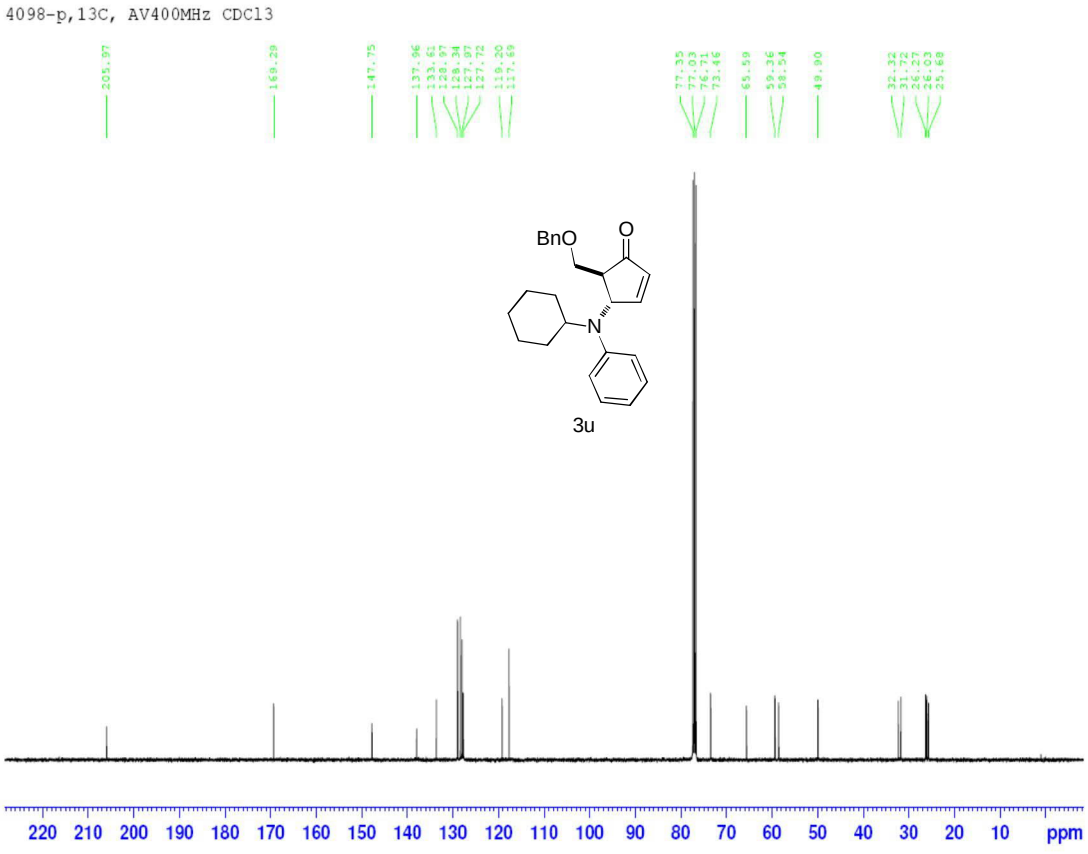
^{1} H NMR of compound 3t



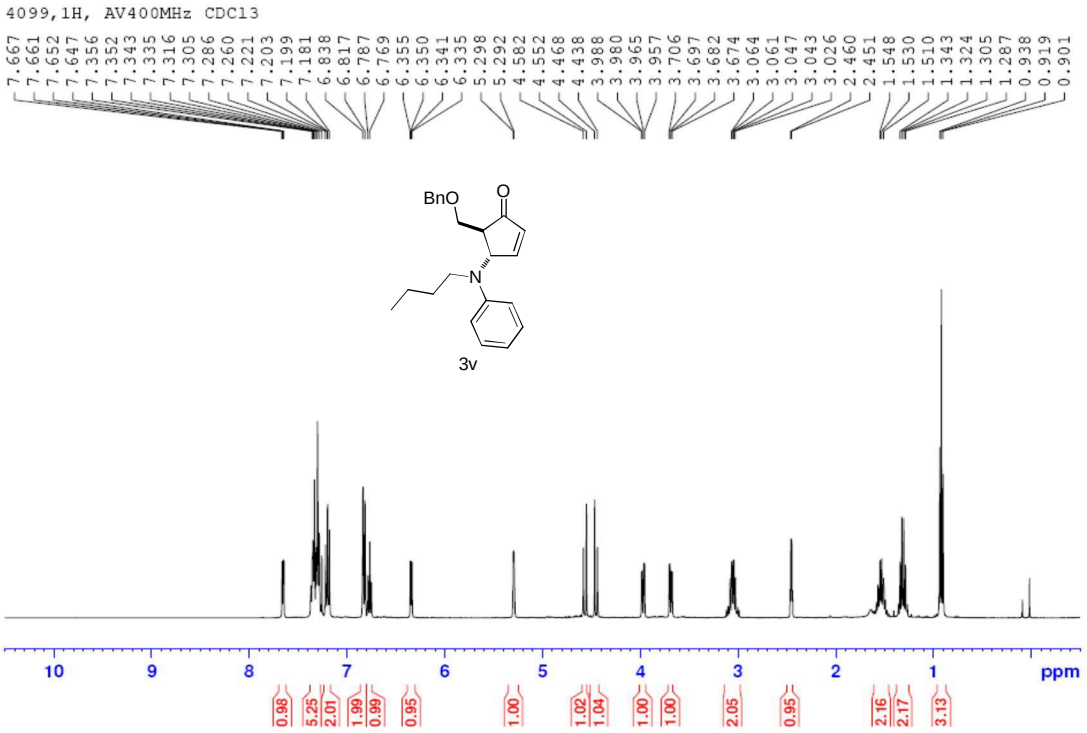
^{13} C NMR of compound 3t



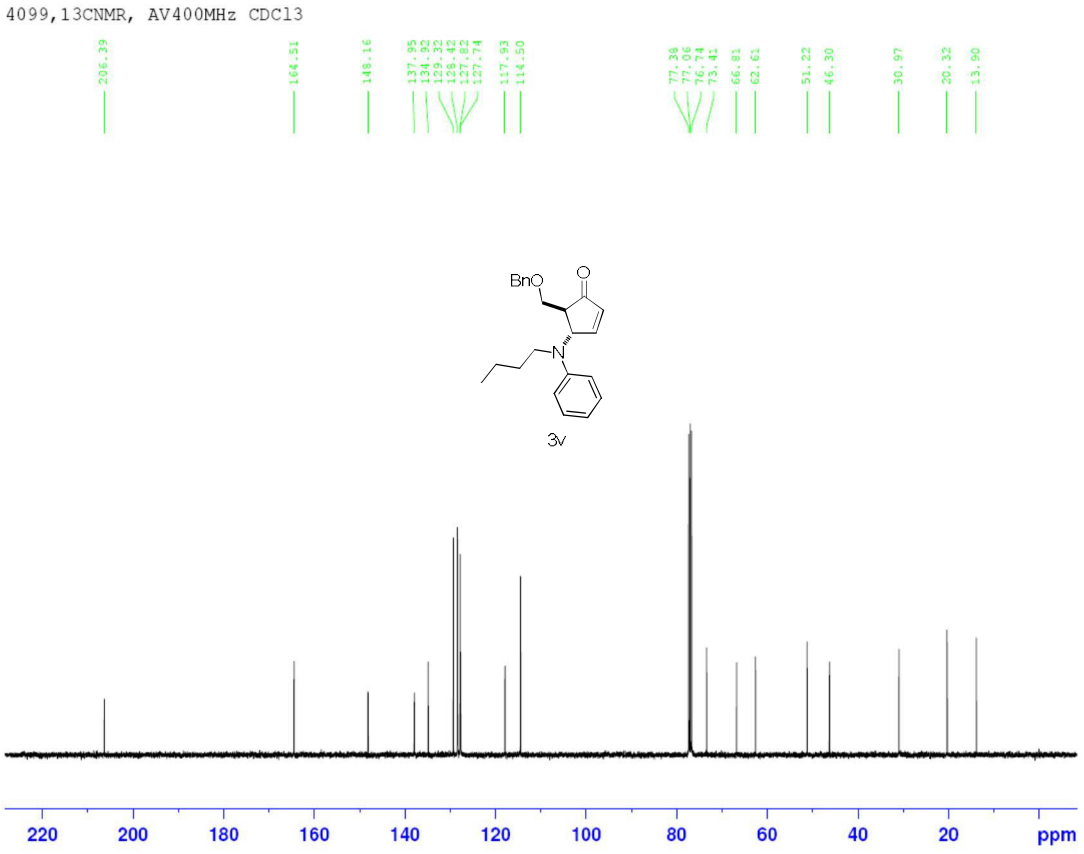
[1] H NMR of compound 3u



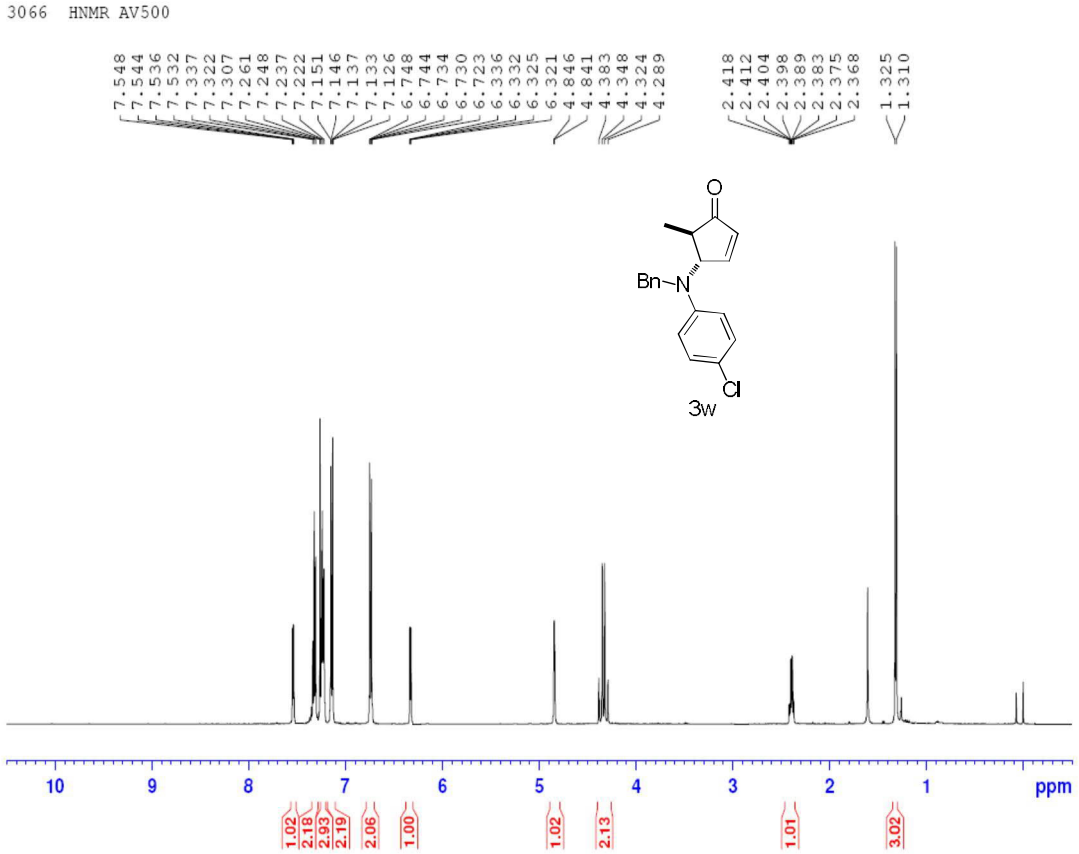
[13] C NMR of compound 3u



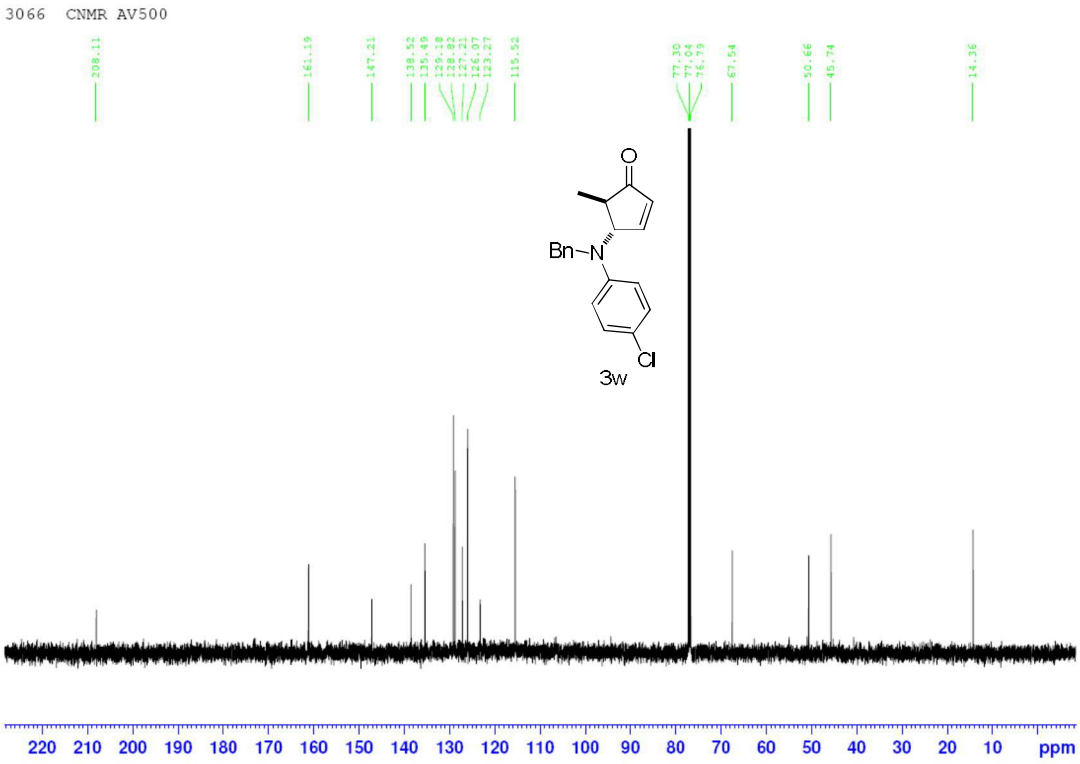
[1] H NMR of compound 3v



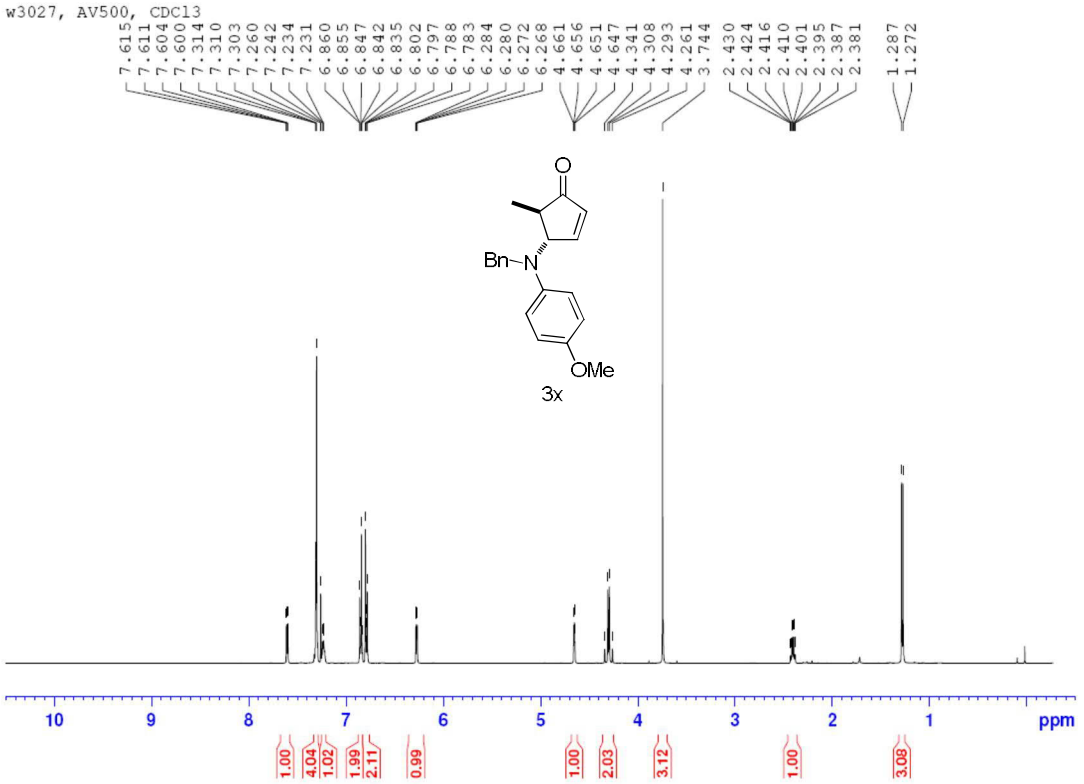
[13] C NMR of compound 3v



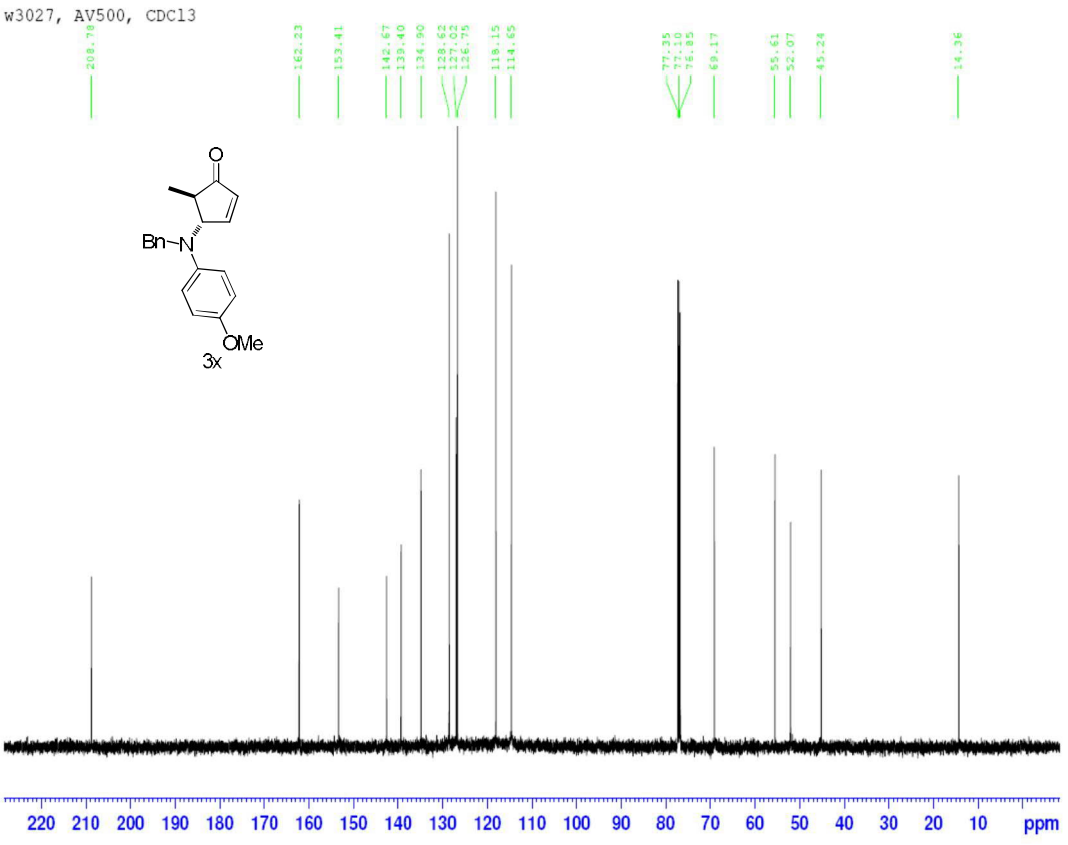
[1] H NMR of compound 3w



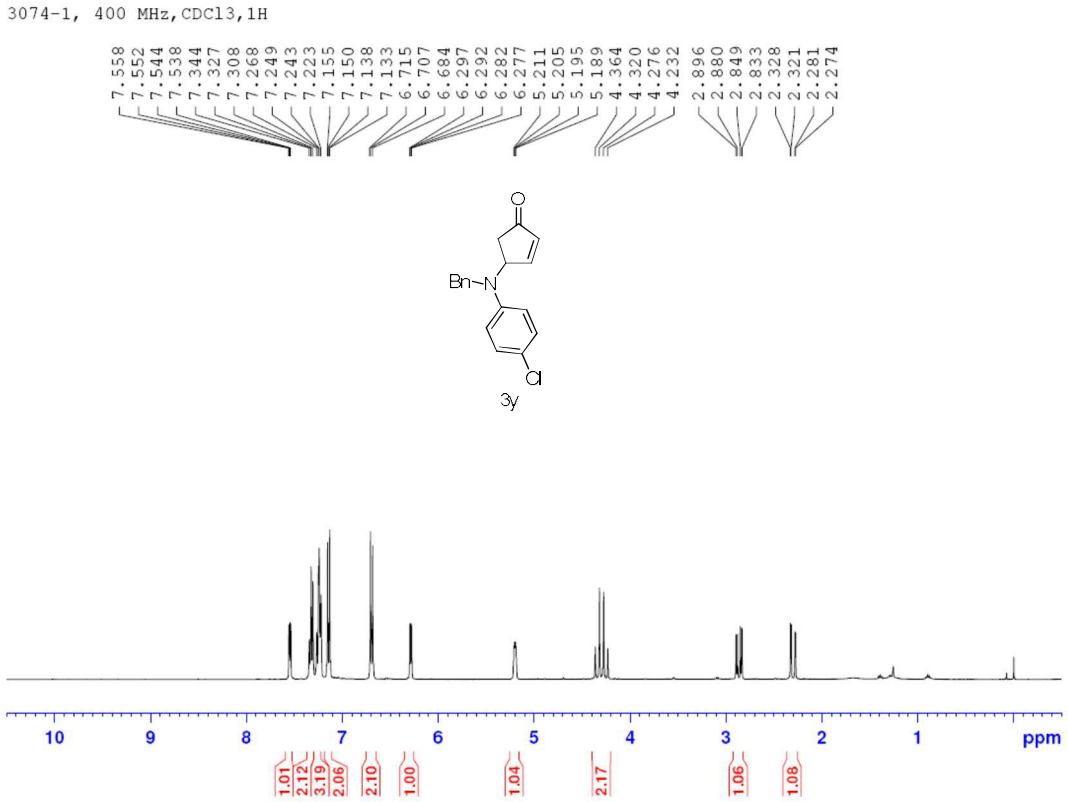
[13] C NMR of compound 3w



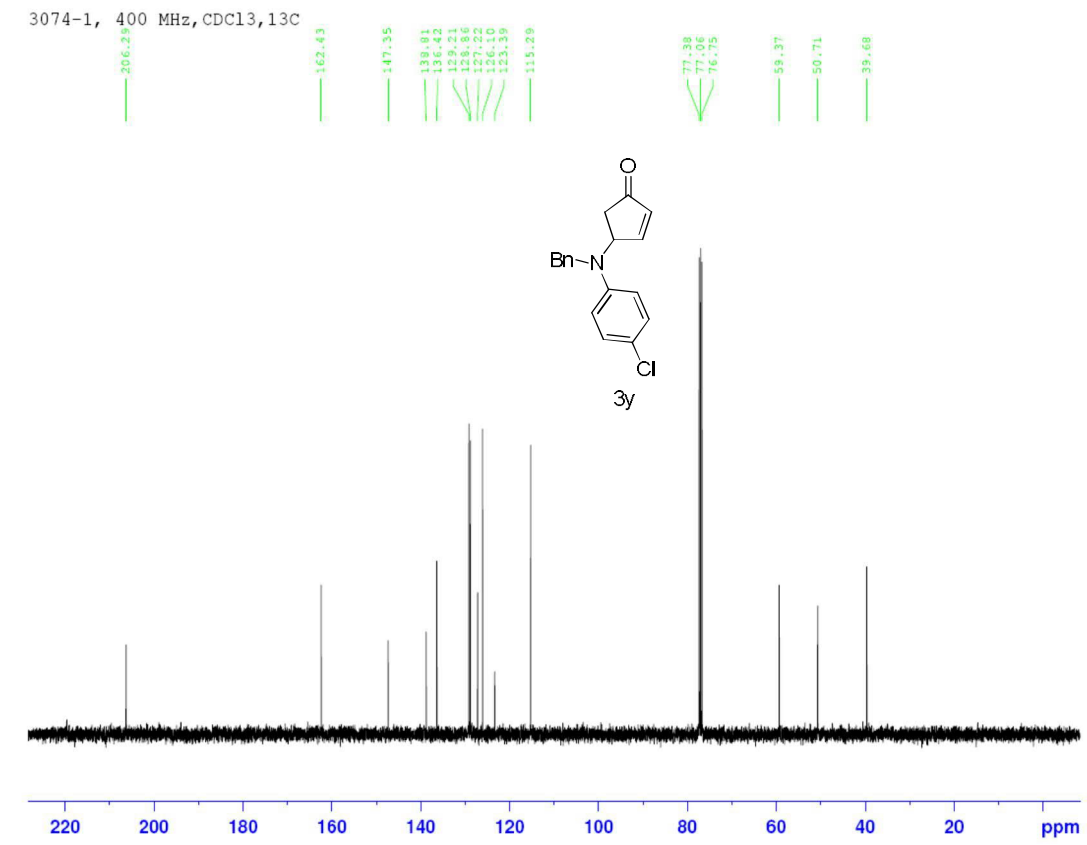
[1] H NMR of compound 3x



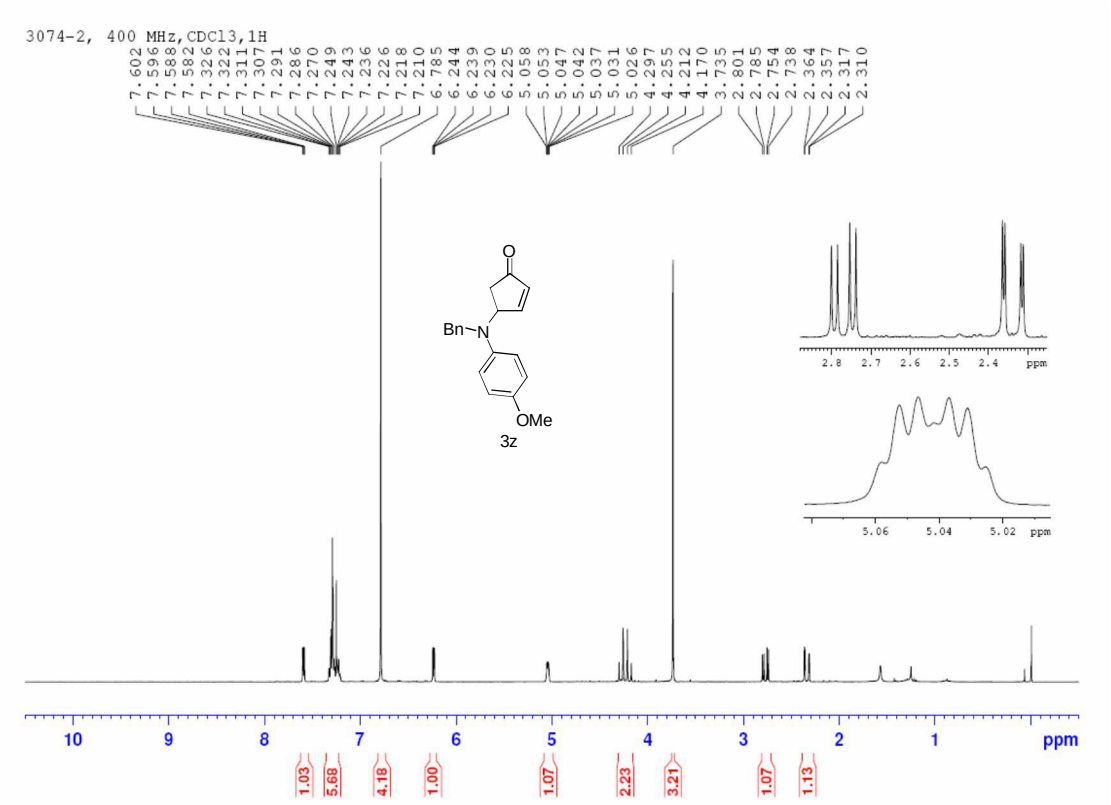
[13] C NMR of compound 3x



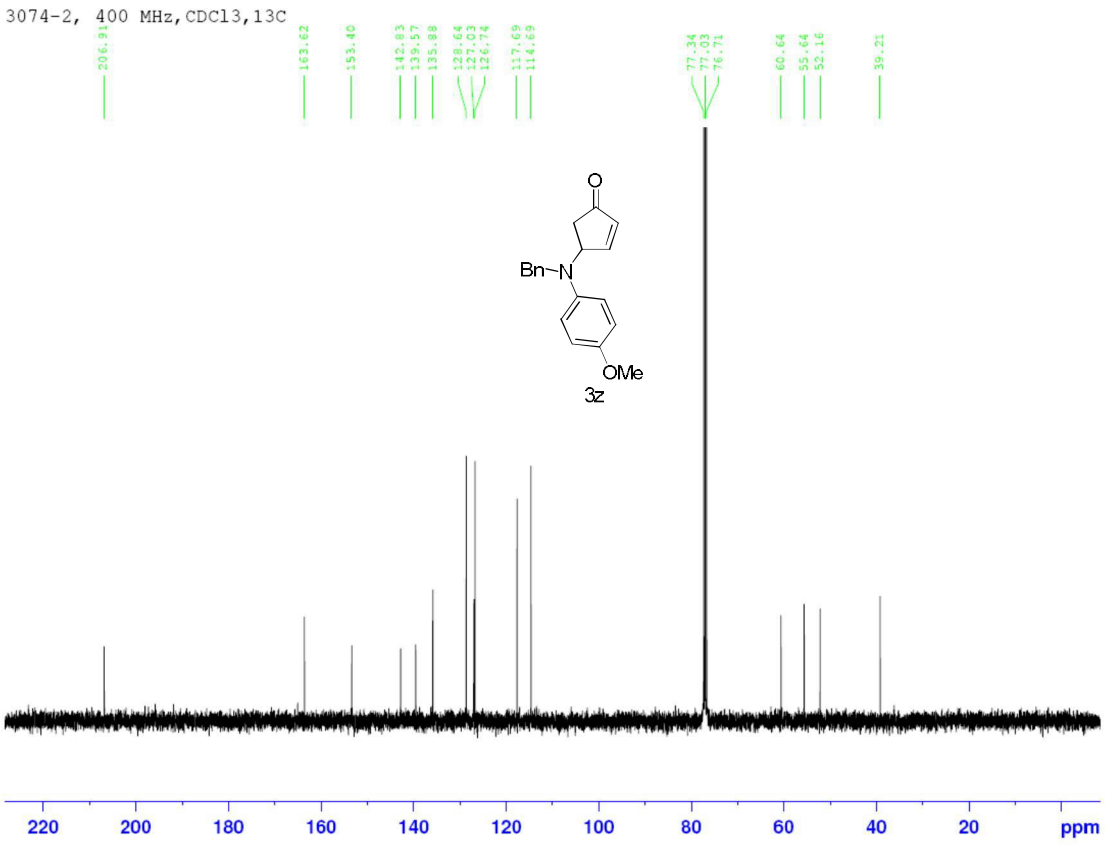
[1] H NMR of compound 3y



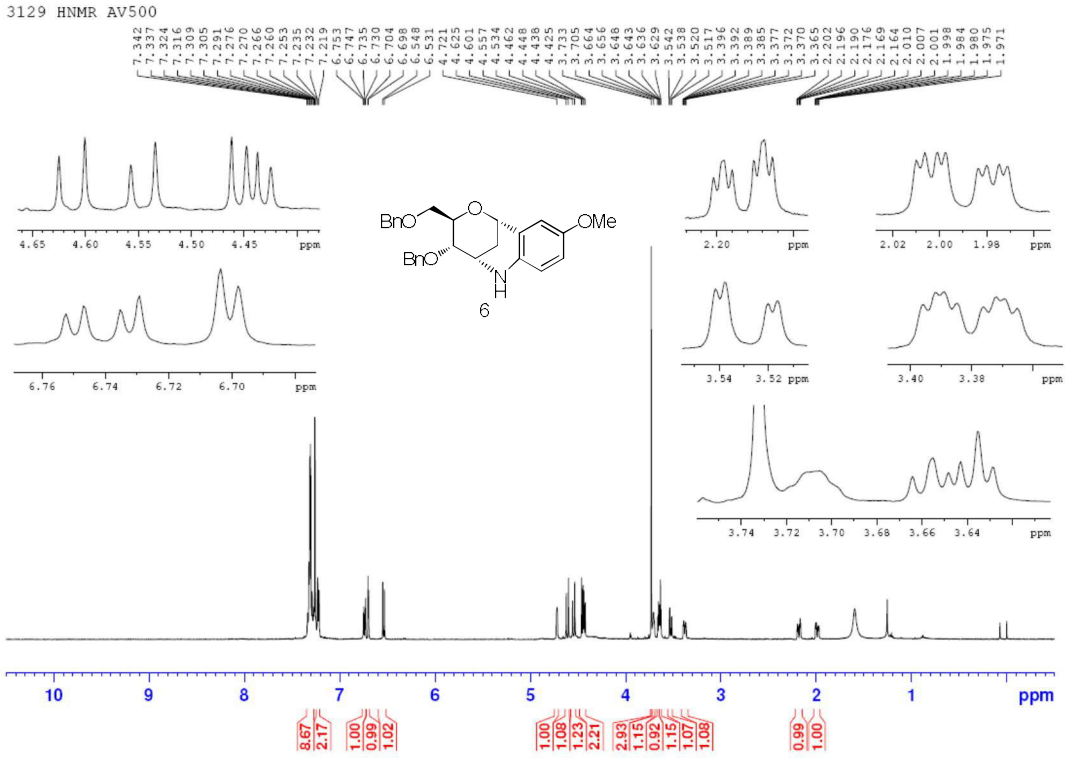
[13] C NMR of compound 3y



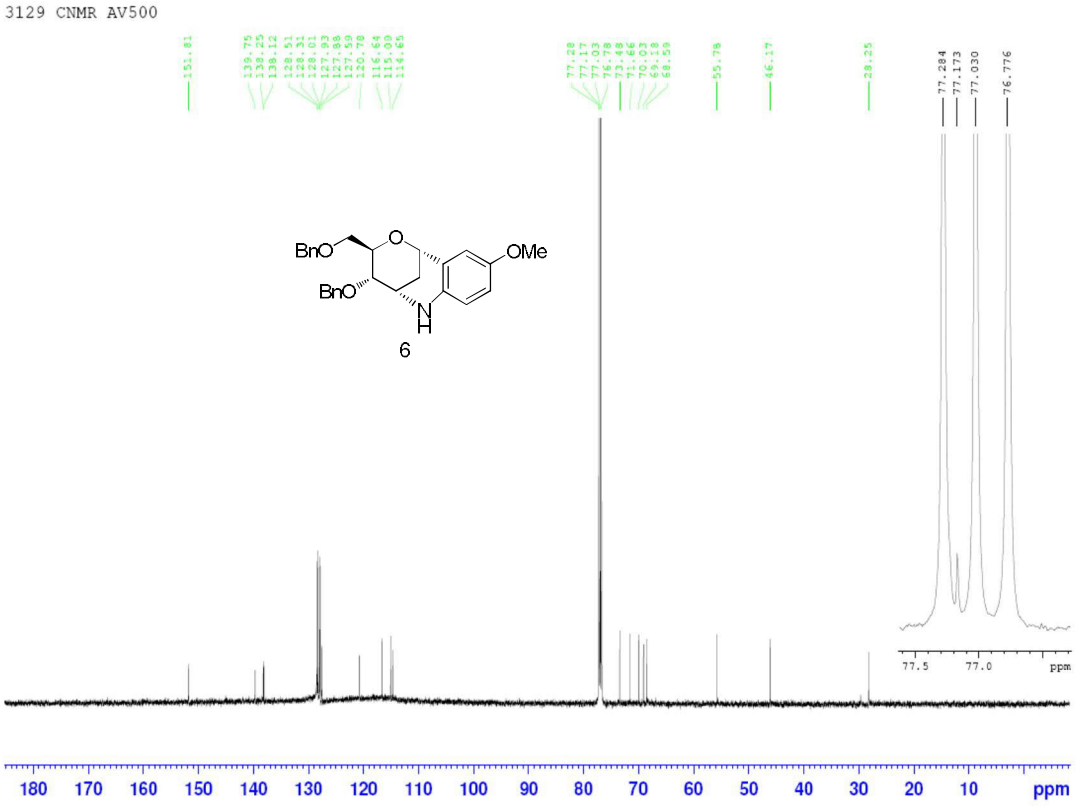
[1] H NMR of compound 3z



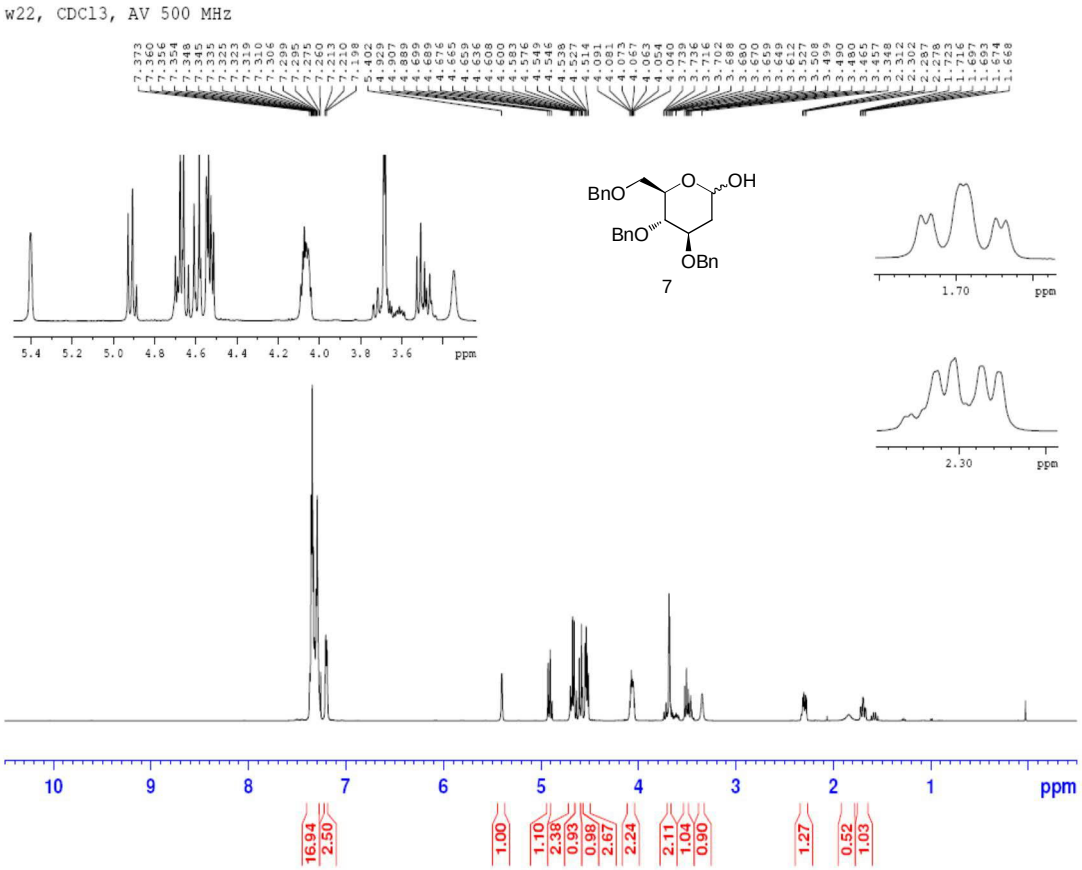
[13] C NMR of compound 3z



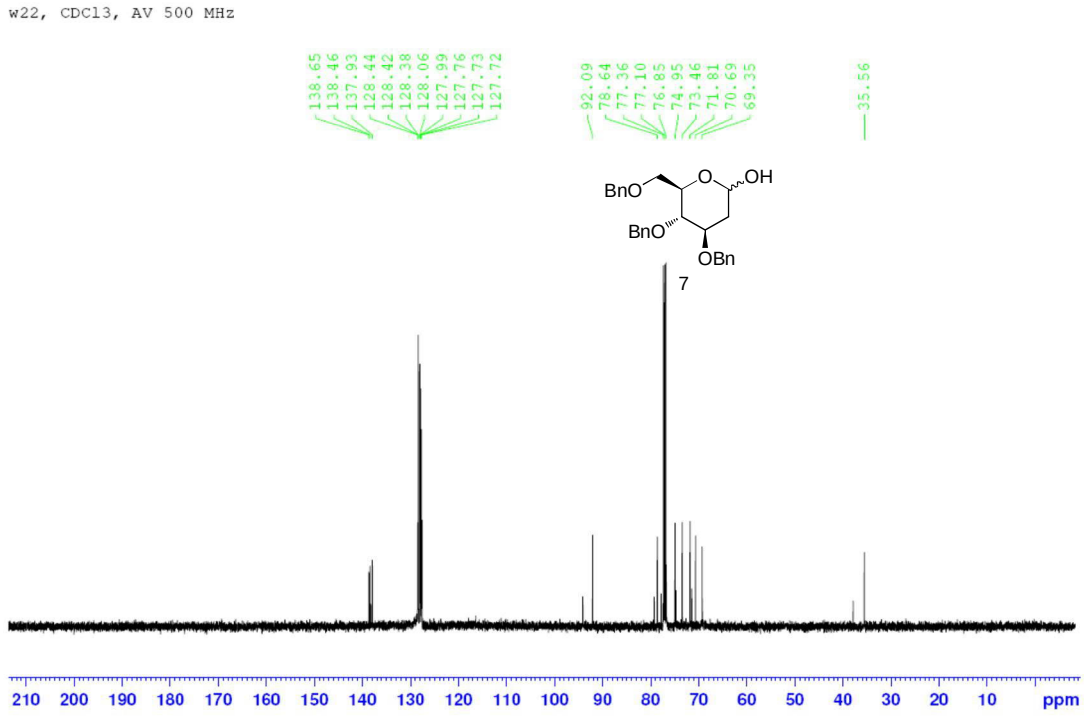
[1] H NMR of compound 6



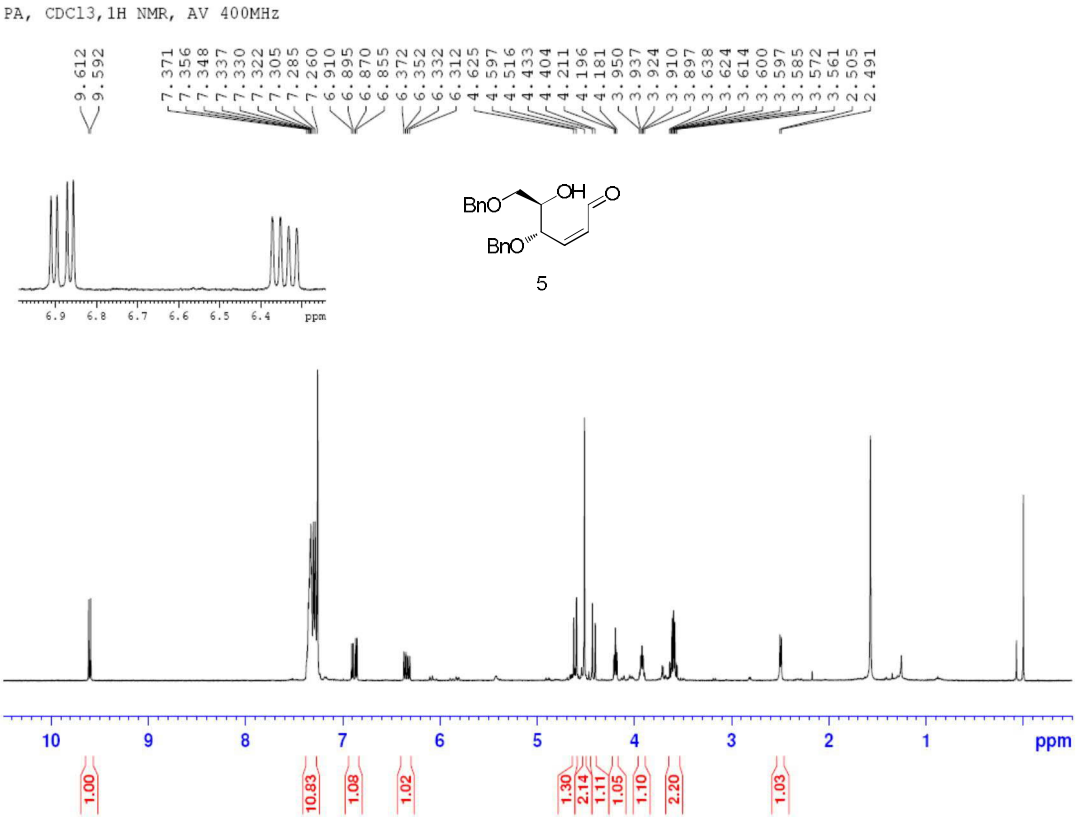
[13] C NMR of compound 6



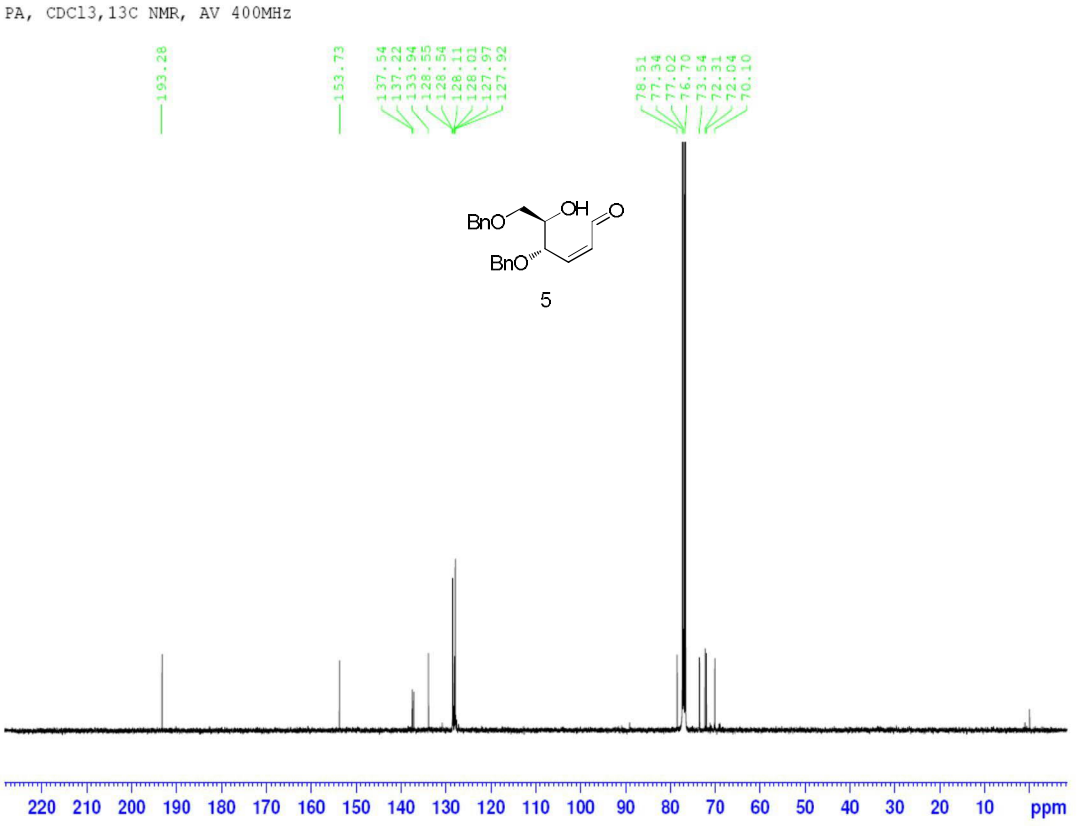
[1] H NMR of compound 7



[13] C NMR of compound 7

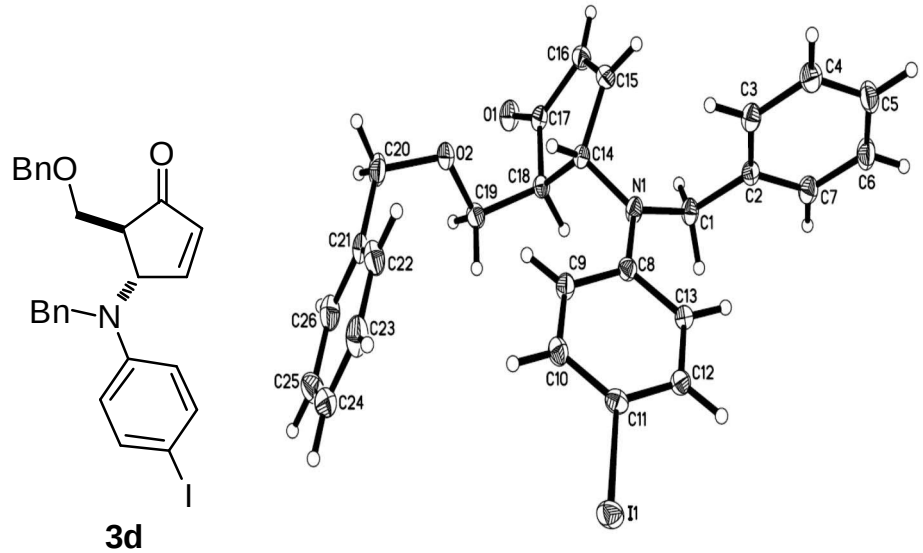


^{1} H NMR of compound 5



^{13} C NMR of compound 5

X-Ray data for compound 3d



3d

Table 1. Crystal data and structure refinement for **3d**.

Identification code	3d	
Empirical formula	C26 H24 I N O2	
Formula weight	509.36	
Temperature	103(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group	P2(1)/c	
Unit cell dimensions	a = 11.4974(4) Å	α= 90°.
	b = 10.8284(4) Å	β= 93.080(2)°.
	c = 17.7117(6) Å	γ = 90°.
Volume	2201.89(13) $Å^3$	
Z	4	
Density (calculated)	1.537 Mg/m^3	
Absorption coefficient	1.477 mm^{-1}	
F(000)	1024	
Crystal size	0.40 x 0.30 x 0.24 mm^3	
Theta range for data collection	2.21 to 29.75°.	
Index ranges	-15<=h<=15, -15<=k<=13, -23<=l<=24	
Reflections collected	33406	
Independent reflections	6183 [R(int) = 0.0356]	
Completeness to theta = 29.75°	98.5 %	

Absorption correction	Semi-empirical from equivalents
Max. and min. transmission	0.7182 and 0.5896
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	6183 / 0 / 271
Goodness-of-fit on F^2	1.051
Final R indices [I>2sigma(I)]	R1 = 0.0278, wR2 = 0.0647
R indices (all data)	R1 = 0.0370, wR2 = 0.0688
Largest diff. peak and hole	1.185 and -0.551 e.Å^{-3}